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THE OSTEOLOGY OF *EMBOLOPHORUS DOLLOVIANUS*, COPE, WITH AN ATTEMPTED RESTORATION.

THE Pelycosaurian fauna of the Permian beds of Texas has been described from fragmentary material in very large measure, from fragments of the skull, from isolated portions of the vertebral column, and from separate limb bones; rarely is any large portion of one animal found preserved. The result has been the almost inevitable description of different portions of the skeleton of forms belonging to the same genus and species under different names. This fact has been very apparent in the attempt to locate the correct taxonomic position of the very complete specimen described below, but at the same time it has made apparent the compactness and coherence of the family *Clepsydropsidae* in a most striking manner.

In the collection of the University of Chicago is a specimen, No. 114, of a Pelycosaurian in which a very large portion of the skeleton is represented, warranting an attempt at a description of the complete osteology. The bones were incased in the peculiarly refractory cement of iron and sand which is common on the bones in this locality, and this has rendered the preparation of the skeleton and its study a matter of long time. The specimen was discovered in slightly inclined strata with the head downward and the tail exposed, so the forequarters and skull were well preserved.

The type genus and species, *Embolophorus fritillus*, was described in 1878[1] as follows:

This form reposes on some dorsal vertebræ with intercentra and ribs in place, which display some interesting characters. The neural arch is co-ossified, and the zygapophyses and diapophyses are well developed; the latter not elongate, and standing on the base of the neural arch. The centra are notochordal. The intercentra are narrowed and transversely elongate. The ribs are two-headed; the capitulum is received into a fossa on the posterior border of the intercentrum in advance of the vertebra which supports the diapophysis, to which the tuberculum is attached.

The curious mode of articulation I have not observed in the species of the genera heretofore described, unless the forms of some of the intercentra of *Clepsydrops limbatus* indicate it. If so, that species must be removed to *Embolophorus.*

Char. spef.—Centra with circular section at all points and contracted in at the middle. No carinæ or grooves. The intercentra project beyond the edges of the centra, giving the column the appearance of supporting annular ridges. Their lateral angles extend upward nearly to the base of the neural arch. The diapophyses are short and directed upward and forward; their extremities are concave. The zygapophyses are large and their faces are nearly hortizontal. The size of this species is small, little exceeding that of *Bolosaurus striatus.*

MEASUREMENTS.

Length of a centrum with an intercentrum attached	0.0056^{m}
Length of a centrum	0.0040
Diameter of a centrum, vertical	0.0035
Diameter of a centrum, horizontal	0.0035
Expanse of diapohyses	0.0080
Expanse of heads of rib	0.0035
Elevation to summit of neural canal	0.0045

Later, in 1884,[2] Cope described other features of *Embolophorus:*

The articulation of the ribs in Embolophorus.— The ribs of the Theromorpha are two-headed. While the tubercular articulation has the usual position at the extremity of the diapophysis, the capitular is not distinctly, or is but partially indicated, on the anterior edge of the centrum, in Clepsydrops and Dimetrodon. In Embolophorus, as I showed in 1869 [misprint for 1878], the capitular articulation is distinctly to the intercentrum. A second and larger species of that genus, recently come to hand, displays this character in

[1] "Description of Extinct Batrachia and Reptilia from the Permian Formation of Texas," *Proc. Am. Phil. Soc.*, Vol. XVII, pp. 518, 519.

[2] "Fifth Contribution to the Knowledge of the Fauna of the Permian Formation of Texas and the Indian Territory," *ibid.*, Vol. XXII, p. 43.

a striking degree, since the intercentrum possesses on each side a short process with a concave articular facet for the head of the ribs. From the slight corresponding contact with the intercentrum seen in Dimetrodon and the other genera, there can be little doubt that this is the true homology of the ribs in the Theromorpha.

These remarks were accompanied by a figure of the vertebra of *Embolophorus*, but no name was given to the new genus.

In 1886,[1] the name *E. dollovianus* is proposed for this last species without further description.

In 1890,[2] Lydekker lists this genus as present in the collections of the British Museum and presents figures of dorsal vertebræ. The specific name is respelled as *dolloverianus*.

From a careful comparison of the type material now preserved in the American Museum of Natural History in New York city, it seems to me that there is little doubt that the species *E. dollovianus* is very much closer to the genus *Dimetrodon* than to the type of *Embolophorus*, and that it must eventually be placed there where the material is better known.

The specimen described below is nearly anatomically complete, the only parts lacking being the ribs, the posterior foot, and the ends of the dorsal spines, with, probably, a few dorsal vertebræ. The right side of the skull is nearly perfect as far back as the posterior edge of the orbit, and the bones are preserved in their natural relations; the weak temporal arches are destroyed, but the articular portion of the suspensorium with the faces for the lower jaw attachment are preserved. The basicranium is separate, as in most specimens of the *Pelycosauria*, but both this and the greater part of the lower jaws are preserved. The bones of the palatal region are badly disturbed and flattened against the inner side of those of the facial region, so that their position cannot be made out further than that they were much as in the specimen of *Dimetrodon* previously described by the author (1). The bones of the shoulder girdle, the clavicles, and the inter-clavicle, a complete fore-limb with the fore foot, of the

[1] "Systematic Catalogue of Species of Vertebrata Found in the Beds of the Permian Epoch in North America, with Notes and Descriptions," *ibid.*, Vol. XVI.

[2] "*Catalogue of the Fossil Reptilia and Amphibia in the British Museum*, Part IV, pp. 109, 110.

left side with part of the fore limb of the right side, the pelvis nearly perfect on both sides, and parts of the bones of the posterior limb are all preserved. Thirty-five vertebræ, beginning with the atlas and terminating with several caudals, represent the vertebral column; it is possible that the column is not complete, but, considering the series and comparing it with Cope's published figure of the vertebral column of the *Dimetrodon*[1] it seems that only the end of the tail and possibly a few anterior dorsals are missing. The figure given by Cope shows the column complete to the second sacral. The dependent portion figured as a part of the attached pelvis on one of the vertebræ is the rib of the first sacral, such as is shown in Figs. 20 and 21, but covered by a portion of the matrix. The peculiar shortening of the lumbar vertebræ is evidently just beginning. There are twenty-five presacrals figured by Cope, but there is a break between the twentieth and twenty-first; there are twenty-seven in the present specimen. From the seeming necessity of proportions and because of the uncertainty as to the correct number, I have added four vertebræ in the anterior dorsal region, making the total thirty-two. This may be too many. The numbers given to the vertebræ in the following descriptions are such as indicate their position in the accompanying restoration, and are arbitrary in that the vertebræ were not all discovered in series, but have been located by their anatomical peculiarities. Beginning with the seventh presacral, the series is complete and was found in position to the second caudal.

The skull.—The individual bones of the skull show such slight differences from the bones of the skull of *Dimetrodon incisivus* already described by the author (1) that it is unnecessary to repeat the descriptions. In Fig. 1 is given a side view of the skull, showing the bones in their natural positions; the bones are so slender and the matrix so hard that it has been impossible to remove it all from the bones; in consequence the drawings have been made somewhat diagrammatic, but this has been done only so far as necessary to eliminate the matrix; the relative positions of the bones, and even their distortion, has been pre-

[1] *Proc. Am. Phil. Soc.*, August, 1880, Figs. 3 and 3*a*, Pl. VI.

served. The skull is broken on the mid-line, and the top, which was originally quite flat, has been turned up so that the bones appear in the same plane as the bones of the face. The prominent outer process of the pterygoid bone, which abuts against the inner side of the lower jaw, appears at the lower posterior angle of the skull, and to its posterior edge is attached the articular bone of the lower jaw in an inverted position. The lower jaw

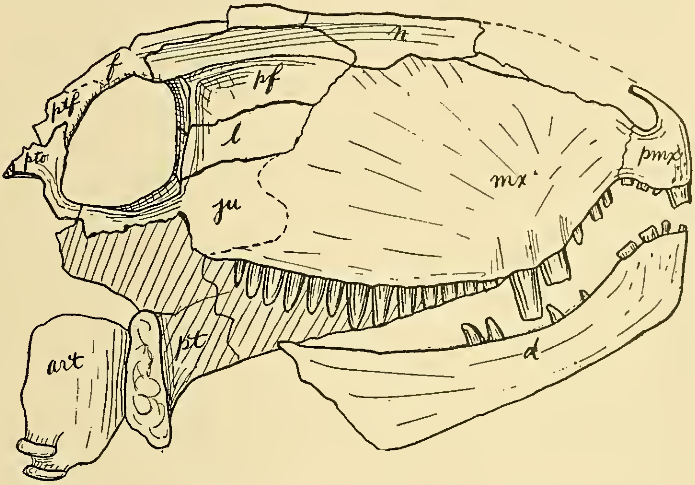


Fig. 1.—Anterior portion of the skull; left side. ⅓ natural size.

is distinct from the mass containing the skull, but in the figure is placed in the correct position.

Noticeable is the large size of the orbit, with its prominent border all around, and its elevated position at the posterior angle of the skull. There is but a single large canine tooth in the upper jaw where *Dimetrodon* has two, but this is, perhaps, of no great taxonomic value, as in forms with successional teeth it is very possible that one may be lost before the other is far enough developed to appear. Neglecting this difference, the number of teeth in the upper jaw is the same (seventeen) in both genera. In Fig. 2 is shown a restoration of the skull of the *Pelycosauria* published in 1899 (1). A comparison with Fig. 1 will show that this restoration is in all essentials correct, at least as regards the side and top. Such structures of the base of the

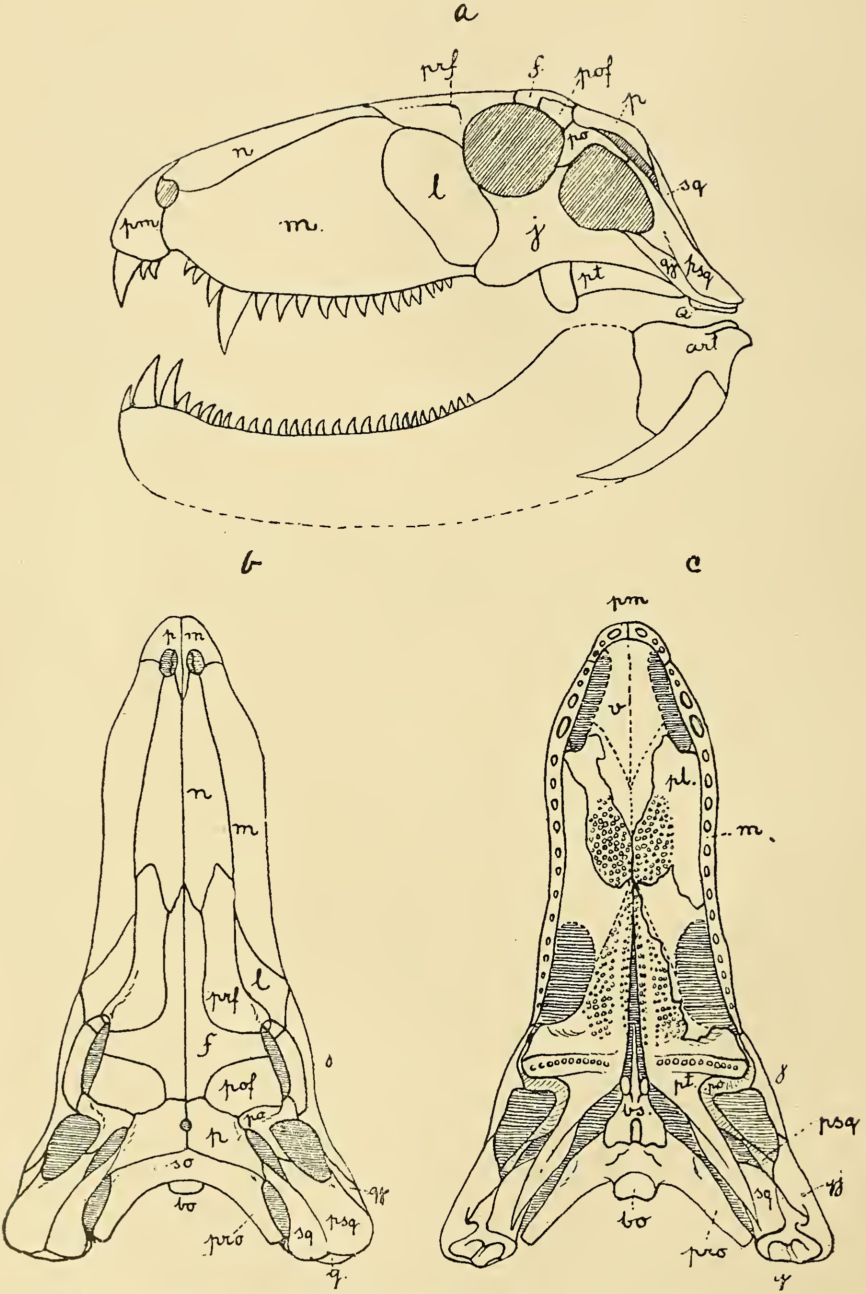


FIG. 2.—Restoration of the skull of the Pelycosauria; *a*, from the side; *b*, from above; *c*, from below.

skull as are preserved also go to show the correctness of the restoration. The basi-cranium is separate from the rest of the skull and shows but few differences from the basi-sphenoid and basi-occipital figured in the description of *Dimetrodon* (1), Pl. I, Figs. 11-14. The bones are somewhat smaller and a little broader in proportion than in *Dimetrodon*.

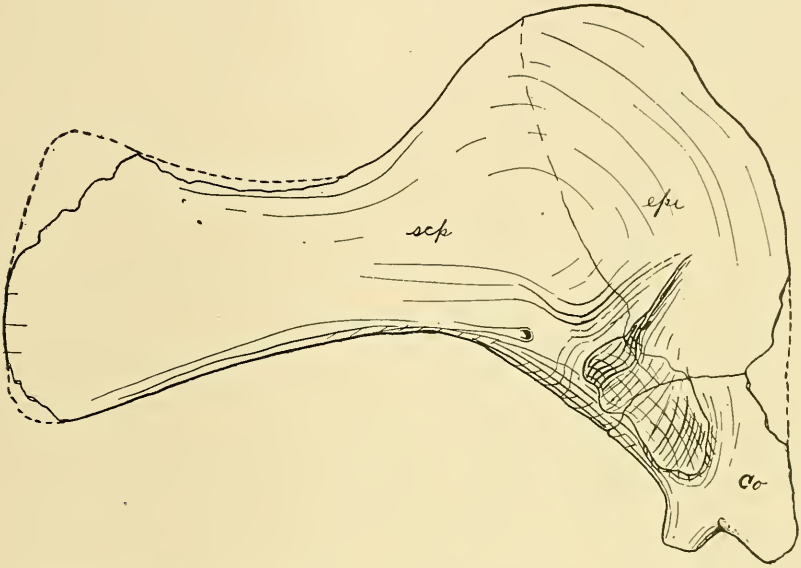


FIG. 3.—United scapula, coracoid, and epicoracoid, *scp*, scapula; *co*, coracoid *epi*, epicoracoid. ⅓ natural size.

MEASUREMENTS OF THE SKULL.

Length of skull from anterior end of nose to posterior edge of orbit	0.225^{m}
Height from just back of last tooth to top of skull	0.080
Antero-posterior and vertical diameters of orbit	0.050
Greatest height of side of skull	0.100

The shoulder girdle.—The left side of the shoulder girdle is preserved almost without distortion, so that it is possible to make out the natural curvature of the structure. In Fig. 3 are shown the united scapula, coracoid, and epicoracoid; the true length of the scapula is not shown because of the foreshortening due to the curvature, but in Fig. 4 are shown the scapula and epicoracoid in profile, showing the true length and the curvature. The coracoid remains free from the scapula through life, but the suture between the scapula and epicoracoid is closed near the outer edges of the bones. The posterior (upper) edge of the cotyloid cavity is formed by a very strong ridge or process of bone which extends out somewhat, upon the epicoracoid. At the base of this ridge the epicoracoid is perforated by a large foramen, and just posterior to the ridge the shaft of the scapula is penetrated obliquely from behind forward by a somewhat smaller foramen. The epicoracoid is very thin, and the greater portion of the scapula is also thin and expanded, but the region near the cotyloid cavity is thicker and very strong.

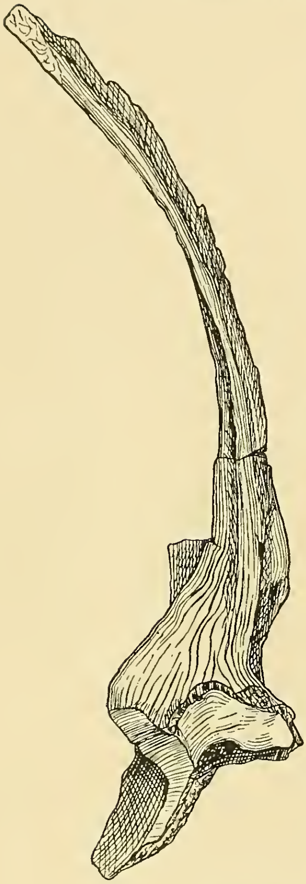


FIG. 4.—Side view of the scapula and epicoracoid. ⅓ natural size.

MEASUREMENTS OF THE SHOULDER GIRDLE.

Length of the scapula - -	0.330–40^{m}
Width across the scapula and epicoracoid opposite the cotyloid cavity	0.120

The clavicle lies in nearly the natural position on the scapula and epicoracoids. It is a peculiarly shaped bone, with the inner ends much expanded and very thin, and the inner edge almost straight. The distal ends are very slender and rod-like and contract to a point which is marked with strong striations. Near the middle of the posterior edge is a rugose process for ligamentous attachment. Fig. 5 shows the clavicle of the right side.

The interclavicle is less well preserved than the other bones of the shoulder girdle, but the size and form are easily made out. There is a long and slender median process which projected posteriorly and is well preserved; the anterior end was thinner and much expanded; the edges are broken, but by comparison with the figure of the interclavicle published by Cope (2), Pl. III, Fig. 5, it would seem that there were strong radial processes. The length of the bone was about 0.31–32^{m}, and the width of the expanded exterior end about 0.120^{m}.

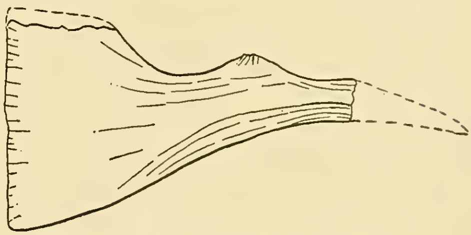


FIG. 5.—Clavicle of the right side, lower view. ⅓ natural size.

In Fig. 6 is shown in diagrammatic manner the shoulder girdle with bones in their proper positions.

The fore limb.—The humerus and radius conform very closely in size and shape with the same bones of *Dimetrodon;* see (1), Pl. III, Figs. 32 and 33. The ulna is represented by the proximal end only, but this is quite different from the ulna of *Dimetrodon.* Compare Fig. 7 with (1), Pl. III, Figs. 34 and 35. The olecranon fossa is more widely open,

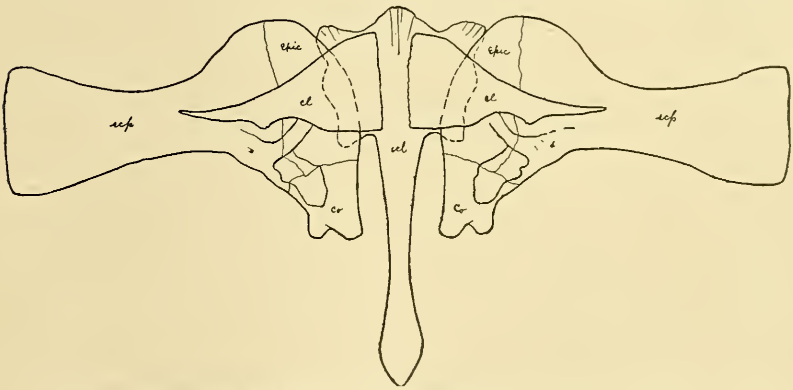


FIG. 6.—Diagram of the shoulder girdle seen from below, *scp,* scapula; *co,* coracoid; *epi,* epicoracoid; *cl,* clavicle; *intc,* interclavicle.

and the whole bone is more clumsy and less finely moulded—a remark which may apply to all the bones of the skeleton in a general way.

Length of the humerus	0.191^{m}
Width lower end humerus	0.103

The front foot of the left side is nearly perfectly preserved, a few of the phalanges only being lost. Unfortunately the bones were not all preserved in position, so that it is impossible to give the position of all the elements with certainty; the bones of uncertain position are those marked carpals 3, 4 and 5, and *centrale* and digits 3, 4 and 5. The other bones and digits 1 and 2 are in the position in which they were found, which is seemingly the correct one. Most notable is the small size of the first digit and its possible wide diversion from the other digits in life. It lies attached to the side of the metacarpal of the second digit and turned at right angles to the other digits, so that it appears in profile when the others are seen from the top or bottom. All the digits terminate in claws of relatively great size, and that of the reduced first digit is as large or larger, absolutely, than those of the other digits. There must have been considerable cartilage in the carpus, for, although the bones have been separated and carefully cleaned, it is impossible to articulate the elements with any accuracy. Fig. 8 shows the most probable position of the bones.

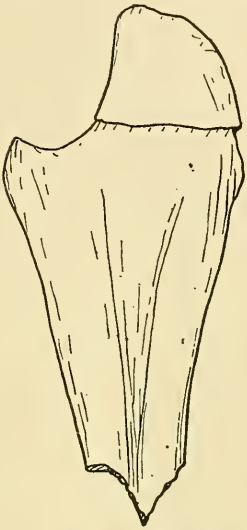


FIG. 7.—Upper portion of the ulna of the left side. ⅔ natural size.

The pelvic girdle.—The pelvis is nearly perfect. The two sides are preserved, so that the missing parts of one side are supplied by the other. The only point of uncertainty is the exact shape of the thin lower edges of the ischium and portions of the edges of the pubis and ilium. As shown in Fig. 9, the three bones meet in the acetabular cavity and are separate through life. The ilium ends anteriorly in an abrupt elevated crest and posteriorly is continued as a slender rod. The ischium is a broad and very thin plate, nearly semicircular in outline; the bones of the two sides evidently met in a ventral symphasis. The acetabular edge of the ischium is very strong and prominent, and looks rather forward and upward than straight upward. This is similar to the condition found in the *Crocodilia* and other forms where the belly is carried very low between the legs. The pubis lies nearly parallel to the axis of the body.

MEASUREMENTS OF THE PELVIS.

Greatest length of ilium	0.150m
Length articular face in the cotyloid cavity	0.061
Width articular face in the cotyloid cavity	0.040
Greatest length of the pubis	0.121
Length of distal edge of the ischium	0.155

The posterior limb.—The posterior limb is represented by the distal end of the femur and the proximal end of the tibia. The femur is very badly preserved. The whole outer shell of bone is scaled off so that what remains is practically a cast of the interior cavity and of the cancelous tissue of the condyles; but it appears that it is very different from the femur of *Dimetrodon*, (1) Pl. III, Figs. 36 and 37. The condyles are less well separated and lie both near the distal end of the bone instead of one at the side; the whole appearance is of a lower type.

From all appearances of the skeleton the posterior portion of the animal seems to have been somewhat weaker than the anterior.

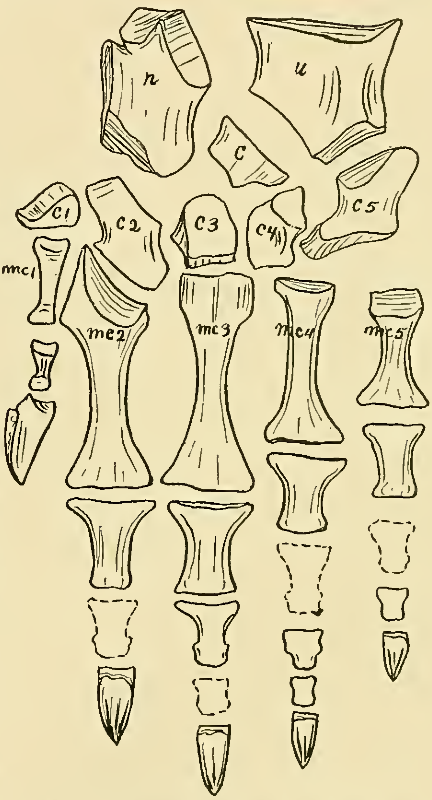


FIG. 8.—Front foot from the upper surface. ⅔ natural size. *r*, radiale; *u*, ulnare; *c*, centrale; *1–5*, carpals one to five; *mc–mc 5*, metacarpals one to five. ⅔ natural size.

The vertebral column.—The most notable feature in the skeleton is the wide diversity in the form of the elements of the vertebral column. In the cervicals and lumbars the neural arch is co-ossified with the centrum and in the dorsals it is free. The ribs of the cervicals and anterior dorsals are united by the tuberculum to the transverse process and by the capitulum to a process of the preceding intercentrum, but in the lumbars, caudals, and posterior dorsals there is no process on the intercentrum for the capitulum of the rib which is attached to edge of the centrum. The intercentra change remarkably through the series; in the anterior portion of the column they have

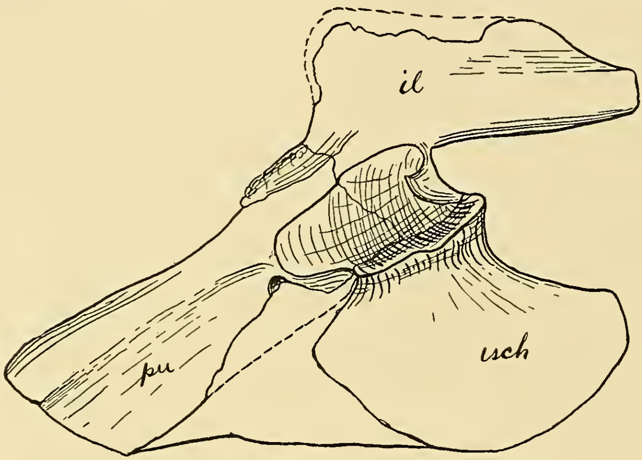


FIG. 9.—Pelvis from the left side. ⅓ natural size.

considerable vertical height and prominent lateral processes for the capitula of the ribs; in the posterior part of the series they become shallower and wider in an antero-posterior direction and lose all trace of the process for the ribs in the lumbars and even in the posterior dorsals (?). In the cervicals, the dorsals, and the anterior caudals there is a prominent facet on the lower portion of the anterior face of the centrum for attachment of the intercentrum. This is absent on the lumbars and sacrals. The anterior and posterior zygapophyses change from broad in the cervicals to narrow in the dorsals, and broad in the lumbars and caudals again; in the same order the articular faces of the zygapophyses change from horizontal to oblique and back to horizontal, so that the faces of the post-zygapophyses of the dorsals look out as well as downward, and of the pre-zygapophyses in as well as up. The bottom line of the centrum in the cervicals and dorsals has a prominent and very thin keel, while this is absent in the posterior lumbars and the sacrals. All these are characters which have been used to define different genera and species, and their union in one form goes to show how close are the different genera of the family *Clepsydropsidae* and how difficult it is to identify forms from isolated vertebræ.

The atlas.—The first cervical is represented by a centrum only; there was probably a very rudimentary and loosely attached neural arch which has disappeared. The first intercentrum,

a *b* *c*

FIG. 10.—*a*, second intercentrum from below; *b*, same from the anterior face; *c* an intercentrum from the posterior portion of the dorsal series. Natural size.

between the atlas and condyle, is not preserved. That such an element did exist is shown by its presence in *Dimetrodon* (1), Pl. II, Fig. 20. The second intercentrum, between atlas and axis, is large and presents a deeply concave face for the posterior face of the atlas. On either side of the intercentrum are strong posteriorly projecting processes for articulation with the cervical rib. In the collection of the University of Chicago there are specimens of the atlas of *Pelycosauria* with the pre-atlas inter centrum strongly attached to the atlas by co-ossification (Fig. 10 *a* and *b*).

MEASUREMENTS OF THE SECOND INTERCENTRUM.

Greatest breadth - - - - - - - - -	0.027 m
Antero-posterior length on mid-line of lower surface - -	0.012

The *axis* (Fig. 11) has a strong neural spine, with considerable antero-posterior extent; in the last respect it differs quite markedly from *Dimetrodon* where the spine is rather thick and not expanded in the antero-posterior diameter to such an extent,

(1) Pl. II, Fig. 20. The posterior edge of the spine is much thicker than the anterior and is quite flat; the upper end shows a broad surface, smooth and slightly concave, probably for ligmentous attachment. On the anterior edge there are two small areas very similar to the one on the top of the spine. The anterior edge of the neural spine overlapped the centrum of the atlas so that the zygapophyses at the point of contact were weak, if developed at all. There is no trace of the sutural connection between the spine and the neural arch, though such a connection did undoubtedly exist in the youth of the animal. There is no pronounced keel on the lower surface of the centrum, but the whole body of the vertebræ slants obliquely backward, so that the posterior face of the centrum is much lower than the anterior. The transverse process is attached to the base of the neural arch and the upper portion of the centrum; it curves sharply outward and downward. The distal end of the transverse process is lost, but it evidently reached as far down as the lower line of the centrum. The post-zygapophyses are well developed, and the articular faces are horizontal; the region of the pre-zygapophyses is somewhat injured, but enough remains to show that the processes, if present, were small. The upper half of the centrum only, is occupied by the notochordal canal, so that the notochordal funnel of the anterior face occupies the upper portion of the face, the lower half of the face is occupied by the facet for the intercentrum; this is shown in profile in the figure.

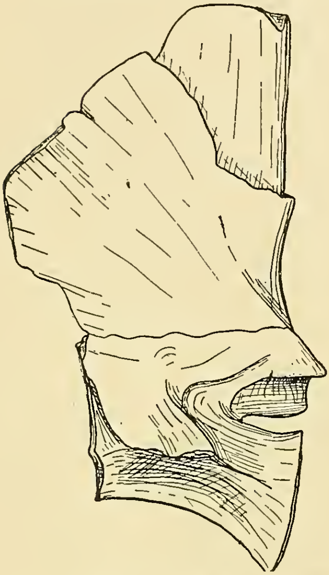
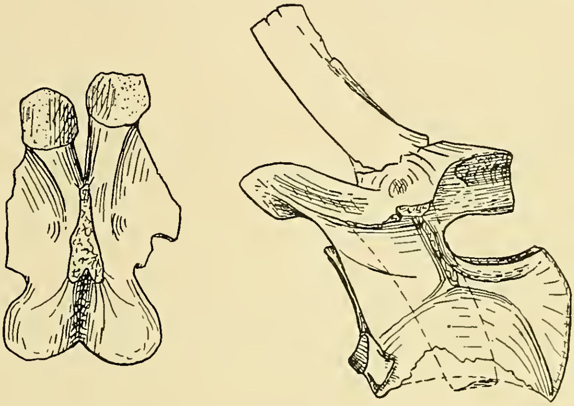


FIG. 11.—Axis. ⅔ natural size.

MEASUREMENTS OF AXIS.

Length along bottom line of centrum	0.038 m
Distance from top of spine to lower line of the posterior face of the centrum	0.113
Greatest width of spine	0.054
Width of the posterior zygapophyses	0.032

The spine of the *third cervical* (Fig. 12) is quite slender and, though incomplete at the upper end, was evidently quite short. The spine is curved forward, so that it lay close to the spine of the axis, and its base is quite narrow, as it is sharply pinched in by a deep fossa on each side. The anterior and posterior zygapophyses are well developed, and the faces are nearly horizontal, so that in the natural condition of the bone they looked straight up and down. The transverse process was attached to the base of the neural spine and to a ridge rising from the upper portion



a *b*

FIG. 12.—Third cervical. *a*, from above; *b*, from the side. ⅔ natural size.

of the centrum; the lower end of this ridge is supported by slight ridges running toward the anterior and posterior faces of the centrum. These last ridges assume considerable importance in the more posterior vertebræ. The transverse process is present on the vertebræ, but broken from position and displaced somewhat to the rear. It has been figured in outline in its proper position, so that the nature of the posterior portion of the vertebra may be seen, but the dimensions and form are correct as figured. The process starting from the base of the spine decurved rapidly, and its distal face reached to the lower edge of the centrum. The notochordal portion of the centrum is confined to the upper half, and the lower is occupied by a narrow and prominent keel. The posterior face is somewhat lower than the anterior, but this is not so pronounced as in the axis. The lower half of the anterior face is a flat surface, to which is still attached the intercentrum. This is crescentic in shape and rather broad on the lower face. On either side there are two prominent processes for the capitula of the ribs. Without the intercentrum the profile of the anterior face would be very similar to that of the axis.

MEASUREMENTS OF THE THIRD CERVICAL.

Length along bottom line of the centrum - - - -	0.038 m
Width posterior zygapophyses (somewhat crushed) - -	0.033
Horizontal diameter of posterior face of centrum - - -	0.028
Vertical diameter same - - - - - - -	0.028
Horizontal diameter anterior face - - - - - -	0.024

The *fourth cervical* is less well preserved than the third or fifth, and presents no great difference from the third. The transverse process is very wide, the width being due to a very thin extension of the anterior edge; this character persists through the anterior dorsal vertebræ. The ridges supporting the transverse process upon the centrum become very prominent running to the anterior and posterior edges of the centrum; these, with the prominent keel on the lower line of the centrum, form three very prominent ridges on the centrum about equally distant from each other. As in the third, the base of the spine is pinched by the deep fossæ on each side of its base.

MEASUREMENTS OF THE FOURTH CERVICAL.

Length along the bottom line of the centrum - - -	0.038 m
Width of posterior zygapophyses - - - - - -	0.032
Horizontal diameter of anterior face of centrum - - -	0.024
Vertical diameter same (including face for intercentrum) - -	0.028

The *fifth cervical* (Fig. 13) differs from the preceding in the greater relative width of the pre- and postzygapophyses. This may be due in part to crushing of the preceding vertebræ, as the fifth is almost free from distortion, though not entirely so. The distal end of the transverse process is missing, but the whole process was inclined somewhat more to the rear than in the anterior cervicals. The ridge rising from the upper portion of the centrum and supporting the lower edge of the process is still present but is shorter. The transverse process is rising from any contact with the centrum to a position on the base of the neural arch. The intercentrum is in position and is similar to the earlier ones. The keel on the lower edge is very thin and sharp and of considerable vertical extent. The posterior face of the centrum is no lower than the anterior. The base of the spine is still very thin, so that the spines probably were not greatly elevated.

MEASUREMENTS OF THE FIFTH CERVICAL.

Length along the bottom line of the centrum - - -	0.032^{m}
Width of the posterior zygapophyses - - - - -	0.043
Width anterior zygapophyses - - - - - -	0.039

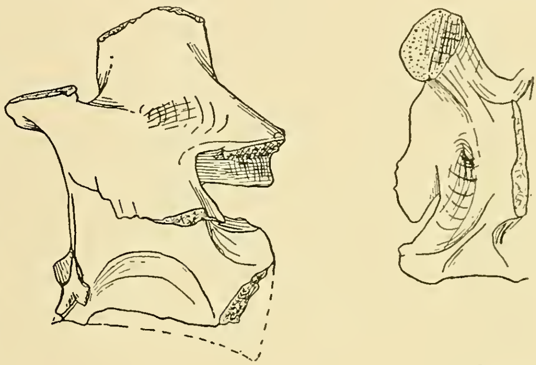


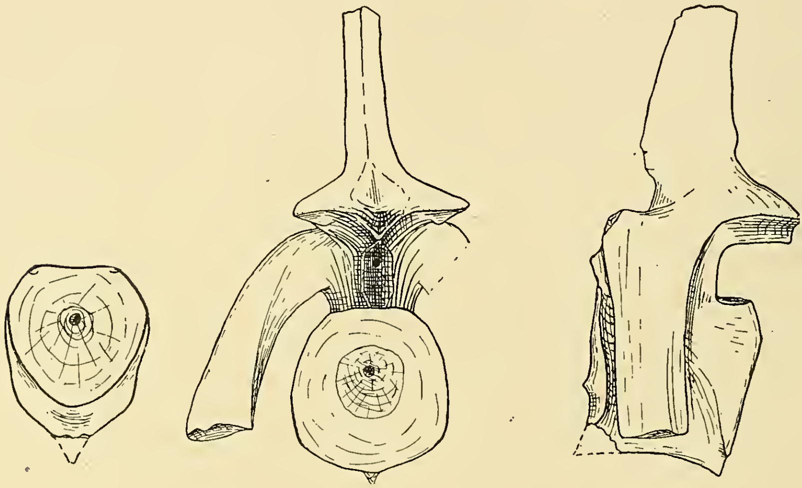
FIG. 13.—Fifth cervical. *a*, from above; *b*, from the side. ⅔ natural size.

The *sixth cervical* differs from the others in the relative shortness and the greater height of the centrum. The transverse process rises from the upper portion of the neural arch and is well above the neural canal and the centrum; the ridges on the centrum which supported the transverse process have lost connection with it and are present as rudiments which are evidently disappearing. The transverse process curves downward close to the centrum and trends very slightly to the rear; the lower end does not extend below the lower edge of the centrum. This is the first of the vertebræ posterior to the axis in which the intercentrum is not attached, but from the size of the articular space on the lower edge of the anterior face of the centrum it is evident that it was as large as the others and that its displacement is accidental. The articular faces of the zygapophyses are horizontal, and the keel on the lower portion of the centrum is very thin and prominent.

MEASUREMENTS OF THE SIXTH CERVICAL.

Length along bottom line of the centrum	0.029[m]
Height of centrum from bottom to bottom of notch beneath post-zygapophyses	0.030
Width post-zygapophyses	0.040
Vertical and horizontal diameters of the posterior face of the centrum	0.033

The *seventh cervical* (Fig. 14) has the centrum relatively higher and shorter than the preceding, and the keel is much more



a *b* *c*

FIG. 14.—Seventh cervical.—*a*, anterior face of the centrum; *b*, posterior view of vertebra; *c*, side view. ⅔ natural size.

prominent. The edge of the keel forming the lower edge of the centrum is nearly straight. The intercentrum is absent, and the recurving of the lower portion of the edge of the anterior face in forming the face for the centrum shows very prominently the "twisted" appearance described by Cope. The transverse process rises from the neural arch quite above the neural canal and the centrum and decurves close to the side of the centrum. There is no trace of the ridges which supported the transverse process on the centrum in the anterior vertebræ; its distal end does not reach below the lower edge of the centrum. The transverse process lacks something of the thin plate extending from its anterior edge which gives it the very broad appearance in the anterior cervicals and it is much stouter. In this vertebra for the first time the suture between the neural arch and the centrum is quite evident. On the upper edge of the anterior face of the centrum near the sides are small prominences seemingly articular in nature, but I can find no corresponding structure on the posterior faces of any of the vertebræ. The base of the neural spine is much stouter than in the preceding vertebra, and the spine was probably much more elevated.

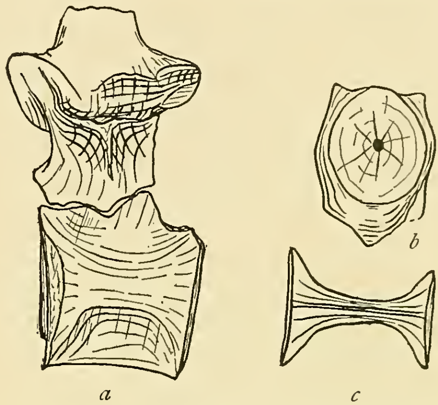


Fig. 15.—An anterior dorsal vertebra, the twelfth of the restoration. *a*, from the side; *b*, anterior face of the centrum; *c*, profile of the centrum from below. ⅔ natural size.

MEASUREMENTS OF THE SEVENTH CERVICAL.

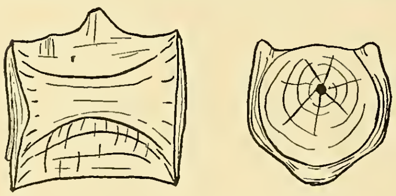
Length along the bottom line of the centrum - - -	0.029^{m}
Height of centrum as in the sixth - - - - - - -	0.032
Horizontal and vertical diameters of the posterior face of the centrum - - - - - - - - - - -	0.030
Width of the post-zygapophyses - - - - - - -	0.033

The next vertebra (Fig. 15) probably belongs farther back in the series. It is the twelfth of the restoration. The numbers used below are those of the restoration. This vertebra is typical of the dorsal series. It differs markedly from the vertebræ described as cervical, and not least in the fact that the neural arch and spine are separate from the centrum. The centrum is more high than long, and the keel is very prominent, forming at least half of the vertical extent of the centrum. The transverse process rises from the base of the neural spine and probably extended almost straight outward (this is true in *Dimetrodon*). The distal end of the transverse process is missing, but the base even rises slightly after leaving the spine; at this point the process is very thin vertically and quite broad in an antero-posterior direction. The base of the transverse process rises from three ridges, two rising from beneath the anterior and posterior zygapophyses and a third vertical ridge on the side of the neural ral arch. The base of the spine is quite broad and strong. The spine was elevated. The pre- and postzygapophyses differ from the cervicals in that their antero-posterior diameter is relatively much less and the articular faces are no longer horizontal, but inclined outward as well as downward and inward as well as upward.

MEASUREMENTS OF THE TWELFTH VERTEBRA.

Length along the bottom line of the centrum - - - -	0.025^{m}
Horizontal diameter of the posterior face of the centrum. -	0.028
Vertical diameter same - - - - - - - -	0.029
Antero-posterior extent of zygapophyses - - - -	0.040
Width of anterior zygapophyses - - - - - -	0.030

The *thirteenth* to the *sixteenth* vertebræ, inclusive, are very similar to the twelfth, and all belong in the dorsal series; the notable point is the gradual elongation of the centrum so the antero-posterior diameter becomes greater than the vertical. The neural arches are detached in all the dorsal vertebræ, but in the seventeenth the arch lies near the vertebra and shows that the character of the articular faces of the zygapophyses gradually change so that they are becoming more and more horizontal. The base of the neural spine is very broad, but there is a deep pit on either side. The anterior face of the centrum shows an articular face for an intercentrum. In Fig. 10 *c* is shown an intercentrum, probably from this region. It is noticeably smaller than the intercentra from the anterior portion of the column, and the faces for the capitula of the ribs are very small and are not supported on tubercles.



a *b*

FIG. 16.—A dorsal, the sixteenth of the restoration. *a*, from the side; *b*, anterior face of the centrum. ⅔ natural size.

MEASUREMENTS OF DORSAL VERTEBRÆ.

Length along bottom line of thirteenth	0.0275^{m}
Length along bottom line of fourteenth	0.0245
Length along bottom line of fifteenth	0.032
Length along bottom line of sixteenth	0.031
Length along bottom line of seventeenth	0.0325
Length along bottom line of eighteenth	0.034

The *nineteenth* vertebra (Fig. 17) is characterized by the diminution of the keel. The lower edge of the centrum is rounded and the keel is indicated by a narrow line only. The anterior face of the centrum is rounded and quite similar to the posterior, there being but a small facet for the intercentrum. The zygapophyses are narrow and nearly horizontal, and the transverse process stood out at nearly right angles to the body of the centrum.

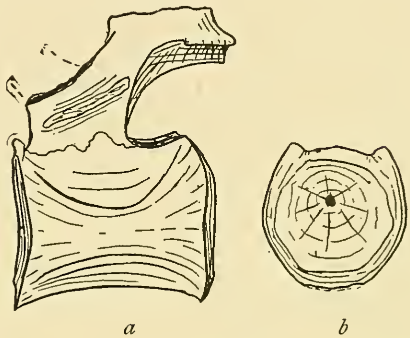


FIG. 17.—A posterior dorsal, the nineteenth of the restoration. *a*, from the side; *b*, anterior face of the centrum. ⅔ natural size.

MEASUREMENTS OF THE NINETEENTH VERTEBRÆ.

Length along bottom line of the centrum	0.035^{m}
Horizontal diameter of face of centrum	0.029
Vertical diameter of face of centrum	0.028
Vertical height of centrum to base of notch beneath postzygapophyses	0.029

The *twentieth* to the *twenty-fourth* vertebræ, inclusive, are quite similar to the nineteenth, but show a gradual decrease in length, as shown by the measurements below:

MEASUREMENTS.

Length along bottom line of twentieth	0.036^{m}
Length along bottom line of twenty-first	0.037
Length along bottom line of twenty-second	0.033
Length along bottom line of twenty-third	0.030

The edge of the anterior face of the centrum of the twenty-fourth vertebra is expanded into a slight face for the capitulum of the rib; it is probable that the main portion of the capitulum was attached to the intercentrum, but we have here the first step in the formation of the type of articulation which is present in all posterior vertebræ. In other respects the vertebra resembles those immediately preceding it; the neural arch is attached to the centrum, but the sutural connection is very distinct. Attached to the spine of this vertebra is one of the intercentra such as is found in the posterior portion of the column. It is broadly crescentic, with but slight curvature, and is of considerable antero-posterior extent on the mid-line. The bone is very thin, and there are no faces for the capitulum of the rib; it is probable that the intercentrum is displaced and belongs farther back in the series. One thing seems very certain: the width of these intercentra is too great to permit their having occupied a position between the vertebræ in the anterior portion of the column, and there are no articular faces for them on the lower portion of the anterior face of the centrum. They must have rather underlain the point of union of the two vertebræ.

MEASUREMENTS OF THE TWENTY-FOURTH VERTEBRA.

Length along bottom line of centrum - - - - -	0.0285^{m}
Length intercentrum attached to spine - - - -	0.032
Width of the intercentrum antero-posterior - - - -	0.009

Beginning with the twenty-fifth, the series is complete and in position to the second caudal, so that it is certainly the seventh presacral.

The *twenty-fifth*, seventh presacral vertebra (Fig. 18), has the articular face for the capitular portion of the rib well developed, and the posterior edge of the face is supported by a strong protuberance from the side of the centrum.

Length along the bottom line of the centrum - - -	0.027^{m}

In the *twenty-sixth*, sixth presacral (Fig. 18), the base of the rib is still attached to the vertebra and shows clearly the change in the manner of articulation. The tuberculum is attached to a very short transverse process extending from the side of the neural arch and the capitulum to the articular face formed on the edge of the anterior face of the centrum. The articular face is quite large and stands out prominently from the side of the centrum. The vertebræ are rapidly shortening again and the articular faces becoming relatively larger.

Length along the bottom line of the centrum - - - 0.026ᵐ

In the *twenty-seventh*, fifth presacral (Fig. 18), the rib seems to have completely lost its connection with the intercentrum. The tuberculum is attached to the downwardly inclined face of a very short transverse process and the capitulum to the edge of the centrum. The capitulum is gradually shortening. The neural spine is rather thin, but has considerable antero-posterior extent. The anterior and posterior zygapoyhyses are nearly horizontal, but the articular faces are somewhat curved.

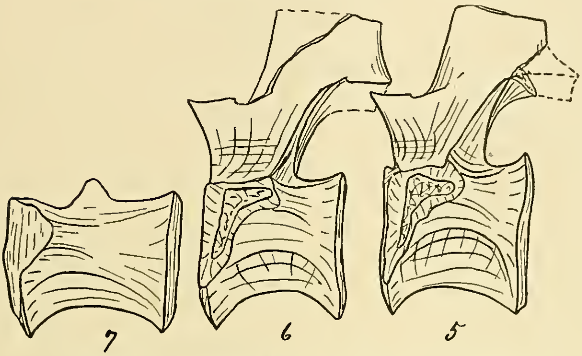


FIG. 18.—The fifth, sixth, and seventh presacrals. ⅔ natural size.

Length of the bottom line of the centrum - - - - 0.023ᵐ

The remaining presacrals show a considerable similarity. The *twenty-eighth*, fourth presacral (Fig. 19), has the broken base of the rib still attached and show that both tuberculum and capitulum are still present.

In the *twenty-ninth*, third presacral (Fig. 19), the capitulum is much reduced and the rib stands out almost straight from the upper portion of the centrum.

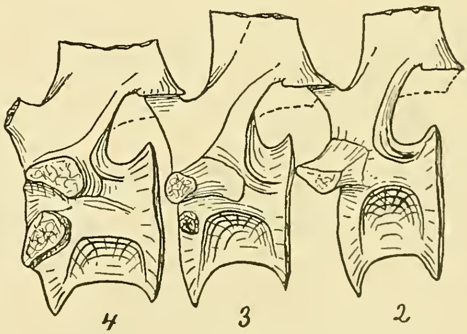


FIG. 19.—The second, third, and fourth presacrals. ⅔ natural size.

In the *thirtieth*, second presacral (Fig. 19), there is no trace of a capitulum, and the rib is a short stubby process.

The *thirty-first*, first presacral (Fig. 20), resembles the preceding in the arrangement of the rib.

As before mentioned the vertebræ are rapidly growing shorter and the last presacral is remarkably shortened. The length of the vertebræ is shown by the measurements given below.

Length along bottom line of the centrum of the twenty-eighth	0.022 m
Length along bottom line of the centrum of the twenty-ninth	0.019
Length along bottom line of the centrum of the thirtieth	0.016
Length along bottom line of the centrum of the thirty-first	0.013
Vertical diameter of the thirty-first	0.039
Horizontal diameter of the thirty-first	0.039

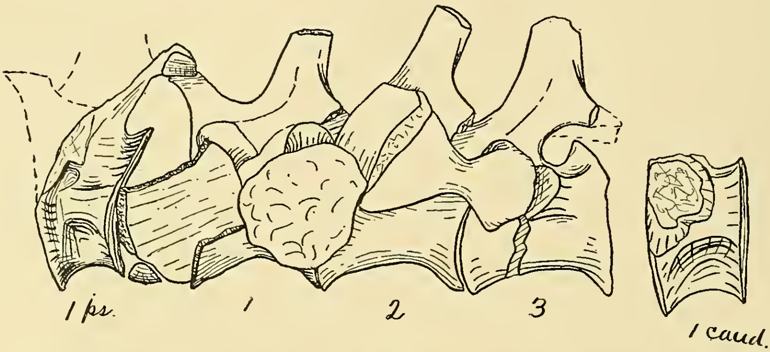


FIG. 20.—Sacral vertebræ from the side with the last presacral and the first caudal. ⅔ natural size.

In the specimen as preserved there is quite a space between the first sacral and the last lumbar, and in this space is a rather large intercentrum. It is quite broad antero-posteriorly and only slightly curved. The lower surface is quite rough, but this may in part be due to accidents of preparation. There is no possibility that there was a space between the vertebræ equal to the width of the intercentrum, so that it must have underlain the line of juncture.

Length of the intercentrum	0.032 m
Width of intercentrum antero-posteriorly	0.014

There are three *sacrals* (Figs. 20 and 21), which differ very markedly from the last presacral and the first lumbar in that they are of considerable relative length. The ribs are attached to the transverse processes and sides of the centrum; as in the lumbars, and are very short, but the distal ends are greatly expanded for attachment to the ilium. The rib of the first sacral extends out almost straight from the sides of the vertebra, but in the second and third the ribs are strongly inclined forward; this is in part due to crushing, but is largely natural, as the articular faces for the proximal ends of the ribs, especially on the third sacral, are inclined forward quite sharply. The sacral vertebræ meet quite closely on the median line below, and there were no intercentra present, but there was no co-ossification. The spines are quite thin, noticeably more so than in the lumbars and first caudals, but of considerable antero-posterior extent; they were possibly not so elevated as the adjacent spines.

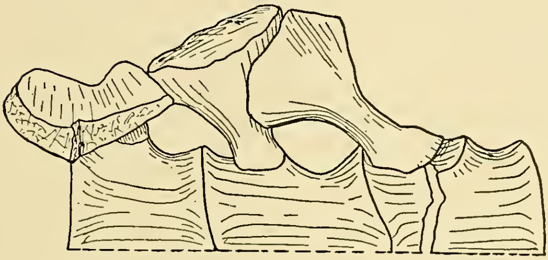


FIG. 21.—Sacral vertebræ from below. ⅔ natural size.

The *first sacral* is somewhat shorter than the others, and the bottom line of all is somewhat concave and is devoid of a keel.

Length along bottom line centrum of first sacral - - -	0.027 m
Length along bottom line centrum of second sacral - -	0.0325
Length along bottom line centrum of third sacral - - -	0.030

The *first caudal* is again short, 0.020 m. Along the bottom line of the centrum it is rather imperfect.

The *second caudal* (Fig. 22), is well preserved. The rib is short and rises much as in the lumbar vertebræ, from the neural arch and from a prominent process on the side of the centrum. The capitular portion extends well down the side of the anterior face. The process on the centrum

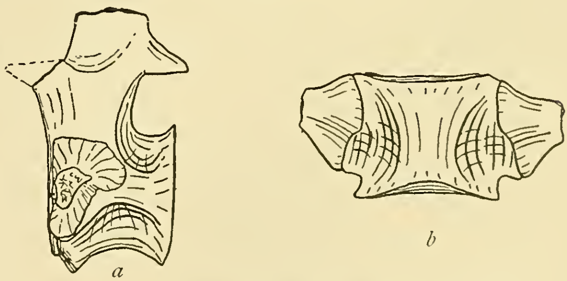


FIG. 22.—The second caudal vertebra. *a*, from the side; *b*, from below.

supporting the capitulum stands out as a rather prominent ridge separated from the obtuse keel of the lower line of the centrum by a deep pit; the whole effect is to give the vertebræ a triangular appearance in section. There are broad intercentra attached to the caudals, but not in position; there is no trace of chevron bones. The lower edges of the anterior faces of the caudals are reflected, making a face for the intercentrum, but those which are found on the vertebræ are too large to have been located between the vertebræ. The whole series of caudals decreases rapidly in size, indicating a short tail.

Length on bottom line of second caudal - - - -	0.0205 m
Length on bottom line of third caudal - - - -	0.018
Length on bottom line of fourth caudal - - - - -	0.015

The accompanying restoration is largely from the specimen described above, but some parts have been taken from other specimens, and the ribs have been supplied *in toto* by comparison with the living *Spenodon.* The spines of the vertebræ are largely absent and have been supplied from a specimen of *Dimetrodon* in which the length of the limb bones was almost exactly the same as in the present specimen. The posterior foot has been drawn with Cope's figure of the posterior foot of *Clepsydrops* as a model. The notable weakness of the base of the spines of the sacral vertebræ has suggested that they were in all probability shorter than the others. Four vertebræ have been supplied in the anterior dorsal region, as there is an evident hiatus in the series at that point. The total number of presacral vertebræ is represented as thirty-one, and this cannot be very far from the correct number; this determination is made from the vertebræ of the present specimen and from the figure of the vertebral column of *Dimetrodon* published by Cope.[1] As explained above, this figure probably does not represent the complete column.

The body is drawn somewhat elevated from the ground. At first it seemed probable that the belly was dragged on the ground, but an attempt to place the bones of the fore limb in such a position showed that the relation of the femur to the cotyloid cavity and the head of the radius to the articular

[1] *Proc. Am. Phil. Soc.*, August, 1880, Figs. 3 and 3*a*, Pl. VI.

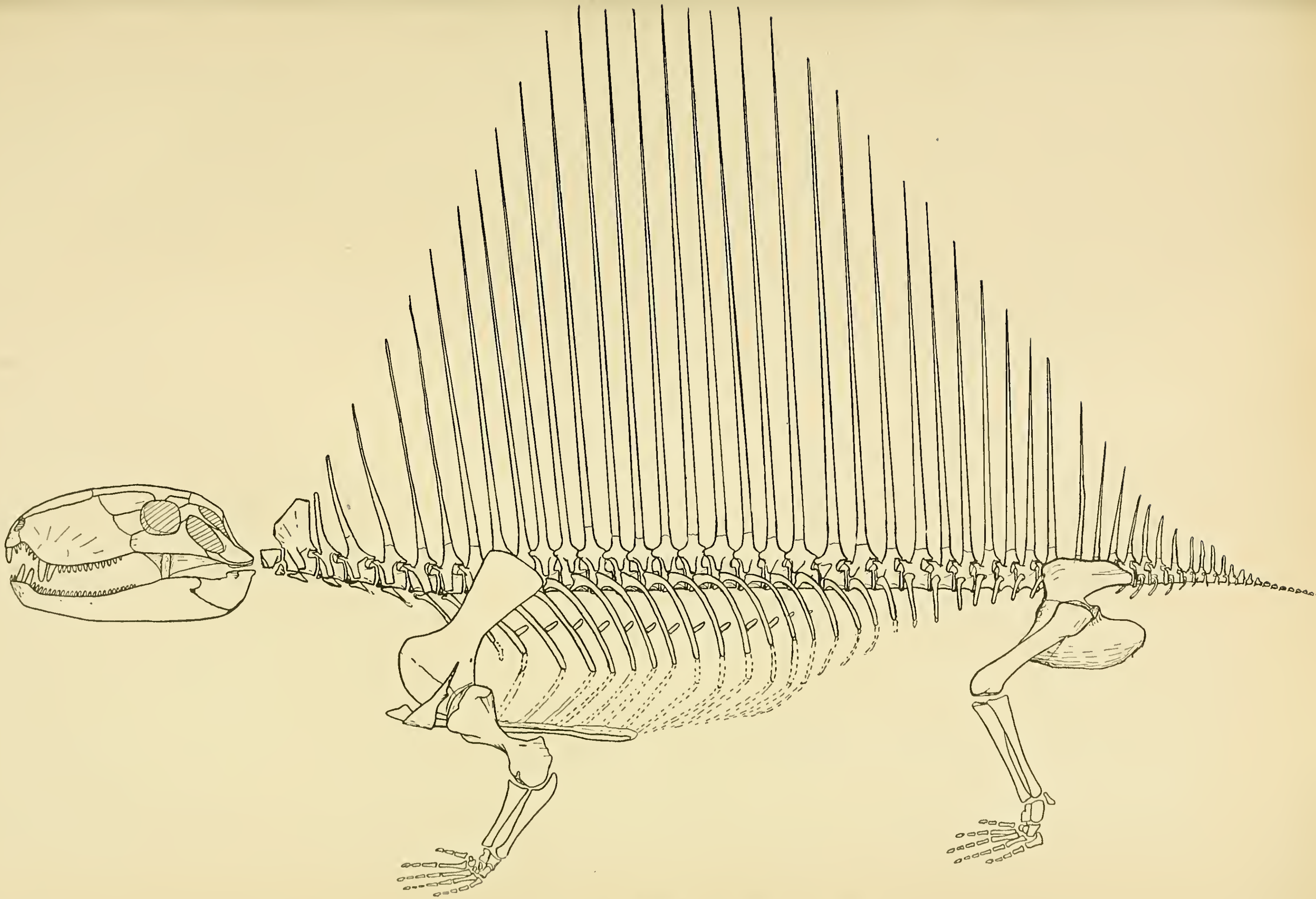


FIG. 23.—Restoration of *Embolophorus*. About 2·9 natural size.

process on the lower end of the humerus would not permit this. The tail would naturally seem to have been pretty long, if for no other reason, than to preserve the symmetry of the animal; but the condition of the caudal vertebræ seems to negative such a proposition. The vertebræ of all long-tailed forms gradually decrease in size and the middle and posterior ones assume the form of simple cylinders. In this specimen the vertebræ decrease rapidly in size and the ones which are only half as large as the first and second are as perfectly formed and as specialized as any in the series.

1. Baur and Case. "The History of the Pelycosauria, with a Description of the Genus *Dimetrodon*." *Trans. Am. Phil. Soc.*, N. S., Vol. XX (1899).

2. E. D. Cope. "Systematic Catalogue of the Species of Vertebrates Found in the Beds of Permian Epoch in North America, with Notes and Descriptions." *Ibid.*, Vol. XVI (1886).

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THE CINCINNATI GROUP IN WESTERN TENNESSEE, BETWEEN THE TENNESSEE RIVER AND THE CENTRAL BASIN.

A. The subdivisions of the Cincinnati group in Ohio.
B. The Cincinnati group in the Tennessee river valley.
  1. The Saltillo limestone.
  2. The Warren limestone.
  3. The Richmond limestone.
  4. The Mannie shale.
C. The Cincinnati group between the Tennessee river valley and the Central Basin.
  5. The Leipers creek limestone.
  6. The Swan creek limestone.
D. Conclusions.

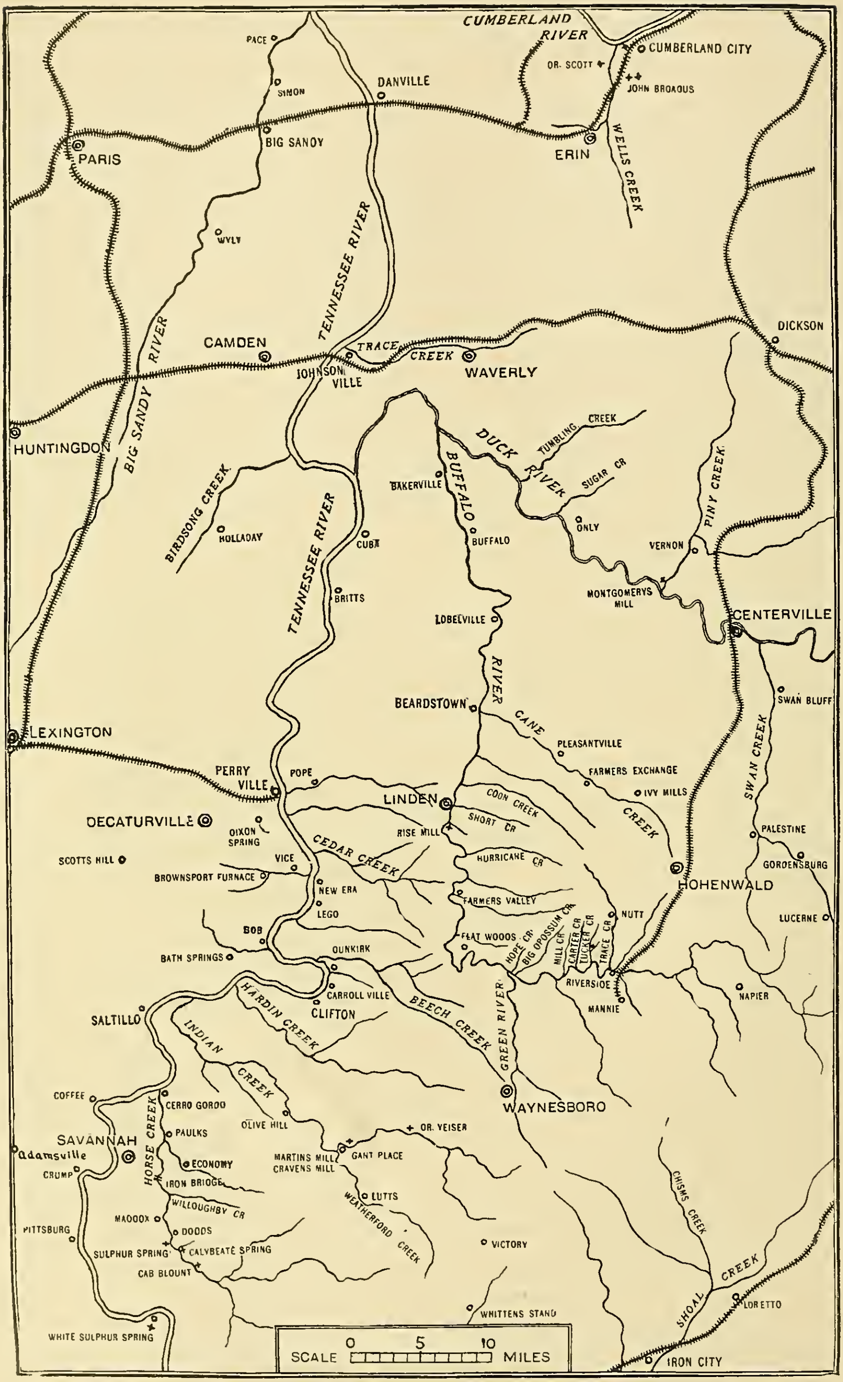
A. THE SUBDIVISIONS OF THE CINCINNATI GROUP IN OHIO.

In 1865 Meek and Worthen[1] proposed the name "Cincinnati group" for that part of the Ordovician which is exposed in Ohio.

In 1873 Professor Orton[2] divided the Ordovician of Ohio into three divisions. The middle division included all rocks exposed within the boundaries of the city of Cincinnati; its inferior limit was at low water of the Ohio river, its upper boundary was formed by the highest stratum found in the Cincinnati hills. This middle division was called by Professor Orton the *Cincinnati beds proper.* All rocks above the highest stratum exposed in the Cincinnati hills and below the lowermost beds of Silurian age (the Upper Silurian of the Ohio Survey and of most authors) were included in the upper division. The strata that form the summit of the Cincinnati hills are found also in the immediate vicinity of Lebanon. The base of the upper division is also well exposed here, and its fauna has been carefully studied by local collectors. Therefore the name *Lebanon beds* was given to the upper division, although the nearest outcrops of the top of the Lebanon beds are about seven miles north of Lebanon, and

[1] *Philadelphia Acad. Nat. Sci., Proc.,* Vol. XVII, p. 155.

[2] *Ohio Geol. Surv.,* Vol. I, pp. 370–73.


CUMBERLAND RIVER
CUMBERLAND CITY
DR. SCOTT
JOHN BROADUS
PACE
SIMON
DANVILLE
BIG SANDY
PARIS
ERIN
WELLS CREEK
WYLY
TENNESSEE RIVER
BIG SANDY RIVER
CAMDEN
TRACE CREEK
WAVERLY
DICKSON
JOHNSONVILLE
HUNTINGDON
BIRDSONG CREEK
HOLLADAY
DUCK RIVER
TUMBLING CREEK
SUGAR CR
BAKERVILLE
BUFFALO
BUFFALO RIVER
ONLY
PINY CREEK
VERNON
CUBA
BRITTS
MONTGOMERYS MILL
LOBELVILLE
CENTERVILLE
SWAN BLUFF
BEARDSTOWN
CANE CREEK
PLEASANTVILLE
LEXINGTON
FARMERS EXCHANGE
IVY MILLS
PERRY VILLE
POPE
LINDEN
SWAN CREEK
DECATURVILLE
DIXON SPRING
RISE MILL
COON CREEK
SHORT CR
PALESTINE
CEDAR CREEK
SCOTTS HILL
VICE
HURRICANE CR
HOHENWALD
GORDENSBURG
BROWNSPORT FURNACE
NEW ERA
LEGO
FARMERS VALLEY
NUTT
LUCERNE
BOB
FLAT WOODS
HOPE CR
BIG OPOSSUM CR
MILL CR
CARTER CR
TUCKER CR
TRACE CR
BATH SPRINGS
DUNKIRK
CARROLL VILLE
RIVERSIDE
MANNIE
NAPIER
SALTILLO
CLIFTON
HARDIN CREEK
BEECH CREEK
GREEN RIVER
INDIAN CREEK
COFFEE
CERRO GORDO
WAYNESBORO
SAVANNAH
Adamsville
PAULKS
OLIVE HILL
DR. VEISER
HORSE CREEK
ECONOMY
MARTINS MILL
CRAVENS MILL
GANT PLACE
CRUMP
IRON BRIDGE
CHISMS CREEK
WILLOUGHBY CR
LUTTS
WEATHERFORD CREEK
MADDOX
DODDS
PITTSBURG
SULPHUR SPRING
CALYBEATE SPRING
VICTORY
CAB BLOUNT
SHOAL CREEK
LORETTO
WHITTENS STAND
WHITE SULPHUR SPRING
SCALE 0 5 10 MILES
IRON CITY

the intervening section is poorly exposed. Those Ordovician rocks of Ohio which stratigraphically belong below those exposed at low-water mark in Cincinnati were included in the lower division. The best and clearest section of these rocks is seen near Point Pleasant, about twenty-five miles above Cincinnati, on the Ohio river. Although the upper boundary of the lower division cannot be readily determined with exactness at this locality, the rocks included within this division were called the *Point Pleasant beds*.

At present the term *Cincinnati group* no longer includes all of the Ordovician rocks exposed in Ohio. Since the Point Pleasant beds and the lower fifty feet of rock at Cincinnati have been identified as equivalent to the upper part of the Trenton, the term *Cincinnati group* has been restricted so as to include only the remainder of the *Cincinnati beds proper* and the *Lebanon beds* of Orton.

In 1897 Winchell and Ulrich[1] divided the *Cincinnati beds proper* of Orton into two divisions, identifying the lower with the *Utica*[2] of New York, and the upper with the *Lorraine*. For the term *Lebanon beds* they substituted the term *Richmond group*, since the name *Lebanon* had been used by Professor Safford for a formation included in the Trenton group of Tennessee, before Professor Orton applied it to his upper division of the Cincinnati group. No sections are described, but at Cincinnati the Utica is said to be over 250 feet thick, and the Lorraine about 200 feet. The line between the Utica and Lorraine is sufficiently well established, to anyone acquainted with the Cincinnati section, by the statement that at the base of the Lorraine there are some arenaceous layers that on weathering frequently preserve the fossils as casts, and that above these there are numerous layers of crystalline limestone, three to ten inches in thickness, separated by relatively thin bands of shale. The line of division between the Utica and Lorraine is evidently the same as that between beds XI and XII of Ulrich.[3]

[1] *Minnesota Geol. and Nat. Hist. Surv., Final Rept.*, Vol. III, Part II, p. ci.

[2] Ulrich, "Correlation of Lower Silurian Horizons," *Am. Geol.*, Vol. I (1888), p. 315.

Ibid., Vol. II, p. 41

In 1896 Harper and Bassler[1] adopted the division of the Cincinnati group made by Winchell and Ulrich in the preceding paper, written at an earlier date but still unpublished. The Lorraine is said to be terminated above by a widely distributed bed containing rolled fragments and entire specimens of the large form of *Platystrophia lynx* in great abundance. The Richmond group comprises the overlying part of the Cincinnati group and is, therefore, the exact equivalent of the Lebanon beds of Orton.

In 1900 Nickles and Bassler[2] adopted the division of the Cincinnati group into the Utica, Lorraine, and Richmond. Their lists of fossil bryozoa established still more definitely the line between the Utica and the Lorraine, as identified by Ulrich. The line between the Lorraine and the Richmond is apparently still the same as that between the Cincinnati beds proper and the Lebanon beds of Professor Orton.

In 1902 J. M. Nickles[3] referred the lower 80 feet of the Lebanon beds of Orton to the Lorraine, thus increasing the section to be identified as Lorraine and diminishing the section to be included in the Richmond. The strata including the thin *Dinorthis retrorsa* bed are for the first time definitely[4] excluded from the Richmond. The base of the Richmond was placed just beneath the lowest beds containing *Strophomena rugosa* (the *Strophomena planumbona* of the Ohio Survey), *Rhynchotrema capax*, *Dalmanella jugosa* and *Streptelasma rusticum* (the *Stroptelasma corniculum* of the Ohio Survey. The Lorraine of Ohio, as extended by Nickles, was then subdivided into six sets of beds, called, in descending order: the Warren beds, 80 feet thick; Mount Auburn beds, 20 feet; Corryville beds, 60 feet; Bellevue beds, 20 feet; Fairmount beds, 80 feet; and the Mount Hope beds, 50 feet. The Warren beds include those formerly referred to the Lebanon beds by Orton, but transferred to the Lorraine by Nickles. The Mount Auburn beds include the highest strata

[1] *Catalogue of Fossils in Vicinity of Cincinnati, O.* Private publication.

[2] "Synopsis of American Fossil Bryozoa," *Bulletin U. S. Geol. Surv.*, No. 173.

[3] "The Geology of Cincinnati," *Jour. Cincinnati Sec. Nat. Hist.*, Vol. XX, No. 2.

[4] ULRICH, "Correlation of Lower Silurian Horizons," *Am. Geol.*, Vol. II (1888), p. 41.

exposed in the Cincinnati hills. They are also known as the *Platystrophia lynx* beds, on account of the great abundance of a characteristic variety of this fossil which attains a large size and has a short hinge line. Both the Warren and the Mount Auburn beds are well exposed north of Lebanon, O. The Fairmount beds are well exposed immediately west of the river at Hamilton.

Mr. J. M. Nickles determined the thickness of the Utica to be 260 feet at Cincinnati, and the thickness of the Lorraine at the same locality as 310 feet. The thickness of the Richmond was stated to be between 200 and 300 feet, the locality not being mentioned. At the more northern exposures in Indiana its thickness appears to be 240 feet, according to measurements by the present writer.

Judging from exposures in Nelson and Washington counties in central Kentucky, and from outcrops along the Cumberland river in southern Kentucky, the Lorraine becomes thinner southward. The rate of thinning, however, is much less than that of the Richmond in the same distance. In Marion county in central Kentucky the Richmond does not exceed 35 feet. Along Fishing creek,[1] a tributary of the Cumberland river, the Richmond is at least 27 feet thick.

B. THE CINCINNATI GROUP IN THE TENNESSEE RIVER VALLEY.

The Utica, Lorraine, and Richmond groups may be identified also in Southwestern Tennessee, along the Tennessee river and some of its tributaries.

1. *The Saltillo Limestone*.—The Utica consists of fine-grained, gray or bluish-gray limestone layers, from 2 to 5 inches thick, interbedded with equal thicknesses of shaly clay. At Clifton, on the Tennessee river, attempts were made before the war to burn it into a cement; it is, therefore, referred to by Professor Safford[2] as the hydraulic limestone. He estimates its thickness at Clifton as 70 feet down to low water, its base not being exposed at any point in the Tennessee river valley in western Tennessee.

[1] "The Cincinnati Anticline in Southern Kentucky," *Am. Geol.*, December, 1902.

[2] *Geology of Tennessee*, 1869.

The limestone is exposed also twelve miles eastward, three and one-half miles northwest of Waynesboro, near the home of W. D. Helton on Beech creek; here it is overlaid by the limestone forming the base of the Richmond group. It occurs off and on down Beech creek as far as its junction with Little Beech creek, and is exposed also along the road from Waynesboro to Clifton, a short distance west of the home of W. D. McAnally, near the crossing of Eagle creek, three miles east of Clifton.

The most southern exposure occurs about twenty miles southwest of Clifton, at the mill variously known as the Maddox, Welch, or Old Graham mill, located on Horse creek. Here only the upper fifteen feet of the limestone is exposed, overlaid by a few inches of clayey material belonging to the Richmond. The Utica is the only Ordovician rock exposed along Willoughby creek from its mouth at Lick Ford, for several miles up stream. It occurs along the lower parts of Indian and Hardin creeks. The most western outcrop is located on Miles creek, one mile south of Saltillo, at the site of an old mill, a quarter of a mile above the mouth of the creek.

The typical section occurs at Clifton, on the Tennessee river; however, since the name Clifton has already been applied by Professor Safford to the Silurian of Tennessee, the name *Saltillo* has been chosen.

The Saltillo limestone contains comparatively few species of fossils, and most of these are not abundant. The most widely distributed species is a variety of *Dalmanella emacerata*,[1] 20^{mm} in width, which is abundant at Clifton and on Beech creek, northwest of Waynesboro. There is also a smaller variety of Dalmanella at Clifton, with coarser plications, identified as *Dalmanella multisecta*.[2]

In addition to the Dalmanellas named, the following fossils have been found in the Saltillo limestone at Clifton. *Zygospira modesta* is very abundant in several layers near the top of the limestone. A globular sponge with acicular spicules is very abundant in one of the lower layers; it is probably a species of

[1] *Pal. New York*, Vol. VIII, Plate V *c*, Fig. 2.

[2] *Pal. Olivo*, Vol. I, Plate VIII, Fig. 1, *a*, *b*, *c*.

Hindia related to *Hindia gregaria.* In some layers a brachiopod, identified as *Leptobolus insignis*, is abundant and well preserved. This fossil occurs at Cincinnati only in the lower third of the Utica, and it is the presence of *Leptobolus insignis* and *Delmanella emacerata* in the Saltillo limestone which has led to its identification as equivalent to the Utica.

In the Wells creek basin, along the railroad southwest of Cumberland City, in northwestern Tennessee, a series of limestones interbedded with shaly clays occur which lithologically resemble the Saltillo limestone of southern Tennessee. A slight resemblance is shown also by that part of the Cape Girardeau limestone which is interbedded with shaly clay. The top of the Cape Girardeau limestone belongs to the Silurian. The fossils so far collected from the Ordovician part of the Cape Girardeau limestone indicate merely an age corresponding to the lower part of the Cincinnati group, but whether they are Utica or Lorraine cannot be determined with the evidence at hand. The Richmond group appears to occur in Jefferson, Warren, and Pike counties, in Missouri, judging from the presence of *Dinorthis subquadrata*, *Platystrophia acutilirata*, and *Strophomena planumbona*.[1] While Richmond group fossils are listed from localities farther south, along the Mississippi, nearer to Cape Girardeau, they are listed together with other fossils which are certainly not of Richmond age, suggesting a possibility of incorrect determination.

2. *The Warren limestone.*—If the occurrence of *Leptobolus insignis* is sufficient to refer the Saltillo limestone to the Utica, then the Lorraine has a very limited geographical extent in the Tennessee river valley. At Clifton, above the landing, the northeastern end of the outcrop of Lorraine has a thickness of three feet four inches. At the old cement mill at the southwestern end of town, its thickness is only a few inches. The Lorraine has not yet been detected elsewhere. This is rather surprising, since Mr. J. M. Nickles states that at Columbia, sixty miles east of Clifton, Mount Parnassus is a noted locality for Lorraine fos-

[1] *Missouri Geol. Surv.*, Vol. V, 1894; also SHUMARD, *Reports* for 1855–71, and SWALLOW, *Reports* 1 and 2, 1855.

sils,[1] and the section there is considerable.[2] The Lorraine at Clifton consists of gray or bluish-gray, coarse-grained limestone which may be readily distinguished from the Richmond limestone immediately above by the presence of considerable chert. It is very fossiliferous, but the fossils must be broken out of the rock and do not form good cabinet specimens.

The most common and at the same time most characteristic fossil is *Dinorthis retrorsa.* In Ohio and Indiana this fossil has a very limited vertical range, being confined to a bed, rarely exceeding one or two feet in thickness, near the top of the Lorraine. This bed is included in the subdivision to which Mr. Nickles gave the name "Warren bed." The Lorraine bed at Clifton, here described, is therefore identified as the Warren limestone.

Another rather abundant species is a form of *Rhynchotrema dentatum* which differs from that found in the Richmond in the possession of three distinct plications and one indistinct plication on either side of the dorsal fold instead of four distinct and one or two indistinct plications, as in the Richmond group. In consequence, the plications appear more angular. This form occurs also at the top of the Lorraine half a mile southwest of Howards mill, in Montgomery county, Ky.

Leptæna rhomboidalis is fairly common. This species occurs associated with *Dinorthis retrorsa* also at the base of the Morris Hill section, in the hollow directly west of the mouth of Cæsar's creek, in Warren county, O.

A Dalmanella, belonging to the group of *D. testudinaria*, is very common. The dorsal valve is flat and has a distinct mesial depression, extending from the beak to the anterior margin. The plications bifurcate two or three times. It resembles most the form identified in Indiana and Ohio as *Dalmanella jugosa*[3], and differs chiefly in having a flat dorsal valve and coarser plications. The typical forms of *Dalmanella jugosa*, on the contrary, have a moderately convex dorsal valve. Both forms are common at the

[1] *The Geology of Cincinnati*, p. 74.

[2] SAFFORD, *The Geology of Tennessee*, p. 265.

[3] HARPER AND BASSLER, 1896, *Catalogue of Fossils of Cincinnati*, p. 16; NICKLES, 1902, *Geology of Cincinnati*, p. 92.

base of the Richmond in Indiana, Ohio, and northeastern Kentucky, and at some of the more northern localities they occur also at the top of the Lorraine, but usually in much smaller numbers. In fact, the base of the Richmond in Indiana and Ohio and northeastern Kentucky is usually indicated by the presence of several thick layers of limestone, often wave-marked, and a first appearance or sudden increase of *Dalmanella jugosa* and of its related form.

A large form of *Cyclonema bilix*, having a vertical height of fully one inch, is not rare. It appears most closely related to the typical forms as illustrated by Ulrich.[1]

Helcionopsis striata is represented by a single specimen, showing the characteristic markings on the surface. The specimen is, however, only 14^{mm} long. The type specimen[2] was found in "the upper beds of the Cincinnati formation, Marion county, Ky." Since the thickness of the Richmond formation in this county does not exceed 35 feet, it is very probable that the type specimen also came from the upper part of the Lorraine.

Columnaria stellata (*Columnaria alveolata* as identified by Nicholson)[3] is represented by a single specimen, showing alternately larger and smaller septa, the larger extending nearly or quite to the center of the visceral chamber.

3. *Richmond limestone*.—Immediately above the Warren bed, at Clifton, there are nineteen feet of Richmond limestone. The lower and middle part is coarse-grained, often cross-bedded, has a lighter color, and contains very few fossils. The upper part is more clayey and finer grained, forming a transition to the Richmond shaly clays immediately above. The top of the coarse-grained limestone and the clayey limestone above contains a greater number of fossils, but these are usually imbedded in the rock and cannot be secured without a considerable expenditure of time.

The identification of this limestone as Richmond is based upon the presence of a single specimen of *Rhynchotrema capax*

[1] *Minnesota Geol. Surv.*, Vol. III, Part II, Pl. LXXVII, Fig. 35.

[2] *Ibid.*, p. 827.

[3] *Pal. Province of Ontario*, 1875; also, *Paleozoic Tabulate Corals*, 1879.

at the base of the limestone near the old abandoned cement mill at the southwestern end of the town, and of a specimen of *Strophomena planodorsata*.

The form of *Rhynchotrema capax* found at the base of this limestone is much more abundant at the top of the limestone and in the overlying Richmond clay; it is most numerous near the top of the clay, one specimen being found even included in the Clinton rock, half an inch above its base. This form differs from the Rhynchotrema capax of the Richmond of Ohio, Indiana, and Kentucky, chiefly in size. It is smaller; the largest and most obese specimen so far found does not exceed 20^{mm} in thickness and 16^{mm} in width. It is also more narrow, and while the typical specimens from the Richmond of Indiana and Ohio have five distinct plications on either side of the fold of the dorsal valve, the Tennessee specimens here described have seven, and occasionally even eight, plications. The internal markings are the same. It may be called *Rhynchotrema capax manniensis*.

The dorsal valve of *Strophomena planodorsata*[1] is slightly concave over an area exceeding half the length of the shell, and has a flat appearance over an area equaling two-thirds of its length. The striæ are even finer than those figured by Winchell and Schuchert. One specimen occurred nine and one-half feet above the base of the Richmond limestone and others were found near the top. *Rafinesquina alternata*, *Plectambonites sericeus*, and *Hebertella sinuata* also occur.

The most interesting fossil is a species of *Lingulops* belonging to the subgenus typified by *Lingulops granti*,[2] a Silurian species from Hamilton, Ontario. It agrees in having the muscular area of the pedicle valve developed into a well-defined platform the anterior edge of which is not prolonged into a septum. Its length is 6^{mm}. The median impression between the central muscular scars is relatively more narrow; the platform does not extend as far toward the beak; the position of the pedicle may be recognized. The name *Lingulops cliftonensis* is suggested.

[1] *Minnesota Geol. Surv.*, Vol. III, Part I, p. 393.

[2] *Pal. New York*, Vol. VIII, Part I, Pl. IV K, Fig. 15.

Richmond limestone is also exposed a short distance up stream from the home of W. D. Helton, on Beech creek, northwest of Waynesboro. It is seven feet thick, is rather coarse-grained, varies in color from light brown to bluish-gray, and is fossiliferous.

Among these fossils are the forms identified as *Strophomena planodorsata; Rafinesquina alternata;* a large *Cyclonema bilix* similar in form to that found in the Warren bed at Clifton, but having a vertical height of 36^{mm}; and a form of Dalmanella with a moderately convex dorsal valve, evidently related to *Delmanella jugosa* as found in the Richmond of Ohio and Indiana.

4. *The Mannie shale, or shaly clay.*— Immediately above the Richmond limestone, at Clifton, there is 15½ feet of brownish and bluish shaly Richmond clay. It contains *Rafinesquina alternata, Plectambonites sericeus,* and *Rhynchotrema capax manniensis.* A single specimen of *Dinorthis subquadrata* was found imbedded in the Clinton, one inch above its base. The characteristic muscular area is exposed. The plications are somewhat finer and more numerous than in the Richmond of Ohio, Indiana, and Kentucky. The presence of *Rhynchotrema capax manniensis* in the base of the Clinton has been noted already. They are simply Richmond specimens loosened from the clay beneath and mingled by the wash of Clinton seas with living Clinton forms.

Northwest of Waynesboro, on Beech creek, near the home of W. D. Helton, the 20 to 25 feet of section between the Richmond limestone and the Clinton, not exposed, probably consist of Richmond clay.

The upper part of the Richmond clay is seen beneath the Clinton just north of the west end of the railroad bridge across the Buffalo river northwest of Riverside, a mile and a half north of Mannie or Allens creek. Six feet is exposed; unfossiliferous.

About three-quarters of a mile west of Riverside, west of Mr. Howard's home on the road to Flat Woods, east of the mouth of Trace creek, the Richmond shaly clay is exposed on the north side of the road. The exposure is 33½ feet thick; the base of clay is not seen. The lower 11 feet of the section consists of fossiliferous weathered clayey rock; the fossils are found chiefly in the upper half of this rock. Above this are 8 feet of weathered clayey limestone in which fossils are very few. This is overlaid by 14½ feet of clay, apparently unfossiliferous at this locality. The name "Mannie shale" is suggested for the shaly clay which forms the upper part of the Richmond in western Tennessee.

The most common fossil is *Rhynchotrema capax manniensis.* A form identified as *Dalmanella jugosa* is also abundant. A single pedicle valve of *Strophomena rugosa* (*Strophomena planumbona* of the Ohio Survey) was found, exposing the interior, also a single dorsal valve of the form identified as *Strophomena planodorsata. Platystrophia cypha* is not rare. The largest specimen is 37^{mm} wide, the postero-lateral angles equal about 65°, the fold of the brachial valve is occupied by four plications, and on each side of the fold there are about twelve lateral plications. In Ohio and Indiana this form extends from the upper part of the Lorraine to the top of the Richmond. *Platystrophia acutilirata* may be regarded as the most aberrant variation. One specimen of *Platystrophia crassa* was found, and one of *Plectambonites sericeus.* The most interesting specimen, however, is a single specimen of *Lingulasma*[1] preserving the characteristic ornamentation of the surface, and showing enough of the interior structure to suggest its generic relationship, but it is too poorly preserved to warrant a more specific description. It is about half as large as the species hitherto described.

North of Clifton, both the Richmond limestone and the Richmond clay may be traced for a considerable distance along the Tennessee river. Southward, the Richmond thins out rapidly. At the Maddox mill, on Horse creek, a few inches of clayey material intervenes between the top of the Saltillo limestone and the base of the Clinton. In this clay was found a specimen which is identical with *Helcionopsis striata* in form, but it does not preserve the surface striæ, being evidently an internal cast. Its length is 21 mm. There is also a single specimen of *Rhynchotrema capax manniensis*, and of *Leptaena rhomboidalis.* Possibly

[1] *Pal. New York,* Vol. VIII, Part I, Pl. II; also, *Minnesota Geol. Surv.*, Vol. III, Part I, Pl. XXX.

this clay represents residual material both from the Warren limestone and from the Richmond beds It is impossible to determine from the evidence at hand. There is no doubt, however, of the thinning out both of the Warren bed and of the two members of the Richmond group southwestward, on approaching the southern part of Hardin county.

C. THE CINCINNATI GROUP BETWEEN THE TENNESSEE RIVER VALLEY AND THE CENTRAL BASIN.

It should be noticed in this connection that the Clinton also thins out southwestward. At Newsom it is 30 feet thick. At Centreville 20 feet of Clinton is exposed and the base is not seen; it may therefore approach 30 feet in thickness. However, at Riverside, north of the railroad bridge, the thickness of the Clinton is only 5 feet 9 inches, and it consists of strongly cross-bedded limestone. At Dunkirk, about three miles below Clifton, its thickness is 3 feet 9 inches. At Clifton it does not exceed one foot. South of Clifton it has not been recognized. If it occurs at Maddox mill, it cannot be distinguished from the Osgood limestone at that point.

5. *The Leipers creek limestone.*— About thirty-two miles northeast of Riverside, along Leipers creek, Richmond limestone is well exposed. It occurs two and one-fourth miles south of Fly, near the top of the bluff north of the home of J. M. Gardner; also a quarter of a mile north of Fly, in the bed of the creek, and for some distance along the branch of Leipers creek which passes the homes of Carol Litton and Tom Fox, near the old *Oil Well.* The limestone varies from 6 to 9 feet in thickness, is coarse-grained, often crinoidal, and frequently has a salmon-brown color. It contains a species of Strophomena regarded by Mr. Charles Schuchert as closely related to *Strophomena Wisconsinensis*, as far as could be determined without seeing the interiors; also forms resembling *Strophomena rugosa*, and the form identified as *Strophomena planodorsata.* To this Richmond limestone the name *Leipers creek limestone*[1] has been given.

Overlying the limestone is a clay shale which corresponds

[1] "Silurian and Devonian Limestones of Tennessee and Kentucky," *Bull. Geol. Soc. Am.*, Vol. XII (1901).

stratigraphically with the *Mannie shale.* Above the limestone at the J. M. Gardner locality it contains *Rhynchotrema capax manniensis.* A quarter of a mile northeast of Fly, beyond the home of R. S. Elam, the bed is 6 feet thick, and contains about 1 foot of poor shaly limestone 1 foot above the base. In the shale and in the interbedded shaly limestone are found *Orthis proavita; Dinorthis subquadrata;* a form of *Hebertella insculpta* with finer striæ, and with a deeper median depression in the dorsal valve than is usual in Ohio specimens ; a typical specimen of *Platystrophia acutilirata;* typical specimens of *Strophomena neglecta;* and specimens of Rafinesquina which belong to the group of *Rafinesquina minnesotensis inquassa*, showing distinctly the median septum and less distinctly the lateral septa characteristic of the dorsal valve. A very large form of *Hebertella occidentalis*, often 50^{mm} wide, occurs both at the Elam locality and in the 4 feet of clay which overlies the Leipers creek limestone north of the home of Tom Fox. At some localities the clay is absent.

The Leipers creek bed crops out again ten miles north of the Tom Fox locality, along the valley of the South Harpeth creek. It is still a coarse-grained limestone, usually crinoidal, but its color is bluish, with small brownish spots. Its thickness is also about the same, varying from 5 to 9 feet. It occurs in the creek bed south of Fernvale; one mile southeast of Fernvale on the road to Leipers Fork post-office, at the home of Mrs. Annie Inman; at the schoolhouse two miles north of Fernvale; north of the mouth of the branch entering South Harpeth creek a quarter of a mile south of the home of Jim Linton, Sr.; and apparently also back of the home of W. M. Forehand, half a mile west of Tank.

At the first two localities the limestone is directly overlaid by the Chattanooga black shale (Devonian). At the other localities it is overlaid by Richmond clayey shale, equivalent to the Mannie shale. The thickness of the Richmond shale does not exceed 10 feet at any locality visited.

At the Inman locality the limestone contains *Dinorthis subquadrata*, and a species of *Strophomena.* At the schoolhouse north of Fernvale, the limestone contains *Orthis proavita*, *Dinorthis subquadrata*, *Hebertella insculpta*, and *Strophomena rugosa subtenta*. The clay shale immediately above the limestone appears to be unfossiliferous.

Richmond limestone is exposed three miles north of the Forehand locality, along the banks of the Harpeth river, at Newsom. It is a coarse-grained limestone, varying from bluish to light brown, and at least 10 feet thick. Its age is indicated by the presence of a single ventral valve of *Dinorthis subquadrata*, showing the muscular scar. The unexposed part of the section, between the Richmond limestone and the base of the Clinton, may be occupied by Richmond clay.

The most northern exposure of Richmond limestone, equivalent stratigraphically to the Leipers creek limestone, occurs at Baker, twenty-three miles northeast of Newsom. Here it is four feet thick, is a coarse-grained limestone, and contains *Strophomena Wisconsinensis*, or at least a form closely resembling this species in general appearance. No Richmond shale was noticed.

6. *Swan Creek Limestone.*—At Newsom the coarse-grained limestone is underlaid by clayey rock which contains numerous specimens of the form identified in Ohio and Indiana as *Dalmanella jugosa;* it there extends from the upper beds of the Lorraine through the lower part of the Richmond; the dorsal valve is slightly convex. Four typical specimens of *Rhynchotrema dentatum* were found. The presence of a single specimen of *Platystrophia lynx* with a short hinge line suggests the Lorraine age of this rock. The thickness of the clayey rock is not known, only a few feet being exposed above the level of the river.

Platystrophia lynx was also noted below the Leipers creek bed at the Inman locality, a mile southeast of Fernvale.

At the J. M. Gardner locality the Leipers creek limestone is underlaid by a considerable thickness of more or less cross-bedded limestone containing very few fossils, and this in turn is underlaid by clayey limestones in which fossils are numerous.

All along the Swan Creek valley, cross-bedded Ordovician limestone containing very few fossils is very well exposed. At the spring, a quarter of a mile south of Swan Bluff, it measures about fifty-six feet, and is underlaid by the richly fossiliferous, more clayey layers, containing *Platystrophia lynx*. It also occurs up the valley along the railroad south of Centreville, To this cross-bedded, nearly unfossiliferous, Ordovician limestone the name "Swan creek limestone" is here given. Judging from the exposures at Swan Bluff and at the J. M. Gardner locality, it is of Lorraine age, probably below the *Dinorthis retrorsa* horizon.

At the quarry, a sixth of a mile up the hollow, east of the home of J. D. Dean, this cross-bedded limestone has disintegrated into a brownish mass which has been quarried as brown phosphate. The cross-bedded limestone which occurs at Clifton, and which has there been identified as Richmond, has also disintegrated into a brown phosphate rock immediately below the old cement mill at the southwestern end of the town. It appears, therefore, that waters sufficiently turbulent to produce cross-bedding were present during the deposition of both the upper Lorraine and of the lower part of the Richmond in western Tennessee. The Leipers creek bed is often cross-bedded, as well as coarse-grained. Between the cross-bedded Swan creek limestone and the coarse-grained Leipers creek limestone, a thin section of clayey rock, apparently of Lorraine age, intervenes in places. This is probably the position of the clayey rock at the base of the section at Newsom.

D. CONCLUSIONS.

According to the preceding observations, the Ordovician exposures in the valleys of the Tennessee river, the Buffalo river, Swan creek, Leipers creek, and South Harpeth creek suggest the following lithologic succession, in descending order:

Cincinnati Group.	Richmond	Mannie shale.
		Leipers creek limestone.
	Lorraine	Warren limestone; clay rock at Newsom.
		Swan creek limestone.
		Richly fossiliferous Lorraine limestone in the eastern part of the area studied, containing *Platystrophia lynx*.
	Utica	Saltillo limestone.

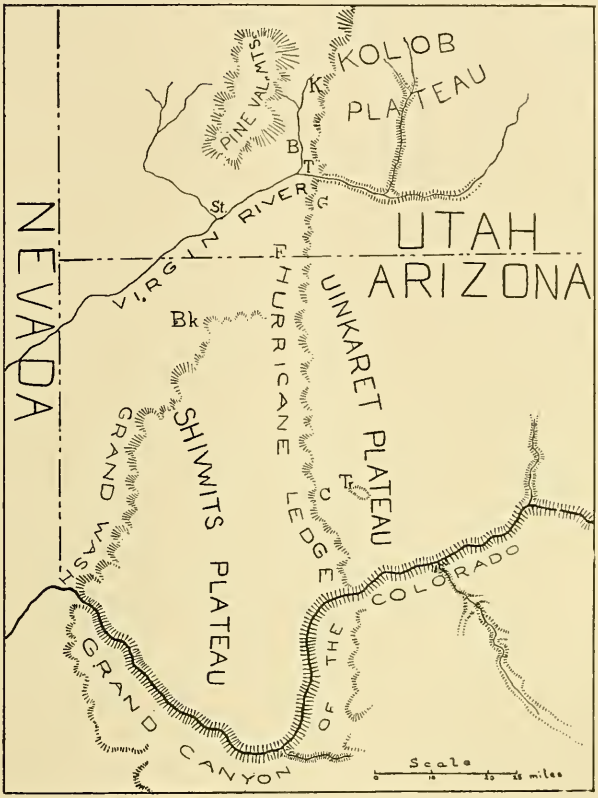
The Lorraine appears to become thinner west of the Cincinnati anticline, so as to be represented by thinner sections or so as to be entirely absent along the Mississippi in Missouri and adjacent Illinois, in the Wells creek basin in northern Tennessee, and along the Tennessee river in southern Tennessee. The Richmond also appears to become thinner west of the northern half of the Cincinnati anticline. It becomes thinner also southward along the flanks of the anticline. In some parts of Tennessee it is entirely absent along the western flank of the anticline. West of the southern half of the anticline, in Tennessee, the thickness of the Richmond appears to vary irregularly. It has not been detected in the Wells creek basin. A thicker clay section than usual is seen west of Riverside. Both the limestone and clay are thicker at Clifton than at most points nearer the anticline. In the southern part of Hardin county, the Richmond thins out to a few inches. If the identification of the Saltillo limestone as lower Utica, and of the overlying limestone at Clifton as the Warren bed, is correct, a very considerable interval of erosion occurred during the middle of the Cincinnati age in western Tennessee.

AUG. F. FOERSTE.

THE HURRICANE FAULT IN SOUTHWESTERN UTAH.

TABLE OF CONTENTS.

DURING the summer of 1902 the writers, under the direction of Professor William M. Davis, of Harvard University, made a study of the region around Toquerville, in the southwestern corner of Utah, on the line between the High Plateau province and the Basin Range province. Some stratigraphic work was done, and an area of about two hundred square miles was mapped. The main interest, however, centered in the relative age of the two displacements by which the plateaus of the Colorado river were elevated above the region of the Basin Ranges, and by the last of which the cutting of the Grand Canyon was inaugurated. These displacements were studied for about a hundred miles, from a point near Kanarra, twenty-five miles north of Toquerville, to the Colorado river. The older one runs almost directly south from Kanarra to the Colorado, along the Hurricane Ledge; the younger follows nearly the same course, but at the Arizona line all except a small branch turns west along a monocline and finally joins the Grand Wash fault. In this paper we shall give in outline the history of the two displacements, reserving details of evidence and references to the work of earlier observers for a more complete report which will be published later.



Sketch-Map of part of the region traversed by the Hurricane Fault.

K—Kanarra.
B—Bellevue.
T—Toquerville.
G—Gould's Ranch.
St—St. George.
F—Fort Pierce.
Bk—Black Rock Spring.
Tr—Mt. Trumbull.
C—Coal Spring.

FIG. 1.

THE SEDIMENTARY ROCK SERIES.

The scarcity of known fossil horizons in the rocks of the High Plateau region led Dutton to divide that part of the conformable series between the known Carboniferous and the known Cretaceous into three formations on the basis of color and texture and a somewhat doubtful correlation with formations in neighboring provinces. To these lithological divisions he assigned the time-names "Permian," "Trias," and "Jura." Since, therefore, these names given by Dutton apply to arbitrary divisions instead of formations known to represent the three geological periods, Permian, Triassic, and Jurassic, we prefer not to adopt them, but to use only local names for those formations whose exact age is questionable, retaining the one already in use—Shinarump—and applying new names to others of the series, as shown in the following table:

Eocene Tertiary	Conglomerate pink sandstone and limestone.	
Cretaceous	Yellow sandstones and shales.	
Jurassic (of Dutton)	White sandstone	Colob.
Triassic (of Dutton)	Red sandstone	Upper Kanab.
	Red sandstone and shales	Lower Kanab.
	Conglomerate	Shinarump.
Permian (of Dutton)	Chocolate sandstone Red and white shales Red shales.	Upper Verkin.
	Gray sandstones and shales Red shales	Lower Verkin.
Carboniferous	Variegated shales and cherty limestone	Super-Aubrey.
	Gray limestone	Aubrey.

SEQUENCE OF EVENTS IN THE TOQUERVILLE DISTRICT SINCE THE EOCENE PERIOD.

From Carboniferous to Eocene time, the history of the region is one of essentially continuous deposition, during which sediments accumulated in an almost unbroken series to a thickness of more than 7,000 feet. In contrast to this long period of accumulation, the post-Eocene history is one of vast changes—of tectonic movements that preceded and accompanied the Colorado Plateau uplift, of volcanic activity, and of profound erosion

—all of which will be briefly described below. The sequence is as follows:

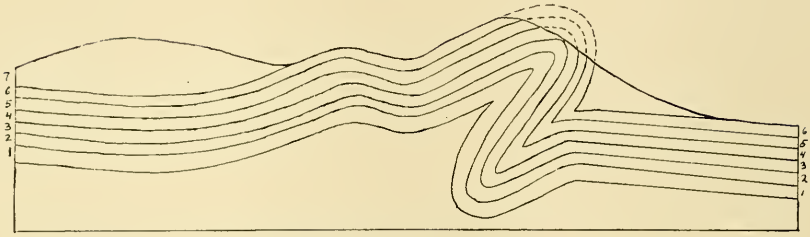
(A) Early deformation and volcanic eruptions.
(B) The first Hurricane faulting.
(C) The inter-fault or plateau cycle of erosion, ending with basalt eruptions.
(D) The latter faulting.
(E) The post-fault or canyon cycle of erosion.

DEFORMATION AND VOLCANIC ERUPTIONS.

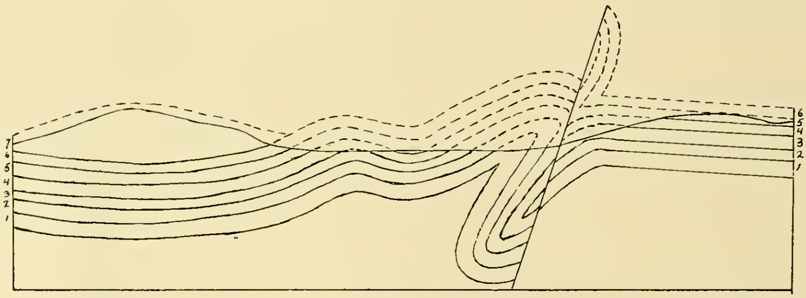
a) *Earlier folding.*—The earlier disturbance of the strata in the plateau province after their long period of quiet accumulation resulted in a number of gentle folds and flexures with slightly curved axes trending roughly north and south. In the eastern regions, according to Dutton, these were monoclinal flexures with a dip to the east by which a series of great steps was formed descending from the then relatively high Basin Range province to the lower Plateau province. In the Toquerville district the folds became intensified and took the form of well-arched anticlines and synclines. Among these more marked folds, we are chiefly concerned with the most western—a shallow syncline in which lies what now remains of the andesite mass of the Pine Valley mountains, and the most eastern—a sharp anticline that lies along the boundary between the Plateau province of relatively level strata interrupted only by the gentle monoclines, and the broken Basin Range province. South of Toquerville the sharp anticline faded out into a gentle eastward-dipping monocline, while to the north the intensity of folding increased, so that the anticline was steepened and finally at Kanarra completely overturned. The formation of these sharp folds seems to have been due to an east-and-west tangential pressure whose effects are confined to the immediate vicinity of the Pine Valley mountains.

b) *Andesite eruptions.*—The mass of the Pine Valley mountains, 3,000 to 4,000 feet thick, and twenty to thirty miles long, is composed of a heavy sheet of andesite, called by the earlier geologists a "trachyte." Wherever its base is seen, the lava lies upon a surface of Tertiary strata which seems to have suf-

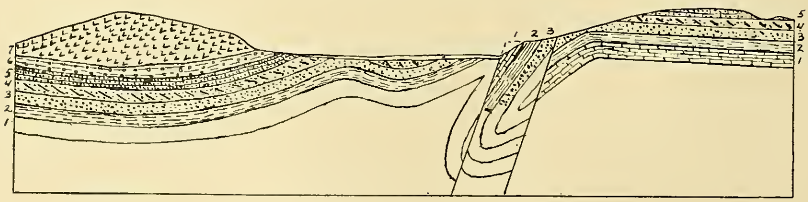
FIG. 2.



A.—Ideal section after the early folding.



B.—Restoration of section at the end of the inter-fault cycle of erosion. The dotted lines represent the sections at the beginning of the inter-fault cycle.

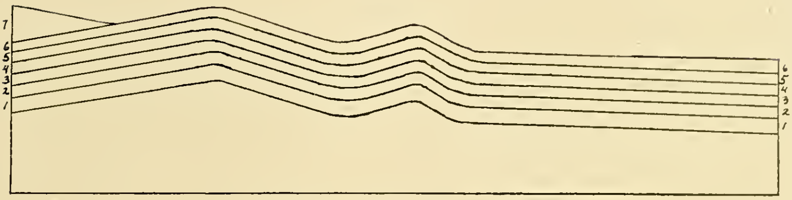


C.—Section representing present conditions.

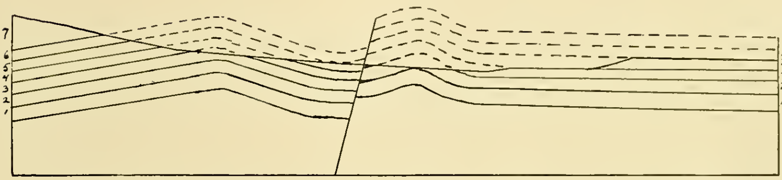
1. Aubrey limestone.	4. Colob sandstone.	7. Andesite.
2. Verkin shales.	5. Cretaceous.	8. Basalt.
3. Kanab sandstone.	6. Tertiary.	9. Alluvium.

CROSS-SECTION OF THE HURRICANE FAULT, NEAR KANARRA, LOOKING NORTH.

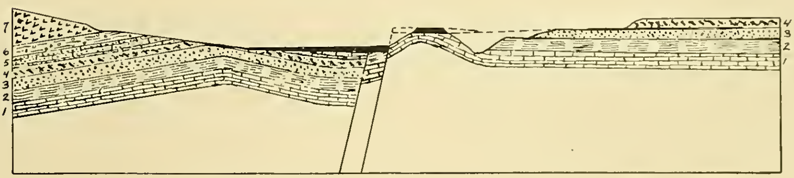
FIG. 3.



A.—Ideal section after the early folding.



B.—Restoration of section at the end of the inter-fault cycle of erosion. The dotted lines represent the sections at the beginning of the inter-fault cycle.

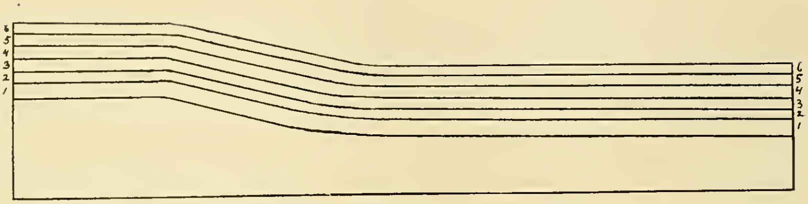


C.—Section representing present conditions.

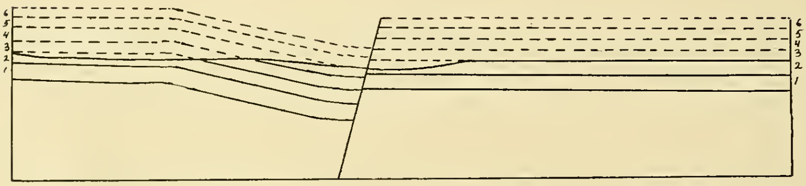
1. Aubrey limestone.	4. Colob sandstone.	7. Andesite.
2. Verkin shales.	5. Cretaceous.	8. Basalt.
3. Kanab sandstone.	6. Tertiary.	9. Alluvium.

CROSS-SECTION OF THE HURRICANE FAULT, NEAR BELLEVUE, LOOKING NORTH.

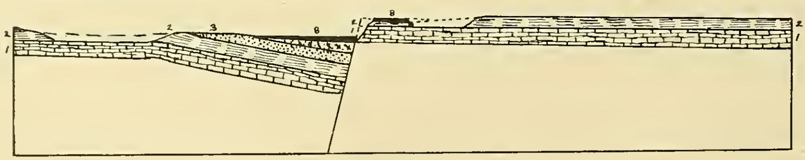
FIG. 4.



A.—Ideal section after the early folding.



B. Restoration of section at the end of the inter-fault cycle of erosion. The dotted lines represent the sections at the beginning of the inter-fault cycle.



C.—Section representing present conditious.

1. Aubrey limestone.
2. Verkin shales.
3. Kanab sandstone.
4. Colob sandstone.
5. Cretaceous.
6. Tertiary.
7. Andesite.
8. Basalt.
9. Alluvium.

CROSS-SECTION OF THE HURRICANE FAULT, NEAR GOULD'S RANCH, LOOKING NORTH.

fered little or no erosion; hence it must have been poured out before the country had been elevated above the sea long enough to allow extensive erosion—probably long before the completion of the folding.

THE HURRICANE FAULT—THE EARLIER FAULTING.

After the folding had been completed, the tangential pressure must have been relieved and a strain of another character set up. Instead of compression there seems to have been extension, whereby numerous faults were formed which followed the lines of the old folds, but moved the strata in exactly the opposite direction, so that a new series of steps descended toward the west, and the Basin Range province stood lower, relative to the Plateau province. It is noticeable that the greatest fault took place along the line of the greatest fold, and like it increased from south to north. This Hurricane fault has been traced for fully two hundred miles. For the greater part of the hundred miles which we examined from the Colorado river to Kanarra, the displacement was a true fault, with a lift of from 2,000 to 3,000 feet; but for a short distance at Toquerville it passed into a torn flexure, accompanied by an offset of three miles to the west. North of Toquerville the fault is concealed by gravel and lava, but reappears at Kanarra, where with a much increased throw it cuts the overturned anticline already mentioned. It has long been recognized that the whole displacement of the Hurricane fault did not take place at one time, but was divided between two periods. It is thought, however, that both these periods of faulting were very recent, and there is uncertainty as to the time interval between the two periods and as to the relation which they bear to the cutting of the Colorado canyon. Evidence has been found which seems to show that the first faulting is of early date, possibly in the first part of what Dutton calls the Miocene, and has no immediate connection with the formation of the Grand Canyon. The second faulting, on the other hand, is of recent date, and accompanied the single uplift which allowed the cutting of the canyon.

THE INTER-FAULT OR PLATEAU CYCLE OF EROSION.

After the first Hurricane faulting came a long period of erosion, during which the region as a whole was reduced to a condition of moderate relief and the original topography due to folding and faulting was almost entirely effaced. Near the main drainage lines there was an approach to baseleveling, and the topographic effect of hard and soft strata was largely lost. The initial fault scarp was entirely effaced, and the line of displacement came to be marked by an escarpment on that side where hard strata overlooked soft. At the same time the south-facing cliffs on the two sides of the fault retreated northward at different rates. In the more northern district, with the head-water development of a large drainage system, a rounded sub-mountainous topography was produced. Everything indicates that the interval of erosion that followed the first faulting was very long. At the end of the period the lowlands were strewn with waste. Finally came a time of volcanic activity, when craters were formed and the old land surface was partly sheeted over with basaltic lava. It is chiefly to these basalt flows that we owe our knowledge of the two periods of faulting and of the interval between them, for they have preserved the old lowland surface. This is exposed in many places, especially where the lava sheets have been traversed by the later fault.

a) *The lava-covered Hurricane fault at Coal Spring.*— Dutton states that near the Colorado river the Hurricane fault splits into four branches, two of which must be of recent date, since they are described as cutting recent lava beds. The other two are not known to cut any lava. At Coal Spring, however, twenty-five miles north of the Colorado canyon, where no branches have been observed, an unbroken sheet of lava, showing no sign of a new fault, lies across what seems to be the main Hurricane fault, preserving a surface which is level in spite of the fact that the down-thrown side consists of soft Verkin shales and the other of hard Aubrey limestone. Since at the time of the basalt flow hard and soft strata lay side by side with an almost level surface, this part of the fault must have occurred so long before the flow that during the interval there was time for the erosion of the surface nearly to baselevel.

b) *The lava-covered surfaces on the Shivwits plateau.*—West of the Hurricane, on the Shivwits plateau, lava is seen lying on a level surface of soft Verkin shales—rocks so easily eroded that they can assume a level surface only when close to baselevel. The wide distribution of these lava-covered surfaces points to an approach to peneplaination over a considerable area in the southwest.

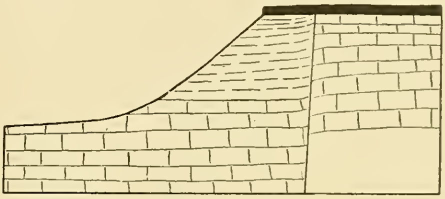


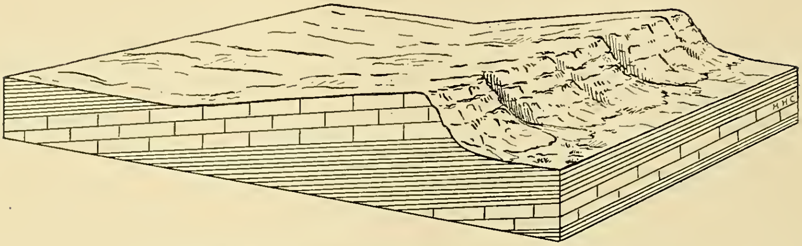
FIG. 5.—The Hurricane Fault at Coal Spring, looking north.

c) *The old fault, the old lowland surface, and the new fault.*—At several points between Fort Pierce and Kanarra, where the Hurricane fault-line is crossed by basalt flows, a displacement of two different dates is clearly shown, and it is seen that at the end of the interval between the two the relief of the region was much less than now. Where the first faulting had brought resistant strata, such as the Aubrey limestone or Upper Kanab sandstone, into contact with softer strata, such as the Verkin shales, the harder strata rose in a low escarpment, whether they lay on the heaved or thrown side of the fault. Against this the lava flowed, and thus was checked soon after crossing the line of displacement, while in other places, where the strata on the two sides of the fault were of nearly equal resistance, the lava flowed across the faults to a much greater distance. In still other cases the strata underlying the basalt are more or less tilted, but nevertheless they were reduced by erosion to a level surface that bevels the edges of the layers. Sometimes these are shales, such as those at Gould's Ranch, which under present conditions of active erosion rarely form a level surface; for they are so soft that when the overlying cap of hard strata is removed, they are at once minutely dissected into a rough bad-land topography and are soon wholly swept away, in so far as they lie above grade. In other places, as near Bellevue, five miles north of Toquerville, highly inclined layers of alternating hard and soft strata are truncated by a level lava-covered surface, although at present hard formations lying in the same attitude form marked ridges. Surfaces of all these various types have been covered by lava flows, and have been exposed to view by a recent fault or series of faults, and the renewed erosion consequent on uplift. They all indicate that between the earlier and later times of faulting there was a long period of erosion, at the end of which the region had been reduced to relatively low relief.

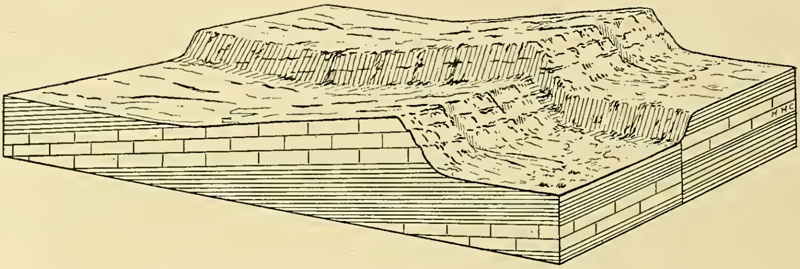
d) *Mature topography of the Colob plateau.*—Two miles north of Kanarra coarse Pleistocene gravels rest on the rather level surface formed by the dissection of the inverted strata between the old and new faults. On the gravel lies lava which seems to have come from the high plateau of Colob, east of both faults. The lava probably did not cross far west of the old fault, because it soon encountered the down-thrown Aubrey limestone which stood relatively high on account of its hardness. The recent faulting depressed the limestone area and allowed it to be covered with deep alluvium. This displacement also gave rise to a renewal of erosion by which the lava on the edge of the up-thrown block has been dissected into mesas and buttes, although back from the borders on the main mass of the maturely dissected plateau the revived activity of erosion has not as yet penetrated. The lava there lies on a surface of just the same sort as that which still characterizes the neighboring parts of the plateau which are not protected by a basalt covering. So it seems probable that the topography of the central mass of the plateau, even where it has not been protected by lava, is almost the same as that which prevailed previous to the basalt flows and the second faulting. The rounded mountainous hills, rising to a height of two or three thousand feet, the graded slopes, well-established drainage, and broad valleys, are strongly in contrast to the precipitous slopes and new aspect of the peripheral regions, and seem to represent the conditions previous to the second uplift.

e) *Differential recession of cliffs on the two sides of the old fault.*—Still another line of evidence shows that there have been two periods of faulting separated by a considerable interval of erosion. The unequal recession of outcrop cliff on the two sides of a fault is a principle that has already been discussed in connection with the plateau region. It was recognized by Powell that when a set of outcrop cliffs is cut by a transverse fault the cliffs on the up-thrown side will be subjected to more powerful weathering and erosion than those on the lower side; consequently they will retreat faster and the outcrops on the two sides will in time become discordant. Professor Davis has recently pointed out that the amount of discordance gives a measure of the length of the period of erosion that succeeded the faulting. In the plateau region the apparently level strata, which really dip slightly to the north, form steep south-facing cliffs which are gradually worn northward along their gentle dip. Since the original Hurricane fault took place the Kanab red sandstone cliffs on the eastern side have retreated over fifteen miles farther than their low-lying counterparts on the western side. Inasmuch as this distance represents, not merely the whole amount of retreat, but the excess of retreat on one side over that on the other, the time during which the process went on must have been very long.

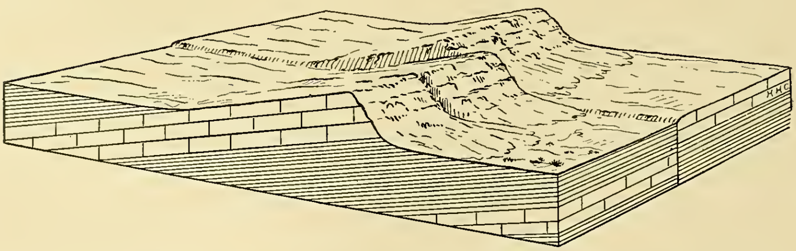
f) *General review of the topography at the end of the inter-fault cycle.*—The fragments of old surface that are preserved under the lava sheets generally belong to lowland topography, and have been examined chiefly in the subsequent valley that seems to have followed the old fault line, first on one side, now on the other, according as the strata were hard or soft. The mature mountainous hills of the old still unchanged plateau preserve the ancient form of the uplands. Between the highlands and the lowlands were long graded slopes which have now been revived into steep, rapidly receding cliffs of naked rock. All this signifies a long period of erosion — so long that the main valleys were reduced nearly to baselevel, although the more remote regions to the north were still somewhat mountainous and there was still considerable relief in the intermediate regions. At that time no Grand Canyon can have existed, although the Colorado river must of necessity have been a very important feature in the topography. Its valley must have



A.—Unfaulted block showing a continuous line of cliffs.



B.—The same block cut by a north and south fault.



C.—The same block after erosion has almost obliterated the fault scarp. The cliffs on the eastern or upthrown side of the fault have retreated much farther than those on the down-thrown side.

BLOCK DIAGRAMS ILLUSTRATING THE DIFFERENTIAL RECESSION OF CLIFFS ON THE TWO SIDES OF A FAULT.

FIG. 6.

been like those of its tributaries—a broad open depression where the river flowed on an extensive flood-plain close to baselevel. Near the end of this cycle of erosion there was extensive aggradation, forming the heavy gravel deposits of Kanarra, the Virgin river, and the Grand Wash. Then came an abundant outpouring of basalt from many craters, especially in the region

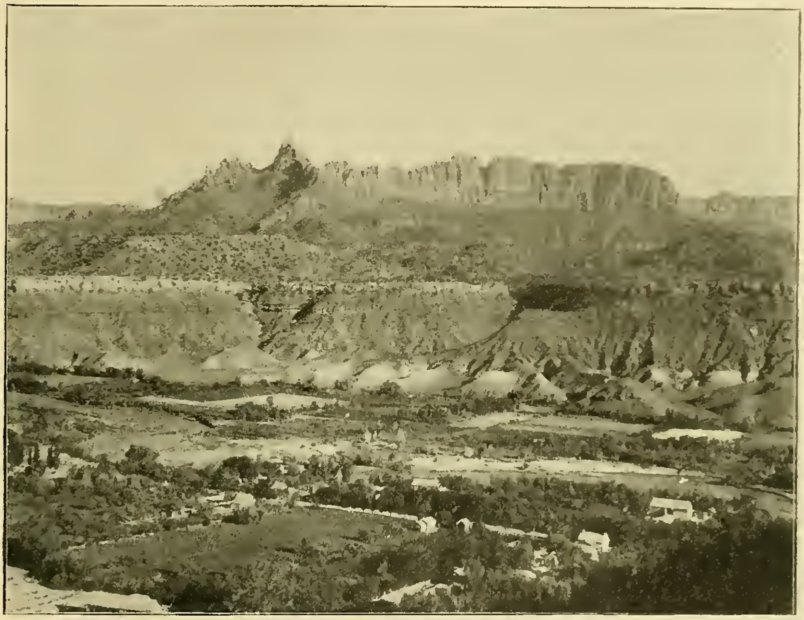


FIG. 7.—View south across the valley of the Virgin river at Rockville. The sharp cliffs of Red Kanab sandstone in the background rise 3,000 feet above the river. Below them are soft lower Kanab shales, the rapid weathering of which has undermined the Upper Kanab, causing the great landslides that are seen lying on the Shinarump platform which extends across the middle of the picture. Below the Shinarump the soft Verkin shales are minutely dissected into a bad-land topography, whose roughness and aridity contrast strongly with the irrigated fields of the Mormon village of Rockville on the flood-plain in the foreground.

that was nearest baselevel; and thus a new and very durable element was introduced into the topography.

THE HURRICANE FAULT—THE LATER FAULTING.

The newer displacement, like the older one, changed at Toquerville from a fault into a flexure. South of Toquerville, however, the displacement continued as a true fault to Fort Pierce, beyond which it split. One part, which followed the old fault line, seems to have greatly diminished, but, as indicated by the broken lavas that Dutton describes, was of considerable importance where it crossed the Grand Canyon. The other passed into a long gentle monocline, and, leaving the old

FIG. 8.—Mukuntuweap canyon, looking north. The sky-line on the right shows a portion of the mature topography of the Colob pleateau. On the left the Temples of the Virgin, of red Kanab sandstone capped by the white cross-bedded Colob formation, rise 2,500 feet. They have been carved by the erosion consequent upon the uplift which introduced the canyon cycle. The level foreground is a lake plain, formed when the stream was obstructed by landslides similar to those seen in Fig I.

Hurricane fault line, bent to the southwestward until at Black Rock it joined the Grand Wash fault. This, like the Hurricane, is a young displacement following the line of an old one, as is shown by the relation of lava flows to the strata preserved under them. The line of dislocation, then, which separated the uplifted Plateau province from the Basin Range province reaches the Colorado river in much the greater part by the Grand Wash, and only in small part by the Hurricane. It is to this great uplift, limited on the west by the Grand Wash and Hurricane faults, that we owe the inception of the canyon cycle of erosion and the cutting of the Grand Canyon of the Colorado.

FIG. 9.—The Hurricane escarpment just north of Toquerville, as seen from the northwest. The Aubrey escarpment, 2,000 feet high on the left, diminishes as it passes into the torn flexure, which is shown in Toquer hill, the black lava-covered hill in the middle distance. Beyond this are the Shinarump capped mesas of Verkin shales that lie east of Gould's ranch.

THE POST-FAULT OR CANYON CYCLE OF EROSION.

During and since the later uplift there has been a cutting of canyons in the hard strata, and a general stripping of unprotected soft strata. In the Plateau region erosion has gone just far enough to emphasize very successfully the topographic value of hard and soft strata. Thus, along the fifty miles of the Hurricane south of where most of the new displacement turned westward, the rapid wearing away of weak Verkin shales on the western side of the old fault line has left the hard Aubrey limestone on the eastern side as an erosion escarpment so strong that Dutton took the whole of it for an actual fault scarp of recent date. At Coal Spring, where the basalt flowed west across the old fault line onto the Verkin, the weak shales were locally protected, so that the modern cliff front at this point is west of the old Hurricane fault line. Of this 1,800-foot escarpment all but a few hundred feet is the product of erosion on the line of the old fault during the canyon cycle. There could be no better illustration of the progress of erosion since the later faulting than this, which shows that the existing cliff has been shaped almost

FIG. 10.—Sugarloaf mesa, on the edge of the Hurricane escarpment, west of Gould's ranch. A small basaltic cap protects a few hundred feet of Verkin shales, which recent erosion has elsewhere stripped off to the level of the Aubrey platform seen in the foreground.

wholly by erosion, working under the conditions imposed by the old fault, the erosion interval, the basalt flows, and the recent uplift.

SUMMARY.

The post-Eocene history of the Toquerville district has been characterized by two periods of upheaval, separated and followed by periods of relative quiet. In the first period, which was doubtless of great duration, with an unknown amount of erosion, occurred the original folding, the eruption of andesite upon a surface, but slightly, if at all, dissected, the reversal of the direction of deformation, and the earlier faulting. In the Kanarra section the fault followed the greatest of the folds, while in the portion south of Toquerville it traversed nearly horizontal plateau strata. These disturbances introduced the inter-fault cycle of erosion—a long period of comparative quiet, during which the outcrop-cliffs on the two sides of the fault receded northward at different rates, and the whole country was reduced to a degree of relief far less than the present. The southern region approached peneplaination, while toward the north the surface rose into graded mountainous hills separated by broad valleys. The close of this period was heralded by aggradation in the main valleys, and by extensive lava flows. In the second period of upheaval came the uplift of the Plateau province, marked by a displacement along the Hurricane and Grand Wash faults. The last period, or Grand Canyon cycle, has seen the cutting of numerous deep canyons and the stripping of large areas of soft strata; but its main work as a cycle of erosion is as yet only begun.

ELLSWORTH HUNTINGTON.
JAMES WALTER GOLDTHWAIT.

Studies for Students

THE CRITERIA REQUISITE FOR THE REFERENCE OF RELICS TO A GLACIAL AGE.[1]

INTRODUCTION.

The criteria herein discussed are given shape with special reference to human relics because these possess pre-eminent interest, but they are equally applicable to all relics, whether they are those of man, of animals, or of plants. The criteria are also defined with special reference to America, though they are equally applicable to the Old World. This is not by any means to say that the facts are the same on the two continents.

The theoretical grounds for assuming the existence of man *somewhere* on the globe in preglacial times are very strong. In Europe the evidences of man's presence during some of the interglacial periods appear to be substantial. So far as America is concerned, the question is purely one of fact to be determined strictly by scientific evidence. There seems to me little or no legitimate ground for a predisposition to accept or to decline to accept a glacial or preglacial antiquity for man in America. The existence of the race upon the eastern continent in glacial times does not carry any special presumption of its existence upon the western continent at that time. The belief that man originated upon the eastern continent rather than upon the western has something of strength in biological considerations, and is supported by the preponderance of existing geological evidence. If man originated in the Old World, the time when he migrated to the New is an open question until it is closed by thoroughly sound evidence, precisely as it is in the case of the migration of any of the mammals which originated upon the eastern continent and is now a denizen of the western. If it is

[1] Read in abstract before Section E, A. A. A. S., Washington Meeting, January, 2, 1901.

a more important matter to us, it is the more important that its evidence be sound. The notion that the life-history of one grand division is to be "brought into accord" with that of another is a perilous guide. In certain general aspects, the life-history of the several subdivisions may indeed have points of accord, but in its special phases divergence is quite as much the rule as concordance. In any given case, the probabilities are that a given form originated in one grand division rather than in all, and that more or less time elapsed before it migrated to distant regions. There is therefore no presumption that all the early stages of evolution will be found on all the continents.

Nor do I see any good scientific reason to desire one result rather than another. I see no scientific grounds for a predisposition to match European antiquity by American antiquity, or the European stages of evolution by American stages of evolution. It is quite as much in the interest of ethnological science, so far as I can see, to limit the duration of the human species on the western continent as it is to extend it. Given three or four great divisions of the earth's surface in which a species may develop in measurable independence, probably as much, and perhaps more, can be learned from the introduction of the species into these several divisions at different and rather widely separated intervals, as can be learned by its introduction into all of them simultaneously, or in close succession. Evolution through periods of different lengths in the different divisions would probably show at least as much, if not more, of the rate and nature of development as would evolution for equal periods in all the divisions. We shall probably learn quite as much of the great lessons of human evolution if it shall be shown that the American races have developed since the glacial period, so far as they are endogenous, as if it shall be shown that the period reaches back to one or another of the interglacial epochs or to the preglacial period. In any case, to the ideal scientist, it is purely a question of fact to be settled by demonstrative evidence. Our concern here is what constitutes demonstrative evidence.

Evidence to be sought in the glacial formations themselves.—Grounds for assigning man to a glacial period are to be sought primarily in the glacial formations themselves. This is the principle we recognize in the assignment of a pebble or a bowlder, and it should hold good for human relics. A few years ago two of our most experienced glacialists and three younger associates reconnoitered seven states, and then held their conclusions in abeyance for several years, because they were not fully convinced that certain crystalline pebbles in certain gravels outside the true glacial formations were or were not truly glacial in origin. Had these pebbles been found in glacial deposits, their reference would not have caused a moment's hesitation. It is only applying to human relics the standards adopted by careful glacialists relative to pebbles, to insist that there is a profound distinction between the value of evidence from the direct glacial deposits and that from derivatives or secondary deposits.

I. EVIDENCE FROM PRIMARY GLACIAL DEPOSITS.

There are three good classes of cases connected with the primary glacial material:

1. The first of these is *imbedment in the till sheets or the moraines.* If the identification of the glacial deposits and of the relics be beyond question, relics found imbedded in the true glacial deposits constitute very strong evidence of contemporaneous or previous origin. There is some danger of error even here, however. Secondary deposits of till are liable to be confused with true original deposits. Slides, creep, and wash not infrequently bury recent material under what at first seems to be true bowlder clay. Many a time has the experienced and alert glacialist had occasion to use the most careful circumspection to avoid error in assigning wood, buried soils, and other fossils to a glacial or interglacial age, whose burial proved on close inspection to be secondary and utterly worthless for chronological purposes. There are also incidental intrusions by means of burrows, root holes, cracks, etc., which require elimination. If all these are excluded by expert observation *controlled by unrelaxing alertness and persistent caution*, evidence of a high order of value is theoretically derivable from the tills and the moraines.

I say "theoretically derivable," because no fully authenticated case of this kind has been presented as yet, so far as I know.

2. *Evidence from assorted drift included in till and moraines.* — Relics found in gravels or sands interbedded with true bowlder clays, when they are clearly of immediate glacial derivation, furnish nearly as good evidence as relics in the bowlder clays themselves, but their identification requires more circumspection.

3. *Evidence from kames and eskers.* — So also relics found in true kames or eskers may furnish good evidence if the sources of error are sufficiently avoided, but still more caution and alertness are required here.

Confirmatory evidence in these cases. — Glacial *striation*, besides being a source of evidence in itself, may afford supplementary evidence in these cases and may serve as a check on the sources of error previously noted. Unmistakable glacial striation may even make good what would otherwise be worthless evidence. For example, a well-striated bone found in secondary till might be accepted as good evidence of glacial antiquity, whereas if unstriated it would have to be excluded because the rearrangement or disturbance of the till would vitiate its trustworthiness. Striated stone implements must, however, be received with great caution, for, in the first place, stones that had long before been striated may be used in the construction of implements without obliterating all the striation, and, in the second place, use may give rise to grooves and scratches very like true glacial work. Erroneous identification of striæ are by no means uncommon in the history of glacial geology.

Combined evidences. — When well-authenticated striation is combined with imbedment in original glacial deposits, the evidence reaches its highest value. We have, however, so far as I know, no such cases as yet in America.

The culminative value of repetition. — The evidential value of *good* cases rises rapidly with their multiplication, for the doubts that might legitimately arise in a single case notwithstanding all precautions against error are effectually reduced by additional good cases. But, true as this is, no amount of multiplication of *bad cases* makes a *good* case. On the contrary, the multiplication of weak and false cases throws doubt on all and is a legitimate ground for rejecting all. The first step toward a firm ground of confidence is the sweeping away of all bad cases of the past and the effectual barring out of all new ones.

The interpretation of imbedded and striated relics. — Human relics found in the true glacial deposits, whether striated or not, do not necessarily tell whether man lived in the immediate presence of the ice or whether he had lived in the region *before* the ice invasion. (1) The relics may have been picked up from the preglacial surface by the ice as it pushed over the region, just as rock fragments and earthy matter were, or (2) they may have been dropped on the ice or at its border or on the moraines in the presence of the ice. If the relics are found to be associated with other organic remains that imply a warm climate, the former inference is favored; if the associated organic remains imply a cold climate, the latter inference is the more probable, but as all the relics are disturbed, the inference is not firm in either case. If human bones are found that show evidence of long weathering and subsequent striation, there is good ground for inferring the existence of man in the previous interglacial or preglacial period. The absence of weathering would not be equally good ground for the opposite inference, because certain kinds of burial exclude weathering.

A demonstration that man existed before a given glacial invasion would imply his existence during it in some part of the globe, and presumably in the grand division in which the relics were found, but a closer interpretation than this requires special evidence.

II. EVIDENCES FROM THE INTERGLACIAL DEPOSITS.

The interglacial deposits include those surface accumulations that were formed in the interval between the ice invasions of a given region. They are chiefly soils, muck, peat beds, and various wash products, including fluvial, lacustrine, and occasionally marine clays, silts, sands, and gravels. There were similar deposits outside the glaciated regions, but as these were not buried by later glacial deposits, they cannot generally be connected demonstrably with the glacial invasions, and are therefore not here included. The abandoned surface of a recently glaciated region furnishes excellent conditions for the burial and preservation of relics, for it usually presents an uneven surface which becomes dotted with ponds, swales, and ungraded valleys, so that erosion and deposition are the natural order of things. The basins furnish alluring grassy meadows and the ponds offer enticements to drink, while the bordering bogs and springy grounds lie in wait to mire the weak and unwary, and clayey inwash from the higher ground provides a preservative burial. Although the interglacial beds were subject to much disturbance and to removal during the succeeding ice invasion, they were preserved in a singularly large number of cases, and fossils, often in the most excellent state of preservation, are sometimes found in them. The delicate tissues of mosses are occasionally admirably retained.

The fossils of these beds have the further merit of definite fixity in time and localization. In this respect there is not the uncertainty of the previous class. The imbedded plants and animals lived subsequent to the deposition of the underlying drift and previous to that of the drift above.

But even here there is a source of some vagueness, though it is not radical. It is a not uncommon practice of glacial geologists to include among the interglacial formations gravels, sands, and clays, which overlie an earlier bowlder clay, even though it may be quite possible that these were formed in the last stages of the preceding glacial epoch, and are indeed nothing but the glacio-fluvial deposits of that epoch. Of course, this is not done by the discriminating glacialist where the case is determinate. But usually the case is not determinate, and then the interglacial epoch is given the benefit of the doubt. Any error in date arising from this source would be a conservative one, since the relics are, at the worst, only referred to a slightly later date than they are entitled to.

Sources of error connected with interglacial deposits.—The liability to error here is not very serious, if due circumspection is exercised.

There may be false identifications of the overlying and underlying glacial deposits and of the interglacial beds themselves, and there may be misinterpretations arising from that *bête noire* of the incautious glacialist, secondary displacement and rearrangement, but a duly trained and fairly skilful worker should avoid all these. These interglacial beds present by far the most promising field for the demonstration of the presence of man in America during the glacial period, if he really lived here then. No good case of relics from them, however, has yet been presented, so far as I know.

III. EVIDENCES FROM ASSORTED DRIFT LYING UPON OR OUTSIDE OF THE TRUE GLACIAL SERIES; RIVER DEPOSITS ESPECIALLY.

Nearly all the relics upon which the presence of man in America in the glacial period has been claimed are from deposits of this sort, and they hence deserve critical attention. For the greater part, these deposits are valley trains or frontal aprons of gravel, sand, and silt. There are three different classes of deposits of this kind that are remarkably similar in their general characters, but which must be positively distinguished from each other before any safe conclusions can be drawn. This is a work of grave difficulty, and in many cases I know of no way in which it can be successfully done. One of these classes is glacial, and the two others are postglacial. Before relics in these can be referred to the glacial period, it must be shown that the deposit bearing them belongs to the first class, and certainly does not belong to either of the other two.

1. The first class consists chiefly of gravel, sand, and silt borne out from the ice by the glacial waters and deposited along the glacial waterways. These are truly glacio-fluvial and strictly contemporaneous with the ice action. Contemporaneous burial in these means of course a glacial age.

2. The second class consists of sand, gravel, and silt of almost identical composition and structure formed by postglacial waters working on the drift surface and washing out from it the same class of material that the true glacial waters did and spreading it along the valleys in an almost identical way. More than this,

the deposits of this class are likely to be the uninterrupted successors of those of the previous class, and hence to overlie them conformably. There is therefore the most extreme difficulty in distinguishing the two under most conditions. In the case of outwash aprons and certain abandoned valleys, and in other particular cases closely adjacent to the ice edge, the discrimination can be made, but in most cases at a distance from the ice edge I know of no certain means by which it can be done. The postglacial modified drift should theoretically be somewhat more weathered than the true glacio-fluvial drift, but the amount of weathering which took place after the ice retreated and before the material was carried away and deposited would not in most cases be great, and what there was would largely be worn off in the transportation preliminary to the deposit of the material as modified drift. It is therefore an unavailable criterion.

3. The third class consists of the first and perhaps the second class reworked by the postglacial streams after they exchanged their *aggrading* habits to *degrading* ones. In this class the material is identical, or essentially identical, with that of the preceding classes, since it is the same material reworked, with some addition from the same general source, the drift of the region, and its structure is so closely similar that a careful glacialist would hardly venture to discriminate between them. The topography, especially the relations of the deposits to the terrace systems, where such exist, often aids in forming an impression of the probabilities, but in most cases it cannot go much beyond that.

Scour-and-fill.—The process which is most concerned in introducing the confusion of this third class is *scour-and-fill*, one of the most obvious processes in all geology, but one of the most neglected. It is a very familiar observation, if we but recall it, that every active stream has shallows and deeps, and that the differences in depth of water are very considerable. It is also certain that these are constantly changing, and that with the shifting of the course of the river they undergo complete obliteration and are replaced by flood plains. The whole bottom of the valley, so far as involved in the range of the river's meanders and other shiftings, is subject to this alternate erosion and filling. It is equally clear that any relics that may come within the river's action, except such as float, are liable to be buried to depths equal to the difference between the height of the flood plain and the depth of the deep holes in the bottom of the river. In the great rivers, this range not infrequently reaches 100 feet and more, and is very commonly three and fourscore feet. In many cases the scour reaches the rock bottom, and at such places the entire bottom deposit is undergoing reworking, and modern relics may be introduced into any of its depths. This phenomenon is most strikingly displayed in the Missouri river, where the engineers tell us that transient scour often reaches bed rock, and that the scooping out and filling up follow one another with almost seasonal frequency. So pronounced is this action that the impression has been given that the *whole bottom deposit is being shifted turn-by-turn down stream.* While this may be an overstrained deduction, it is supported by a great mass of very important facts, too much neglected. The erosion of the rock bottom of most streams is accomplished by such alternate shiftings of the loose bottom material. At any one time, this loose material covers most of the bottom of most degrading streams even, and the wear on the rock bottom is accomplished first here and then there by the shifting of the covering of loose material. In practically no streams at all, except perhaps mountain cascades, is the whole bottom exposed to erosion at the same time. In the drift-filled bottoms of the great branches of the Mississippi system, it is wholly within bounds to regard at least the upper 40 or 50 feet of the deposit over which the river meanders as subject to scour-and-fill and to entertain the suspicion that the deeper portions down to 100 feet or more may be similarly affected. To make out a good case for the antiquity of relics buried in such a deposit seems well-nigh impossible.

Scour-and-fill affects more or less every portion of a river deposit that has formed a part of the channel bottom at any time in its history. This action does not usually much affect the flood plains while they *remain such.* There are exceptions even here, and not very infrequent ones, but scour-and-fill is not normally an effective mode of action on the flood plains. And so a portion of a fluvial plain that has never been occupied by the river channel, but only by its upper floods, if indeed there be such a portion, would not be greatly open to the suspicion of having been reworked by scour-and-fill. But every part of the flood plain that is occupied at intervals by the stream's channel is subject to scour-and-fill, during the whole period of such periodic occupancy, and the contents of its deposits are subject to all the uncertainties of origin already pointed out.

Unequal effect on aggrading and degrading rivers.—Scour-and-fill affects both aggrading and degrading rivers, but it does not affect them equally. In aggrading rivers, especially those rapidly and declaredly building up their bottoms, as in the case of typical glacial streams, the river is usually broken up into a plexus of branches by the successive filling up of the channel bottoms and the diversion of the streams. Deep scour-and-fill is not a pronounced habit of such streams. Already overburdened with detritus, they have not that reserve capacity for taking up a new burden that clearer streams have, and their division into numerous weaker branches takes away the cumulative power which the combined and concentrated current of the clearer degrading streams possesses. The action reaches its greatest efficiency, it would seem, when the whole stream concentrates its full force in a limited portion of its channel, and when it is free to take on temporarily a large additional burden of detritus. The action is greatest at the turns of the streams where the arrested or diverted momentum of the current develops a powerful rotary movement of the water.

Breadth of action in the great streams of the glacial area.—Now this reworking of the fluvial deposits along the courses of the Missouri, the Mississippi, the Ohio, and many of the other large streams in the glacial area, occupies or has recently occupied nearly or quite all the space between the bounding bluffs. Here and there within protected recesses, or in other favored spots, there may be a few exceptions, but in most of these cases even it may be difficult to prove that the remnant deposits were not reworked in postglacial times, though somewhat remote ones. The only cases that can be held to be exempt from this suspicion are terraces that can be shown to be remnants of the original glacial flood plain and can be discriminated demonstrably from remnants of some one of the many flood plains that succeeded this original one in the history of the subsequent erosion of the valley deposits. Except quite near the former ice edge, where the true glacial plain is demonstrably connected with a distinctive head at the ice edge, this discrimination is practically impossible. In many cases the terraces themselves bear characters that awaken the suspicion that they do not represent the true glacial plain. In many cases they do not stand at consistent heights, and in many others they bear a suspicious configuration.

In the immediate vicinity of the ice edge from which the gravel trains originated, it is possible to identify with confidence the original glacio-fluvial plain, if due circumspection is exercised, but I think that it is only within a few miles of the parent ice border and in a few special cases of other types that the conditions are favorable for a trustworthy reference of buried relics, to the ice age.

Adjustment plains as sources of deception.— The chief source of misplaced confidence by even glacialists of ability and experience lies in mistaking a *post-glacial adjustment plain* for a *true glacio-fluvial plain.* It is a familiar observation that the true glacial flood plain rises rapidly as its head at the ice edge is approached. There is for this the obvious reason that the waters issuing from the ice edge are usually heavily overloaded with detritus, and on this account they build the stream bottoms up to a high gradient. When the ice retires and the waters become purer a readjustment of the gradient follows. This is accomplished usually by cutting down the high gradient at the head and redepositing the material so removed at some point of lower gradient below. Later this adjustment becomes the subject of a new adjustment by which the gradient is again lowered in the upper part, and the material removed in so doing is redeposited still farther down the valley, and so on by a progressive series of partial readjustments until the whole gradient of the valley has been brought into working harmony. The earlier readjustment plains may often be seen a few miles below the terminal moraines on which the true glacio-fluvial plains take their origin. At such points the valley is often filled from bluff to bluff by a smooth plain of gravel of glacial aspect, and the impression is apt to grow into great strength that this is the true glacial flood plain. But as it is traced up toward the moraine, terraces of higher altitudes and higher gradients are seen to rise on the sides of the valley, and grow in strength and continuity until they clearly disclose the earlier plain of which they are the remnants, and this plain is found to merge into

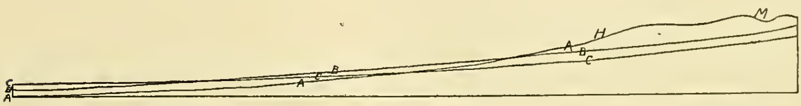


FIG. I.—Illustration of the successive formation of a true glacio-fluvial and two adjustment plains. *M*, moraine at which the true glacio-fluvial plain heads; *H*, head of the valley train of true glacio-fluvial gravel: *AAA* down-stream portions of the same; *BBB*, first adjustment plain, lower than glacio-fluvial plain at the right, and higher at the left; *CCC*, second adjustment plain crossing the horizons of both the preceding. The portions of the adjustment plains at the left are liable to be mistaken for the true glacio-fluvial plain.

the moraine, while the other plain of lower gradient is found to connect with a channel cut through the moraine. In such a declared case, it is clearly seen that the plain of lower gradient (and lower position at the moraine) is the higher plain a few miles down the valley, and is there altogether likely to be taken for the plain of true glacial date. Still farther down the valley a yet later adjustment plain may be uppermost and prevailing, and so liable to be misinterpreted. Errors of interpretation of this kind are liable to be made within five miles of the moraines on which the gravel trains head.

Amount of the errors.—At such a distance probably the amount of error in time may not be great, but we really do not know how fast or how slow such a readjustment takes place. While geologically rather rapid, it may be rather slow in terms of human migration. In the nature of the case, the farther the locality is down the valley from the head of the gravel train, the later is the readjustment.

It will be seen from this that even where the valley train of modified drift is well preserved and is clearly the highest plain of the kind in the valley at that point, it may be an error to refer it to strict contemporaneity with the ice presence. For aught that we know, it may have been formed several hundred, and perhaps a few thousand, years after the ice retired. The difference is trivial in geologic terms, but it may be of much moment in human history. No readjustment of this importance, I think, is known to have taken place naturally during the invasion and wide occupancy of this continent by the white race. We should have to draw our geologic lines closer than this to fix the not unimportant period of our people by geologic data.

Without going farther into the refinements of the case it appears—

1. That even where the valley train is well preserved and constitutes a broad plain or extensive terrace, and is the highest deposit of the kind in the valley at that point, and its material is indistinguishable in kind and structure from true glacio-fluvial material, there is danger of appreciable error in referring it to the ice age. In the case of relics imbedded in it there are the added dangers already referred to, unless some special evidence excludes them.

2. That where nothing but isolated terraces are involved much doubt as to the correlation of these is liable to arise legitimately.

3. That where the terraces are below the maximum height for the locality, there is definite ground for suspicion.

4. That in all cases where there is any chance that the river in its degradational stages has meandered over the locality, the possibility of scour-and-fill gives grounds for serious suspicion. The possibilities of natural deep intrusion by this prevailing process are only limited by scores of feet; indeed, only by a hundred feet, or more.

The general purport of these combined sources of possible error is to emphasize *the very unpromising character of valley grav-*

els as a source of really good evidence of man's glacial age. It is clear that these gravels are liable to present many misleading cases, and this is a reason for special caution on the part of geologists, while it is a sufficient ground for anthropologists to withhold the acceptance of supposed evidence of this class until it shall be conceded to be demonstrative by the most critical glacialists.

IV. FLOOD-PLAIN DEPOSITS.

The preceding discussion relates to clear, well-stratified gravel, sand, and silt deposits of the same composition as the true glacio-fluvial formations and of the same general aspect and part of the same complex train of assorted drift deposits. Over these deposits of glacio-fluvial aspect there is usually spread a layer of more or less structureless silt, with intermixed sand and gravel, in which human relics are not infrequently found. There is scarcely a presumption that these surface deposits are of glacial age. They are generally the products of the river floods formed during the stages when the river is sinking its channel into the underlying gravel plain, a stage which is usually reached some time after the glacial floods ceased their work of aggradation. Usually it is not until after the work of adjustment following the close of the glacial stage has been completed, and probably in some cases only after a period of aggradation, due to the special erosion of the drift succeeding the retreat of the ice, has passed.

All flood-plain surfaces of this class should be excluded from ground likely to give any good evidence of contemporaneity with the ice age.

V. BLUFF-BORDER ACCUMULATIONS.

There is a class of deposits closely correlated with river bluffs that have played a part in the discussion of man's antiquity in America. In these cases the bluffs have been cut from plains of glacial or glacial-like gravels, and the deposits on the borders of the bluffs have on this account been referred to a glacial age. There are at least two classes of these. The first is a form of the preceding flood-plain surfacing. As is well known, where a river overflows its bordering bluffs and banks, its largest, and in general its coarsest, deposits are likely to be made on their borders where a low ridge or natural levee is built up. This takes place while the stream is still overflowing its bluffs at high stages. But these may remain on the bluff border after the stream has cut its valley so deep as to cease this overflow. This, of course, depends upon the chance whether the river encroaches upon its bluffs at the given place or not. Such deposits and their contents are to be referred normally to an advanced stage of degradation of the river, and hence presumably some considerable time after the glacial aggradation of the valley and the sequent adjustments had ceased. The strong presumption is against the reference of these deposits or their contents to a glacial age.

The second class are formed by wind action conditioned by the bluff itself, and hence are subsequent to the formation of the *bluff*. The sloping face of the bluff directs upward the wind that blows against it from the valley, and this upward current lifts the horizontal current at the level of the top of the bluff and causes an eddy of relatively quiet air just back of the bluff edge, in which sand, and such pebbles as the intensified wind at the bluff edge may be able to roll back, to lodge and form a low flat ridge. Mr. Knapp has observed many of these in New Jersey and assigned to them their true cause, as it would seem. Their relationship to the bluff edge and to the strong winds leaves no serious ground to doubt their origin. As these are later than the bluff and the bluff is later than the gravels in which it is cut, and as these gravels may even be later than the close of the ice invasion, there is no ground for referring relics found in such deposits to the ice age.

VI. DERIVATIVE FORMATIONS.

These have been touched upon at several points already, but as they are the special danger-ground of the unwary and are liable to deceive the very elect, some further special notice seems required.

Inverted deposits.— The reversal of the order of deposition in the *process of bluff formation* is a special instance. A river that has depressed its channel deeply into a plain of glacial or glacial-like gravels develops its bluffs on either hand, and from time to time forces them back by under-cutting at its aggressive bends. This action for the time is likely to develop nearly vertical bluffs; at least steep bluffs. While the cutting is in progress, the top of the bluff falls into the river and its surface material, with whatever human relics may lie on it, is liable to be strewn along the stream bed under the bluff and beyond. When the stream shifts its course and the cutting ceases, the top still continues to fall or slide or be washed to the bottom. In this way the upper part of the bluff recedes, while the lower part is built forward until a slope of stability is reached. In the process some of the surface material is quite certain to become deeply buried if the bluff be high. This has been amply pointed out and illustrated by Holmes.[1]

As already remarked in other connections, deposits are subject to slumps, creep, and other displacements that introduce chances of error that must be carefully eliminated.

So also loess bluffs are notably subject to creep in successive large masses, which preserve their internal integrity, and hence are liable to be regarded as undisturbed. This process is grandly displayed at Vicksburg, where the displacements range through some 200 feet.

VII. RECOMPOSED SECONDARIES.

Misleading as the inverted drifts may be, they are less illusory than some recomposed secondaries. The leading class here consists of *subærial aggradation accumulations.* Nearly every valley is subject to oscillations in the relative activity of erosion and of transportation within its own limits Sometimes the derivation of material in one part of the valley exceeds transportation in another part, and deposition is the result. The consequence is wash in one part and lodgment in another. These oscillations may be due to changes in the precipitation, in the vegetal clothing, in the relative stages of erosion, in the relations to other streams and to other causes. In these cases the material is derived mainly from the steeper slopes or steeper ravines,

[1] Holmes, Journal of Geology, Vol. I, No. 1, 1893.

and is chiefly deposited on the lower slopes or in the flatter portions of the valley. The secondary deposit is therefore chiefly a low slope deposit and a valley-bottom deposit. It therefore conforms to the natural configurations of the valley; indeed, the new deposit is the very element that gives to the valley its proper configuration under the new conditions. It therefore blends quite perfectly into the common configuration of the new and old surface formations, and the distinction between the new and the old thus blended in configuration is pre-eminently calculated to escape observation.

The formation does not arise from simple displacement or reworking of any one deposit, but is a *recomposition* of material derived from everything exposed to wash in the portion of the valley undergoing erosion at the time. It may be in itself a consistent formation with definite characters and quite free from signs of post-depositional disturbance. As its material was derived from that which prevails on the upper slope of the same valley, it is very liable to resemble it more or less closely, and this, taken with the harmonious topographic configuration, adds to its liability to be confounded with the original deposit. For example, in a valley whose upper slopes are mantled with loess, with few exposures of older formations, the slope wash is necessarily loess-silt in the main, and the recomposed formation on the lower slope or in the valley must be made up of similar silt merely modified by exposure and transportation. The older formations can only make such contributions to the new deposit as their exposure and erosibility permit, which in the case supposed — a common case — is small. The new aggregation must necessarily bear a close *general* resemblance to the original loess and may easily be mistaken for it.

The criteria for discrimination are found in the effects of partial weathering, in the element contributed by the older formations, and in the structure of the new aggregation, besides the special features which most individual deposits possess as their personal characteristics, so to speak. In a valley whose upper slopes are till or other form of drift, similar recomposition formations of an illusive nature take place.

It should be noted in passing that these are not true alluvial deposits in the typical cases, though they may grade into alluvial deposits and be interstratified with them. They are not habitually well assorted and stratified. They are not formed by persistent streams, but are the products of periodic surface wash and are heterogeneous, unassorted, and, in a sense, structureless, and hence again their liability to be mistaken for one or another of the unassorted drifts.

Among the favoring conditions for such recomposition deposits, there is one which is systematic and recurrent, and is peculiarly adapted to occasion the burial of relics, since it causes a succession of alternate erosions and depositions at localities specially liable to be frequented by primitive man. It is the effect of the meandering of a principal river on erosion and deposition in the mouths of its tributaries.

The meandering of a principal river as a cause of alternate erosion and deposition in the mouths of its tributary valleys. — A meandering river with a deep, readily shifted bottom-filling of the glacial type imposes upon its tributary valleys alternate stages of excavation and filling. These result (1) from the action of the aggressive bends of the river loops against the mouths of the tributaries, and (2) the replacement of these, after a time, by the flood-plain peninsulas that lie within the loops. More specifically, it is the alternate cutting of the stream itself, working hard against and under the mouth of the tributary valley, followed by the building up of the river's higher flood-plain across the mouth of the valley. The first causes the waters of the adjusted tributary to erode; the second, to make deposits in the mouth of the tributary; for in the first stage the axis of the tributary opens out on the river itself, which may be twenty or thirty feet or more lower than the upper flood-plain, and hence the tributary then has its lowest and best opportunity to discharge its waters and their detrital burden. Besides this, the river itself, while in this aggressive attitude, sweeps into the mouth of the tributary in its flood stages and aids in its excavation, and the rushing by of the river's strong current drags out by friction, on the principle of draft, the waters of the tributary and, by acceleration, aids their excavating action. It is at this stage pre-eminently that the tributaries cut down their valleys into adjustment with the main stream bed. On the other hand, when the active impinging bend of the river has shifted elsewhere, and in its stead a flood-plain is being built up across the mouth of the tributary, the drainage of the latter is checked, and if the tributary be small and its waters incompetent in comparison with the flood-plain aggradation of the river, the valley mouth will be filled to a height corresponding to that of the highest flood-plain.

Further, if the mouth of the tributary be blocked by the upper flood-plain beyond the time of the latter's growth, the wash from the tributary will build a delta or fan upon it, and this further growth will continue until the waters from the tributary valley have built up a suitable gradient for themselves across the flood-plain to the river. This only holds good in valleys of incompetent drainage which cannot cut and maintain a trench for themselves. If the tributary valley has a large competent stream, it will maintain a channel-way across the flood-plain to the river, and less aggradation will result from the shifting of the meanders.

A series of aggradation deposits of the recomposition type are to be looked for on the lower slopes and in the mouths of all tributary valleys, caused by the shifting action of the primary stream, and these may reach depths of twenty or thirty feet, and theoretically much more. As these deposits are subject to geologically rapid construction and removal, they are peculiarly well adapted to bury whatever may occupy the surface in the erosion stage. But such burial must be referred to the date of the recomposition and aggregation of the material, and not to that of the chief parent formation.

Beside this systematic, constantly recurrent case there may be others assignable to the causes named and to more special agencies.

Palæontological criteria.—The previous discussion has been confined to formations within the glaciated area, or immediately connected therewith. Formations not physically connected with the glacial deposits cannot usually be correlated with the glacial stages so definitely by stratigraphic or other physical means as to furnish unquestionable evidence of their glacial age. In special cases it may be possible, but these cannot well be treated here. The question is, however, pertinent whether palæontological evidence cannot bring these outlying non-glacial deposits into sure correlation, as it does in other parts of the geological column. It is certainly to be presumed that palæontology can do for the Pleistocene period what it has done for earlier ages, but the real question is whether this meets the minute requirements of the question in hand. Has palæontology at any stage reached a degree of refinement that enables it to discriminate surely between stages of the order of the glacial epochs *by the use of criteria developed in other regions than those immediately concerned?* It will not be questioned that when the faunas and floras of each of the glacial stages in America have been well worked out and demonstrably connected with those stages, and when it is shown by ample evidence that certain species lived in America in certain stages, *and not in others*, the criteria so determined can be used in confident correlation ; *but these criteria must first be demonstrated to be true criteria in their American application.* General inferences as to the rate of evolution or the rate of extinction are not sufficiently refined for the purposes of this case, without such specific local demonstration. General inferences and faunal aspects may be applicable to periods measured by hundreds of thousands or millions of years, and yet be quite too broad to discriminate epochs of a few thousands or even tens of thousands of years. The historical period of eight or ten thousand years gives little basis for confidence in palæontological refinements of this latter order ; certainly not until their specific trustworthiness in a given application is demonstrated. Here as everywhere else in the geological column the range and limitation of species must be demonstrated stratigraphically before the occurrence of these species can be used to fix horizons and determine correlations except in a general and tentative way. The palæontology of the American glacial series is yet to be developed in the main. It is known that many species survived the earlier and more extensive ice invasions, and became extinct either during the later stages or since the glacial period. It is known that some species survived for some appreciable time after the last glacial stage, and yet became extinct before the American historical period, as, notably, the mammoth and mastodon. The fauna of which the mammoth and mastodon were the elephantine types not unlikely bore an aspect measurably different from that of the same region today, and, but for the stratigraphic proof to the contrary, would undoubtedly be regarded as evidence of rather high antiquity, as indeed was the actual case before the recency of this fauna was demonstrated. The association of man's relics with those of extinct animals merely raises the Janus-faced question whether it means the antiquity of man or the recency of extinction of the animals. General considerations and Old World analogies are incompetent to decide this question in America. It must be worked out by specific stratigraphic and correlated evidences of a degree of precision and refinement commensurate with the geologic minuteness of distinctions involved in the problem.

CONCLUSIONS.

The foregoing analysis has not been carried into all the refinements that special cases involve, but it has perhaps been extended far enough to make clear the general fact that the reliable reference of human relics to a glacial age is attended by many possibilities of error, and that these can be avoided only by the exercise of sagacity, guided by experience and controlled by the most diligent circumspection.

Promising grounds.—Two general classes of formations furnish promising grounds for search, so far as their *trustworthiness* is concerned, when critically studied, viz.: (1) the immediate glacial formations, *i. e.*, the till sheets and the moraines; and (2) the interglacial formations.

Unpromising grounds.—Certain other classes of formations are so subject to error, or at least to the suspicion of error, that there is very slight ground of hope that they will furnish incontestible evidence, and hence cases founded on these formations should be relegated to the category of doubt, unless the special features of the cases themselves give them convincing force. These classes are: (1) the valley trains of gravel, sand, and silt, except where immediately connected with moraines or possessed of special features that demonstrate their strict contemporaneity with an ice invasion; and (2) all secondary or disturbed deposits, and all recomposition deposits.

All deposits connected genetically with river channels, with eroded bottoms or bluffs formed in valley trains of gravel, are *to be entirely excluded from serious consideration.* They not only do not help on the cause of glacial man in America—if one may speak as an advocate—but they hinder it by throwing doubt over the whole evidence with which they are associated.

The important question of man's antiquity in America will, in my judgment, be helped on to solution most effectually by freely relegating to the shelves all doubtful evidence and by turning search toward the sources whence reliable evidence is most likely to be forthcoming, and by giving to that search the highest possible credentials of scientific trustworthiness. A few really good cases standing by themselves in their own good company would be decisive; a thousand weak ones can only leave the question in doubt.

T. C. CHAMBERLIN.

Reviews.

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Description of the materials and plant of the Pacific Portland Cement Co. The plant is located fifty miles from Newport, Wash., and a mixture of clays, shales, and limestone is used. Analyses of materials and product are given.

Baker, I. O. *A Study of Road-Building Gravels.* Engineering News, Vol. XLVIII, pp. 345–8, 1902.

Detailed discussion, by a leading engineering authority, of a fresh subject. The requisites of a road gravel are: (1) the fragments should be so hard and tough as not easily to be ground into dust by the impact of wheels and hoofs; (2) the pebbles should be of different sizes, each in the proper proportion; and (3) there should be intermixed with the coarser particles some material which will cement and bind the whole into a solid mass. These requisites are separately discussed at some length, and eight typical and well-known road gravels are described.

Brown, C. C., *editor. Directory of American Cement Industries and Hand-Book for Cement Users.* 2d ed. 8vo, pp. 740. Price, $5. Municipal Engineering Co., Indianapolis, Ind., 1902.

A second (revised and enlarged) edition of this valuable work first published in 1901.

A chapter on cement-testing gives, in addition to the methods adopted by the American Society of Civil Engineers, the recent reports of the Board of Engineer Officers (U. S. A.), on "Testing of Hydraulic Cements," and of the committee on methods of cement analysis appointed by the New York section of the Society of Chemical Industry. In the second chapter, dealing with cement specifications, samples are given of specifications in use by the War and Navy Departments, the New York Central, Pennsylvania, and Philadelphia & Reading railroads, and the public-works departments of several cities. Under the head of uses of cement are given data on the methods and costs of mixing concrete-and-steel construction, cement pipes, concrete blocks, etc. A long chapter on specifications for the use of cement quotes various specifications covering most of the uses to which cement or concrete may be put. Data on which to base estimates on cement work are given in detail. Several typical laboratories for cement-testing are described. The technology of lime and plaster is discussed more briefly. A large number of typical plants, manufacturing Portland, puzzolan, or natural cements, is described.

Following these valuable contributions to the general subject of cements comes the directory proper. This contains lists of American cement manufacturers; cement brands; sales agents; foreign cement manufacturers; dealers in cement; contractors, engineers, and other large users of cement; cement-testing laboratories; manufacturers of cement machinery; manufacturers of lime; plaster plants; and dealers in lime and plaster.

CLARKE, F. W. *Analyses of Rocks, Laboratory of the U. S. Geological Survey, 1880 to 1899.* Bull. 168, U. S. G. S. 8vo, pp. 308, 1900.

Contains many analyses of building stone and other material of economic interest.

COONS, A. T. *The Stone Industry in 1901.* Extract from Mineral Resources U. S. for 1901. 8vo, pp. 67, 1902.

The value of the stone produced in the United States during 1901 is given as $56,615,926. This total includes granite, $14,266,104; trap, $1,710,857; marble, $4,965,699; limestone, $21,747,061; slate, $4,787,525; sandstone, $6,974,199; and bluestone, $1,164,481.

CUMMINGS, URIAH. [*Production of*] *American Rock Cement* [*in the U. S. during 1900*]. Mineral Resources U. S. for 1900. Pp. 745, 746, 1901.

Résumé of the condition of the American natural cement industry during 1900, with statistics of production.

DAVIS, C. A. *A Contribution to the Natural History of Marl.* Journ. Geol., Vol. VIII, pp. 485–97, 1900.

The influence of lower forms of plant life upon the formation of siliceous sinter, calcareous tuffs, etc., in the neighborhood of hot and mineral springs has been discussed by Weed and Cohn. In the present paper the relation of certain low plant forms to the formation of marl is treated in detail, special attention being given to marl deposits of the type commonly found in Michigan.

The Michigan marl (excluding its contained vegetable matter) is, undoubtedly, derived ultimately from glacial clays and disintegrated rock masses. These clays are rich in finely divided limestones, and in rock-forming minerals containing calcium compounds. Percolating waters, carrying carbon dioxide in solution, readily take up the calcium salts, to a certain limit. If the amount of carbon dioxide contained in the water be considerable, part of it will escape whenever the pressure is lowered. This should result in the precipitation of a corresponding part of the calcium carbonate. As the streams of the area under consideration do not deposit marl where they reach the surface, and as the waters of those springs and streams show no milkiness on exposure to ordinary atmospheric pressures and temperatures, it is inferred that no large amount of carbon dioxide is carried, and that there is no approach to the saturation point for calcium bicarbonate in the springs and streams of the Michigan marl region.

Three alternatives are therefore left: (1) the marl was formed under conditions differing from those at present; (2) the amount of dissolved salts is so small that the saturation point is not approached until after the lakes are reached and the slow evaporation and reduction in the amount of dissolved carbon dioxide brings about deposition of the lime carbonate; or, (3) animal or vegetable agencies, or both, cause the deposition of the marl.

The writer disposes of the first two possibilities, stating that the marl is formed at and below the present water level, even coating pebbles and living shells; and that the outlets of the marl lakes of Michigan are so large that little, if any, concentration occurs in the lakes.

Molluscan and other invertebrate shells, in fragments of recognizable size, do not contribute largely to the deposits of commercial value; and it is improbable that wave action in these lakes has been sufficiently strong to reduce shells to powder or mud. The sole remaining possible cause, then, is plant action; and this the author discusses in detail.

All green plants absorb carbon dioxide and release oxygen. If the calcium salts are in excess in the water, and are held in solution by carbon dioxide, then the more or less complete abstraction of the carbon dioxide from the water near the plant will cause direct precipitation of lime carbonate upon the leaves and stems. If, however, only minute percentages of lime salts are present in the water, the precipitation of lime carbonate is accomplished, not by the abstraction of carbon dioxide, but through the agency of the oxygen released by the plant, according to the following equation:

$$CaH_2(CO_3)_2 + O = H_2O + CO_2 + O + CaCO_3 \ .$$

Not all plants are equally active agents. The algæ seem to be of the greatest importance in the formation of marl deposits, one group—the *Characae* or Stoneworts—being of particular importance. Professor Davis collected five stems, each about 60^{cm} long, of a species of *Chara;* these yielded 3.6504 grains of solid matter, the mineral portion of which carried 93.76 per cent. of lime carbonate, 2.93 per cent. of magnesium carbonate; 2.40 per cent. of silica and undetermined, and 0.89 per cent. of oxides of iron and aluminum. *Chara fragilis* seems so be the most active form in the Michigan marl region, but it is probable that close examination will reveal a number of allied species engaged in the same work.

Pebble-like masses of marl, characteristically ellipsoidal in shape and showing both radial and concentric structure, are attributed to the action of another alga, determined to be a species of *Zonotrichia.* Similar, if not identical, material has been described by Murray, who identified the alga as *Schizothrix fasciculata;* but comparison of these materials was not possible.

Davis, C. A. *Second Contribution to the Natural History of Marl.* Journ. Geol., Vol. IX, No. 6. September to October, 1901, pp. 491–506.

Continued investigation, along three distinct lines, confirms the writer's opinion that close relationship exists between certain algæ (especially *Chara*) and marl deposition.

A series of careful mechanical analyses of typical marls from various (Michigan) localities was made. In general, it is easily possible to recognize with a simple microscope the particles held by a hundred-mesh sieve as being *Chara* incrustations or *Schizothrix* concretions; and it is therefore evident that a large part of the samples are of demonstrable algal origin.

The milky appearance of certain lakes has been cited as evidence of the probable presence of calcium carbonate, precipitated from the water by loss of carbon dioxide or change of temperature on reaching the lakes. Experiments show, however, that this turbidity is probably caused by the stirring up of marl deposits by wave action.

Tests showed that a large amount of a soluble calcium salt, determined to be calcium succinate, was present in *Chara*, diffused through the cell sap of the plant. The method of formation of this salt is not at present explainable. It seems probable, however, that it accumulates in the cells until it attains a sufficient density to diffuse through the cell walls by osmosis. Outside the cells or in its passage through the walls, it is decomposed directly into the carbonate. This decomposition is effected possibly by oxidation of the succinic acid due to free oxygen given off by the plants, possibly by some substance in the cell walls, or, more probably, by some organic compounds in the water due to bacterial growth in the organic débris at the bottom of the mass of growing *Chara*.

ECKEL, E. C. *The Quarry Industry in Southeastern New York.* Twentieth Report New York State Geologist, pp. r. 141–r. 176, Pls. XLII–LXI, map, 1902.

Preliminary report on the quarry industry in the counties of New York, Queens, Westchester, Putnam, Dutchess, Rockland, and Orange. Detailed descriptions of formations and quarries are preceded by a summary of the structural and stratigraphic geology of the area.

ECKEL, E. C. *The Utilization of Iron and Steel Slags.* Extract from Mineral Resources U. S. for 1901. 8vo, pp. 17, 1902.

A fairly detailed discussion of the various methods of utilizing slags. In the present connection it is of interest to note that slags are used in the manufacture of Portland and natural cements, slag blocks, slag brick, and glass; and also as road metal and railroad ballast.

This paper was not printed in the completed volume of the *Mineral Resources* for 1901, and is therefore obtainable only in the form above cited.

FISHER, C. A. *Methods of Studying and Displaying Quarry Products as Employed by the University of Nebraska Geological Survey.* Proc. Nebraska Acad. Sci., Vol. VII, pp. 153–5, Pls. XI–XIII, 1901.

Brief description of the methods of gathering data regarding quarries, and of utilizing this information in the display of specimens.

GILLETTE, H. P. *The Cause of Masonry Disintegration.* Engineering News, Vol. XLVIII, pp. 340–42.

Discussion of masonry disintegration in high latitudes; with arguments tending to prove that this disintegration is due primarily, not to frost, but to alternate expansion and contraction attending changes of temperature. The paper cannot well be summarized, but is included here as being closely connected with the subject of the decay of building stone.

KIMBALL, L. L. *The Production of Cement in 1901.* Extract from Mineral Resources U. S. for 1901. 8vo, pp. 17, 1902.

During 1901, fifty-six plants produced 12,711,225 barrels of Portland cement, valued at $12,532,360. Natural cement was manufactured by sixty plants, the product being 7,084,823 barrels, valued at $3,056,278. Five plants are said to have produced 272,689 barrels of slag cement, valued at $198,151.

McCallie, S. W. *Some Notes on the Trap Dikes oj Georgia.* American Geologist. Vol. XXVII, pp. 133–4, Pls. XII–XIV, March, 1901.

Notes on the distribution and character of the trap dikes, which are possibly of Triassic age.

Middleton, J. *Statistics of the Clay-Working Industries in the United States in 1901.* Extract from Mineral Resources U. S. for 1901. 8vo, pp. 78, 1902.

The total value of clay products in the United States during 1901 was $110,211,587; the number of firms reporting being 6,421.

Newberry, S. B. *Fuel Consumption in Portland Cement Burning.* Reprinted July, 1901, from Cement and Engineering News. 8 pp.

Discussion of the theoretical and actual fuel requirements of the various types of kilns in use, and of the effects of the different methods of mixing the slurry.

Newberry, S. B. [*Production of*] *Portland Cement* [*in the U. S. during 1900*]. Mineral Resources U. S. for 1900, pp. 737–44, 1901.

Résumé of condition of American Portland cement industry during 1900, with statistics of production. A discussion of fuel consumption is given, abstracted from the previous paper.

Parsons, A. L. *Recent Developments in the Gypsum Industry in New York State.* Twentieth Rep. N. Y. State Geologist, pp. r. 177–r. 183.

Descriptions of the gypsum deposits at Fayetteville, Union Springs, Marcellus, Mumford, and Oakfield; with notes on the technology of calcined plaster — the manufacture of which has recently become an established industry in the state.

Ries, H. *Occurrence of Glass-Pot Clays in the United States.* Extract from Mineral Resources U. S. for 1901. 8vo, pp. 17, 1900.

Glass-pot clays should be highly refractory, very plastic; dense burning, low in flexing constituents and silica, and high in tensile strength. These requisites are briefly discussed, and certain typical foreign pot-clays are described in detail. American pot-clays are derived from the Carboniferous of Pennsylvania and Missouri, occurring in close association with other refractory clays. Analyses and tests of a number of these domestic materials are given.

Ries, H. *The Production of Flint and Feldspar in 1901.* Extract from Mineral Resources U. S. for 1901. 8vo, pp. 9, 1902.

A quantity of 34,420 short tons of "flint" (quartz), valued at $149,297, was produced in the United States during 1901. This was mined in Maine, Massachusetts, Connecticut, New York, Pennsylvania, Maryland, and Wisconsin; and is largely utilized in potteries and in the manufacture of wood-fillers and scouring-soaps.

Feldspar was produced in Maine, Connecticut, New York, Pennsylvania, and Maryland, the total amount being 37,741 short tons, valued at $220,422. It is used in the manufacture of pottery, wood-fillers, scouring-soaps, and glass.

Russell, I. C. *The Portland Cement Industry in Michigan.* Twenty-second Ann. Rep. U. S. G. S., Part III, pp. 629–85.

Brief notes on the history of the Portland cement industry in Michigan and the general technology of Portland cement are followed by detailed discussions of the limestones, marls, shales, clays, gypsum, and fuel supplies of Michigan, in connection with the cement industry. Following these are notes on factories, processes, product, etc. The sections on materials will be summarized.

Limestones from two formations (Dundee and Traverse) have been used in making Portland cement, while other limestones may be so utilized in the future. The Dundee limestone occurs at the base of the Devonian, and contains at least one bed of sufficient purity to be used in Portland manufacture. Material from this bed is utilized by the Michigan Alkali Co. at Wyandotte. The limestones of the Traverse group (Devonian) are used in the manufacture of Portland cement at Alpena.

Certain Silurian limestones may furnish a natural cement, while Eo-Carboniferous limestones, not at present used in Portland cement manufacture, are sufficiently low in magnesia to be a possible future source of Portland material.

Marl deposits of great area and depth occur abundantly on the lower peninsula of Michigan. A map of this portion of the state showing the location of the best-known deposits and of actual and proposed Portland cement plants, is presented. Numerous analyses of Michigan marls are given, and their physical properties, chemical composition, and probable origin are discussed in detail; the conclusions of Davis as to origin being restated and carefully considered.

Shaes of the Traverse (Devonian) and Coldwater (Carboniferous) formations are used in Portland cement manufacture; the former at Alpena, the latter at Union City and Coldwater. The Antrim shales of the Devonian and the Saginaw shales of the Carboniferous, are referred to as of possible use.

The surface clays are, in general, too sandy to be of use in cement manufacture, though they have been so used at Wyandotte. Several Michigan cement plants obtain their clay from Ohio.

Most of the gypsum used in the Michigan cement plants is procured from the extensive deposits near Grand Rapids.

The coal used is mostly from Ohio and Pennsylvania, though Saginaw Valley coal has been used to a small extent.

During the year 1900 five Portland cement factories were in operation in Michigan, while several others were in course of construction. Of those in operation, four were equipped with rotary and one with dome kilns. As regards materials, two plants used marl and clay; two, marl and shale; while one plant used precipitated lime carbonate (caustic soda waste) and clay. Only one of the plants in construction is designed to use limestone and shale; the others using marl with clay or shale.

STRUTHERS, J. *The Production of Gypsum in 1901.* Extract from Mineral Resources U. S. for 1901. 8vo, pp. 13, 1902.

An amount of 659,659 short tons of gypsum, valued at $1,577,493, was produced in the United States during 1901. Of this amount, 521,292 tons were calcined, the remainder being largely used as land plaster.

TAFF, J. A. *Chalk of Southwestern Arkansas;* with Notes on its Adaptability to the Manufacture of Hydraulic Cements. Twenty-second Ann. Rep. U. S. G. S., Part III, pp. 687–742, Pls. XLVII–LIII, Figs. 57–69, 1902.

Descriptions of the general geography and geology of the region are followed by a detailed discussion of the two chalk-bearing formations, with local details of the available deposits. Following this is a summary of the technology of Portland cement; notes on the chalks (Taff) and clays (Branner) of southwest Arkansas as Portland cement materials; and a brief description of the Whitecliffs cement plant. The subjects are well arranged; and the section on cement technology is rather more satisfactory than the material usually offered under this heading.

The sandy basal member of the Upper Cretaceous, prominent in Texas and Indian Territory, is concealed throughout its extent in Arkansas by post-Cretaceous gravels and sands. The lowest member of the Upper Cretaceous visible in Arkansas is therefore the marl overlying this basal sandy member. This marl is a continuous formation, and increases gradually in thickness from 30 feet at Austin, Tex., to 300 feet at Whitecliffs, Ark. Overlying this marl is the Whitecliffs chalk, which in turn is overlain by 200 feet of blue limy marl. Above this is the Saratoga chalk, which is succeeded by greensands and clay marls. The Whitecliffs and Saratoga formations will now be discussed in some detail, as being possible sources of Portland cement materials.

The Whitecliffs chalk is exposed, in Arkansas, in three separate areas, being covered in the intervening regions by post-Cretaceous deposits. These areas are in the vicinity of Rocky Comfort, Whitecliffs, and Saline Landing. In the Rocky Comfort area the thickness of the formation could not be precisely determined, but probably exceeds 100 feet. Farther east, at Whitecliffs, nearly 100 feet of chalk is exposed, and the top of the formation is concealed. Still farther east, at Saline Landing, less than half this thickness is shown. At Okolona no chalk occurs, its stratigraphic position being occupied by a chalky marl. The Whitecliffs chalk therefore occurs as a wedge, thickest toward the west, and coming to an end near the middle of the Cretaceous region of southwest Arkansas.

The Saratoga chalk formation occurs 200 feet above the Whitecliffs formation, and separated from the latter by marls. The maximum thickness of the Saratoga chalk is 30 feet; it is exposed in three areas in Arkansas, located respectively at Washington, Okolona, and Deciper.

Analyses show that these chalks of both formations vary greatly in composition; the lime carbonate varying from 49.90 per cent. to 90.01 per cent.; the silica and insolubles, from 4.91 per cent. to 43.72 per cent. In one respect the specimens agree: they are all sufficiently low in magnesia to come well within Portland requirements.

WILDER, F. A. *Present and Future of the American Gypsum Industry.* Eng. & Min. Jour., Vol. LXXIV, pp. 276-8, 4 Figs., 1902.

Brief review of the origin and distribution, both geographical and geological, of gypsum deposits; followed by a somewhat more detailed discussion of the uses of gypsum and the methods of manufacture of the various gypsum products, with interesting notes on recent German practice in the manufacture of plasters.

Origin of the Oligocene and Miocene Deposits of the Great Plains.— By J. B. HATCHER. (Proc. Am. Phil. Soc., Vol. XLI. [April, 1902].)

AFTER an introductory statement regarding the various horizons of the Tertiary deposits of the western plains, the author proceeds to a consideration of their origin. He shows that up to the present time the lacustrine theory has been generally accepted, but that recently the difficulties of that theory have been pointed out. The lacustrine origin of the Upper or Loup Fork formation has been rejected by many observers, and now it is generally considered to be as of combined lacustrine, fluviatile, flood-plain, and æolian origin. The lower division or White River beds are still regarded by many to be of lacustrine origin. To these deposits the author turns his attention.

The lacustrine origin of the White River beds was called seriously in question in 1899 by Dr. W. D. Mathew, of the American Museum of Natural History. W. D. Johnson, also, in the *Twenty-first Annual Report of the United States Geological Survey*, regards all of the Tertiary deposits of the plains as of fluviatile and flood-plain origin. Mr. Hatcher draws from his wide experience in these beds and presents facts which seem overwhelmingly conclusive in favor of their fluviatile origin as opposed to their lacustrine origin. The physical and palæontological evidences combine to fortify his position. The invertibrate remains were examined by Dall, Pilsbey, and Stanton, who agree that "they belong to species inhabitating swamps and small ponds." Dr. Knowlton reports that the plants are those of "springs, shallow ponds, and brooks," while the author shows that the evidence derived from the vertebrate remains indicates that the lacustrine hypothesis is untenable.

Mr. Hatcher does not rest with an attempt at destroying the old hypothesis, but presents in its place a rational explanation which satisfactorily accounts for the observed phenomena. He still further strengthens his position by quoting from Mr. H. H. Smith, who describes a region in South America which presents, at the present time, conditions similar to those postulated for the accumulation of the White River deposits. This region exhibits a somewhat remarkable condition of meandering and interlacing streams over a low-lying tract of country which is annually submerged by the floods. The region is comparable in size to the Tertiary deposits discussed, and gives a picture of the possible conditions of our western plains during Oligocene and Miocene times. Seldom do we find an article more replete with valuable and interesting observations. It would seem that those who still entertain a strict lacustrine hypothesis in explanation of the White River deposits would do well to strengthen their position in some more substantial manner than has hitherto been done.

Willis T. Lee.

AUTHOR'S ABSTRACTS.

THE GEOLOGICAL SOCIETY OF AMERICA. CORDILLERAN SECTION.

FOURTH ANNUAL MEETING.

THE fourth annual meeting of the Cordilleran Section of the Geological Society of America, was held partly in the rooms of the Academy of Sciences, San Francisco, and partly in the rooms of the Department of Geology of the University of California, Berkeley, December 30 and 31, 1902. The officers elected for the ensuing year were H. W. Fairbanks, chairman; Andrew C. Lawson, secretary; and W. C. Knight, councilor. The following papers were read and discussed :

The Synthesis of Chalcocite and its Genesis at Butte, Mont. By HORACE V. WINCHELL, Butte, Mont.

IT was stated that chalcocite is the principal ore of copper at Butte, and that it is one of the latest minerals to be formed in the veins. It is believed that the mineral was formed by a chemical reaction between copper sulphate in solution in descending waters and the iron pyrites and other sulphides below. Some synthetical experiments were described to prove this. The active agent in the reduction of the copper salt to the cuprous state seems to have been sulphurous anhydride, SO_2, as the experiments showed that when pyrite was digested in a solution of copper sulphate containing SO_2, it became coated with a layer of chalcocite, while in the same solution without the SO_2 the pyrite remained just as bright and yellow as before immersion.

A Geological Reconnaissance of the Region of the Upper Main Walker River, Nevada. By D. T. SMITH, Yerington, Nev., presented by Andrew C. Lawson.

THIS region is in the western part of the state of Nevada, between latitudes 38° 50′ and 39° 10′. It comprises the greater portion of a valley of general north-south trend. Nearly ten miles of the eastern range and sixteen of the western have been mapped geologically.

The eastern range is made up of granitic rocks—andesite, rhyolite, and limestone. The western range is also made up of these, together with basalt, schists, garnetiferous rocks, and intrusives. In both ranges are some later Tertiary strata. The metamorphics are nearly transverse to the axis of the valley. In them are deposits of copper ore, and directly across the valley and having the same trend as the metamorphics are copper-bearing veins in the granitic rocks.

In several instances the genesis of the deposits has been ascertained. This came out through a study of the deposits and the country rock. In some places sufficient mining has been done to give helpful exposures of the deposits in depth.

The relation of the country rock, bearing the deposits, to the other rocks of the region was discussed in detail. Structural features, both general and local, were given special attention. It was hoped to correlate events with some other well-known part of the Sierras, but this was not entirely possible. No fossils from the limestone were found, nor have any been reported, so far as could be learned. The limestone however, is much plicated and petrographically borders closely on to marble. This would seem to suggest a relationship with that of the Sierra Nevada. The Tertiary strata are made up of material of all the rocks above mentioned, except the basalt, and perhaps an andesite, which seems to occur later than the ryolite, and is different from the andesite above mentioned. In the strata were found Pliocene vertebrates and a few triassic shells—presumably from the limestone.

The Correlation of the John Day and the Mascall. By JOHN C. MERRIAM and WM. J. SINCLAIR.

THE age of the John Day is commonly given in geological text-books as Middle Miocene. A study of the large collection of vertebrate fossils from these beds made by the University of California, leads to a different view of the age of this formation.

The state of evolution of this fauna is practically identical with that of the Upper White River. Several genera occur in the Middle John Day which are found for the first time in the Protoceras beds. Associated with these are such persistent types as *Elotherium* and *Mesohippus*, which range far back into the Lower White River. But that the Middle John Day is not older than the Oreodon beds is shown by the total absence of Creodonts and Titanotheres, while it differs from the Oreodon beds in containing later introduced types, which are not known to range farther back than the Protoceras beds.

The Upper John Day contains several genera which have not been found in the Middle John Day (*Protomeryx*, *Protapirus*, *Promerycochœrus*). These seem to have entered Oregon as migrants from some of the eastern basins of accumulation. There are no related forms in the Middle John Day. With the exception of *Promerycochœrus*, and possibly some of the Rhinoceroses which have not yet been fully worked up, all the ungulate genera of the John Day are the same as those of the White River.

The Upper John Day has its closest affinities with the Middle John Day, and is probably in greater part Upper Oligocene, although it may overlap on the Lower Miocene. The Middle John Day is to be correlated with the Protoceus horizon of the White River Oligocene. The lower limit of the Upper John Day is determined by the downward range of *Promerycochœrus* in the beds.

This genus, which also occurs in the Mascall, and *Mylagaulodon angulatus*, gen. and sp. nv., and later types unite in a measure the gap between the Upper John Day and the Mascall faunas.

The presence of *Desmatippus crenidens* in the Mascall serves to correlate this formation with the Deep River beds. The flora preserved in the lower levels of the Mascall formation determines its age very definitely as Upper Miocene.

The Columbia lava represents in the stratigraphic series an erosion interval between the Upper White River and the Loup Fork in the plains region.

The Valley of Southern California. By E. W. Hilgard, Berkeley, Calif.

This paper treats of the orographic relations and post-Tertiary formations of the valley region extending from Los Angeles to Redlands, showing it to have been a topographic unit anterior to the subdivision of the drainage into the San Gabriel and Santa Ana systems by the extraordinary development of débris fans which now form the sources of artesian waters.

The Potter Creek Quaternary Bone Case. By Wm. J. Sinclair; presented by J. C. Merriam.

The case, which is situated near Baird, Shasta county, Calif., contains a thick deposit of alternating layers of clay, case breccia, and stalagmite resting in part on a stratum of volcanic ash. The ash reposes, either directly or with the intervention of some clay, on a floor of cemented case breccia known to be in part about a foot and a half thick. Excavation has not yet been prosecuted beneath this floor. The volcanic material is composed of fine fragments of glass.

Bones, in an excellent state of preservation, recur in all the deposits except the ash. They represent an *Equus* fauna of plains and forest type combined, much richer in species than any Quaternary fauna known from this coast. Among the larger forms represented are *Elephas*, *Mastodon*, *Megalonyx?*, *Rhinoceros*, *Equus*, and *Arctotherium*. Many smaller carnivora are present, many of them of extinct species. Among the rodents there is a new rabbit, a new squirrel, a new *Teanoma*, etc. Two species of deer are represented by numerous specimens.

At the time of the accumulation of the case deposit, the topography of the adjacent region had not assumed its present rugged character. The case was formed by percolating waters during the cutting of the McCloud river canyon. Infilling does not seem to have been contemporaneous with the excavation of the case. It is possible that much of the accumulation in the case antedates the Red Bluff epoch.

Further study will be required before the exact position of this fauna in the Quaternary case can be stated.

The Physiography of Southern Arizona and New Mexico. By H. W. FAIRBANKS.

THE great plain-like valleys of southern Arizona and New Mexico are extremely interesting. They stretch eastward from Yuma, where they are but slightly elevated above the sea, toward the continental divide, where they attain an elevation of 5,000 feet. From this point they gradually descend to 4,000 feet at El Paso, and are known to reach still farther eastward toward the Gulf of Mexico.

The plains are dotted with mountain ranges, which in southwestern Arizona are completely isolated and rise very abruptly, but toward the east the mountains break up the plain to such an extent as to form nearly inclosed basins.

A discussion of the origin of the nearly level surfaces of the broad valleys of the southern portion of the Great Basin and those adjacent to the lower Colorado led to the conclusion that three distinct types are to be distinguished: (1) those produced by erosion, as in the Mohave desert north of Kramer; (2) those of stream accumulation in old valleys, formed by the coalescing of débris fans; (3) those of accumulation in bodies of water.

The delta accumulations of a large stream like the Colorado are very different in nature of material and manner of arrangement from those constituting the waste slopes or débris fans: and besides, at the time the great valleys of Arizona were filled to their present level there is no reason to suppose that there was such a river as the Colorado in this region.

As a result of the attempt to discriminate the origin of the nearly level surfaces of the plain-like valleys of the Southwest, the conclusion was reached that those of southern Arizona, as typically represented in the region about Tucson, are the result of accumulation under a body of water, and that this water could have been none other than the northern and eastern extension of the Gulf of California. At Tucson the plain has an elevation of about 2,200 feet.

Professor Blake has described the extension of the beds of this plain into southeastern Arizona, where in the San Pedro valley they attain an elevation of 4,000 feet. In the lower end of the valley he has found beds of diatomaceous earth which are thought to be of marine origin.

The floors of these plain-like valleys appear dissected as they rise toward the continental divide, and upon the middle Gila river are exposed in cliffs several hundred feet high and capped by flows of basalt. Basalt also forms a portion of the floor of the plain between Yuma and Tucson. The beds appear nowhere to have undergone other disturbance than simple uplift. Their materials are but slightly consolidated, and the writer believes with Professor Blake that they probably belong in the late Tertiary or early Pleistocene.

Valleys filled with similar well-stratified material extend across the continental divide, but their surfaces are in places modified by débris fans and in others dissected by erosion.

At El Paso well-stratified beds of fine detrital material have been cut through by the Rio Grande. There can be no question about their belonging with those farther west. They extend many miles east of the city, but just how far the writer does not know from personal observation. The presumption is that they reach the Gulf of Mexico.

From the facts presented it is legitimate to draw the conclusion that during the late Tertiary the whole of the southwestern portion of the United States as well as northern Mexico was very much lower than now, and that the sea reached in through long arms among the mountains toward the present continental divide. Just how far it is impossible to say from present knowledge, but the facts point toward the presence of bodies of water in all the large plain-like valleys in the region of the present continental divide in the latitude of the Mexican border. They may have been more or less isolated by the low divides connecting the mountain ranges, but were probably at or near sea level.

During the deposition of the beds and following them flows of lava occurred in places, and then the uplift and arching of the crust along the present divide.

This differential uplift gave rise to the conditions necessary for the excavation of the great canyons of the Plateau region and perhaps originated the Colorado river. The lower portion of this stream as well as the Mohave river has been superimposed upon an old topography as shown at numerous points.

Some Gypsum Deposits of Northwestern Nevada. By GEO. D. LOUDERBOCK, Reno, Nev.

A DEPOSIT of gypsum occurs some six or seven miles south of Virginia City. It is an isolated mass inclosed in limestone walls, the whole surrounded, in the main, by diorite. The principal body gives a surface exposure of over 100 yards in width and over 150 yards in length. This is practically all gypsum almost vertical in attitude. The mineral occurs as a milk-white holocrystalline granular aggregate, with some soft secondary earthy material at the surface and along a gully draining the area. The granular variety is quite pure, running generally over 90 per cent. $CaSO_4.2H_2O$, the chief impurity being $CaCO_3$.

Another large deposit occurs in the Humboldt range some five miles east of Lovelock. It occurs interstratified with limestone and a little quartzite. While undisturbed by intrusion, it is faulted and folded. Surface exposures of 300 yards or more in width occur, some two-thirds of which is gypsum, the rest mainly limestone. The thickest gypsum bed is about 150–175 feet thick. The mineral occurs as a holocrystalline granular aggregate except on the surface and lower slopes down which it has washed. It runs from 95–97 per cent. $CaSO_4.2H_2O$, practically the only impurity being calcite.

Reasons are given for believing that both of these gypsum deposits are original members of the stratigraphic series—*i. e.*, that they were formed by deposition from a saline water-body, and are probably of Middle or Upper Triassic age.

Physiography and Geology of the Siskiyou range. By F. M ANDERSON.

THE Siskiyou range forms the central portion of the mountain system often referred to as the Klamath mountains. It follows approximately the boundary line between Oregon and California, and, branching toward the west, divides the drainage of the region in three directions, on the north toward Rogue river, on the south toward the Klamath river, and on the west toward Smith river. The topography of the range, together with its main geological features, suggests a system of transverse folds, one of which is older than the other. The areal geology of the range consists of an alternate succession of igneous and sedimentary, or metamorphic, belts crossing the major axis of the range nearly at right angles. The axis of the range is interpreted as being an expression of, or representing, an earlier topography, and the geological zones as representing a later system of folding.

There is a variety of both igneous and sedimentary, or metamorphic, rocks. The igneous rocks range from ultra-basic to acid types, and are mainly deep-seated. Three belts of igneous rocks cross the range. The sedimentary rocks are for the most part Palæozoic in age, though Triassic rocks may also occur. They include radiolarian cherts, siliceous and calcareous slates, limestones, and crystalline schists. The character of the metamorphic rocks varies in accordance with the character of the original sediments and with the character of the plutonic which has effected their metamorphism.

Magmatic differentiation in the plutonic rocks is extreme, the granitic rocks passing by gradations into diorites, gabbros, and other pyroxene-bearing rocks.

The Genesis of Ore Deposits in Boulder County, Col. By RUFUS M. BAGG, JR., Brockton, Mass.

THE geology of Boulder county was outlined. The formation of veins was considered. A description was given of the occurrence of fissure veins along irregular fracture zones which, after faulting, have been secondarily filled with solutions and sublimation products, chiefly the tellurides of gold, mercury, and the sulphide of iron, marcasite. The genesis of these rich ore pockets was discussed. A description of some of the principal mines was given. A summary of field observations when examining mines in the district was given.

A Contribution to the Geology of the Leucite Hills, Wyoming. By J. F. KEMP, New York, and W. C. KNIGHT, Laramie, Wyo.

The Mechanics of Igneous Intrusion. By R. A. DALY, Ottawa, Canada.

THE more important facts of the writer's summary are:

1. *The facts of the field.*—(*a*) Lack of sympathy between structural planes in the invaded formation and form of intrusive body. (*b*) Respective magmatic chambers are not prepared for intrusion by circumferential faulting. (*c*) Contact phenomena demonstrate some kind of active assimilation of their corresponding country rocks by the respective magmas. (*d*) In the normal stock there is a lack of any enrichment of the endomorphic zone by the invaded formation; general freedom in the interior and characteristic abundance of angular inclosures near the contacts; exceedingly sharp lines of contact with country rock; a high degree of homogeneity in the igneous body, and common occurrence of many long and narrow apophyses form the igneous body. (*e*) Isolated observations prove that solid rocks may sink in molten magmas because of differential density.

2. *The facts of experimental research.*—The experiments of Barus, Doelter, Daubree, Cossa, Bischof, Cotling, Morozewicz and others show: (*a*) that representative natural or artificial silicate mixtures, at ordinary atmospheric pressure, become thinly molten at a temperature only slightly above that of solidification; (*b*) that, in every instance, a great increase of volume characterizes the change from the solid to the liquid state; (*c*) that, with strong probability, the volume increment and resulting density decrement are so far preserved in rock magmas under plutonic conditions as to forbid the flotation of blocks of the average country rock immersed in the average magma in depth; (*d*) that the chief rock-forming minerals are soluble in all of the melted silicate mixtures yet investigated and at the temperature ruling when those mixtures are thinly molten; (*e*) that rock magmas become thinly molten at temperatures very slightly above the melting point.

3. *The tests of the hypotheses of overhead stoping and enlargement of magma chambers.*—Reasons are given for concluding that the cause cited for overhead stoping is quantitatively sufficient for the majority of stocks and "batholiths," and the detailed phenomena associated with these inclusions are facts of nature expected on the hypothesis.

Finally the author concludes that "dikes, sheets, laccoliths, 'byamaliths,' and perhaps a few of the smaller stock-like plutonic bodies are conceived to be due to crustal displacement permitting intrusion; that marginal assimilation in the preparation of subterranean magma chambers is quite subordinate to magmatic overhead stoping; and that *abyssal* assimilation, in contrast to marginal (*hypabyssal*), is responsible for the preparation or notable modifications of magmas whence come, through differentiation, the igneous rocks of the globe."

A Structural Section of a Basin Range. By GEORGE D. LOUDERBOCK, Reno, Nevada.

THE prevalent idea of the structure of the "Basin ranges" having been called into question, a structural section of the Humboldt Lake Range and adjoining country is presented as a contribution to the discussion. This range, where studied, is shown to be made up of strata of the Triassic and Jurassic periods, faulted, folded, in places overturned, which were greatly eroded, in fact were practically in a peneplained condition, before the outpouring of the Cenozoic volcanics. Over their upturned and eroded edges lies a volcanic series made up of rhyolites, rhyolite tuffs—some being current bedded, and with conglomerate layers—capped by basalt. This series is faulted and tilted in a simple manner, in great contrast to the older rocks. Reasons are given for believing that these volcanics were laid down at an approximately horizontal attitude, and that the volcanics of the range and those of the valleys on either side were continuous. On the east slope of the range, the series passes from the summit to the base, with some 20° dip, and disappears under the detritus of the valley. On the west slope they are not to be found, but they occur at the west base, butting into the range at an approximately horizontal attitude, indicating a fault on the west side and simple tilting of the range as a comparatively rigid block.

A well-checked use of the volcanic rocks, which are so abundant in the Great Basin region, to determine the character and extent of the more recent earth movements is urged, and examples are given from other ranges where it has proved of value.

The structure of the range may also be arrived at by the application of the physiographic criteria so concisely stated by Davis;[1] for (1) the range has a unity, and a consistent front, and while lying between broad flat valleys, it shows no approximation to broad intermontane valleys; and (2) the form of the range does not agree with the structure of its bed rock series, which latter is variously folded and tilted, in ways not expressed by the physiography, and shows varying degrees of obliquity to the front of the range.

The great erosion of the fault scarp, and lack of erosion of the basalt at its base, shows that the valleys have, during the history of the range as a faulted block, been anything but seats of great erosion; and the great thickness of alluvium and lake deposits shows that they have been areas of deposition.

The following papers for lack of time were read by title:

The Probable Cause of Water Flow in the Mines of Cripple Creek, Colo. By Rufus M. Bagg, Jr., Brockton, Mass.

The Paddles of Shastasaurus. By John C. Merriam, Berkeley, Calif.

The Quaternary of the Middle Coast Ranges of California. By Andrew C. Lawson, Berkeley, Calif.

Andrew C. Lawson,
Secretary.

AUTHORS' ABSTRACTS OF PAPERS READ AT THE WASHINGTON MEETING OF THE GEOLOGICAL SOCIETY OF AMERICA.

Direction of Flow of the Ancient Beaver River, Shown by Pot-holes. By Richard R. Hice.

The evidence of the slope of the remaining fragments of abandoned fluvial plains may not always be conclusive as to the direction of flow of the stream that formerly flowed over them. Pot-holes, one of the features of stream erosion, are conclusive. On the Beaver River from Beaver Falls to below the Fallston dam, the present channel, cut in the Homewood Sandstone, is marked by typical pot-hole erosion. Views of pot-holes below the Fallston dam show in all cases that the up-stream side of the hole is abrupt, and often undercut, while the down-stream side is rounded off and eroded by the action of the flowing water. This also applies to channels formed by

[1] *Science*, September, 1901, p. 457.

pot-holes cutting into one another. Near Rock Point the abandoned bed of the old stream, 150 feet above the present stream, is also in the Homewood Sandstone. A number of pot-holes have been seen here, and views show that the steep side is on the southern side, and the eroded, rounded side on the northern side of the hole, thus clearly indicating that the former stream flowed northward.

The fragments of the bed of this old north-flowing Beaver are practically level from Pittsburg to Rock Point, a distance of about forty miles. The next fragments found a few miles north of these pot-holes are, however, some 80–100 feet lower than at the pot-holes. Observation shows that pot-holes are formed only where the stream is very rapid, and these pot-holes, therefore, indicate that the old north-flowing stream had a greatly increased fall northward for several miles, and a series of rapids here occurred, or perhaps a fall. The pot-holes, therefore, bring the fragments farther north (810 feet) into harmony with the level at the pot-holes (900 feet), and harmonize the almost horizontal fragments southward to Pittsburg, with the 80–100 feet of fall found immediately northward.

Ames Knob, North Haven, Maine; A Seaside Note. By Bailey Willis, Washington, D. C. (Abstract of Paper to Appear with Illustrations in *Bull. G. S. A.*)

Ames Knob is a mass of andesitic volcanic rock rising 160 feet above the sea, on the neck of land between the Fox Island thoroughfare and South Harbor, North Haven Island, in Penobscot Bay. Its petrographic character and geologic relations have been described by G. O. Smith, in his essay on the geology of the Fox Islands, Me. It is bounded on the north by a low plain cut in shales and limestones, of Niagara age, and its northern slope is a cliff resulting from the relatively great hardness of the igneous rock. The other slopes of the knob are of practically uniformly resistant rock, and variations in profile are attributable to conditions of attack, rather than of resistance. At an altitude of approximately 80 feet above the sea, on the southeastern and southern sides facing the Atlantic ocean, is a well-marked bench from which a steep facet rises 40 to 60 feet to the summit of the knob. This bench, which has an average width of about 200 yards, is attributed to the action of waves cutting at rock level. The rocks in place exposed upon this bench and about its margin exhibit rounded glaciated profiles, but no longer bear striæ, so far as observed. Hence it is inferred that the date of submergence to this level preceded and continued to the latest episode of glaciation, and that later influences have removed the minor evidences of ice action. Upon this glaciated bench there are now deposits of glacial gravel having the characteristic forms of spits and bars, which are accordingly attributed to wave and shore currents. These deposits indicate the presence of the sea at this level after the retreat of the ice.

The simplest explanation of the facts is that Ames Knob was submerged beneath the sea to a depth of 80 feet above the present sea level before, during, and immediately after the latest glacial episode.

Permian Elements in the Dunkard Flora. By David White.

The Dunkard series (Upper Barren Measures, XVI) comprises the topmost Paleozoic sediments in the Appalachian trough. It occupies a considerable area in southwestern Pennsylvania, northern West Virginia, and eastern Ohio, and the total thickness in northern West Virginia is probably over 1,200 feet. In the absence of marine organisms, the determination of the age of the beds rests on the fossil floras, the only important palæontological evidence at present available.

Extensive plant collections made at several localities were fully described in 1880 by Professors William M. Fontaine and I. C. White, who from their study of the flora and the lithology concluded that the entire series was Permian. This conclusion has been questioned by some American geologists and palæobotanists on account of the large proportion of Coal-measures types, the paucity of genera and species characteristic of the Permian of Europe, and the similarity as well as continuity in the sedimentation.

Additional material recently collected materially increases the number of identical characteristic Permian species, which now includes three species of *Callipteris*, in or above the Washington limestone, while the examination of the types in other genera emphasize the Permian aspect of a number of other forms. The data now available leave little room for doubt that the upper part, of the Dunkard at least is Permian, the stratigraphical occurrence of the species rendering it probable that the beds down to and including the Washington Limestone, about 175 feet above the base of the series, may with safety be referred to that period. The evidence as to the age of the lower beds of the series is, in the judgment of the writer, not yet sufficiently complete to be satisfactory or conclusive. On account of the continuity in sedimentation, with little epeirogenic movement and but slight lithological differences as compared with the preceding formations, and on account of the presence of a transitional flora including many persistent Upper Coal-measures species, a much more thorough investigation of the plant fossils of the Dunkard and Monongahela measures will be necessary before the boundary or approximate limit between the Coal-measures and the Permian can be drawn.

Walchia and *Ullmannia*, though present in other Permian basins of this continent, have not yet been found in the Appalachian trough. The upper part of the Dunkard is referable to the Rothliegende, probably to the Lower Rothliegende. Beds of the Zechstein or Upper Permian do not appear to have survived in the Appalachian basins.

Glacial Bowlders Along the Osage River. By E. R. Buckley, S. H. Ball, and A. T. Smith.

The discovery of glacial bowlders along the Osage river, fully thirty miles south of the known southern limit of the ice sheet, was simply an "episode" in the systematic strategraphic work which the Missouri Bureau of Geology and Mines is at present conducting in the Ozark region. The fact, however, that in no less than eight localities along the Osage river in Miller county granitic bowlders of undoubted foreign origin were observed is in itself a contribution to the glaciology of this region. This discovery also has a bearing on the physiographic history of the region, giving evidence of the age of the Osage river channel.

In brief it may be said that, if one were to include foreign erratics of all sizes observed at the eight localities, he might perhaps account for several hundred bowlders. These bowlders consist of several varieties of granite, granite-gneiss, and diorite. They range in size from pebbles having a diameter of several inches to bowlders three feet in diameter.

They occur along the present river channel and also back from it, along the tributary streams. In no case, however, were they found at a greater elevation than 605 feet A.T., which in that region is about 70 feet above the low-water level of the Osage river. Nowhere on the ridge land between the Osage and Missouri rivers is there any evidence of glaciation.

The evidence at hand warrants us in believing that the glaciers did not override the ridge land to the north and that the bowlders above referred to do not indicate the former extension of the ice sheet to that point. Although it has lately been pointed out that the ice sheet extended beyond the head waters of the Osage river in Kansas, it is thought very improbable that these bowlders could have been carried that distance on ice floes. The more reasonable explanation of their present location is through icebergs or floating ice carried from the Missouri river on back-water caused by an ice-jam below the mouth of the Osage. This is the present accepted explanation of their origin. Other explanations, such as changes in the course of the river, have not proved tenable.

Accepting the above explanation of the source of the bowlders, it leads to the important conclusion that the channel of the Osage river was, in part at least, defined prior to the glacial period. The history of the Osage river, with its meandering course as it flows between steep cliffs on either side, has presented to the geologists of Missouri a very interesting problem in physiography, and one which has not yet been settled. It is hoped that this occurrence of glacial bowlders will be of some assistance to the next physiographer who undertakes to read the history of the river.

Age of the Atlantosaurus Beds. By WILLIS T. LEE.

THE paper deals with the southern extension of the Atlantosaurus beds along the eastern foothills of the Rocky Mountains into New Mexico, and shows that certain shales in the Canadian Canyon are probably equivalent to these beds. The shales are also traced south and east from their type localities through a new Dinosaur locality and into Oklahoma, where shales, which are apparently the continuation of the Dinosaur beds, contain fossils of Lower Cretaceous type. The observations thus tend to confirm the opinion held by many geologists that the Atlantosaurus beds are of Lower Cretaceous age.

On the Porphyritic Appearance. By ALFRED C. LANE.

THERE are some five different kinds of phenocrysts, or crystals, which may give a porphyritic appearance, viz :

Coarser relics of a previous consolidation.

Crystals whose formation took place during the migration of the igneous magma.

Crystals which were formed early in the process of cooling and solidification so that their grain continues to increase clear to the center, while later-formed constituents increase only for a shorter distance, their grain thereafter remaining uniform. This porphyritic type will be most obvious at the center of the igneous mass.

Crystals, the conditions (temperature) of whose formation were nearly half way between those obtaining initially in the igneous magma and the country rock. Such crystals will be most conspicuously porphyritic at or near the margin.

Finally there may be crystals, which like the staurolite of schists, are formed by metamorphic actions, of secondary origin, and occur in sediments, and only casually occur in igneous rocks.

Attention is particularly called to the third and fourth classes, the possibility of the existence of which has been almost overlooked, though their possible existence may be readily inferred from inspection of diagrams of the cooling of an intrusive. Certain field observations render their actual existence probable.

The Basal Conglomerate in Lehigh and Northampton Counties, Pennsylvania. By FREDERICK B. PECK, Easton, Pa.

THE term "basal conglomerate," as here used, refers to that lowest member of series of beds, belonging to the Cambrian, which lies uncomformably upon the pre-Cambrian gneisses, but is conformable with the overlying lower Cambrian dolomites. It occurs here, as elsewhere in Pennsylvania and New Jersey, fringing the pre-Cambrian areas. In eastern Northampton county it fails occasionally as a result of faulting. It has a thickness varying from a few feet near Easton to one hundred or possibly several hundred feet at Alburtis, twenty-four miles southwest of Easton.

Petrographically, it is quite variable. At times it is a coarse conglomerate, made up of quartz pebbles, an inch or two in diameter. Frequently it is a medium to fine grained arkose, consisting of about one part feldspar (orthoclase or microcline) to two or three parts quartz, the former usually thoroughly kaolinized, the latter badly crushed, and under the microscope exhibiting an undulating extinction. Other phases of it present a dense bluish or grayish quartzite. It occasionally contains interstratified beds of a very fine-grained argillaceous sandstone with numerous worm borings (scolithus), but as yet no distinctly lower Cambrian fossils have been found. The seemingly uppermost member is a highly ferruginous, almost jaspery quartzite, which locally contains iron enough to constitute a low-grade ore. From this horizon a considerable amount of iron ore was formerly obtained. The lowest member of the series, in a number of instances, was found to pass by almost imperceptible gradations into the underlying granitoid gneiss, in such a manner as to suggest the decidedly rapid submergence of a deeply weathered Cambrian land mass, with a correspondingly rapid advance of the sea over the same, affording insufficient time either for the thorough sorting of the loose materials already at hand or the bringing in of any considerable amount of sediment from a distance. The entire basal series, representing, as it does, distinctly littoral or at least shallow-water deposits, has a total thickness of only a few hundred feet at the most, and the conditions under which it was deposited must have rapidly changed to those necessary for the deposition of the off-shore and distinctly deep-water sediments represented by the two or three thousand feet of dolomites and the dolomitic limestones, which immediately succeed it.

The series is the northeastern extension of beds which in York county have been called by Walcott "the Hallam quartzite"[1] and is the equivalent of the Hardiston quartzite of Kümmel and Weller[2] in northern New Jersey.

Post-Glacial Time. By A. H. Elftman.

Hitherto the St. Anthony gorge has been ascribed to the St. Anthony falls, which is regarded as having decreased in height from Fort Snelling to Minneapolis. Several features of the gorge were described, showing that it was formed largely by rapids. The falls did not assume prominence until two miles above Fort Snelling was reached, and they have been increasing in height. Account is taken of the terraces in the Mississippi valley, and the differential uplifts are recognized as affecting this region. The gorge represents a much longer period of time than has been assigned to it. This is further strengthened by the evidence afforded in the postglacial gorge of the St. Croix river.

The Relation between the Keewatin and Laurentide Ice-sheets. By A. H. Elftman.

Evidence was presented to show that the glacial drift of the upper Mississippi river valley was deposited by independent lobes of the

[1] *Bull. U. S. Geol. Surv.*, No. 134, 1897.

[2] *Bull. Geol. Soc. Am.*, Vol. XII, pp. 149 ff.

Keewatin and Laurentide ice-sheets, alternating in their advance and retreat.

A lobe of the Keewatin ice-sheet first invaded this region from the northwest and extended into Iowa and to western Wisconsin. This lobe formed the Kansan drift in Minnesota and the Kansan and pre-Kansan drift further south. Glacial Lake Grantsburg was formed in the upper Saint Croix valley, and for a time had its outlet northward into Lake Superior. The retreat of this ice was followed by a marked interglacial period.

The second great ice invasion, the Iowan, came from the northeast. The Rainy Lake and Lake Superior lobes of the Laurentide ice-sheet extended to western Minnesota, and the latter lobe was deflected southward into Iowa. This ice does not appear to have retreated far beyond the limits of Minnesota, and was followed in this region by a comparatively short interglacial period.

During the third invasion, the Wisconsin, the Minnesota lobe of the Keewatin ice-sheet again advanced from the northwest across central Minnesota into Iowa. At the same time the lobes from the Laurentide ice-sheet advanced southwestward until they reached the northeastern limit of the Minnesota lobe. The final retreat of the three lobes was contemporaneous, forming glacial lakes and numerous moraines. The Keewatin ice-lobe appears to have completely retired from Minnesota slightly before the lobes of the Laurentide ice.

A new mapping of the moraines formed by the various lobes during their final retreat is presented in support of the views advanced.

The movements of the several lobes of the Laurentide ice-sheet present a combination not noticed heretofore. The lobes from Green Bay and Lake Michigan eastward over the Great Lakes show three well-defined advances—the Illinoian, Iowan, and Wisconsin. The Chippewa, Lake Superior, and Rainy Lake lobes show two advances, the Iowan and Wisconsin. The western lobes in Canada, north of Minnesota, show only one advance, the Wisconsin.

It appears that the advance of the northern part of the ice-sheet to the west was much slower than the advance to the south, and the time required for the Laurentide ice-sheet to reach Lake Winnipeg was sufficiently long to allow of two and three advances and retreats in other portions of the ice-sheet.

The Bellefonte, Pa., Section of the Ordovician. By GEORGE L. COLLIE.

THE section described is located at Bellefonte, Pa., the geographical center of the state. It lies in the Nittany valley, a denuded anticline, between the isoclinal Bald Eagle ridge on the northwest and the synclinal Nittany ridge on the southeast.

The rocks dip to the northwest, the dip varying from 8° at the crest of the anticline to 80° and 90° at the top of the section in Bald Eagle ridge. The total thickness of rocks in the section is 6,000 feet, of which 5,000 feet are limestones and 1,000 feet shales. The lithological features of the rocks have been described in detail in the various geological reports of the state, and do not need further description. Little attention has been given to the faunas found in the rocks, and this paper aims in a measure to supply this deficiency.

Four fossiliferous horizons have been recognized in the limestones and two in the shales. The lowest horizon (A^1 of the paper) is 345 feet above the base of the section. It occurs in an oolitic limestone and is but a few inches in thickness. Ophiletas are the most abundant types found, though Murchisonias occur sparingly. The Ophiletas are related chiefly to *O. Complanata.* This indicates the Calciferous age of this horizon.

Between this lowest horizon and the next succeeding horizon (A^2) there are 600 feet of unfossiliferous rocks. Horizon A^2 contains a mixed fauna. Its relationships are in part with the Calciferous, in part with the Quebec, and in part with the Chazy. The most abundant fossil is *Asaphus Marginalis,* a Chazy form in New York. Various species of Ecculiompholus occur, all of which are closely related to forms described by Billings from the Quebec of Canada. *Ribenia Calcifera* and *Ophileta Uniangulata,* typical Calciferous fossils, are found also. Provisionally this horizon is referred to the Calciferous. Above A^2 are 1,200 feet of unfossiliferous rocks before the third horizon A^3 is reached.

Horizon A^3 is characterized by an overlapping of faunas. Stratigraphically speaking, the horizon is Chazy, but it contains few Chazy fossils. The relationships of the fauna are with Canadian and Newfoundland types rather than with those of the interior as represented in New York. The most interesting fossil found is *Bothyurus amplimarginatus,* a form described by Billings from the Calciferous of the Mingon Islands, Gulf of the St. Lawrence. *Macluna Magna, M. Affinis, M. Acuminata* are common. The mention of these names gives some idea of the commingling of faunas at this horizon. For the present this horizon is referred to the Chazy. Two thousand feet of unfossiliferous rocks intervene between this horizon and the Trenton horizon, A^4. The total thickness of the exposed Calciferous is about 1,900 feet; of the Chazy, 2,200 feet; of the Trenton, 900 feet.

Unlike the lower horizons, the faunas of A^4 are closely related to those of New York. They need no description in this place, the only unusual form found being a Brougniartia, a homalonotoid trilobite, which is quite common in the shaly limestones at the top of the Lower Trenton. The shales of the section are fossiliferous at the base and again at the top. The intervening beds are not fossiliferous. At the base the characteristic Utica form, *Triarthrus Beckii*, is very common; its vertical range is 300 feet, and this is taken to be the thickness of the Utica shale. The Lorraine shales contain characteristic fossils similar to those found in similar horizons in New York. Not only is there a marked similarity in the fossils, but in the lithological features of the rocks, indicating very similar conditions in the two fields. During the earlier stages of the Ordovician there seems to have been free communication between Pennsylvania and the Canadian provinces. In the later Ordovician this seems to disappear, and direct communication is established with central New York.

The Devonian and Carboniferous of Southwestern New York. By L. C. GLENN.[1]

THE paper is based on work done by the United States Geological Survey, in co-operation with the states of New York and Pennsylvania, in the areal geological mapping of the Olean and Salamanca quadrangles, together with reconnaissance work southward and westward in Pennsylvania.

The oldest rocks exposed are the upper 700 feet of the Chemung, consisting of argillaceous and sandy shales, with the Cuba sandstone as a thin lentil near the bottom. The Wolf Creek conglomerate succeeds the Chemung and is regarded as a lentil marking the base of, and belonging to, the Cattaraugus shale formation. It is a flat pebble conglomerate, quite variable in thickness, but usually thin and inconspicuous, and thins out and disappears westward on the Salamanca quadrangle. Bright red shales first appear within a few feet above the Wolf Creek and with interbedded greenish shales and soft, fine, greenish-

[1] Published by permission of the Director of the U. S. Geological Survey.

gray, micaceous sandstones characterize the next 300 to 350 feet. This red-shale interval constitutes the Cattaraugus formation. In its upper part a second lentil, the Salamanca conglomerate, occurs. It lenses out eastward, but becomes prominent westward in the Salamanca region and is regarded as the same as the Pope Hollow and Panama conglomerates farther west. A third lentil, called the Kilbuck conglomerate by Mr. M. L. Fuller, occurs about 50 to 70 feet above the Salamanca. It is found in the Salamanca region only.

The next formation is the Oswayo, characterized by rusty olive colored, limonitic sandy shale, from 160 to 250 feet thick. Over this the Sub-Olean, or Shenango, conglomerate is found in some areas, usually 20 to 30 feet thick, but apparently cut out in other places, and on the Olean quadrangle losing its conglomeratic character and merging into a sandy shale similar to the Oswayo shale. Over it, when not apparently cut out also, are 30 to 50 feet of Sub-Olean, or Shenango, shale. This is overlaid by the Olean conglomerate, usually massive and round-pebbled, 50 to 90 feet thick. A few feet of thin, rusty, sandy Sharon shale overlies the Olean conglomerate at Rock City.

The shales below the Wolf Creek are Devonian. From the base of the Wolf Creek to the top of the Oswayo a mingling of Devonian and Carboniferous faunas makes it best to designate these rocks, for the present, as Devono-Carboniferous. Above the Oswayo the rocks are regarded as Carboniferous.

The rocks dip 25 to 30 feet per mile slightly west of south. Minor rolls causing local reversals of dip are known to occur.

AUTHOR'S ABSTRACTS OF PAPERS READ AT THE WASHINGTON MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. SECTION E.

Geological Age of the West Indian Volcanic Formations. By J. W. Spencer.

The Greater Antilles appear to be nearly devoid of volcanoes. The writer has seen only the remains of one in Jamaica (at Low Layton), and none in Cuba. But there are extensive underlying igneous formations in all these islands. However, in the inner zone of the Caribbean or Windward Islands there are many cones, and beneath these and the outer islands there is an underlying volcanic basement. In such of the outer islands as St. Martin, and better still in Antigua, and in St. Croix one gets some knowledge of the antiquity of the older eruptive formations. In Guadeloupe the geological records are equally well preserved, on one side, while on the other there are the more recent volcanic cones, which can also be seen in St. Kitts, Statia, Dominica, Martinique, St. Lucia, St. Vincent, etc.

In St. Martin and Antigua the old volcanic basement forms mountains still uncovered by modern cones, as also in St. Croix. The rocks are essentially an andesite in form of both lavas and tuffs. Their surface topography is molded by atmospheric agents into low mountains and valleys. Overlying such a basement in St. Croix and St. Thomas, according to Cleve,[1] there is a conglomerate containing pebbles with Cretaceous fossils. In this region these basement rocks are so dissected that their remains constitute many of the islands of the Virgin group.

But in Antigua and Grande Terre of Guadeloupe the strata overlying the denuded igneous basement is a subaqueous redistributed tuff with some calcareous beds in the upper zone, over which rest conformably the white limestones, a marly deposit containing Oligocene corals and shells.[2] South of the Guadeloupe Archipelago and Monserrat, the outer islands disappear, and the writer is not aware of the occurrence of the early Tertiary limestones remaining so as to leave evidence of the age of the igneous basement, though by its lithological characteristics and the physical features of its ancient surface one can hardly be far astray in concluding that they are of the same age as the similar formations on the islands to the north. In Barbadoes the Oligocene limestones reappear, but here there are no igneous deposits. It thus seems that the whole Caribbean plateau beneath both the volcanic ridges and the limestone islands is underlaid by an igneous formation dating back to the commencement of the Tertiary periods at least, if indeed these rocks are not as old as those of St. Croix, that is, as ancient as the Cretaceous period.

In St. Martin, St. Bartholomew, and Antigua the mountain belts are entirely made up of the denuded rocks of this old igneous formation without a covering mantle. So also, part of Statia, St. Kitts, Monserrat, the southern end of Martinique, portions of St. Lucia, and the southern end of St. Vincent have their surfaces molded out of the ancient igneous accumulations; but elsewhere in these islands, as also

[1] "On the Geology of the Northeastern West India Islands," *Trans. Roy. Swedish Acad. Sc.*, Vol. IX., 1870–71.

[2] See "Geological and Physical Development of the Various Windward Islands," six papers by J. W. Spencer, in *Quar. Jour. Geol. Soc. Lond.*, Vol. LVII (1901), pp. 409–543, and Vol. LVIII (1902), pp. 341–65.

in Guadeloupe proper and Dominica, they are covered with volcanic materials which constitute more or less of the cones and ridges, rising to a height of 3,000 to 4,000 feet. In these mountainous islands there is not merely a combination of late and ancient eruptive deposits, but there are several formations secondarily derived from the remains of the older basement, and here is room for more study than has been attempted.

The history of one is more or less the history of all of these conical islands. For instance, in Dominica there is the old andesitic rock, overlaid by volcanic breccia or conglomerate. At other points the age of the tuffs cannot at present be assigned, but some of them have been denuded into relatively large valleys, which have been partly refilled with still newer tuff (like that of the Roseau valley), containing an abundance of water-worn pebbles, often arranged in lines among the more angular material. Such may correspond to the early Tertiary subaqueous tufaceous beds of Grand Terre (Guadeloupe). And these beds have been subsequently tilted outward at considerable angles. As in St. Martin and Antigua and Grand Terre, there is nothing to show that there were any mid-Tertiary eruptions when the whole region was somewhat elevated and the denuding agents were molding the surface into rounded outlines. From the corresponding topography in the more volcanic islands, where not surmounted by the modern cones, the impression is left that the volcanic activity of the region was quiescent during much of the Miocene-Pliocene period, before the building up of the cones and ridges, which were constructed at a relatively late date, for we find the sea bed elevated along with these ridges. Thus we find in Statia and in St. Kitts volcanic cones raised by an upward thrust which carried along with it the sea-floor, covered by about thirty feet of marl now forming broken mantles surrounding the cones to elevations of from 400 to 900 feet. Elsewhere, however, we find fragments of a similar formation appearing with the volcanic rocks brought up by a general elevation of the island. These limestone marls contain practically a living fauna, thus showing the elevation to date no farther back than the end of the Pliocene period. Again, there are two series of gravel formations, one of which is older than the coralline strata just mentioned as interbedded with the volcanic ejectamenta; but this gravel formation had its surface greatly denuded before the formation of the marl. Again, both the marl and the gravel have been further subjected to erosion so as to be often left only in broken series. The newer gravel has not been subjected to so much denudation. The youthful lavas have been seen both in Dominica and St. Kitts beneath the stratified gravel beds, but at present it has not been determined whether they belong to the older or newer series. The lower gravels in their succession correspond in position to the Lafayette of the continent, and the upper gravels to that of the Columbia. The eruption which raised the cones in St. Kitts and Statia, above referred to, appears to have occurred during the subsidence which gave rise to the upper gravels provisionally regarded as the equivalent of the Columbia series — a mid-Pleistocene formation — and the marl beds thus raised rest upon an incoherent bed of volcanic ashes, containing a living fauna. From all facts before the writer it seems that the volcanic ridges owe their origin to volcanic activity which recommenced about the close of the Pliocene period, and that the eruptions have continued with more or less interruption down to the present day; for we find that the cones and ridges have not become so deeply dissected by rains and streams as would be expected, had their growth not been continued more or less continuously from their rebirth at the close of the Pliocene period to the present year of recorded activity.

The Marl-Loess of the Lower Wabash Valley. By M. L. Fuller and F. G. Clapp.

The fine silts bordering the Wabash valley have in the past been correlated with the ordinary loess of the region by many geologists, including Owen, Collett, Wright, Chamberlin, Salisbury, and Leverett. The recent field work of the writers brought out many points of difference in the silts lying respectively above and below the 500-foot contour. The lower type, which we have termed "marl-loess," is coarse and frequently carries as high as 30 per cent. of $CaCO_3$, while the common or upland type carries less than 5 per cent. Numerous exposures of distinctly stratified silts, interbedded in a few instances with pebble layers, were noted. Fossils consisting mainly of land species abound, but are not in general regarded as indigenous, as the perfection of the laminæ in the fossil-bearing layers points to an absence of vegetation during its accumulation, and would indicate — if the deposit were eolian — the probable absence of both moisture and food, the two chief requisites of the molluscan life. Instead of forming a mantle conforming to surface inequalities, as does the upland loess, the marl-loess frequently occurs as extensive flats or broad, gently sloping terraces, usually burying a somewhat rugged topography. Fossils, stratification, terraces, and silted divides occur at all altitudes below 500 feet, but never above, and although the greater abundance of the marl-loess on the east side of the valley is suggestive of eolian action, the character and range of the features mentioned afford a preponderance of evidence in favor of an aqueous origin of the deposit up to an altitude of 500 feet, or 120 feet above the river. The upland loess is regarded as an eolian derivative of the marl-loess.

The Hanging Valleys of Georgetown, Colo. By W. O. Crosby.

The paper describes chiefly the break of several hundred feet between the floor of the valley of Clear Creek and that of one of its principal tributaries, Leavenworth Creek, and explains it as due, not to fluvial or glacial erosion, but to faulting, of which abundant independent evidence is afforded by mining developments. Other and similar features in the vicinity are correlated with this, and it is shown that the part of the main valley occupied by Georgetown is a depressed fault block or *graben*, and that the valley is due, in part, to displacement, and not solely to erosion, suggesting comparison with Yosemite. The idea is also advanced that the elevation of this part of the Colorado Range has been recently, and may be still, in progress, and that, while in the past the movement has been chiefly massive, developing the great fault scarp overlooking the plains, it has, in later time, affected the axis more than the margin of the great orographic block, leading to a marked tilting of the Cretaceous peneplain, and, in part at least, it is very locally differential, and, in the Georgetown instance, in a way to accentuate the topography.

Glacial Features of Lower Michigan. By Frank Leverett.

This paper presents results of an investigation of the Pleistocene deposits and features of Michigan carried on for the past three years under the supervision of Professor T. C. Chamberlin, chief of the glacial division of the United States Geological Survey.

Lower Michigan lies within the limits of the latest or Wisconsin drift sheet, but inequalities of earlier drift sheets may have given rise to some of the topographic features and possibly to the strong features, such as basins and the high bordering rims. The high country northwest of the Saginaw basin has 350 to 500 feet or more of drift, while the basin itself has an average of scarcely 100 feet. It seems doubtful if this difference, with its resulting relief, should be referred wholly to the Wisconsin or last stage of glaciation.

Evidence of distinct ice invasions is found in the northernmost part of the lower peninsula in the constituents of the drift, which are such as to show a movement east of south from the Lake Superior region into the Huron basin, another and probably later movement from the Georgian Bay region southwestward across Michigan and onward to southeastern Iowa, as well as the still later movement referable to the Wisconsin stage of glaciation. A single hill north of the Saginaw basin was found to carry Potsdam sandstone from the Lake Superior region, jasper conglomerate from the Georgian Bay region, and gypsum from the borders of the Saginaw basin. In the western and southern parts of the peninsula, interglacial soils and peat beds are struck in wells, while in the southeastern part striæ, as noted by Sherzer, suggest distinct ice invasions.

The paper discusses the lobing of the Wisconsin ice sheet, the development of a succession of moraines, and the lines of discharge for glacial waters. Attention is also given to drumlins which occur near Charlevoix, and to the eskers in the region covered by the Saginaw lobe.

The drumlins seem to be subglacial accumulations, since they consist of till which is more thoroughly kneaded or worked over than the till of the neighboring moraines. They appear also to have been built up slowly as the ice moved over them, there being traces of lamination concentric with the upper surface of the drumlin. The ice then apparently extended to a strong moraine that passes along the southeast border of the drumlin area.

The eskers of this region are commonly found in shallow valleys, termed "esker troughs," which were cut in the till. This situation, together with the fact that the eskers, like the till, are composed largely of local rocks, strongly favors the view that their material was derived from the till through the agency of subglacial waters.

On the Evidence of Post-Newark Normal Faulting in the Crystalline Rocks of Southwestern New England. By WILLIAM H. HOBBS.

STRUCTURAL work within the belt of crystalline schists of southwestern New England has until recently been carried out upon the assumption that the rocks have been deformed solely by a process of folding. Both Dana and Pumpelly have emphasized this assumption in their papers upon the geology of the region. The effect of this assumption has been far-reaching and has profoundly affected the mapping during the past twenty years, so that faults have in but few instances been entered upon the maps. The study by the writer in the summer of 1899 of the complexly faulted basin of Newark rocks lying within the Pomperaug valley in Connecticut, and the consideration of the work of others upon the Newark areas to the east and to the southwest of the New England crystalline belt, led inevitably to the conclusion that a system of joints and faults produced in post-Newark time must have been superimposed upon the earlier structures produced by folding, and perhaps by faulting also, within the intermediate belt of crystalline rocks. The problem was then to find means of recognizing these faults within the complexly deformed province. The methods which have been found available are dependent, not so much upon the location of individual faults by the ordinary means, though such methods have not been overlooked, but by the reading of the fault *system* as a whole through the study of the topography, drainage, known formation boundaries, joint system, etc. Five small and widely separated areas were selected in the crystalline belt within each of which a considerable number of formations were found in small masses in juxtaposition. The structure of these areas, while difficult to determine, was found in each case to require only patience and industry, whereas the areas in which formations were found in larger masses by their very simplicity of areal distribution generally allowed several equally adequate explanations.

Briefly to summarize, it may be stated that in all of the areas a system of joints in correspondence with a system of faults was found superimposed upon the older folded structures of the region. The relative importance of deformation by folding and by faulting within the region in question is somewhat difficult to estimate, but it seems probable that the present attitudes of the rocks are at least as largely to be accounted for by the fault structure as by the system of folds.

On a Record of Post-Newark Depression and Subsequent Elevation Preserved in the Crystalline Rocks of New England. By WILLIAM H. HOBBS.

ALONG the course of the Housatonic river, between the townships of Sheffield, Mass., and Salisbury, Conn., is found a somewhat remarkable belt of largely silicified dolomite whose length is not far from twelve miles and whose breadth varies from a half mile to two miles or more. This somewhat remarkable backbone of rock early attracted the attention of Percival. It is noteworthy for its hummocky structure, but it nowhere rises more than one hundred feet above the general level. Careful study shows that the skeleton-work of silica forms an intricate network which goes out from parallel vertical walls of considerable thickness. These trunk lines or feeders are shown to have the direction of parallel series of vertical joints which had their origin in post-Newark time and were unquestionably conditioned by a compression of the southwestern New England region as a whole. The width of the silica walls forming the feeders and the peculiarities of the silica network lead to the belief that the same process of solution and removal of the dolomite which is now widening joint planes in the area, operated subsequent to the formation of the joint planes and previous to the infiltration of the silica. If it be true that surface conditions operated to widen joint fissures, we must assume a depression of the area until this surface zone came within the belt of cementation, for here only could the infiltration of the silica have obtained, and thus a cycle of depression and elevation of the area within post-Newark times must be supposed.

The Freshwater Tertiaries of Green River, Wyoming. By W. M. Davis.

A brief visit to the Tertiary formation of Green River, Wyoming, in the summer of 1902, sufficed to discover many variations of texture in the strata that have usually been regarded as lacustrine. Fine bedded cardboard shales frequently alternate with sandy layers in which cross-bedding and ripple-marks are not uncommon; some of the strata contain small clayey pebbles cemented by calcareous material, and closely resembling certain specimens of "tepetate" brought from Mexico by R. T. Hill. It is believed that so great a variation of texture is inconsistent with the generally accepted theory that the Green River formation was deposited in a large and deep lake. The deposits are better accounted for by deposition in a variable shallow lake. possibly alternating from time to time with subaërial or fluviatile conditions.

The Basin Ranges of Utah and Nevada. By W. M. Davis.

Several mountain ranges in the Great Basin of Utah and Nevada, examined in the summer of 1902, are believed to be faulted blocks, progressively displaced from late Tertiary to the present time, and maturely carved by contemporaneous erosion. The evidence for this conclusion is not structural, but physiographic. The base line of the ranges is of gentle curvature, unrelated to the mountain structure. The ravines by which the ranges are often dissected are narrow and steep-walled to their very mouths. The spurs between the ravines are often truncated systematically in a triangular facet at the mountain base. All these features are necessary results of progressive faulting and contemporary erosion, while they are not explainable on the theory that the ranges are residuals of much larger masses, unrelated to faulting.

The Blue Ridge in Southern Virginia and North Carolina. By W. M. DAVIS.

A RECENT visit to southern Virginia and North Carolina brought clearly to my attention what many students of that region must know already, but what is certainly unknown to geographers in general, namely, that the Blue Ridge is there not a ridge in any proper sense of the word, but a southeast facing escarpment. The escarpment is not due to any persistent rock structure, but results from the reduction of the land surface to a relatively low level by the headwaters of the short Atlantic rivers, whose drainage area therefore underlies that of the larger west-flowing rivers of the Mississippi system. The escarpment occurs where the Atlantic streams are undercutting the uplands of the Mississippi system. Residual mountains rise over the rolling uplands of the Atlantic rivers and over the rolling highlands of the Mississippi river: Kings and Pilot mountains are examples of the first, and Mount Mitchell and Roan mountain of the second. Grandfather mountain stands on the escarpment.

The Protection of Terraces in the Upper Connecticut Valley. By C. H. HITCHCOCK.

THE conclusions derived after many years of study relative to the origin of the Connecticut river terraces north of Massachusetts are as follows: (1) The higher terraces are part of a flood-plain deposited by the waters derived from the melting of the ice-sheet. (2) A differential depression of level amounting to about one and one-fourth feet to the mile in proceeding northerly greatly diminished the velocity of the current, so that the material is much finer than it would have been had the southerly slope been the same as now. For example, at the Wells river, Vermont, the altitude of the river is now 407 feet above tide; but anciently it was 356 feet. The highest terrace is now 630 feet; formerly it is estimated to have been 373 feet, a fall of 257 feet. The reduction of the descent was from 2 to 1.4 feet to the mile. (3) The carving of the greater terraces was effected while the land was resuming its present level — probably lower than its original altitude. (4) The lower terraces and the intervals were formed later.

The following features were not clearly understood: (1) Why should the terraces upon the opposite sides of the valley commonly vary in numbers, altitude, and bulk? (2) Why are the deltas of the tributaries so often higher than the normal flood plain? (3) Why should the number of the terraces of the tributaries so often exceed those of the main stream, their upper surfaces being the same? These queries may be answered partly by assuming that the flood plain was not entirely filled out and that the tributary may often have had an extraordinary volume, bringing down a disproportionate amount of sediment. But there remained this problem: Why is there such a great irregularity in the altitudes and number of the lower terraces?

A better understanding of this subject has been afforded by the recent paper of Professor W. M. Davis,[1] who applies to the solution of the problem the theory of Hugh Miller the younger. Miller recognizes a slow regional uplift while the river wears away the accumulated sediment, and ascribes the presence of each lower terrace to a species of protection afforded by such obstacles as ledges and till, as the degrading river swings laterally to lower and lower levels. At the Westfield locality the presence and altitude of every terrace are clearly shown to be due to this cause. The simplicity of this explanation causes one to wonder why it had not been understood earlier. I have applied it extensively the past season to the modified drift of the upper Connecticut and adjacent streams and found it very generally acceptable; in fact, its well nigh universal adaptation became quite monotonous. Diagrams were prepared to show how the terraces had been protected over an area fifteen miles long in the neighborhood of White River Junction and Hanover. The villages of Hartford, Wilder, and Hanover occupy such protected situations. Between East Hartford and Wilder an esker with underlying stiff clays has assisted in the preservation of the ancient flood plain. In Haverhill, thirty miles northerly, the absence

[1] "The Terraces of the Westfield River, Massachusetts," *American Journal of Science*, Vol. XIV (August, 1902).

of protection seems to have led to the extensive scouring out of the valley, and for that reason the interval is unusually broad. Elsewhere it was observed that tributary streams have cut across the higher terraces, whose exposed scarps remain in spite of the absence of any protecting underlying ledges.

Shore Phenomena on Lake Huron. By M. S. W. Jefferson.

Kincardine, Ontario, is nearly one hundred miles north of Port Huron, on the east shore of Lake Huron. As the shores there are

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undergoing uplift, there is an interesting contrast with geographic conditions south of Gilbert's isobase, as at Muskegon, Lake Michigan. There a line of dunes margins the "Big Lake," standing on a bar which almost closes the river mouth, that expands behind into a considerable lake, and is marshy, with typical drowned-character for miles back. At Kincardine and similar points the bar and ancient lagoon behind it are now high and dry. The sand bar south of the old entrance serves the town for a cemetery. The basin behind is drained by the palmate branches of the Penetangore, which have all cut deep, young valleys in which they rush along over beds of stony waste. The lowest reach of the river serves, like Forel's plemyramêtre on Lake Geneva, to show the Lake or Harbor seiches, by alternate down and reversed flow of the river. Elevated beaches under bluffs in till occur on the lakeward side to the north and south.

The shore and the immense dunes in the southern region at Holland, Muskegon, Pentwater, or Ludington, are all of the finest sand, which only the strong west winds save from the lake as the land settles down. To the northward at Kincardine the rising of the land brings continuous new levels of the till into the play of the waves, which pick out pebbles and bowlders to line a beach on which sands make only patches, and where the dunes are of but moderate significance, since the sand supply is small. Petowsky, also north of the isobase, on Lake Michigan shows a similar beach.

Studies continued from Lynn, 1898, to Martha's Vineyard, 1901, show the beach cusps to be component features of a *beach ridge*, prominent on the tideless Great Lakes, and faint but recognizable on the ocean. Cusps are found at numerous points on the lakes, are always developed with abating surf or off-shore winds, with an interval that bears some proportion to the strength of the waves, often having three-foot spaces at Kincardine and eighty on the ocean. The ridge is often without cusps; has at times been seen and photographed with water caught behind and rushing out at breaks in the line, as with the weed line at Lynn; and at times grades from continuity to regions of perfect cusps. The cusps seem related to a long-shore current, their precise cause not being evident. The cross waves noted by Bramer, 1898, were seen habitually at every point, and photographed, but were not seen to be accompanied by cusps, nor were the numerous cusps observed and photographed seen to associate with such cross-waves.

Land and sea breezes were observed; the small deflagration wrought by blown sand on rock-material; and the small dimensions of Lake waves that seriously endangered shipping.

Valley Loess and the Fossil Man of Lansing, Kan. By WARREN UPHAM, St. Paul, Minn.

THE loess in the Missouri and Mississippi valleys is attributed to deposition by these rivers during a time of somewhat lower altitude of this region, at the beginning of the Champlain epoch, when the glaciated area of this continent sank from its previously high elevation to be mostly 300 to 500 feet lower than now. By this depression a temperate climate was restored on the border of the continental ice-sheet, which became greatly reduced by its surface melting, so that much of the drift before contained within the ice was at last exposed on the thinned ice-fields, as now on the Malaspina ice-sheet in Alaska.

The ice-melting and rains probably swelled these great rivers to twice or three times their present average annual volume; and their supply of silt, brought in abundance by the rills, brooks, and rivers that flowed down from the waning ice-sheet, was very probably fivefold to tenfold more than now. Under these conditions of very abundant silt, rivers swollen to floods throughout the summers, and less current of their sluggish descent to the Gulf, it is estimated that the Iowan stage of chief deposition of the valley loess, gradually building up the river flood plains to heights of 150 to 250 feet above the bottom lands of today, may have occupied only about a thousand years.

During the same time the winds are thought to have blown away much of the loess from the valley flood plains, and from the ice surface, spreading it far and wide as the general sheet of upland loess, mostly 10 to 25 feet thick, mantling the high and low lands upon the great areas between the rivers with a surprising uniformity of thickness. It is evident, also, that this silt mantle includes some contribution, most considerable westward, of wind-borne dust from the great western plains, this part not being of glacial origin.

After the accumulation of the loess, and before the moraine-forming Wisconsin stage of the waning and wavering glaciation, this region was uplifted 300 to 500 feet, or perhaps somewhat more, on account of the diminution of the ice weight and pressure, thereby giving to the rivers the same steeper gradients and more powerful currents as now. They therefore eroded the valley loess to depths somewhat below the present bottom lands, and sculptured the valleys in nearly their present forms, with high inclosing bluffs of loess, before the moraines of Wisconsin, Minnesota, and northern Iowa, were amassed along the ice boundary at pauses of its general retreat.

Again, during this Wisconsin stage much modified drift was borne into the valleys. Its coarser portion of gravel and sand filled the valleys anew to heights of 100 to 200 feet, or more, near the ice border; but the strong river currents, with nearly their present slopes, carried the fine silt, corresponding to the former loess deposit, far down the valleys to the lower Mississippi and the Gulf.

Along the Big Sioux Valley, on the northwest boundary of Iowa, a flood plain of modified drift associated with the moraines has an average width of one and a half miles, as described in Vol. X of the Iowa Geological Survey, and is only about 10 feet above the present relatively insignificant bottom land, which averages about a fifth of a mile in width. Below the junction of the Big Sioux with the Missouri, this flood plain of Wisconsin time continues with a width of 6 to 12 miles on the east side of the Missouri through the distance of 90 miles to Council Bluffs and Omaha, having only the same slight altitude above the river. Southward from the mouth of the Platte river, as I think, the old Wisconsin flood-plain was lower than the bottomland today, which has gained in thickness, rather than lost, ever since the Ice age. Conditions requisite for silt deposition 30 to 50 feet above the Missouri at Lansing, Kan., where a skeleton was discovered last February under 20 feet of a deposit, which I regard as the original Iowan loess, appear thus not to have existed during the ensuing Wisconsin stage of glaciation, nor during any part of the Postglacial period.

The antiquity of the Lansing man is, I think, to be measured by about 12,000 years, or, at the longest, 15,000 years. But men are known to have been living in Europe, and very probably they may also have migrated to America, in the early part of the Ice age, or even before it, that is, very surely as long age as 100,000 years. Therefore the resemblance of the Lansing skeleton to the average type of our American aborigines, called Indians, appears in no degree surprising to one who believes that the creation of plants and animals has proceeded by the gradual methods of generic and specific development which are collectively termed evolution.

History of the Caribbean Islands from a Petrographic Point of View. By Dr. Persifor Frazer.

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Reconstruction of the Antillean Continent, by J. W. Spencer, *Bull. G. S. A.*, August 14, 1894.

Geographical Evolution of Cuba, by J. W. Spencer, *ibid.*, December 27, 1894.

Zur Geologie von San Domingo, by W. Bergt, Abhandlung der naturw. Gessell. "Isis" in Dresden, 1897.

Cuba and Porto Rico, with the Other Islands of the West Indies, by Robert T. Hill. New York: The Century Co., 1898.

This last work is a compendium of information on the subject and contains an extensive bibliography of the less scientific and more descriptive treatises on the West Indies.

At the Bath meeting of the B. A. A. S. in 1888 I presented numerous rock specimens and thin sections cut from them illustrating a region of about forty miles around Santiago de Cuba. The rocks were partly eruptives and partly clastic, but almost all exhibited profound alteration. The thin sections from these eruptives were examined with me by Dr. Hensoldt, Mr. Kunz, and Mr. Lacroix in this country, and later by Mr. Teall, Mr. Rudler, the Abbé Renard, Professor Judd, and the lamented Professor George H. Williams in London; all of whom were practically agreed as to the main constituents.

The specimens were divided into:

A. Those from the hills containing the West mine of the Jurugua Iron Co. near Firmeza: (1) diorites, some of which contained much altered hornblende and viridite (chlorite), the thin slides filled with microlites and the rocks traversed by epidote veins; (2) dolerites (gabbros) with chloritic groundmass, magnetite, rods of feldspar, and some olivine.

B. From the hills southeast of that in which the East mine was located and about fifteen miles northeast of Santiago de Cuba: (1) garnet rocks with iron ore (sp. gravity 3.962); (2) fibrous actinolite and brown iron oxides partially altered to an epidotic mass; (3) iron ores (some showing cross lines like the Widmanstätten figures in meteoric iron).

C. From the Sietes Altarés, about thirty-five miles east of Santiago de Cuba: orthofelsite porphyry (rhyolites) like those erroneously referred to by the late Professor H. D. Rogers as "jasper," and later recognized by the late Dr. T. Sterry Hunt as a mixture to which he gave the general name "orthophyre," also like the Arvonian tuffs of Hicks near St. David's Head, Pembrokeshire, Wales.

D. The specimens from the region of the La Plata mines were quartzites containing hornblende, iron ores, and among the incidental minerals a claret-red garnet.

In the area described were found upon or associated with the eruptives sandstones, conglomerates and crystalline limestones, laminated iron ores with masses of pyrite not yet converted into the latter. The alteration of the areas of contact in these rocks by the more recent diorite dykes which cut them was evident.

From the zoölogical and geological researches of Alexander Agassiz in Caribbean and Mexican waters, and the careful studies by Gabb, Crosby, Spencer, and Hill, the probability of very great changes of level in the Antilles since the close of the Cretaceous period is fortified by several different lines of proof, *i. e.*, the ledges and shelves of the island borders, the wide distribution of the white radiolarian limestones, etc. Professor Crosby pointed out orographic reasons for assuming a former "bridge" (*i. e.*, causeway) between the greater and lesser Antilles. As he says, the mountains of "the northern arm of the island of San Domingo pointing toward Cape Maysi on Cuba," and the northern range in Cuba "regains the western trend and points directly toward Yucatan." He also alludes in his paper of December 13, 1882, to the "axis of old eruptive rocks," of which, so far as he has been able to learn, "each member of the group consists." He does not give his authority for the fact, nor say to what age he ascribes these eruptives; but if he contemplated the possibility of this age being pre-Cambrian, he anticipated by six years two of the strongest reasons I adduced for belief in the physical continuity of the great and little Antilles, and the present exposure of parts of the nucleus which are of great age and possibly have never been very deeply covered by sedimentary rocks.

His observation that this nucleus is flanked on either side by schists and slates I have confirmed, and I have been tempted to class these with the damourites of the Appalachians, and the feldspar porphyry (rhyolites), with the Arvonian tuffs of South Wales.

[1] *Zur Geologie von San Domingo.* Abh. der naturw. Gesel. "Isis" in Dresden, 1897, Heft II, p. 64).

It is gratifying to find that Dr. W. Bergt supports unreservedly the Archean age of the nucleal axes of the Caribbean islands in the following words:[1]

> Das archäische Alter, welches, P. Frazer für die Centralketten des südöstlichen Cuba feststellen konnte, und das er für ganz Jamaika, für San Domingo, Puerto Rico, und die Windwardinseln vermuthete, kann nunmehr bestimmter für San Domingo angenommen werden.

It may be, as Mr. Hill suggests, that no "Paleozoic nucleal rocks" have been established with certainty in "Cuba and Santo Domingo" or any other of the border lands of the "American Mediterranean" (*Cuba and Porto Rico*, p. 384) although de Castro imagined he had discovered such near Cienfuegos, yet this fact would not invalidate the evidence that part of these nucleal rocks are pre-Cambrian.

And one purpose of this paper is to recall the fact that we have proofs of physical connection with the western continent of these outlying islands not only from the physiographic features, drowned valleys, submerged plateaus, trend of conformation through the major axes of the present detached islands, paleontological analogy with South American forms of life, etc., but, in addition to all these, the close petrographical relationships of the crystallized and crystalline rocks and their congeners with those of the main land.

The island of Cuba seems to be constructed of an original igneous mass, diorite, on which clastic rocks, including mica-schists which may be Paleozoic, and sandstones and limestones of Mesozoic and recent ages, are deposited without apparent effects of metamorphism. Through all these are veins of newer eruptives which have generally altered the rocks they have fissured, *i. e.*, giving crystalline character to the radiolarian limestones lifted since Cretaceous time out of the adjacent seas, producing magnetite in the iron-oxides derived in part from the pyrite, changing to quartzites the siliceous slates, etc.

The lithological character, great alteration, complexity of the series, analogies in paragenesis and alteration-products with rocks of Archean areas in various distant parts of the earth's surface, and the physiographic relations of the greater and lesser Antilles to the peninsula of Yucatan and to Venezuela, suggest a physical connection with the South American continent, and a former American Mediterranean (Caribbean) sea.

These conclusions are in harmony with those of Professor Crosby, Professor J. W. Spencer, and Mr. R. T. Hill, and are specifically confirmed by Dr. Bergt (*supra*). They constitute a reinforcement of the results arrived at by geotectonal, through petrographic, considerations, in the attempt to retrace the geological history of the West Indies.

A paper received December 27, from Dr. Callaway presents in the description of the structure of the island of Anglesey a remarkable parallel with that of the island of Cuba.[1]

Some Results of the Late Minnesota Geological Survey. By N. H. Winchell.

This paper mentioned some of the scientific conclusions and some of the known economic results reached by the survey, presented in the final report. Among the scientific conclusions have been: the definition of the parts of the Upper Cambrian in the upper Mississippi valley; the identification of the Potsdam sandstone as seen at Potsdam, N. Y., with a quartzitic sandstone which was found to be a part of the Keweenawan; the definition of the Lower Silurian and its parts; the determination of the eastern extent of the Cretaceous; the discovery and announcement of the duality of the ice-epochs; the determination of the length of time elapsed since the last (or Wisconsin) ice-epoch, through the recession of the falls of St. Anthony; the formation of glacial lakes about the ice-border; the origin of kames (now called eskers) in ice-walled gorges; the superglacial position of the drift while being transported, especially in proximity to the ice-margin; the duality of the iron-bearing formations in the Lake Superior region, and the later discovery of a third horizon; the separation of the Archean *en masse* into two non-conformable parts, viz., the upper and the lower Keewatin, with a great basal conglomerate between them; the detection of the oldest known rock in the Lake Superior region (the greenstones called *Kawishiwin*), the supposed earliest crust of the globe; the origin of the Mesabi ores in a greensand which has been altered, affording iron oxide by concentration; the contemporary deposition of oceanic silica from solution; the original greensand, and pebbles and breccia associated with it, as well as sheets of basic lava of the same date, were of volcanic origin; the well-known jaspilytes of both Mesabi and Vermilion ranges were originally the result of silification of volcanic obsidian (supplementary to the hypothesis of Wadsworth), but sometimes were broken and distributed so as to constitute secondary jaspilyte beds; the formation of

[1] "Plutonic complex of Central Anglesey," *Quarterly Journal of the Geological Society*, Vol. LVIII (November, 1902).

sedimentary jaspilyte from the chemical precipitation of silica, this grading into other sedimentary rocks; the derivation of the granites of the Archean from metamorphism and fusion of Archean sediments; the supposed origin of the alkaline quality of these first sediments being in the atmosphere, as the basal crust could not have afforded them; the derivation, in the same manner, of the gabbro and associated basic igneous rocks, from the metamorphism and fusion of the greenstones with their clastic variations; the addition of a large number of minerals to the known mineralogy of Minnesota.

Of economic and educational results the following were mentioned: the discovery of the cause of foul water in common wells in the prairie region of Minnesota, and the suggestion of effective remedies; the discovery, through a series of physical tests, of the excellence of the Hinckley sandstone, now widely used under the name "Kettle River stone." The existence and position of the Mesabi range, as distinct from the Vermilion range, was pointed out in 1884. This was followed by explorations which resulted in the first discovery of important bodies of ore on that range.

"But notwithstanding the scientific discoveries of the Minnesota survey, and over and above all its aid rendered to economic interests, it is probable that the most valuable service it has rendered to geology consists in this: The illustration it has given of the establishment of a state geological survey by the state legislature and the intrusting of the same to the state's university. It is not an uncommon thing now, but when the Minnesota survey was submitted to the board of regents of the state university, it was a novel and unheard-of proceeding, and its progress was scrutinized closely by the authorities of other states. The original law was carried out without a single change. The plan of progress and of the report which was adopted the first year of the survey was faithfully carried out to completion and without a single interruption, lasting a period of twenty-eight years, *i. e.*, from 1872 to 1900."

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THE TIN DEPOSITS OF THE MALAY PENINSULA WITH SPECIAL REFERENCE TO THOSE OF THE KINTA DISTRICT.

CONTENTS.

Geographic position of the Malay tin regions.—The Malay Peninsula is the southeastern extremity of the continent of Asia. It extends from about latitude 14° N. in a southerly and southeastern direction to about latitude 1° 20′ N., and still farther south a chain of islands connects it with the main part of the Australasian archipelago. It is a narrow strip of land about 900 miles in length and from less than 50 miles to over 150 miles in width.

The northern and central parts of the peninsula belong to Siam, though the British possessions of Burma include some of the northwestern part. The southern part of the peninsula is comprised mostly in the native states of Perak, Pahang, Selangor, Negri Sembilan, and Johor, ruled by independent sultans, but

FIG. 1.—Map of lower part of Malay peninsula showing Federated Malay States.

more or less under British influence. These principalities have recently combined under the name of the Federated Malay States. Along the lower coast of the peninsula the British own certain small strips of land and islands, including Province Wellesley, Dindings, and the Malacca Territory on the mainland, and the islands of Penang, Pangkor, and Singapore. These, together with several other islands, represent what are known as the Strait Settlements. The Federated Malay States at present comprise most of the tin regions worked on the peninsula.

The tin deposits occur in greater or less quantities from the state of Johor in the southern extremity of the peninsula, northward to the limit of the state of Perak on the Siamese border, a distance of some 350 miles. To the north of this limit in Siam, even beyond the high peak of Mount Kedah, tin has been reported, but the deposits have not been much explored, and no very prominent mines have been opened. This may possibly be due to the unexplored character of the Siamese part of the peninsula, as the roads are not so good as in the Federated Malay States, and travel and exploration are very difficult in the dense jungle. Even in the Malay states, though the tin is found over a large area, most of the production comes from a few places. By far the larger part of it is mined in the states of Perak and Selangor, while very little has been found in Johor, and the production of Pahang and Negri Sembilan is small.

Perak is the largest producer of the Malay states, supplying considerably over half of the tin of the peninsula, and the Kinta district is at present the most important tin locality in that state, though tin is also mined at Thaiping and other places. In Selangor the most important mining center is Kwala Lumpur, and the production of this region is second only to that of the Kinta district. Besides the places already mentioned, many other smaller tin districts exist, and, in fact, most all of the numerous small native towns on the west slope of the peninsula are largely dependent on the tin industry.

Most of the tin regions are on the western side of the mountains which form the backbone of the peninsula. On the eastern side very little tin is found. On the other hand, a considerable amount of gold occurs on the eastern side, while very little has been found on the western side. Hence the eastern slope is known as the "gold region" and the western slope as the "tin region."

To the southeast of the peninsula, tin is mined on the islands of Banka and Billiton, which are owned by the Dutch. In Banka the mines are worked by the government and are more productive than those of Billiton, which are operated by an independent company. The occurrence of the tin on these islands is said to be similar to that on the peninsula. Tin is found also on the island of Sumatra, off the southwest coast of the Malay peninsula, but has not been worked to any great extent. Its occurrence is said to be somewhat like that of the peninsula, and the fact that the production is small is said to be due to the unexplored character of the country and to the constant troubles between the Dutch authorities and the natives.

General geology of the Malay tin regions.—The Malay peninsula consists of a central axis of rugged mountains, with occasional subordinate parallel or diverging axes and isolated peaks. The whole region is covered by a jungle of tropical vegetation so dense that the roads and trails have to be hewn through it with an ax. In the tin regions the main range is composed of granitic rocks, occasionally intersected by feldspathic and other dikes, while in places are found gneissic and schistose rocks, with occasional areas of a white, highly crystalline limestone. The granite is mostly of a gray color and is composed of quartz, feldspar, and biotite or hornblende, or both. There seem to be all gradations from a granite with biotite and no hornblende to a granite with hornblende and no biotite. Black tourmaline is a common constituent of the granite in the neighborhood of the tin deposits. The limestone is generally a highly crystalline marble of a white color, occasionally streaked or spotted with gray. No fossils were seen in it, and it is said that none have been found. Such as may have existed seem to have been destroyed by the metamorphosis of the rock, though a more thorough search might reveal traces of them. The limestone is especially abundant in the Kinta district, though also found

Mining and washing tin ore near Ipoh, Perak, Malay peninsula.

elsewhere on the peninsula. Occasionally strata of a fine-grained, friable sandstone occur on the lower slopes of the mountains, which appear to be younger than any of the other rocks mentioned. The granitic rocks and limestone, however, are the formations most commonly seen in the few places where any rocks appear through the soil.

All the rocks, especially those of a granitic nature, are much

FIG. 2.—Tin diggings in the alluvium at foot of granitic hills, Kinta district, Perak, Malay peninsula.

decayed, often to a depth of many feet, and the detritus from them has formed large areas of alluvium in the mountain valleys and along the lowlands on the coast. Much of this alluvium contains more or less oxide of tin or cassiterite in particles and fragments of varying size, forming what might be termed "tin placers," and it is from these deposits that the mass of the tin of the Malay peninsula is derived. Tin also occurs in the granitic rocks and limestone, as will be more fully described farther on, but though these rocks were doubtless the source of the alluvial tin, yet the ore in them is at present worked to only a very small extent.

Location of the Kinta district.—The tin region most carefully examined by the writer was the Kinta district in Perak, and this will therefore be described more in detail than the other districts mentioned. The Kinta district has no definite boundaries, but the name is a general term applied to an area in the southern part of the state of Perak, in the valley of the Kinta river. This stream is a branch of the Perak river which flows through the state of the same name into the Strait of Malacca below Teluk Anson. The Kinta district comprises a more or less inclosed valley about 40 miles in length in a north-and-south direction, about 30 miles in width at its south end, and about 5 miles at its north end. To the east is the high granitic range, forming the backbone of the peninsula and rising in some places about 8,000 feet above the sea ; to the west is a lower granitic range, rising some 3,000 feet and separating the valley from the Strait of Malacca. Between these ranges are lower mountains and areas of limestone, surrounded and partly covered with great tracts of alluvium. Twenty years ago the Kinta district was almost unknown, and Thaiping and Kwala Lumpur were the great tin centers, but now it is the most important district on the peninsula. It is intersected from north to south by a railway which is being extended at both ends. Among some of the more important mining centers in the district are Campar, Gopeng, Batu Gajah, Tronoh, Cacha, Lalang, Papan, Lahat, Chongkat Pari, and Ipoh, the last being the commercial center of the district; in fact, the alluvium over large areas has been completely stripped from the bed-rock in search of tin, and has been overturned in great piles, leaving the once fertile soil in a condition of desolation similar to the old gold placer diggings in parts of California.

Mode of occurrence of the alluvial tin in the Kinta district.—Most of the tin ore of the Kinta district is derived from alluvial deposits varying in character according to the nature of the rocks from which they have been derived and the distance to which they have been transported. In the larger valleys where the detritus from areas of different rocks has been mixed, the alluvium is commonly composed of a heterogeneous mass of

Tin mine of Mr. Foo Choo Choon, Tronoh, Perak, Malay peninsula.

white, gray, or red sandy or gravelly clay, often of a mottled character, containing numerous small quartz fragments about the size of a pea, derived probably from the decay of granite and in part from quartz veins, together with pebbles and bowlders of granite, gneiss, schist, pegmatite, limestone, etc. The alluvium in the hills, however, nearer its source, varies more in character, distinctly reflecting, in different places, the nature of the different rocks from which it has been derived. Frequently the alluvium is much stained with iron, and carries layers and masses of rusty ferruginous material consisting partly of sand cemented by iron, and partly of masses of granite and quartz with iron pyrites rapidly oxidizing and forming a brown mass. Sometimes the alluvium contains large quantities of vegetable remains and partly lignitized wood.

The dense tropical vegetation has given rise to large quantities of organic acids in the soil, and these have often leached the iron from the tin alluvium, leaving a clear white or gray mass, while in other places not so much exposed to this influence the gravel is still discolored. This is especially true of the upper parts of the deposits, which have often become entirely bleached, while the deeper parts are still heavily impregnated with iron. The waters in most of the mines are heavily charged with iron, which is deposited on the sides of the pits and shafts, showing that chemical action is still very active.

The tin occurs in the alluvium in different ways. Sometimes it is scattered through it from top to bottom in comparatively uniform quantities; sometimes it is in layers of rich ore separated by layers of lean or barren ground; sometimes it is richest on the bed-rock, and at other times higher up in the deposit. As a general rule, however, there is a covering, or "overburden" as it is called, of barren alluvium from 10 to 40 feet or more in thickness, and the tin ground is found beneath this. The best alluvium occurs immediately at the foot of the mountains. Higher up it is often richer, but of small extent, while farther away it is thicker, but of lower grade. The ordinary tin-bearing strata vary from 1 to 30 feet in thickness, though sometimes they reach over 100 feet. At Gopeng, the Gopeng Tin Mining

Co., an English corporation, works alluvium which carries tin from the surface down to a depth of from 5 to 30 feet without any barren "overburden". At Campar, a French company, known as La société d' étan de Perak, has large open pits in the alluvium of the valley of the Campar river, where the tin-bearing stratum varies from 2 to 10 feet in thickness and is overlaid by a

FIG. 3.—Stripping new tin ground south of Campar, Perak, Malay peninsula.

barren "overburden" of about 40 feet in thickness. At Tronoh, in the well-known mine formerly owned by Mr. Foo Choo Choon, but recently sold to an English company, the "overburden" is from 30 to almost 40 feet in thickness, and the tin-bearing ground below has been penetrated by an open pit and an inclined shaft. The incline is about 400 feet long, equal to about 140 feet vertically, and the bottom of the tin ground has not yet been reached. This thickness of tin-bearing alluvium is, however, very exceptional. Many other cases, showing other variations in the conditions of the tin-bearing alluvium, might be cited.

At the bottom of the alluvium is generally either granite or limestone, though frequently where the tin stops, barren alluvium or rock decayed *in situ* separates it from the bed-rock, so that the solid granite or limestone is not always seen. This is especially true in granitic areas where the surface of the rock below the alluvium is often altered to a soft, partly kaolinized mass. Sometimes beds of coarse granite pebbles and bowlders, forming the substratum of the tin alluvium, have decayed *in situ* in the same manner as the surface of the original rock; and it is not uncommon to see rounded granitic fragments converted into a soft putty-like mass, which when broken up gives rise to angular particles of the original quartz of the rock and a soft clay resulting from the decay of the feldspar. Hence angular quartz may often be found in deposits that have been transported long distances. Such an occurrence is seen on the property of the Gopeng Tin Mining Co., where the tin-bearing stratum consists of a more or less ferruginous deposit of sandy and gravelly material occupying a ridge on the side of a small stream and underlaid by a pebbly stratum like that just described. In the creek bed below, near the native town of Gopeng, tin alluvium washed down from the ridges is extensively worked by the Chinese.

The limestone bed-rock is often leached in deep hollows and caves, as seen at Chongkat Pari and near Tronoh (see Figs. 4 and 6), while elsewhere, as seen between Ipoh and Lahat, it forms an undulating surface with alternating protrusions and recessions, following regular lines, probably influenced by lines of bedding, and resulting in a series of natural riffles behind which cassiterite has concentrated. (See Plate IV.) This occurrence is similar to the way gold has collected behind limestone riffles near Columbia, in California, and the country has been stripped in search of ore in much the same way as in the California region. The road from Ipoh to Lahat runs through a broad valley, and the rough surface of the bare limestone bed-rock is seen in many of the old workings.

Tin alluvium frequently occurs on ridges and hills as well as at lower levels in the valleys and creek beds. This sometimes suggests strongly that, since the formation of tin alluvium began, there has been an elevation of the region followed by subsequent erosion, with the result that the older tin alluvium occupies the higher places, while the younger alluvium, derived probably in part from the older deposits, occupies lower levels, in much the same way as the Tertiary gold placers of California often occupy the higher spots and the more recent placers are found in the present stream beds. This may be true in some of the tin deposits, but it is necessary to distinguish between such occurrences and the cases where the tin deposits on the higher places are simply residual deposits formed *in situ* by the superficial decay of tin-bearing rocks, without removal of the tin from the region of its source.

Nature of the tin ore in the Kinta district.—The tin occurs in the form of cassiterite or oxide of tin (SnO_2), often well crystallized in tetragonal prisms with fine terminations, though the fragments in the alluvium have been more or less rounded by attrition. The ore varies in color from black or brown to gray, grayish-green, white, or transparent, but the commonest kind is of a dark brown or almost black color with a resinous luster. In the mountains, near its source, the ore is angular and in comparatively large fragments, sometimes from an inch to a foot or more in diameter, but this is rare, and farther down hill it becomes more and more rounded and fine-grained, the common alluvial tin fragments ranging from the size of peas to that of sand grains or smaller. In fact, efforts are now being made to work tin ore that exists as a fine powder in the mud banks that line certain parts of the west coast of the peninsula.

The amount of tin in the ore as commercially mined ranges from 69 to 73 per cent., an average of about 70 per cent. being considered very fair. The theoretical amount of tin in cassiterite is 78.6 per cent. The richness of the tin ground varies much in different places. The average value of the alluvium worked in the Kinta district is probably about 1 per cent. of cassiterite, and ground of this grade pays well to work, if favorably situated. If the alluvium contains 2 per cent. of cassiterite, it is considered exceptionally good ground, and with 3 or 4 per cent. it is considered remarkably rich. Sometimes thin strata in the alluvium are very rich in cassiterite, containing from 40 to 60 per cent., but this is very rare.

Minerals associated with the tin ore in the Kinta district.—With the tin in the alluvium are associated much tourmaline, hornblende, wolframite, and magnetite, while in smaller quantities are found white mica, topaz, scheelite, and sapphire, and it is said that in parts of the peninsula small quantities of thorium and cerium minerals have been found. Some beautiful transparent topaz crystals have been found near Tapa, south of Campar. Gold also has been found in small quantities in the tin alluvium.

It is probable that all these minerals once existed *in situ* in the rock in more or less close association with the tin. Certain other minerals, such as iron pyrites, chalcopyrite, bornite, and arsenical pyrites, which occur with the tin in the rock, are rarely seen in the alluvium, as they have decomposed and mostly disappeared during the erosion of the rock, though rusty masses of these sulphides, partly decomposed, and associated with quartz, often occur in alluvium which has not been transported far from its source.

Occurrence of tin ore in the rocks of the Kinta district.—Though the tin mined on the peninsula comes practically all from the alluvium, yet cassiterite also occurs in various places *in situ* in the rocks of the region. It is most often found in granite, but also occurs in the limestone and sandstone. It has been worked in a few localities, notably in the granite at Sorakai in Perak, and at the Rin mine in the Jelibu district in Selangor, while at Chongkat Pari in Perak, it has been worked in limestone. None of these efforts, however, have as yet been more than partially successful, and most of them have eventually failed, as the ore is in too scattered a condition to pay to work. Hence, though tin is frequently found in the rocks as well as in the alluvium, mining is mostly confined to the latter. It seems not impossible, however, that deposits may yet be found in the rock that can be profitably worked.

Where the tin is seen *in situ* in the granite, it occurs in pockets, small veins, or a combination of stringers intersecting each other in various directions in the form of a network, while elsewhere the rock is simply impregnated with particles and crystals of cassiterite over certain areas. The tin is associated with quartz, tourmaline, fluorite, and the other minerals already mentioned, especially iron pyrites and arsenical pyrites, which often occur in very considerable quantities, and with smaller quantities of chalcopyrite. At Sorakai, some three miles southwest of Ipoh, two shafts were sunk on small seams of tin ore in the granite by an English company, but operations did not prove profitable and the works are now closed.

Tin in the limestone is probably rarer than in the granite, as

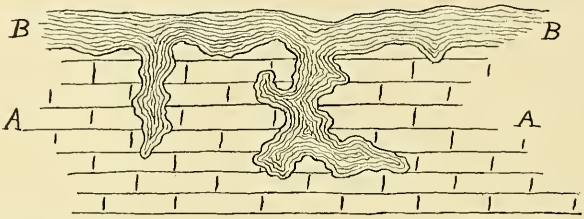


FIG. 4.—Section showing occurrence of tin-bearing alluvium at Chongkat Pari, Perak, Malay peninsula.

Chongkat Pari was the only case seen or heard of by the writer where it had been clearly proved to exist in that rock, while tin in the granite is of common occurrence. Chongkat Pari is two and a half miles southwest of Ipoh, and the region has been extensively worked for alluvial tin. The bed-rock is limestone, and the alluvium occurs in hollows and caves in the leached surface of this rock. (See Fig. 4.) It is from 1 to probably 20 feet in depth, of a reddish-brown color, and contains many large ferruginous masses, probably resulting from the oxidation of iron-bearing sulphides common in the limestone. At the mine of the Leh Chin Tin Mining Co. at this locality tin occurs not only in the alluvium, but also *in situ* in limestone. It is found along a zone of fracturing, marked sometimes by sheeting, running in a general direction of north northeast and south southwest, and dipping steeply to the west northwest. The ore occurs as cassiterite along the zone of fracturing, sometimes as an impregnation in the limestone, sometimes as lenses or irregular pockets from 4 to 24 inches in width, and sometimes along the cracks in the rock, either longitudinally or transversely with the zone of fracturing. (See Fig. 5.) It is associated with large quantities of iron pyrites and arsenical pyrites, and smaller quantities of chalcopyrite and bornite, with some rhodochrosite. On the surface, limonite and malachite are found in the leached hollows of the rock, having been derived from the oxidation of the iron and copper sulphides. The deposit has been opened by

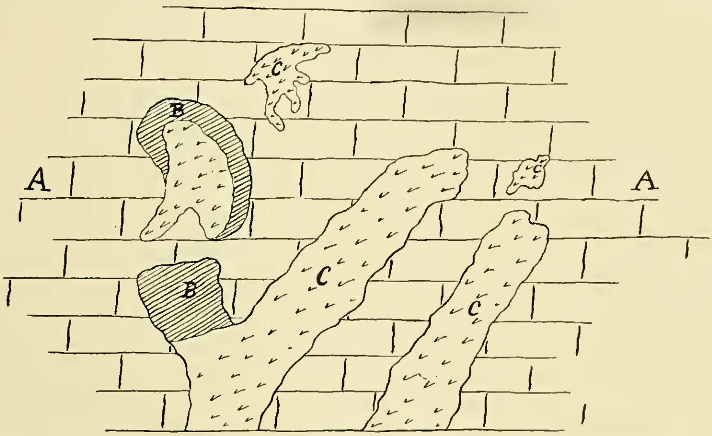


FIG. 5.—Section showing occurrence of tin in limestone at Chongkat Pari, Perak Malay peninsula.

a cut about 20 feet in depth in the limestone, but not much ore has been mined, as it has not yet been found in large quantities.

A few miles southeast of Ipoh, on the road to Gopeng, are a number of limestone hills rising several hundred feet above the valley. On the summits of some of these tin is said to have been found in the soil. It has yet to be determined, however, whether these deposits have been derived by decay *in situ* from tin deposits in the limestone, or whether they are the remains of old alluvial deposits transported there from a distance before the hills were formed. (See Fig. 6.)

At Bruseh, near Tapa, in Perak, tin has been found in thin seams and films along the lines of bedding in a soft, fine-grained, friable sandstone, which bears every evidence of being a comparatively young rock, and it seems probable that the tin in it was derived from tin-bearing solutions from the older rocks percolating along the bedding planes. This special locality was not visited by the writer, but specimens of the ore and the rock were seen.

Origin of the tin deposits of the Kinta district.—The question of the origin of the tin deposits includes the occurrence of both the tin in the alluvium and the tin in the rock. The tin in the

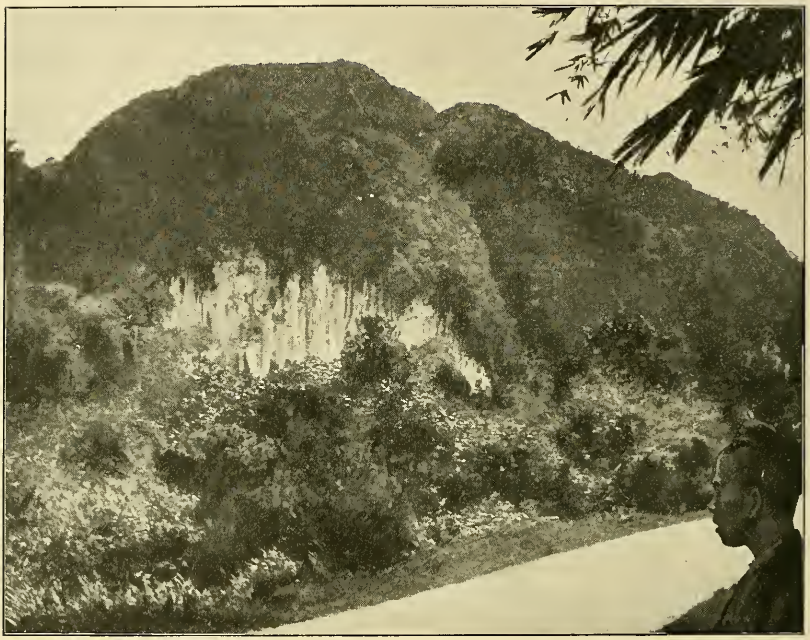


FIG. 6.—Limestone bluffs southeast of Ipoh, Perak, Malay peninsula.

alluvium has clearly been derived by erosion from the tin in the rock, as is proved by the following facts:

1. Tin in noticeable quantities is a constituent of some of the rocks of the region, especially the granitic rocks and sometimes the limestone.

2. The mass of the alluvium is composed of materials derived largely from the decay and erosion of the tin-bearing rocks of the region, and contains numerous pebbles and bowlders of these rocks.

3. Frequently granitic fragments, similar to the granite in

Tin mine near Tronoh, Perak, Malay peninsula, showing limestone bed rock underlying tin-bearing alluvium.

the surrounding hills and carrying cassiterite, are found in the alluvium.

4. The cassiterite in the alluvium, though in a fragmental condition, is of the same character as that in the granite and limestone.

5. The alluvium is as a rule richest in tin, and the fragments of ore are largest, near the areas of tin-bearing rocks.

6. The characteristic minerals associated with the tin in the alluvium are the same as those associated with it in the rock, except in the case of the easily altered minerals, such as the iron and copper sulphides, which have usually been decomposed in the decay of the rocks, and therefore do not often appear in the alluvium, though partly altered masses of these minerals are sometimes found in the alluvium.

Such facts as these leave no doubt as to the origin of the tin in the alluvium. As regards the tin in the rocks, it may be said that in the granite, the occurrence of the cassiterite in veins, stringers, networks, etc., along lines of fracturing, are strong evidences of aqueous deposition of the ore; while the occurrence as an impregnation in the rock where no marked fissuring occurs may be due either to segregation during a more or less molten condition of the rock or to aqueous concentration in a solidified rock. It is possible that the tin was originally a disseminated constituent of the granitic rocks; and in places its concentration may have been due to segregation from a molten mass, but there can be no doubt that some of the concentration, as at present seen, was due to water action after the solidification of the rock.

The tin in the limestone was probably also deposited from solution. It does not seem probable that it was derived mechanically from the erosion of the granite during the deposition of the limestone formation, as it does not occur in the manner of a fragmental deposit, but in seams and clusters along lines of fracturing. Moreover, it is accompanied by iron pyrites, chalcopyrite, arsenical pyrites, etc., just as in the granite, and this would probably not be the case had the tin been detrital, as the iron sulphides in the granite would have been largely decomposed before being enveloped in the limestone. It seems probable, therefore, that the tin in the limestone was deposited from aqueous solution in the same way as at least part of the tin in the granite. It is possible that the tin-bearing waters that deposited the ore in the limestone may have derived their metalliferous contents by solution from the disseminated tin in the granite; and this may account for the rarer occurrence of tin in the limestone than in the granite, for if the latter was the original source of the solutions that deposited tin in both rocks, the granite might get more of the deposition than the limestone, which was less close to the source of the solutions.

The tin found in the bedding planes of the sandstone near Tapa, seems, as already stated, to be a later deposit derived by solution from the older deposits in the granite or limestone.

Commercial features of tin-mining in the Kinta district.— Most of the mines of the Kinta district are operated by Chinamen, and the work is generally crude;[1] but in some localities, like Gopeng and elsewhere, English companies work the mines, while at Campar a French corporation carries on large operations; and in such cases the work is carried on in a more systematic manner. The laborers are mostly coolies from southern China and Indians from the east coast of India. The native Malays do not do much work, and Europeans cannot stand hard work in this climate. The coolies are the most numerous laborers, and here, as elsewhere in southeastern Asia, they are always found where there is any hard work to be done.

The tin-bearing alluvium is worked mostly in open cuts or large pits, except where the covering, or "overburden," of barren ground is very thick, when sometimes shafts are sunk through it to the tin stratum. Most of the workings, especially those of the Chinese, are only very shallow excavations on account of the difficulty of handling the water found at a depth. The average of the Chinese pits is probably not over about 40 feet in depth, though the enterprising Chinese mine-owner, Mr. Foo Choo Choon, reached several times this depth in his mine at Tronoh before he sold it. Some of the more progressive Chinamen

[1] The systematic operations of Mr. Foo Choo Choon, under the management of r. John Addis, are an exception to the usual crude methods of Chinese mining.

have lately introduced pumps to handle water, but even yet it is not uncommon to see the water raised from a shallow pit by a chain of buckets operated by a human treadmill, worked by the feet of two or three men. (See Fig. 7.)

The tin alluvium, after being mined, is carried to the surface in small baskets hung on both ends of a stick suspended on a

Fig. 7.—Pumping water by human treadmill, near Lahat, Perak, Malay peninsula.

Chinaman's back. It is then dumped into wooden troughs supplied with a stream of running water, where, if there is much clay present, it is stirred with shovels and hoes to separate the tin ore. If there is no clay or only a little of it present, the "tin dirt" is simply dropped into the trough in the running water. The materials are carried thence by the water into sluices, where the cassiterite and other heavy minerals sink to the bottom, and the sand, clay, and lighter materials are carried away by the stream. (See Figs. 3 and 8.) The sluices may range from a few feet to several hundred feet in length, as the case may require, and are either made of wood or are cut in the sandy clay of the region. After a certain number of hours, the stream is stopped and the material at the bottom of the sluice is still further concentrated by hand panning in a flat wooden bowl not unlike in shape the ordinary sheet-iron American gold pan.

FIG. 8.—Washing tin ore near Tronoh, Perak, Malay peninsula.

(See Fig. 9.) The final process in the preparation of the ore is the separation, by hand-picking or by very expert panners, of the particles of magnetite and other heavy minerals associated with the tin, finally leaving a product varying from 69 to 73 per cent. in metallic tin. This ore is then sacked and hauled to market.

At Gopeng, the Gopeng Tin Mining Co. is using hydraulic monitors to handle the alluvium, in the same way as they are used in the gold placers of California. At Cacha, an English company has also erected a stamp mill with concentrating tables to crush and concentrate masses of ore. The alluvium here has

Eroded limestone surface in tin diggings between Ipoh and Lahat, Perak, Malay peninsula.

often been indurated by infiltration of iron compounds, while it also often contains masses of the original tin-bearing rock from which the cassiterite has not yet been liberated, so that crushing becomes necessary. At Sorakai, roasting, crushing, and concentrating machinery has been introduced by the Sorakai Tin Mining Co., an English corporation, to handle the ore mined in the

FIG. 9.—Women washing tin ore near Lahat, Perak, Malay peninsula.

granite at that locality, the roasting being necessary to drive off the arsenic in the ore. At Tronoh, some of the alluvium contains much clay which adheres closely to the tin, and the material is treated in large tanks with revolving paddles inside.

The tin was formerly smelted largely at local works in the various mining districts, and some of it is still treated in this way, but most of it is now smelted by the Straits Trading Co., which has a large smelting plant at Singapore. This company has great influence throughout the peninsula, and has established numerous agencies where tin is bought from the miners and sent to Singapore. The total production of tin on the Malay peninsula in 1901 was almost 47,000 tons, which is over half the tin of the world, while the production of the peninsula and the islands of Banka and Billiton together amounted to over three-quarters of the production of the world.

The tin lands on the peninsula are either bought or leased, and the government of the Federated Malay States imposes an export tax on tin ore of about 12 per cent. of its value. As tin is the main product of the peninsula, the tax affords a large income, which is the principal support of the government. The money derived from this source has been wisely expended, generally under British advice, in internal improvements. Excellent wagon roads have been built throughout the different states, and railways have been constructed in a number of localities. As yet the latter have not been connected throughout the peninsula, as they are being extended only so fast as funds are obtained to build them. It is expected, however, that before long the isolated lines of railway will be extended, so that there will be continuous connection from the extreme southern end of the peninsula at the town of Johor to the Siamese boundary on the north.

R. A. F. PENROSE, JR.

PHILADELPHIA,
February 3, 1903.

THE SIERRAN VALLEYS OF THE KLAMATH REGION, CALIFORNIA.

In a series of papers recently published[1] the writer has traced the development of the present topography of that portion of the Klamath mountain region which lies south of the Klamath river, terminating the story with a great uplift at about the opening of the Quaternary era. This history comprised a sharp folding of the sedimentary formations and the injection into them of batholiths of peridotite, gabbro, and granite, at about the close of the Jurassic period; a profound denudation and leveling off by sub-aerial processes in early Cretaceous time; a submergence of the border of the province in late Cretaceous time; a post-Chico deformation, throwing the entire region into a series of deep elliptical basins; a probable partial peneplanation, the product, perhaps, corresponding to the Eocene peneplain of southeastern California; an uplift resulting in the erosion of broad basins whose floors were probably irregular; the production beneath the floors of these basins of broad, deep, canyon-like depressions, apparently the result of stream erosion; the filling of the depressions by thick accumulations of river-channel deposits and the more complete leveling of the basin floors; and finally the uplift, tilting, and erosion of these old alluvial deposits.

Along the western border of the Klamath province and in the adjoining portion of the Northern Coast Ranges, Mr. J. S. Diller has encountered a rich territory (for the physiographer) and has recently published his conclusions in an admirable paper entitled "Topographic Development of the Klamath Mountains,"[2] the result of several reconnaissance trips into that region. He identified, on the older rocks of the Klamath region, numerous remnants of an uplifted and dissected plain of erosion, the Klamath

[1] *American Journal of Science*, Fourth Series, Vol. XIV, No. 79, July, 1902; *Science*, Vol. XV, June 13, 1902, p. 951; JOUR. GEOL., Vol. X, No. 4; May-June, 1902, pp. 377–92.

[2] *Bull. U. S. Geol. Surv.*, No. 196, Series F, Geography, 31, 1903.

peneplain. Below the level of the peneplain he has found various remnants of a series of sandstones and gravels, the age of nearly all of which, on the basis of abundant paleontological evidence, is placed late in the Miocene period. Some of these sandstone areas were uplifted, deformed, and planed off by stream erosion, producing a peneplain (the Bellspring), which is practically continuous with the Klamath peneplain developed on the older rocks, making it apparent that the latter was not materially disturbed until long after the deposition of these supposed late Miocene sediments.

Then the country was uplifted to the amount of 500 feet near the coast, but increasing inland, and there was locally developed a lower peneplain, which Mr. Diller has named the Sherwood. I am unable positively to identify the late Neocene grade level which I have observed in the Trinity basin with either of Mr. Diller's two main pleneplain levels, as there has apparently been an unusual deformation in the vicinity of the south fork of Trinity river, and I am not sufficiently acquainted with that region to give it its true value. The reader is referred to the map accompanying Mr. Diller's paper for the geography of the territory herein discussed.

The few short sections of late Neocene river channels which are known in the southern portion of the Klamath region are evidently mere remnants of an extensive system which must have been developed over the entire territory — a system comparable with the Neocene channels of the Sierra Nevada region. In the latter province there was an uplift without much deformation other than a gentle westward tilting. In the Klamath region, on the contrary, the differential uplifting took the form of broad arches. This may be likened to the arching of the Coast Range region to which is due the present parallel ranges separated by broad valleys, both northward and southward from the Bay of San Francisco. In fact, the arching of the Klamath region was part of the Coast Range system of late Tertiary and early Quaternary mountain-building. But in the Klamath province the entire territory was so greatly uplifted that the streams have trenched deeply beneath the troughs as well as into the arches, and in consequence this arching is not so apparent in the topography as it is in the Coast Range region farther south. Indeed, it is only by studying the cause of the nearly complete destruction of the Neocene river deposits that one is led to recognize the fact and comprehend the nature of this arching.

The main Neocene channels for the most part had courses across this subsequently developed system of arches and troughs. Over the arches they have been carried so high above the present stream level that subsequent erosion has completely removed the old river deposits, and in most cases even destroyed the form of the old valleys. But where some of the main rivers crossed the deeper and broader troughs, their deposits were not lifted high enough above the present stream level to be completely destroyed by erosion. That is precisely the position in which we find the present Neocene remnants of the Trinity basin.

The direction of the axes of the arches and troughs is generally a little west of north. The preservation of twenty miles of the length of the old Trinity river deposit was due to the fact that the portion of it from Weaverville northward ran nearly parallel to a trough. The floor of the old channel rises very gradually toward the north, but where the channel deposit turns westward at Weaverville, the bottom rises rapidly. Apparently the floor of the channel at Weaverville has an altitude less than 1,000 feet above the sea and at the distance of three miles or less this has risen to probably 2,500 feet above sea-level.

The Weaverville Neocene area terminates northward about a mile south of Swift creek, but the broad basin in which it lies continues onward for many miles. The floor of the Neocene valley seems to have reached such an elevation at Trinity Center that the present Trinity river has trenched below it and removed its filling. It is probable that the summit of the low hills just west of Trinity Center reaches nearly or quite to the level of the floor of the old channel, and some of the river deposits near the top of these hills may be actual remnants of the Neocene deposit. The present river valley is abnormally wide at this point, which is due to the fact that here the old and new courses coincide, and further that there was at this locality even in Neocene times the junction of the main Trinity river and the east fork of Trinity river.

I think I can trace the old valley up the main Trinity river to and beyond the mouth of Coffee creek, a distance of half a dozen miles from Trinity Center. There are near the river a number of small mountain ridges rising to about the same height. Back of them the slopes of the high mountains rise very abruptly. Usually this does not indicate a halt in the down-cutting of a deep mountain valley, because the tributary streams in approaching a trunk stream ordinarily reduce the summits of the intervening ridges to much lower levels than the main divides, producing the appearance of a basin, beneath the floor of which has been trenched a later system of valleys : but in this case the observer gains the impression that the ridges near the river have sufficient regularity in height to indicate that they are remnants of the floor of an old valley which was several times as wide as the present river valley. This apparent old valley floor rises upstream more rapidly than the present river, and before it reaches the point beyond which later erosion has so completely destroyed it that one fails to recognize a trace of it, the elevation above the river may be a thousand feet.

For a long time I have entertained the idea that the old Trinity river drained Scott valley. There is no definite evidence of this, but a number of facts in its favor. The abrupt termination of Scott valley at the southern end indicates differential uplift of the Scott Mountain region on the south. This we may call the Scott Mountain arch. The Trinity Neocene valley distinctly rises on the southern slope of this arch. On the summit of Scott Mountain there is a depression which may be a portion of the old valley floor. In that case the amount of the differential uplift would be between 2,000 and 3,000 feet. Some of the important tributaries of Scott river (which flows north), have southerly courses, hardly explainable by the known structure of that region, and suggest a reversal of the direction of drainage in the main valley.

The new valley trenched by Trinity river between Trinity Center and Junction City has an average depth below the late

Neocene grade level of about 1,300 feet. The tributary streams on the west kept pace with the main river in cutting channels through the rock barrier between the old and new valleys, and they have eroded deep canyons into the gravel deposit of the latter. Stewart's Fork and Rush creek have each cut down about 1,600 feet. Weaver creek was especially active and was favored by finer material in the broad portion of the old valley, so this small stream excavated a basin three or four miles in diameter and at least 1,000 feet in average depth. As a means of draining this basin it excavated in micaceous quartz schist and serpentine, a narrow, crooked canyon valley five miles in length and over 1,000 feet in depth.

From Junction City to North Fork, six miles, the present course of Trinity river seems to coincide with the old course. It is directly in line with the last mile of the old channel deposit of the Weaverville area, and there is no other apparent outlet among the hills for the old valley. But between Weaverville and the La Grange hydraulic mine (the latter at the extreme western end of the gravel deposit), as already mentioned, the bed-rock floor of the channel rises rapidly, and westward from the mine it is so elevated above the present drainage level that erosion has completely destroyed the gravel deposit. Yet the influence of the old channel on the present valley is still apparent as far as North Fork ; for the Pleistocene river, being favored in this portion of its course by a broad valley filled with easily eroded gravel, and having cut down deeply among the bed-rock hills, although not nearly to the present water-level, has been enabled to greatly widen its present valley. Such abnormal widening of the present Trinity valley does not occur except at the few points where independent evidence indicates clearly that there the old and new courses coincide.

One mile below North Fork, the Trinity river enters a narrow gorge five miles in length and perhaps 1,500 feet in depth. The extreme narrowness of the gorge is explained by the fact that the river is traversing a resistant formation, a great gabbro batholith. However, it is beyond dispute that this gorge does not represent the Neocene valley which, even in this hard formation, must have been many times wider than the present valley. Yet I think the old valley followed this course, but has been carried up so high by uplift and deformation as to have been completely destroyed by erosion.

After passing the gabbro, the Trinity valley is wider again, and low ridges near the river with the higher mountain ridges some considerable distance back, suggest that the present small valley is trenched beneath an older larger valley. I would not be certain of the value of the evidence, had not Mr. Diller discovered one of the Neocene remnants in this basin.[1] It contains lignite and is otherwise similar to the Neocene deposits of Hay Fork and Hyampom valleys. A short distance below Big Bar the river enters a veritable gorge which it follows for about thirty miles, nearly to Hawkin's Bar, and I am practically certain that this is not the old course of the stream. The gorge widens where it crosses the Paleozoic slates, but where it is trenched in gabbro and allied Plutonic rocks, as it is through most of its course, it is extremely narrow. In many places the slopes rise directly from the river's edge on both sides and continue up as steeply as the loose material will lie to the tops of the neighboring mountains, probably 3,000 feet above the river. Rock precipices are common, and often the trail has to climb hundreds of feet above the river to pass a rocky point. There are no shoulders on the slopes of this valley, and nothing to indicate complexity in its history. It is a simple Pleistocene valley of the gulch type 3,000 feet in depth.

I have some confidence that the Neocene valley followed the present course of the river as far as Big Bar, but what was its course beyond that point is a problem. It is probable that it went more directly west for a few miles than does the present river beyond this point and then turned to the southwest; there is some evidence of this, but it has not been studied in detail. On the line between Big Bar and Hyampom valley there is a depression among the mountain summits which may mark the line of this old valley. Nearly midway is Corral valley, which is described as a flat-bottomed, basin-like depression about a mile

[1] *Fourteenth Annual Report, U. S. Geol. Surv.*, Plate XLV, and p. 419.

in width, drained by an insignificant creek through a narrow valley. From the description, it is probably a short section of the bottom of a Neocene valley, the gravel filling of which has been cleaned out by erosion. It is also probable that at or in the vicinity of the present Hyampom valley the old Trinity river was joined by the Hay Fork river.

It is apparent that the deformation of the Neocene surface in the western part of Trinity county took the form of a broad arch. It is believed that this extended north through Siskiyou county, across the courses of the Salmon and Klamath rivers. It is marked by the deep, narrow, rocky gorges of all the streams which cross it. These gorges invariably have the gulch type, so characteristic of Pleistocene erosion in the Klamath region, and their comparative youthfulness is beyond dispute.

Hay Fork stream, between the Hay Fork and Hyampom Neocene valleys, is said to flow for miles through a deep rocky gorge whose relative narrowness is not satisfactorily explained by the resistant properties of the formations trenched. New river, a northern tributary of Trinity river, has trenched a deep valley into the supposed arch. The New river country, although not high and rugged as the Sierra Costa mountains, is so extremely broken as to be almost inaccessible. An effort was made to construct an especially well-graded trail along New river, yet in places it climbs nearly a thousand feet above the stream to get around a rocky point. The valley is characterized by immense landslides, which form rough terraces and at one place supply enough level land for a farm. These landslides are the result of the very rapid down-cutting of the bottom of the valley. The phenomena witnessed throughout this region tell of the newness of the cycle of erosion. All the valleys are of the same gulch type as those of Trinity Mountain, which are known to post-date the uplift of the Neocene deposits. In the latter region, the vertical element of the erosion hardly exceeded 1,500 feet, but in the lower Trinity and New river country, it was not less than 3,000 feet.

The gorge of the Salmon river between Bennett's and its mouth seems to belong to the same category as those just mentioned. Perhaps the most magnificent example of the class is that of the Klamath river, which has attracted some attention and given rise to speculation as to its origin. I have never visited it, but it is described as just such a narrow, steep-sided, and very deep valley as that of the lower Trinity. The mountains near the so-called canyon rise to altitudes of 6,000 and 7,000 feet, and the valley has a depth below these higher summits of 4,000 to 5,000 feet. Probably 3,000 or 4,000 feet of this erosion belongs to the time following the deformation of the Neocene surface. I suggest in explanation of it the same hypothesis as has been applied to the lower Trinity, namely, that the Klamath river flowed in practically its present course in late Neocene time, and that during the subsequent orographic disturbance a broad arch was formed athwart its course, but the river maintained its position by cutting a deep valley through the arch. Virtually the same opinion has been expressed by Mr. Diller.

In the case of the Trinity river, there must have been first a short, rapid tilting of the Neocene baselevel to cause the river to migrate and then followed a long, gradual uplift; for, had the movement been a simple one and gradual, the river would not have abandoned its course, and had it been rapid throughout, the river would not have been able to maintain its course by cutting a gorge through the arch.

The south fork of Trinity river and the main Trinity river below Hawkins' Bar roughly mark the western limit of this arch. The Post Creek mountains stand on the crest of the arch south from Hay Fork river. From their summit southwestward to near the south fork of Trinity river there is a long, comparatively gentle slope of the general mountain surface, then a sudden descent into the canyon of the river, and on its southern side a comparatively abrupt rise of about 3,000 feet to the even-crested summit of South Fork Mountain. There is here apparently a fault with a throw of several thousand feet or a sharp monocline. I believe that I am correct in referring the long southwestward slope northeast of the river to the late Neocene grade level of Trinity valley, but I am not so sure that it is an equivalent of the Klamath peneplain remnant at the summit of South Fork Mountain. The Hyampom Neocene deposit lies in this relatively depressed area and has an elevation of about 1,400 feet. I am inclined to the belief that before the derangement of the drainage the Trinity and Klamath rivers had independent courses across the area now occupied by the South Fork Mountain, and that this mountain gained topographic prominence by faulting or folding so rapidly that the drainage was deflected toward the northwest along the line of the fault or fold.

The later system of valleys in the Klamath region is comparable to the Sierran valleys of the Sierra Nevada region. In the latter area only in very exceptional instances has the erosion since the uplift of the peneplain exceeded 3,000 feet in depth. The resulting valleys are equally as narrow, when in a formation of like resistant properties, as in the more northern region. Indeed, the evidence of age is rather in favor of the Klamath than the Sierra Nevada region, for the valleys or gorges or canyons, as we may choose to call them, more thoroughly dissect the surface in the former area. However, the contrast is not great when the comparison is made with the Sierra Nevada region south of the Tuolumne river. The latter is more thoroughly dissected than the northern Sierra region because the average slope of the surface is greater. The slopes in the Klamath region, by reason of the arching, were at least as great as in the southern Sierra region, and the remarkable similarity in the nature of the dissection, and the depth and width of the valleys eroded, unmistakably point to a like age. To assert that the inception of the last great uplift of the Klamath region occurred at a time materially antedating or succeeding the inception of the last great uplift of the Sierra Nevada region, one must disregard the most positive evidence to the contrary. I want to emphasize very strongly that there is the best of reason for correlating the last great arching of the Klamath region, which deranged the drainage and caused the erosion of the new valleys, with the westward tilting of the Sierra Nevada region which initiated the canyon cutting.

As already intimated, I consider the arching of the Klamath region as contemporaneous with and merely a portion of the last great folding of the Coast Range region. This occurred at the close of deposition of the Merced series and was the opening event of the Quaternary era. Last winter I recognized[1] in Piru canyon in southern California a valley definitely comparable in size to Sierran canyons of the Sierra Nevada region that have been eroded under like conditions. This canyon dates entirely from a time succeeding the deposition of a late Pliocene formation, apparently an equivalent of the Merced series.

The erosion of the Sierran valleys of the Klamath region has continued practically uninterrupted to the present day. With a few unimportant exceptions, there are no well-marked terraces in the lower mountain valleys to indicate halts in the downcutting, although locally, through the vicissitudes of erosion, remnants of the alluvial deposits are left for a time at some height above the streams. They are commonly known as "old channels," and many of them have been opened as hydarulic mines. Naturally, they are most abundant at low levels, but occasionally one may be found as much as 500 feet above a stream. Sooner or later all will succumb to the undermining of the slopes, and new ones will be formed at yet lower levels.

The exceptions worth noting are in the vicinity of Hawkins' Bar on the lower Trinity river and at the junction of the north and south forks of the Salmon river. These streams there flow, at present, in very narrow rocky canyons trenched in the bottom of much broader, flat-bottomed, gravel-floored valleys. The latter remain intact over comparatively extensive areas and the trenching is quite recent. Whether this is purely a local development or a persistent feature in the direction of the coast I am unable to say.

Late in the Quaternary era there was developed by subaerial agencies on the northern border of the Sacramento valley a plain several miles in width, which traverses the edges of highly inclined pre-Cretaceous strata. Some disturbance, probably a slight and temporary depression, mantled this plain with stream gravel, forming the Red Bluff formation. The Red Bluff grade level is traceable at several points for a distance of several miles

[1] *Bull. Dept. Geol., Univ. Calif.*, Vol. III, No. 1, p. 9.

into the mountain valleys, but in the remainder of the Klamath region it is unrecognizable. At many places there are gravel-covered benches which may represent the Red Bluff level, but they are short and do not fall into a definite system. They may just as well represent some subsequent stage in the down-cutting of the valleys.

Below Lowden's Ranch on the Trinity river the valley contains a heavy deposit of gravel, the genesis of which I do not know, but several features of this locality are evident and interesting. An inspection of a map of Trinity county will attract attention to an unusual meandering course of Trinity river for about ten miles below Lowden's. Nothing similar occurs anywhere else in the Klamath region. The meanders are like those of a sluggish stream on a broad flood-plain. However, this portion of the Trinity valley is quite narrow, and the crookedness of the river is due to the crookedness of the valley. It is a meandering valley cut down about 500 feet below the surface of the gravel deposit mentioned above. The gravel ridges on the inside of the curves scarcely anywhere reach the original surface, but we can reconstruct the old flood-plain on which these meanders originated. It was the floor of a valley several miles wide, which was bounded on either hand by steep mountains which rose 500 to 1,000 feet above it. I am not certain that we are not here dealing with another remnant of the Neocene valleys and their alluvial filling,[1] but the meanders themselves certainly originated after the uplift and rearrangement of the drainage system. Perhaps the new Trinity river used an old Neocene deposit as a stage on which to perform its evolutions.

OSCAR H. HERSHEY.

BERKELEY, CALIF.,
January 28, 1903.

[1] Diller has mapped this gravel deposit in the *Fourteenth Ann. Rept. U. S. Geol. Surv.*, Plate XLV, as one of the Neocene areas of Trinity county, but its relation to the other deposits is not clear.

ANTICLINAL MOUNTAIN RIDGES IN CENTRAL WASHINGTON.[1]

THE recent revival of interest in the Basin range type of mountain structure has caused the review of many of the data bearing upon that subject. Mountain ridges of the same type were early described by Professor I. C. Russell[2] as occurring over an area somewhat removed from the Great Basin. Similarity of climate and the consequent presence of desert conditions east of the Cascade mountains produce a certain resemblance of central Washington to that region farther south, and the great expanse of basalt lava also renders it natural to consider this area as in a way the continuation of the northern portion of the Great Basin. More questionable, however, is the assumption that the type of mountain uplift commonly believed to be so persistent in the Great Basin is likewise characteristic of central Washington.

A critical consideration of the earlier descriptions of the structural features of central Washington is deemed essential at the present time for two reasons. In the first place, the published results of the geologic reconnoissances, containing as they do the first descriptions of the area, possess the authority that naturally goes with priority. Thus these statements of geologic observation and inference come to be generally accepted and cited by writers who have occasion to refer to the region;[3] and this general acceptance prevails, although quite different descriptions of the area have been published which are based upon later geologic studies of the same area.[4] It is therefore desirable to state distinctly the opposition of later field observations to the statements based upon earlier work. This direct

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] "A Geological Reconnoissance in Central Washington," *Bull. U. S. Geol. Surv.*, No. 108, 1893.

[3] An example of this can be found in the *Third Report, Bureau of Soils*, U. S. Dept. of Agriculture, p. 392, 1902.

[4] *Water Supply and Irrigation Paper, U. S. Geol. Surv.*, No. 55, pp. 23, 24, 1901.

comparison of observations must be made that the reader may have the evidence before him. In the second place, this statement of the disagreement between the results of earlier reconnaissance and later detailed mapping is important in that it may contribute something in the way of suggestion to the broader problem of determining the origin of the Basin ranges. In the solution of such problems, the observations, largely physiographic in character, made in the course of a rapid reconnaissance, may be found later not to be in accord with the geologic data secured during a careful survey of the same area or a portion of it. The methods employed in reconnoissance work are of necessity quite different from those possible in the mapping for folio publication, when a topographic base map is available and the area is thoroughly traversed. Thus, the plea for a rehearing of the evidence does not concern the witnesses so much as the different conditions under which their observations were made.

The Ellensburg quadrangle in central Washington has been mapped geologically by the writer and Mr. Frank C. Calkins, and the results of that survey are incorporated in Folio No. 86 of the *Geologic Atlas of the United States*. The area is one of considerable geologic interest, as it lies in the zone intermediate between the Cascade mountains and the Great Plain of the Columbia. It is natural, therefore, that related as this region is to both of these distinct topographic provinces, its geologic study should yield results bearing upon the structure of both the mountains on the west and the plateau on the east. The area is likewise of interest as the one visited earlier by the reconnaissance geologist and as including many localities the descriptions of which apparently contain the basis of generalizations concerning the prevalence of the Basin range type in central Washington. In the following pages such descriptions will be cited, followed by comment based upon the results of the later work. For the full discussion of the geology and physiography of this quadrangle the reader must be referred to the Ellensburg folio, since the present article can contain only such points as bear directly upon this discussion.

A brief statement of the geology may serve to introduce the discussion of the structural features. Only two important formations are involved, and both extend eastward to the Columbia. The older is the great series of Miocene basalts, measuring several thousand feet in thickness, and this is overlain by Miocene sediments 1,500 feet thick in the best-observed section. To these two series the names "Yakima basalt" and "Ellensburg formation" have been given. Reference will also be made to the Wenas basalt, which consists of one or more thin lava flows interbedded with the lower portion of the Ellensburg formation, unimportant except as it often affords more exact datum planes for the determination of structure. Topographically the region is one of moderate relief, and the general absence of erosion subsequent to the latest deformation of the region is a result expressive of the aridity of the climate.

The first recognition of the Basin range structure in central Washington is given by Professor Russell in these words:[1]

> All of the formations mentioned in the preceding section were originally spread out in essentially horizontal sheets, but since the youngest member in the series was laid down they have been broken into blocks, and the blocks tilted and upturned so as to form prominent mountain ridges with horizontally floored valleys between. A structure has thus been given to the beds on which depends nearly all of the present topographic diversity of the region. . . . .
>
> Briefly stated, the main structural features in our field are (1) narrow, sharp-crested ridges having a prevailing east-and-west trend, due to the upheaval of the borders of orographic blocks; (2) broad and comparatively gentle north-and-south elevation, produced apparently by an arching of the strata, parallel to and probably of the same date as the much greater uplift forming the Cascade mountains; (3) regions where the rocks have been but little disturbed and now form plains and valleys.

The author distinguishes monoclinal ridges and monoclinal folds. Of the former he states:

> The prevailing and most typical structure has been produced by the breaking of the strata and the upturning of the beds on one side of the lines of fracture. The fragments, more or less regular, into which the rocks have been broken are termed orographic blocks. (P. 28.)

The monoclinal folds are thus described:

[1] *Op. cit.*, pp. 28–31.

Besides monoclinal ridges there are other types of mountains in the region traversed which are not so simple in their structure. These are long, narrow ridges which were formed by an arching of the strata without breaks. (P. 29.)

In a later publication[1] the structural features of this area are again described:

The monoclinal structure so characteristic of the western portion of the region known as the Great Plain of the Columbia, and of its southern extension in the Great Basin, due to the tilting of fault-blocks, was found to extend to the mountains on the west. As one approaches the Cascade range from the east, the tilted blocks, the upturned edges of which are short mountain ridges, become of larger size, and form the immediate foothills of the main range. This merging of the structure characteristic of the interior basin with the mountains bordering it on the west, so far as my own observations extend, is more pronounced in central Washington than elsewhere.

A third reference to this region is made in a later report by the same author:[2]

Again, to the east of the portion of the Yakima valley just referred to, as described in a previous report, there are several mountain ridges, such as the two bordering Moxee valley on the north and south — known, respectively, as Selah ridge and Yakima ridge — and Satas ridge, which forms the northern border of the tilted plateau termed Horse Heaven. Each of these ridges is due mainly to the tilting of a block of the earth's crust, capped with basalt, along lines of fracture. This series of faults, and perhaps in part of monoclinal folds, trends nearly east and west, and some of them cross the Columbia, as, for instance, the break on the north border of Saddle mountain.

Five ridges of the topographic type mentioned above cross the Ellensburg quadrangle, and, by way of comment on the general statements given above, these ridges may be considered separately, quoting as far as possible any specific mention that may have been made of them in the earlier reports.

The southernmost of these five ridges is Yakima or Atanum ridge, mentioned in the preceding paragraph. In the earlier report[3] this ridge is more accurately described as having "an arched structure throughout" and belonging to the class of "monoclinal folds," but later (p. 52) the possibility of "a break along portions of the northern base" is mentioned. The observations

[1] *Volcanoes of North America*, 1897, p. 248.

[2] "A Preliminary Paper on the Geology of the Cascade mountains in Northern Washington," *Twentieth Annual Rept., U. S. Geol. Surv.*, Part II, p. 138.

[3] *Bull. No. 108*, p. 29.

made by Mr. Calkins and the present writer along this east-west ridge convinced us that the structure is that of a broad arch, somewhat unsymmetrical, in that on the northern limb the dips are steeper than on the opposite side, and for short distances the strata are even overturned. This anticlinal structure in the basalt flows is well exhibited at Union Gap, where the Yakima river has made a steep-sided cut, a mile in length and 800 feet in depth, across the ridge.

The next ridge to the north is Selah ridge, also mentioned above. In the earlier description (p. 29) it is stated that here "the arch is broken longitudinally and the ridge assumes the faulted character described in the preceding paragraph," *i. e.*, it is a "monoclinal ridge." A more detailed description is given on a following page (p. 54):

> The structure of Selah ridge is too complex to be described intelligently without the aid of map and detailed section, but these are not to be had on account of the lack of an accurate survey. The ridge is an exception to other similar uplifts in the same region, for the reason that it changes from a monoclinal ridge at the west, where the dip is toward the north, to a monoclinal ridge at the east having a gentle slope to the south. The general form of the ridge is that of a long, narrow arch, broken at the west end by a fault on the south side, and by another fault on the north side, for the greater portion of its length.

On the preceding page the structural relations at Selah gap are considered somewhat more fully:

> In the west end of the ridge, separated from the main portion by the deep transverse canyon cut by Yakima river, the east side of the fold is wanting. It may have been cut away by the Naches, which flows along its base, but more probably was carried down by a fault which may have been continuous with a break to be seen on the south side of the ridge and east of the Yakima. There is also a cross-break running north and south which determined the course of the Yakima river. This is shown by the lack of correspondence in the dip of the light-colored John Day beds (Ellensburg formation) occurring on the sides of the canyon.

The detailed study given to this locality when it was mapped afforded no reason for considering that Selah ridge possesses a structure more complex than other ridges of the vicinity. There appears to be no necessity for dividing it "into sections having various structures." It is true that farther west where it merges into the basalt plateau it is monoclinal in part, but there it is hardly a distinct ridge, becoming such only as it assumes an anticlinal structure. In the vicinity of Yakima river, where the descriptions quoted above apply, this anticlinal structure is pronounced, and on the edge of Selah gap the anticline is seen to be flat-crested with steep sides. For two miles west of Yakima river the south side of the fold—erroneously termed the east side in the last quotation—is cut away by Naches river, while similar cliffs have been produced east of Selah gap on both sides of the ridge by meanders of Yakima river. That these steep escarpments in no wise indicate faulting seems evident by the presence of efficient agents in these rivers at the base of the cliffs, but is demonstrated by the presence of a remnant of the southern limb of the fold south of Naches river. Here the Ellensburg sandstone occurs with a steep dip to the south, just where this portion of the anticline should be found, while east of Selah gap, immediately beyond Yakima river, the fold is also perfectly preserved. The presence of the Wenas basalt interbedded with the sandstone makes it possible to work out the structure with considerable certainty. As regards the "cross-break running north and south," this appears to be explained as a slight sag or fold, the anticline pitching differently on the two sides of Selah gap. In brief, then, the assumption that this ridge is due in any degree "to the tilting of a block of the earth's crust capped with basalt along lines of fracture" seems unwarranted by observed facts. The anticlinal structure is plainly exhibited, and in this respect the ridge is no "exception to other similar uplifts in the same region."

The ridge next to be treated is Cleman mountain, an uplift which, like those described above, crosses the Yakima, but is most prominent ten to fifteen miles farther west. This has been described as follows:[1]

> The Naches, for a score of miles at least above the mouth of Tiaton creek, flows through a deep canyon, bounded on the east by the precipitous face of a long, uplifted mountain mass having the topographic form of a great fault scarp, in which the inclination of the strata is northeastward. The

[1] *Bull. No. 108*, p. 65.

country about the upper portion of the Naches was only seen from a distance, however, and may have a more complete structure than is here suggested.

Here again the later field study has afforded conclusive evidence that the Cleman mountain anticline is complete, except for a distance of six miles along its southern slope, where a huge landslide has pushed into the canyon of Naches river below. However, it is along the lateral escarpment facing this landslide area that the best exposures of the structure are to be had.

Umptanum ridge succeeds Cleman mountain on the north, Wenas valley separating the two. North of this in turn is Manastash ridge, known also as the Beavertail hills. The reconnoissance description of this region follows:[1]

The rocks on the head waters of Wenas creek are Columbia lava, broken and upturned in fault scarps, which merge into a general region of uplifts to the west, but become separated and well defined in traversing the desert country to the east. The ridges thus found agree in their principal features with nearly all the east and west ridges in Yakima and Kittitas counties. One of the lines of east-and-west faulting between Wenas and Kittitas valleys is marked by Umptanum ridge, which presents its bold escarpment to the northward. North of this, again, are the Beavertail hills, which are also a monoclinal uplift.

Umptanum ridge is perhaps the highest of these east-west ridges where it is crossed by Yakima river. The perfect arch of the ridge at Umptanum gap exposes a thickness of Yakima basalt exceeding 2,000 feet. The anticlinal structure is most evident, the fold being unsymmetrical, with the northern dips steeper. If any faulting is present, it must be of the nature of displacement on the plane between two sheets of basalt, but in any event, judging from the excellent section seen in Umptanum gap, faulting is of minor importance. Along the northern face of the ridge farther west there is a prominent outcrop of black basalt making a scar somewhat suggestive of a bedding fault. At another point, however, an even more prominent feature of this sort was seen in section, and the observation was conclusive as to the absence of any faulting. Thus, on the evidence of detailed study, the assertion is confidently made that in no

[1] *Ibid.*

respect is Umptanum ridge of the nature of a faulted monoclinal fold.

Manastash ridge likewise exhibits the anticlinal structure, unsymmetrical, and again with the steeper dips on the north limb. In the vicinity of Yakima river there is a fault present, as shown in the areal distribution of the formations. This fault, however, produces no scarp, and indeed crosses slightly the topographic axis of the ridge, showing the impossibility of its having any part in the elevation of the ridge. In fact, this fault belongs to a period of deformation antedating the uplift of these ridges to their present elevations. Throughout the region the orographic history has been more complex than is indicated in this article, where only those facts are cited which bear upon the points in question.

Farther east the Manastash ridge uplift unites with others to form Saddle mountain, which is cut through by Columbia river at Sentinel bluffs. The structure of Saddle mountain was described by Professor Russell as follows:[1]

Saddle mountain, as previously mentioned, belongs to the series of monoclinal uplifts due to faulting, which extend eastward from the foothills of the Cascades. This long, narrow, sharp-crested ridge is perhaps the most remarkable of these uplifts, as it extends farther east than any of its companions and clearly reveals its structure where the Columbia has cut through it.

It is there a well-defined monoclinal ridge, dipping sharply southward and presenting a bold scarp to the north. The dip of the strata of basalt of which it is composed corresponds with the gently sloping southern side. The line of fracture is on the north side of the ridge, and the steep northern face is a fault scarp. Toward the eastern end the fault scarp decreases in height and finally dies out, and the John Day beds pass over and conceal the Columbia lava. The dip of the strata on each side of the ridge toward its eastern end becomes about the same, showing that the fault passes into a fold.

Through the kindness of Mr. Frank C. Calkins, the following quotations are made from his description of the same locality from the manuscript of a water-supply paper now in preparation:

The north face of Saddle mountain, where it overlooks the lower stretch of Crab creek . . . . suggests faulting in a very striking way. . . . . It is obvious that we must have here either a normal fault with the downthrow to the north or a sharp flexure, the downfolded portion having been removed by erosion, leaving only the nearly horizontal strata on either side. . . . .

[1] *Ibid.*, p. 96.

On the west side of the Columbia, opposite the mouth of Crab creek, the continuation of the mountain is bounded on the north, not by a cliff, but a steep slope. The mountain shows no outcropping horizontal ledges, but rising through the mantle of soil sloping back on the spurs and forward in the gulches can be traced the outcrop of one or more especially resistant beds of black lava, having a dip a little steeper than the slope. . . . . At another point twenty miles east of the mouth of Crab creek, the slope of the mountain was examined again and a similar state of things observed. . . . . The evidence demonstrates that there is here a sharp flexure and not a fault.

While the fact is not proven beyond doubt, I believe that this flexure, observed both east and west, was once continuous along the entire front of Saddle mountain, that the cliff along lower Crab creek is the product of erosion, and that the flexure is here concealed below the sediments in Crab creek bottom.

This citation of conclusions as to the orography of central Washington based upon reconnoissance observations and their comparison with the results of later and more detailed field work is believed to be justified by the result gained. Further evidence as to the true type of uplift is presented in the accompanying structure sections, Fig. 1. These are drawn to scale, and the structural features indicated are based upon dips observed along the line of section, and upon the general form of the different anticlines as exposed in the Yakima canyon section. The opportunity for direct observation of structure afforded in these gaps cut by Yakima river is exceptional and entitles the structure sections to considerable credence. The use of the scale 1 : 125,000 without vertical exaggeration renders the relief much less prominent than it appears to be in the field, but it is believed that a more accurate conception of structure can be obtained from these sections than from many drawn to illustrate the Basin range type, in which, as the author states, "the vertical scale is exaggerated and no attempt is made to represent the structure of the orographic blocks."

The type of deformation existing in central Washington is of interest in that enough is known of the geologic history to state the amount of load under which the rocks were flexed. Mention has been made of the two periods of uplift. In the earlier, which is believed to have been during either late Miocene or early Pliocene, the Yakima basalt may have been covered by 2,000 feet of Miocene sediments, the thickest section of the Ellensburg formation measuring 1,600 feet. Subsequent erosion, however, removed the Ellensburg, and even some sheets of the Yakima basalt over considerable areas, so that the later deformation was of the nature of flexing at essentially the present surface. This uplift began probably in the Pliocene and continued long enough so that even now erosion has not essentially modified the ridges of deformation. The exception to this statement is found in the water gaps of the Yakima and Naches rivers, in which cases

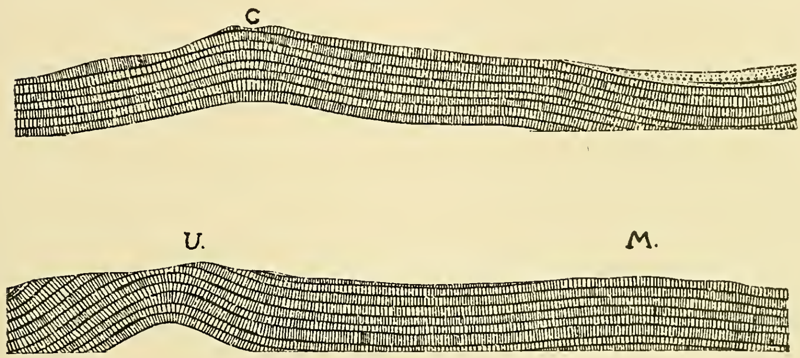


FIG. 1

streams coming from the more humid region to the northwest have possessed sufficient corrosive power to withstand the deformation forces and maintain their right of way across the uplifted ridges. The mechanics of such surface deformation would alone constitute an interesting subject of investigation. It is evident to any observer that a series of basaltic flows in which the columnar jointing is so common a feature would act quite differently under deforming forces than more rigid formations. The type of deformation found here is that termed by Van Hise[1] "joint folds." One distinction must be kept in mind, namely, that the joints in the Yakima basalt are not the product of the deformation forces, but owe their origin to contraction in the cooling lava. During the later deformation these thousands of joints may have been opened sufficiently to allow the production of the broad flexures of the basalt sheets. Adjustment along the planes between suc-

[1] VAN HISE, JOUR. GEOL., Vol. V, p. 191.

cessive lava sheets, as well as between the vertical columns, must reasonably be expected to have been important in whatever flexing took place. Such displacements, however, were at no place observed, and are doubtless on a minute scale, although of considerable importance in the aggregate.

A consideration of the cause of deformation of the nature described here would lead to the discussion of a much broader question. It would involve the origin of the Cascade range, the uplift of which is believed to belong to the same period as the production of these east-west ridges. Such a discussion will be in order after the results of detailed mapping over larger areas of the Cascade mountains are in hand. It may, however, be in accord with the purpose of this paper to take exception to certain assumptions as to origin with which the geologist apparently sometimes enters such a field. An example follows:[1]

> The arches were raised by a force acting from below upward, and not by lateral pressure which forced the strata into ridges and troughs, as is common especially in the Appalachian mountains.

This distinction between the supposed monoclinal structure with faulting and the more common type of deformation appears to be based in large part upon certain *a priori* hypotheses developed in the course of work farther south, viz.: tilted orographic blocks are expressive of lateral extension rather than lateral compression, and the region is one characterized by depression as well as by fracturing. Therefore, central Washington, like southern Oregon, was at once considered as characterized by deformation which involves extension rather than compression. It is now suggested that such assumptions are not the only ones that can be made to account for the facts. A glance at the structure sections will show this assumption of extension to be unsupported by the field evidence. The occurrence of overturned strata on the limbs of folds is, moreover, forcibly suggestive of some degree of lateral compression, while the fact that the Yakima cuts below the floors of several of the transverse synclinal valleys may be considered good evidence that these valleys are not sunken areas, but have simply been uplifted less than the bordering ridges.

[1] *Bull. No. 108*, p. 29.

The search for a force to supply this supposed upward pressure involves further difficulty (p. 29).

Just what the action was which produced these arches it is difficult to determine. It is possible that volcanic rocks, escaping in a molten state through fissures in lower beds, raised the Columbia lava and superimposed beds into arches. In the continuation of the ridge cut through at Union gap, which forms the south wall of Moxee valley, molten rock forced up from below escaped through fissures in the Columbia lava, but raised the lighter beds above into a long, narrow ridge. In this instance the intruded lava has been clearly exposed by the erosion of a longitudinal valley along portions of the crest of the uplift.

In another place (p. 54) Selah ridge is cited as another possible occurrence of uplift by intrusion. "There are also reasons for suggesting that the scoriaceous basalt at the base of the section may have been a subsequent intrusion." In a careful study of the basalt section at the latter locality with a view to substantiate the earlier observation, the present writer failed utterly to find any reason for supposing any of the basalt intrusive. Both here and in the other locality cited the extremely scoriaceous character of the basalt was observed, but was taken by him to indicate the basalt to be extrusive rather than intrusive. Moreover, in both cases the basalt in question is superficial in position as compared with that shown in the deeper cuts of Union and Umptanum gaps.

Relative to the structural features of central Washington, then, the later and more detailed observations conflict with the results of earlier reconnoissance in these respects:

The mountain ridges described as monoclinal fault-blocks, tilted along lines of fracture, are found to be gentle anticlinal folds, with no evidence of faulting at any one of the several localities cited.

The assumption that lateral pressure had no part in this deformation is opposed by the structure section which shows compression, as well as by the occurrence of overturned strata on the sides of one of the synclines.

The hypothesis that igneous intrusions produced the deformation rests upon field evidence, which impresses the later observer as wholly inadequate.

George Otis Smith.

SOME ADDITIONS TO THE CARBONIFEROUS TERRESTRIAL ARTHROPOD FAUNA OF ILLINOIS.

Insect remains of Paleozoic age, representing the advent of a class of organisms which is today the largest and most highly specialized of all animal groups, naturally possess an absorbing interest. Unfortunately but few localities have been discovered that yield these fossils, and these have produced but a small number of forms as compared with those of Tertiary and recent time. From the strata of Silurian and Devonian age, insect-remains are so extremely rare that but little can be asserted of them, the bulk of Paleozoic insects being from strata of Upper Carboniferous age. As might be expected, Paleozoic insects often combine in one individual, characters that at the present time are distributed among several orders, and for these synthetic forms which have no living representatives, the name Palæodictyoptera has been proposed by Goldenberg and followed by Scudder.

With the exception of two species preserved in the collections of the Chicago Academy of Sciences, all the material described in the present contribution is in the palæontological collection of the Walker Museum of the University of Chicago, and most of it is from the Gurley collection. With one exception, the specimens are all ironstone concretions, and nearly all are from the famous Mazon creek locality in Grundy county, Illinois. A portion of the collection studied has already been worked over by Dr. S. H. Scudder, and the results of his investigations have been published in a number of his papers, and all that is desired in connection with this portion of the material is to make known the location of the type specimens. Among the remainder of the collection there are several forms of very great interest.

The new forms here described are all more or less closely allied to those already known from America, and the classification here used is that elaborated by Scudder rather than that of Brongniart which was based upon the quite different European insect fauna of Carboniferous times. Most of the new species here recognized are assignable to genera already known —an interesting fact which would indicate that at the early period when these insects lived there were but comparatively few types, and that the number of genera, even in restricted groups, had not reached the specialization of today.

In the preparation of this paper, acknowledgment is due to the cheerful aid of Professor Stuart Weller, of the University of Chicago, and to the generosity of Curator F. C. Baker, of the Chicago Academy of Sciences, for the loan of specimens belonging to that institution.

CLASS *ARACHNOIDEA*.

ORDER *ANTHRACOMARTI*.

Family *Architarboidae* Karsch.

The genera of this family may be separated in the following manner:

Legs unusually long and slender: basal abdominal segments large: spinneretts present - - - - - - - **Kustarachne**

Legs thickened; basal ventral segments of the abdomen usually shortened; no spinning organs - - - - - - - - - 2

2\. Coxæ radiating from a triangular sternum - - **Anthracomartus**

Coxæ radiating from a median pit or ridge - - - - - 3

3\. Basal segments of abdomen strongly angulated; cephalothorax prominent, not markedly constricted from the abdomen - **Geraphrynus**

Basal segments nearly transverse, though often crowded - - 4

4\. Cephalothorax narrower than the abdomen, or markedly constricted from it, suborbicular, the front more or less broadly angulate 5

Cephalothorax shorter than the abdomen, but not constricted from it, transversely orbicular, the front rounded - - **Architarbus**

5\. Cephalothorax less than one-half as broad as the abdomen; legs short; large species - - - - - - **Hadrachne** gen. nov.

Cephalothorax and abdomen of nearly equal breadth; legs comparatively long though stout; species less than one-half the size of the former - - - - - - - - - **Geratarbus**

Hadrachne gen. nov.[1]

Stout-bodied; cephalothorax small, angulate anteriorly and transverse posteriorly, its sides nearly straight and more or less continuing the outline of the abdomen without a lateral con-

[1] ἁδρός, "stout;" ἀράχνη, "spider."

striction between the two. Post-thoracic plate broadly triangular, but not crowding the basal abdominal segments so that they become angulate. Abdomen greatly enlarged, regularly oval, broadest at the middle, consisting of nine segments. Legs short, coxæ wedge-shaped, radiating from a small central disc.

1. **Hadrachne horribilis**, sp. nov. (Plate V, Fig. 1; Plate VII, Fig. 1).

The cephalothorax is triangular in outline, bluntly pointed in front. Its texture shows no punctation nor other sculpturing. The sutures between the pedigerous segments are finely indicated and converge to a small elliptical, longitudinally disposed central space which may indicate a shallow depression or lie level with the surface. Unfortunately, as in its relatives, although the dorsal surface is exposed, no traces of eyes can be observed. The posterior plate of the thorax has its surface granular. As in its allies, it is crenulate, the ridges curving anteriorly. The post-thoracic shield overlying the base of the abdomen is broad and shallow, its posterior edge quite obtusely rounded, rather than angulate; its surface is impunctate. The six basal segments of the much-swollen abdomen occupy nearly one-half of the body, and are of nearly equal size. At the margin they are widest, and become narrower at the middle to accommodate the post-thoracic shield. The sixth segment is but slightly bowed. These segments are finely punctulate and possibly may have been smooth. The apical half of the abdomen, however, is decidedly granular, the granules becoming irregular, confused, and confluent apically. No anal tubercle is visible. The incisures of the segments do not interrupt the outline of the abdomen. The lateral sulcus extending longitudinally is evident. The legs are remarkably short and slender for so stout a creature. Palpi similar to the legs, equally stout, but somewhat longer. The coxæ consist of closely contiguous, distally expanded, wedge-shaped pieces, which meet about a small median inclosure. The remaining segments of the legs are individually stout, not over twice as long as broad.

Length of whole spider 39^{mm}, of cephalothorax 13^{mm}, of abdomen proper 20^{mm}; breadth of cephalothorax at base 14^{mm}, of abdomen at middle 23^{mm}; length of leg-joints 3.5^{mm}.

A single specimen represented by one-half of an ironstone nodule from Braidwood, Ill., collected by Mr. M. Fischer. This is by far the largest Anthracomart-spider yet discovered. The great size of the abdomen and the contrastingly small cephalothorax will readily distinguish it from the other genera of the order.

Type. Pal. Coll. No. 9232.

2. **Geraphrynus carbonarius** Scudder (Plate V, Fig. 3; Plate VII, Fig. 3). *Proc. Am. Ac. Arts Sc.* Vol. XX (1884), pp. 16, 17.

A beautifully preserved specimen of this common species, measuring 24^{mm}, exhibits nothing unnoticed in Dr. Scudder's lengthy description. The post-thoracic piece is triangular.

Pal. Coll. No. 9233.

3. **Architarbus rotundatus** Scudder (Plate V, Fig. 2; Plate VII, Fig. 2). *Geol. Surv. Ill.*, Vol. III (1868) , p. 568, Fig. 4.

A well-preserved specimen, showing nearly the whole of the legs and the structure of the body, appears to belong to this species.

Pal. Coll. No. 9234.

4. **Kustarachne sulcata** sp. nov. (Plate V, Fig. 5; Plate VII, Fig. 4).

Cephalothorax orbicular, nearly as broad as the abdomen, from which it is evidently, though not deeply, constricted. Coxæ meeting along a narrow median space which extends along the whole length of the cephalothorax, stout, distinctly and deeply punctulate; remainder of legs punctulate also, more slender than the coxa, especially on the tarsal portion; metatarsus as long as the basal portion of the leg together. Mouth parts not distinct. Abdomen somewhat broader than the thorax, elongate elliptical, its segmentation obscured, irregularly but deeply punctulate, the punctures becoming obsolete in the middle, provided with a prominent lateral sulcus concentric with and close to the margin, and with a broader and deeper longitudinal one on the disc on each side of the middle. Abdomen terminated by a triangular sessile pygidium consisting of two and possibly three subsegments, its outline extending beyond the regular oval of the abdomen, not punctured. The basal appendages noticed in *tenuipes* are not indicated, but there is a mark on the stone which might have been caused by a terminal seta. This is as fortuitous as in the other species, but its presence casts even darker gloom over the systematic position of the genus.

Length of body 15^{mm}, width of cephalothorax 6.5^{mm}, length of abdomen without the pygidium 9^{mm}, width of abdomen 7^{mm}, width of first subsegment 2^{mm}, length of second leg (imperfect) 24^{mm}, width of second leg beyond body $0.75–0.3^{mm}$.

Carboniferous. Mazon creek, Illinois.

Type. Pal. Coll. No. 9235.

Although the imperfect type of this genus offers but few salient characters, the present form is placed congeneric with it in entire confidence. It concurs with the characters of no other Anthracomart, but agrees with *Kustarachne tenuipes* in its general form, slender, elongate, but somewhat stouter legs, and similar pygidium. However, it is quite distinct in the sculpture of the abdomen.

5. **Kustarachne exstincta** sp. nov. (Plate V, Fig. 4; Plate VII, Fig. 5).

A single specimen in fragmentary condition. Cephalothorax confused, apparently transversely rounded; the coxæ large and meeting about a deep central depression; the post-plate (if there be one) not indicated. Abdomen rounded oval, its segmentation rather distinct; seven and possibly eight segments indicated, of which the basal segments are longer than the apical, the diminution in size being gradual. The last three segments are outlined by an impressed line. At the termination of the abdomen is a triangular two-jointed pygidium with a prominent mammilliform spinnerett on each side of the last segment. At some distance beyond the body there is an indication of a slender setiform appendage, though whether this is a portion of the post-abdomen or a fragment of a tarsus cannot be ascertained. The latter view seems more likely the correct one, and would also explain the "post-abdomen" of the other species. The lateral sulcus is vague, but seems to be distant from the margin of the abdomen; this may be due to the crushed and contorted condition of the fossil. No median grooves or ridges: surface of the body minutely and densely punctulate, the punctures much finer and denser than in *sulcata.* Legs vaguely indicated as scattered fragments. What remains shows them to have been excessively long and slender; the strong flexure at the coxal joints and the absence of the middle parts of the legs would indicate that the body was carried much as with the Phalangidæ of today.

Length of body 14^{mm}, length of abdomen 9^{mm}, breadth of abdomen (approximate) 7^{mm}, breadth of cephalothorax (approximate) 5^{mm}.

Mazon creek, Illinois. Carboniferous.

Type. Pal. Coll. No. 9236.

This genus possesses some of the characters of the Anthracomarti and some of the true spiders. The formation of the coxal plates is quite suggestive of the former order, while the peculiar segmentation of the abdomen — the basal segments being as large or larger than the apical — and the possession of what are possibly spinning organs are equally incongruous for the group. But two true spiders are known from Carboniferous times, both discovered in Europe. The best-known of these, *Protolycosa anthracophila* F. Roemer, has abdominal appendages and distinctly segmented abdomen. The other, *Palaranea borassifolia* Frič, is fragmentary, but seems to be devoid of these appendages. Even if the appendages at the end of its abdomen be interpreted as spinning organs, *Kustarachne* cannot be included with these, as its relationships are closer with the Anthracomarti, as can be seen by its sessile abdomen and the arrangement of its coxæ. It would seem as if this genus, of which the three species agree pretty closely, was in the line of descent from the ancestors of both the Anthracomarti and the Araneæ, related more closely to the former, but sufficiently removed to be considered now as equivalent to the other genera of the group together.

Although archaic, *Kustarachne* is not ancestral. Even at this early period it had attained a certain degree of specialization in the loss of its abdominal legs, the anchylosis of the basal segments of the abdomen, and the peculiar development of its legs. But that it was not so highly organized as its contemporaries can be surmised from the imperfect fossil remains. Like many archaic or young types, its body-chitinization is not complete, and its frailer structure is represented but vaguely in the same rocks that bear such excellent witness of the rulership of the scorpion and the Anthracomart.

ORDER *SCORPIONES.*

Family *Eoscorpionidae* Scudder.

6. **Eoscorpius carbonarius** Meek and Worthen.

Geol. Surv. Ill. Vol. III, p. 560, text figure.

This specimen is the reverse of the one illustrated by Meek and Worthen, being the opposite portion of the same ferruginous concretion.

Cotype. Pal. Coll. No. 8949.

CLASS *INSECTA.*

DIVISION PALÆODICTYOPTERA Goldenberg.

SECTION ORTHOPTEROIDEA Scudder.

Family *Palaeoblattariae* Scudder.

7. **Mylacris Gurleyi** Scudder.

Bull. U. S. Geol. Surv., No. 124 (1895), p. 43, Plate I, Fig. 5.

Type. Pal. Coll. No. 6389.

8. **Mylacris Mansfieldi** Scudder.

Mem. Bost. Soc. Nat. Hist., Vol. III, p. 47, Plate 5, Fig. 15.

This is the specimen mentioned by Scudder as coming from Vermilion county, Ill., the original type of the species being from Cannelton, Pa.

Pal. Coll. No. 9237.

9. **Promylacris ovalis** Scudder.

Proc. Ac. Nat. Sci., Phila., 1885, pp. 34, 35.

Type. Pal. Coll. No. 6387.

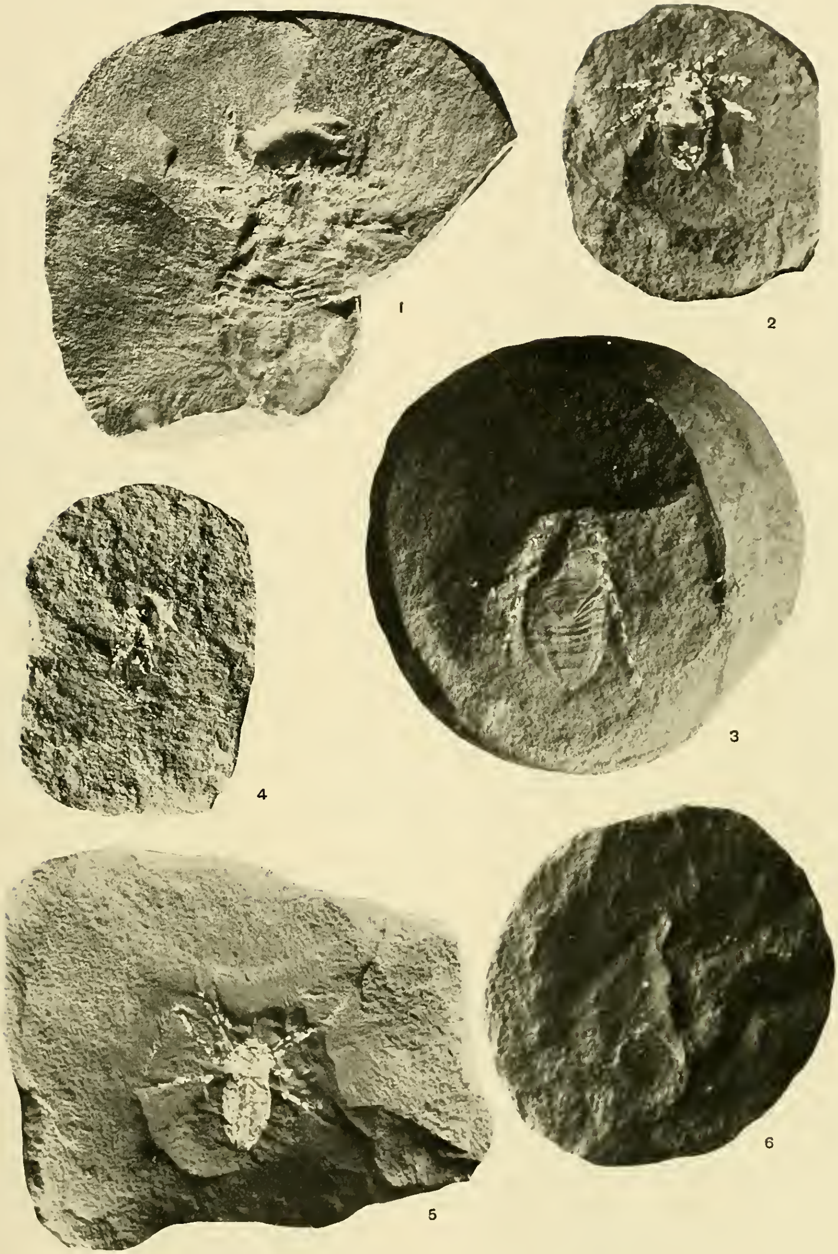
Another well-preserved specimen of slightly smaller size appears to belong with this species. It comes from the same locality and the same formation.

Pal. Coll. No. 9238.

10. **Lithomylacris simplex** Scudder.

Mem. Bost. Soc. Nat. Hist., Vol. III (1879), pp. 51, 52, Plate 5, Fig. 5.

Type. Pal. Coll. No. 6390.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11. **Mylacridae sp.**

Scudder, *Bull. U. S. Geol. Surv.*, No. 124, p. 55, Plate II, Fig. 4.

This is supposedly the humeral angle of the tegmen of a gigantic cockroach.

Figured specimen. Pal. Coll. No. 8948.

The collection contains a large and rather well-preserved specimen of *Dipeltis diplodiscus* Packard (*Am. Nat.* 1885, p. 293), measuring nineteen millimeters in length. The remarkable resemblance between this supposed Phyllopod crustacean and a nymph or wingless female of the cockroaches can be seen from the accompanying figures of the species. (Plate V, Fig. 6; Plate VII, Fig. 6.)[1]

Family *Protophasmidae* Brongniart.

12. **Paolia Gurleyi** Scudder (Plate VII, Fig. 7).

Proc. Am. Acad. Arts Sc., Vol. XX, p. 173.

This interesting specimen, found in a whetstone from French Lick, Orange county, Ind., is here figured for the first time.

Type. Pal. Coll. No. 6393.

13. **Dictyoneura clarinervis** sp. nov. (Plate VI, Fig. 1; Plate VII, Fig. 8).

Wing. Length 33^{mm}; greatest breadth, at middle, 10^{mm}; rather pointed. Humeral angle explanate, filled with very oblique cross-veins from the mediastinal vein; mediastinal oblique and vanishing at the end of the middle third of the wing. Scapular vein parallel with and not distant from the mediastinal, ending in the costa about one-seventeenth the distance from the tip at a slight indentation marking the termination of the marginal vein; near its extreme base the scapular vein emits a lower branch unevenly divaricating from the main stem and furcating just before the last third, the lower branch trifurcating toward the tip and ending at the wing-apex. Externomedian vein not well indicated at the base, owing to the plication of the wing; it furcates once near the point of branching of the lower scapular vein and possibly is split near the tip. Internomedian vein simple, sharply delineated. Anal vein extremely prominent, filling nearly the whole of the hind half of the wing, emitting

[1] In a paper just issued E. H. SELLARDS assigns this species to *Mylacris* (*Am. Jour. Sc.*, April, 1903, p. 309). The shape of the pronotom agrees very well with *Promylacris rigida* Scudd.

four downward offshoots within the wing-area, of which the first and fourth are basally furcate, and one from the anal angle. All the veins are connected by rather distant cross-veins or scrobiculi, which are strongly oblique, though in a sense opposite to those anterior to the mediastinal.

Found in an ironstone nodule six miles southeast of Danville, Ill., at Grape creek, by Mr. W. F. E. Gurley.

Type. Pal. Coll. No. 9240.

This species, while clearly belonging to the genus *Dictyoneura* in the restricted sense of Scudder, not of Brongniart, is markedly distinct from its congeners in the great development of the anal vein. This vein has over twice as many branches as in any of the other species. This is the first American form, all the others being European from the Saarbruck basin.

Section NEUROPTEROIDEA Scudder.

Family *Homothetidae* Scudder.

14. **Didymophleps contusa** Scudder.

Mem. Boston Soc. Nat. Hist., Vol. III, pp. 330, 331, Plate 29, Fig. 6.

Type. Pal. Coll. No. 6392.

15. **Cheliphlebia extensa** sp. nov. (Plate VI, Fig. 2; Plate VII, Fig. 9).

Body elongate, slender, subcylindrical, of moderate size. Head narrow, comparatively small. Prothorax narrow and prolonged. Legs rather robust. Wings large, overlapping on the abdomen, broadest at the beginning of the outer fourth; costal margin nearly straight; apex of wing broadly rounded; mediastinal vein very short; scapular vein long, extending to near the tip of the wing, parallel with the costa, connected with the marginal by a series of moderately close, oblique, curved, simple cross-veins. Externomedian vein first forked at the middle of the wing; its lower stem simple, its upper again forked, and each branch again dichotomizing, the upper twice, the lower once. Internomedian vein emitting a number of gently curved, rather distant, oblique branches from its lower side, parallel with those of the externomedian, and filling the hinder portion of the wing. Cross-veins feeble or possibly wanting altogether, except those on either side of the scapular vein.

Head subquadrate, small, slightly longer than broad, and somewhat broader in front of the eyes, its sides otherwise nearly parallel; posterior angles rectangular, but little rounded; mandibles triangular, short, though strong, much curved on their outer border, pointed; eyes prominent, elongate, narrowly extending along the sides of the head. Head with a broad median longitudinal carina. Antennæ slender, setiform. Prothorax slender, nearly twice as long as the head, divided at the middle by a transverse sulcus. The anterior part of the prothorax is of slightly less breadth than the posterior, its front edge straight. Front coxæ comparatively small, attached to the sternum just behind the transverse sulcus, not contiguous on the median line; remainder of the front legs vague. The indications show them to be short and robust. Mesothorax as long as the head, slightly broader than long, quadrate, simple; the middle legs are attached at the posterior part of this segment, and also are vaguely defined. Metathorax of equal length with the mesothorax, but of gradually increasing breadth, its hind edge circularly excised for the intermediary segment; hind coxæ large, prominent, globoso-quadrate, marked with fine longitudinal striæ, hind femora but twice the length of the coxæ, apparently much compressed, marked with longitudinal furrows on the sides and more or less sulcate for the reception of the slender, outwardly bowed tibiæ; tarsi long and slender, the last joint expanding, elongate obcordiform; claws and empodium visible, one-half the length of the last tarsal joint. Abdomen subcylindrical, slender, slightly longer than the head and thorax together, consisting of eleven segments, including the intermediary segment, gradually tapering to the middle (sixth segment), then suddenly narrowed on the next two segments, thence subparallel to the tip. Anal cerci visible, apparently about one-half the length of one of the segments of the abdomen. Wings long, overlapping over the abdomen, two and one-half times as long as broad, veins fine; costal margin nearly straight, especially on the middle third of the wing; anal margin vaguely defined; apex of wings apparently rounded. Mediastinal vein short, not appearing in the faint basal impression of the wing; scapular vein nearly conforming with the costal curvature, meeting the margin at the outermost eighth of the wing, and connected with the faint marginal vein by a series of about eighteen oblique, curved, simple cross-veins; externomedian vein separated from the scapular by a rather broad interval, its five or six branches filling out the apex of the wing; internomedian vein feeding the greater part of the hind margin with equidistant simple branches; anal veins numerous, straight, simple, indicating a rather full anal area. Hind wings apparently of the same structure as the fore ones, and of nearly the same extent. The venation is obscured.

Length of body from base of mandibles to end of last abdominal segment 41^{mm}, mandible 0.7^{mm}, head 3.7^{mm}, prothorax 8.3^{mm}, mesothorax 5^{mm}, metathorax 3.5^{mm}, abdomen 21^{mm}, anal cercus 1.2^{mm}, hind coxa 3^{mm}, hind femur 6.8^{mm}, hind tibia 5.5^{mm}, hind tarsus 5.5^{mm}, front wing 32^{mm}, hind wing 26^{mm}, breadth of head 3^{mm}, prothorax 3.5^{mm}, mesothorax 6^{mm}, metathorax 6.7^{mm}, sixth abdominal segment 5.5^{mm}, eighth abdominal segment 3^{mm}, wing at widest part 12^{mm}.

Carboniferous. It was found as an opened iron-stone nodule at Mazon creek, Illinois, only one-half of the concretion being obtained. It represents the dorsal aspect of the insect, and is partially water-worn.

This species seems to have its nearest relative in *Cheliphlebia elongata* Scudder, from the same formation, conforming best with the venation of that species. However, the present form differs in the brevity of the mediastinal vein, the narrow scapular area, and the course of the externomedian vein.

The hind legs are stouter than usual for a neuropteroid insect, with ridges and sulci reminding one somewhat of the sculpture of an orthopterous leg. The swelling of the central part of the abdomen would indicate that the specimen is a female with the basal half of the abdomen distended with ripened ova. The prominence of the tenth abdominal segment shows that the abdomen was carried with a dorsal hump and with the tip directed ventrally, somewhat in the manner of living female Embiidæ of today.

Type. Pal. Coll. No. 9241.

16. **Eucaenus mazonus** sp. nov. (Plate VI, Fig. 3; Plate VII, Fig. 10).

Broad-winged species; prothorax longer than broad, meso-

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and metathorax quadrate. Abdomen elongate-ovate, no median keel present. Wings very broad. Legs short, moderately strong, punctulate.

Head ovate, about two-thirds as long as the prothorax, rounded on the posterior angles; eyes bulging, hemispherical, not large; mouth-parts not defined. Prothorax broadly ovoid, rounded behind, straight in front; meso- and metathorax gradually broader posteriorly, their side angles rectangular. Abdomen broad, elongate-oval, more or less depressed, consisting of ten segments, including the segment mediaire, broadest at the sixth segment, and then gradually and broadly rounded to the tip; only the base of the anal stylets visible; last segments not carinate. Legs short, femora stout, compressed; femora and tibiæ minutely and closely punctulate: on the forward side of each femur is a longitudinal boss near the inferior edge. Wings very broad, longer than the abdomen; the costal margin evenly rounded, except at the axillary angle of the hind wings, where it is strongly shouldered; mediastinal vein straight, oblique, distant from the marginal at its base and connected with it by numerous oblique, straight cross-veins; scapular vein close to the mediastinal, the other veins obliterated. Under wings with numerous branches to the externomedian.

Length of body 24^{mm}, of prothorax 4.5^{mm}, of mesothorax 3^{mm}, of metathorax 3.4^{mm}, of abdomen 10^{mm}, of fore wing 20^{mm}, of front femur 3.3^{mm}, of hind femur 6.3^{mm}, of hind tibia 3.5^{mm}. Breadth of prothorax 3^{mm}, of mesothorax 3.8^{mm}, of metathorax 4.7^{mm}, of sixth abdominal segment 5.5^{mm}, of front wing 8^{mm}.

Described from a specimen represented on both sides of an ironstone nodule from the Carboniferous beds at Mazon creek, Illinois.

This species seems certainly to be congeneric with *ovalis* Scudder, and may possibly be the same form. In some respects the state of preservation is better than that of Dr. Scudder's specimen, portions of the head and legs being visible, but the neuration is more obliterated. The shape of the prothorax and of the wings will distinguish this species from *ovalis*. The outline of the body is suggestive of a rather large Reduviid bug, with broad wings, rather than of a neuropteroid insect.

Type. Pal. Coll. No. 9242.

In the collection is another specimen (No. 9246) exhibiting the base of the head, the meso- and metathorax, and the base of the abdomen, together with a portion of the wings. The insect is of the same size as the specimen previously described, and appears to belong to the same species. Nothing further can be supplied to the diagnosis by the characters exhibited by this fossil. In its broadened wings the straight mediastinal and scapular veins alone are clearly cut, the other veins being indefinitely preserved.

17. **Eucaenus attenuatus** sp. nov. (Plate VI, Fig. 4; Plate VII, Fig. 11).

Head indefinite, but with a median carina; prothorax more or less quadrate, its sides nearly parallel; mesothorax transversely quadrate, much broader than long; metathorax and abdomen indefinite, but stout, ovate-pointed caudally; abdomen with nine uniform segments, the apical small, the last two segments with a sharp median keel. Legs compressed, rather short and stout, minutely punctate, the hind tarsi longer than the tibiæ. Wings large, not abrupt at the humeral angle, uniformly elongate-oval; mediastinal vein nearly straight, oblique, meeting the costa at the outer three-fourths, provided with numerous oblique cross-veins to the margin; scapular vein close to the mediastinal, parallel with it, and slightly curved so that the wing-margin and the scapular vein outline an elongate spindle-shaped area; the remaining veins obliterated.

Length about 28^{mm}, length of wing about 25^{mm}, breadth of wing 9^{mm}.

One specimen, an ironstone concretion from the Egan collection of the Chicago Academy of Sciences, No. 4749. Mazon creek.

The three species of this genus show the following interrelationship:

Last abdominal segments provided with a median keel - - - 2
Last abdominal segments not carinate, costa and scapular vein opposedly curved - - - - - - - - - *attenuatus* sp. nov.
2. Scapular vein curved in an opposite sense to the costal margin *mazonus* sp. nov.
Scapular vein subparallel with the margin - - *ovalis* Scudder

Petromartus gen. nov.[1]

Head small, with prominent mandibles. Prothorax elongate; meso- and metathorax quadrate. Abdomen stout, tapering beyond the middle and provided with prominent sexual organs on the antepenultimate ventral segment. Legs rather stout. Wings long, exceedingly slender, rather triangular in outline, broadest at the beginning of the outermost third where the hind margin forms an obtuse angle; neuration simple, nearly straight; mediastinal vein long; scapular simple, unbranched. Externomedian several times branched; internomedian of similar formation. All the veins extend straight from the narrow base and evenly fill out the apical portion of the wing with a gentle curvature. Numerous well-marked and distant transverse cross-veins connect the longitudinal veins. Underwings similar, but probably broader. Wings overlapping the abdomen when at rest.

18. **Petromartus indistinctus** sp. nov. (Plate VI, Fig. 6; Plate VII, Figs. 12, 13).

Male.—Elongate slender insect with thickened abdomen, and very narrow fore wings. Head quadrate, longer than broad; mandibles prominent. Prothorax slender, elongate, provided with a transverse sulcus in front of the middle; sides and posterior edge margined. Mesothorax broader, rectangular, bearing the fore wings at the hind angles. Remainder of thorax and base of abdomen obscured. Abdomen broad, elongate, consisting of ten segments, including the mediary segment, which is supposedly present. At the eighth segment is a large and broad ventral tubercle bearing a pair of clasping valves which meet in a mid-longitudinal line. The sexual apparatus of the last segments and the caudal appendages are obliterated. Legs imperfectly preserved; femora compressed, their sides flat, twisted in position as described for the other species. Front wings more slender than the hind ones and comparatively smaller; veins straight, connected by numerous strong cross-veins; venation reconstructed as follows: mediastinal vein extending two-thirds to the wing-tip; scapular vein straight, parallel with the mediastinal, and connected with it by numerous transverse veins. These cross-

[1] πέτρος, "a stone;" μάρτυς, "a witness."

veins, while angular at the scapular vein, are prolonged to meet the rather distant main branch of the externomedian. The externomedian vein arises close to the scapular and continues parallel with it to the middle of the wing, when it is deflected downward so as to terminate at a distance from the scapular and at the tip of the wing. At the point of flexure it sends off a simple underbranch. Internomedian and anal veins confused, probably simply furcate and nearly parallel with the straightened and uninflated hinder margin. The under wings are broader and comparatively fuller than the upper, neuration probably nearly similar, but the veins less crowded basally.

Length 47^{mm}, length of head 5^{mm}, of mandible 1.25^{mm}, of prothorax 6^{mm}, mesothorax 4.5^{mm}, metathorax 4.5^{mm}, abdomen 27^{mm}, front wing 40^{mm}. Breadth of head 3^{mm}, of prothorax 3.5^{mm}, mesothorax 5.5^{mm}, metathorax 9^{mm}, fourth abdominal segment 7^{mm}, eighth abdominal segment 6^{mm}, front wing 8^{mm}. These measurements are approximate.

Both halves of an ironstone nodule discovered by Mr. William F. E. Gurley at Petty's Ford, Little Vermillion river, fourteen miles southeast of Danville, Ill. This is the same locality where *Termes contusus* Scudder and *Propteticus infernus* Scudder were found.

The metapleuræ have burst apart from the notum in the specimen, so that the hind wings are torn from their normal position. Thus above the abdomen four thicknesses of the wings are superimposed. From the narrowness of the fore wings we might surmise that these early insects were not powerful flyers, but flitted much as the damsel-flies or stone-flies do today.

Judged by the shape of the wings, with their strong distant cross-nervures, this form would be located near the genera *Woodwardia* and *Sphecoptera* of Brongniart, and placed in his family Megasecopterida. However, as this family coincides more or less with Scudder's Hemeristina, which is defined in more specific terms, it appears that the new form would be incongruous with its fellows. The elongate prothorax, the outline of the abdomen, and the course of the longitudinal veins more nearly correspond with the family Homothetidæ Scudder.

Its position in this group may be seen by the table given herewith. At any rate, we find here another link connecting the European fauna with that of America.

Type. Pal. Coll. No. 9243.

The relationships between the insects of this family can be quickly seen from the following conspectus arranged from the descriptions of the genera:

Mediastinal vein terminating before the middle of the wing - **Cheliphlebia**
Mediastinal vein extending beyond the middle of the wing - - 2
2. Mediastinal vein extending parallel with the marginal - - - 3
Mediastinal extending obliquely to the marginal - - - 5
3. Wings excessively narrow, provided with strong and distant cross-veins - - - - - - - **Petromartus** gen. nov.
Wings less narrow, cross-veins less evident - - - - - 4
4. All the veins up to the internomedian parallel with the straight margin; branches of the internomedian oblique, parallel - **Didymophleps**
Veins more irregular; scapular branched near the tip - **Acridites**
5. Costal margin nearly straight - - - - - - - 6
Costal margin bowed outwardly - - - - - - - 7
6. Mediastinal without oblique branches, scarcely shorter than the scapular - - - - - - - - - **Homothetus**
Mediastinal with branches, extending two-thirds the length of the wing; scapular reaching nearly to the tip; cross-veins wanting **Anthracothremma**
7. Branches of the mediastinal and scapular veins crowded, similar **Eucaenus**
Branches of these veins dissimilar, uncrowded - - - - 8
8. Front wings obovate; branches of mediastinal simple, rather distant **Gerapompus**
Front wings less markedly ovate; some of the branches of the mediastinal forked - - - - - - - - 9
9. Internomedian vein with numerous branches like those of the externomedian - - - - - - - - **Genopteryx**
Externomedian vein far separated from the scapular, its branches more important than those of the internomedian - **Genentomum**

Family *Palaeopterina* Scudder.

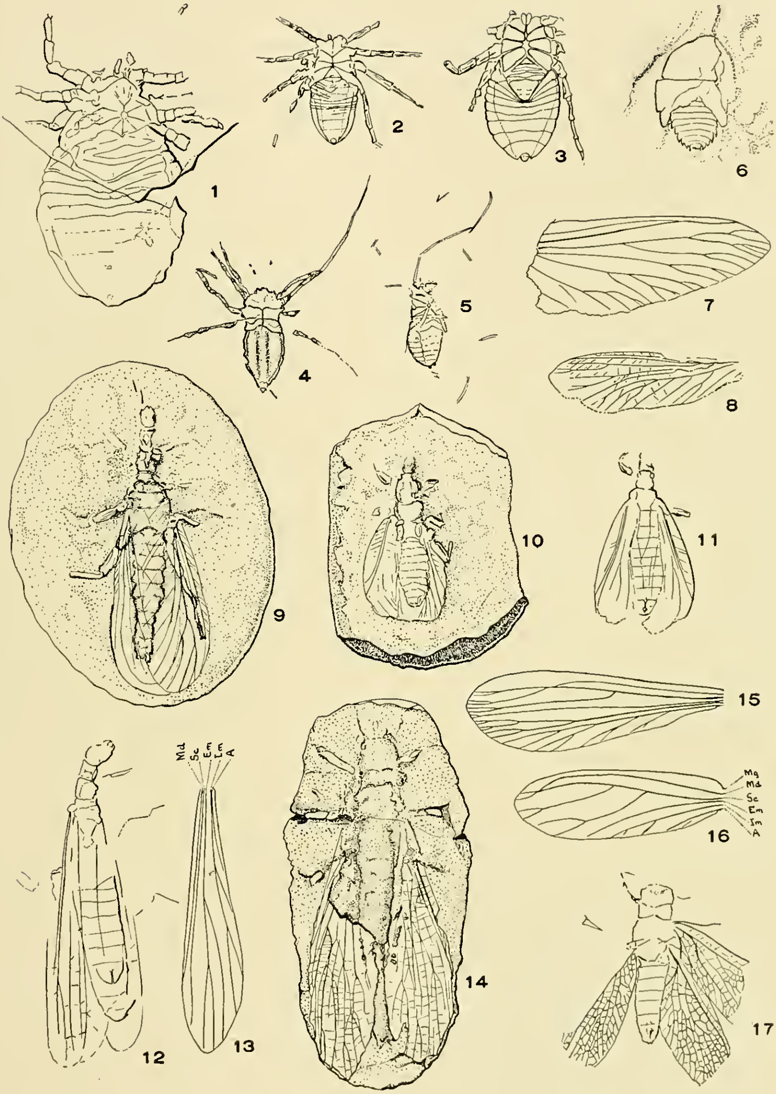
19. **Dieconeura maxima** sp. nov. (Plate VI, Fig. 5; Plate VII, Figs. 14–16).

Large, elongate. Wings long, narrow, broadest at the beginning of the outermost fourth, costa nearly straight; of the fore wings the mediastinal vein is parallel with and close to the marginal, ending in the scapular somewhat beyond the middle of the wing; scapular vein forked before the middle of the wing, the upper branch parallel with the costal margin, emitting a simple under branch, the lower branch simple or simply forked, nearly straight, rather distant from the upper and apically parallel with it. Externomedian vein simple, terminating near the tip of the wing. Internomedian forked at the middle of the wing, each branch simply forked near the tip. The main stem of the anal vein is more or less parallel with the hind margin, terminates in the margin at the beginning of the apical sixth of the wing, and sends a number of lower branches to the hind margin, which are simple or simply forked. Neuration of the hind wings nearly similar; the mediastinal is strong and deeply set in the explanate costal portion; scapular vein more important than in the fore wings, the divarication of its principal branches occupying a large part of the wing and filling the apical portion; remaining veins much reduced. Both wings filled with numerous cross-veins.

Body indefinitely preserved, but indicating a slender, *Corydalis*-like insect. Prothorax rounded in front, its sides parallel behind; mesothorax broader, quadrate; metathorax and abdomen vague, their segmentation scarcely visible. Wings surpassing the abdomen, their hind margins touching above the abdomen, but the wings do not overlap. Neuration of both pairs well preserved in large part. The femora of all the legs are in part indicated, and show that they were provided with prominent longitudinal ridges.

Length about 62^{mm}, length of thorax (pro-) 8, (meso-) 7, and (meta-) 7^{mm}, length of abdomen 31^{mm}, length of front wings 45^{mm}, breadth of front wings 15^{mm}.

The assignment of this species to the genus *Dieconeura* is quite permissible on account of the similarity between the wing-neuration of the different species. But it must be remembered that the new form is considerably the largest that has been placed here. The dissimilarity between the two pairs of wings, which is shown in the somewhat diagrammatic reconstruction, is rather striking for an insect of pre-Tertiary times. The interpretation of the neuration is quite likely the correct one, as large portions of the veins of both wings are well indicated on the fossil.


1
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Sc
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Mg
Md
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17

The three species just described show a marked agreement in the resting position of the hind legs. In each case the femur is twisted in such a manner that the tibia is directed forward and away from the body. This primitive attitude is retained by a few insects of today, such as stone-flies, earwigs, the Embiidæ, *Gryllotalpa*, etc., and by the nymphs of many neuropterous insects.

Carboniferous, Mazon creek.

Type. Pal. Coll. No. 9244.

20. **Propteticus infernus** Scudder.

Mem. Boston Soc. Nat. Hist., Vol. III, pp. 334–6, Plate XXXI, Figs. 3, 4.

Type. Pal. Coll. No. 6391.

The following dichotomy will serve to assist in the assignment of the genera of this group:

Internomedian vein ending in the middle of the lower margin, with numerous branches arising from its upper side - - - **Strephocladus**

Branches of internomedian springing from below; if from above not ending in the hind margin - - - - - - - - - - - 2

2. Internomedian with an adventitious vein running across the externomedian into the scapular - - - - - - **Aethophlebia**

   Internomedian of regular formation - - - - - - 3

3. Externomedian unforked, following the course of the internomedian **Dieconeura**

   Externomedian forked - - - - - - - - - - - 4

4. Scapular vein close to the mediastinal, straight, its principal branch arising near the middle of the wing and nowhere far removed from the stem - - - - - - - - - **Miamia**

   Scapular vein bent, separated from both the mediastinal and its principal branch - - - - - - - - **Propteticus**

Family *Hemeristina* Scudder.

Protodictyon gen. nov.[1]

Body short, very robust. Pro-, meso-, and metathorax quadrate, broad. Abdomen robust, the last segments provided with a median keel. Wings, large, broad, mediastinal vein ending in the costa beyond the middle; scapular vein strong, parallel with the mediastinal, emitting a distant under-branch near the base of the wing, which dichotomizes several times in an irregular manner. Externomedian vein contiguous with the scapular stem on its basal portion and then suddenly deflected.

[1] πρῶτος, "earliest;" δίκτυον "net."

It also dichotomizes irregularly and often. Internomedian and anal veins much reduced. Cross-veins numerous, forming a more or less complete reticulation.

21. **Protodictyon pulchripenne** sp. nov. (Plate VI, Fig. 7; Plate VII, Fig. 17).

Head not indicated. Prothorax large, square, the sides biarcuately sinuate, meso- and metathorax transversely quadrate, narrower than the prothorax; abdomen robust, nine segments visible, the eighth and ninth with a short median keel. Beyond the abdomen are well-preserved indications of two long setiform appendages. Legs vaguely represented, but apparently quite long. The beauty of this specimen, however, lies in the excellent preservation of the wing-neuration, which is clearer cut than in any fossil of its kind yet discovered. Every vein, branch, and cross-nervure is as clearly depicted as in the living insect. Wings full, large as compared with the length of the insect, costal margin nearly straight: mediastinal, scapular, internomedian, and anal areas much reduced; externomedian and scapular veins prominent, occupying the larger part of the wing; mediastinal vein subparallel with the margin, ending in it considerably beyond the middle of the wing. Main scapular stem nearly straight, prominent, gradually converging with the margin and ending three cross-veins beyond the tip of the mediastinal; near the basal fifth the scapular sends down a widely diverging branch, which then continues toward the wing tip, anastomosing in numeroug zig-zag branches with the cross-veins. The externomedian vein is likewise strong, lying contiguous with the scapular branch on its basal portion. Two-thirds of the way toward the scapular branch it suddenly is deflected downward and branches at this point; both branches furcate repeatedly, the lower also connected with the hind margin of the wing by several off-shoots. Internomedian and anal veins poorly developed, occupying the much-reduced anal angle. All the veins connected by rather distant, more or less irregularly disposed cross-veins, which form a conspicuous reticulum with the broken nervures. Fore and hind wings nearly similar, the hind ones slightly broader.

Length without head 25^{mm}, size of wing about 40^{mm} by 10^{mm}.

One specimen, represented by the obverse and its reverse. Mazon creek, Ill., Carboniferous. From the Egan collection of the Chicago Academy of Sciences, No. 4749.

This is by far the best specimen of the ironstone fossils, the insect being preserved with the wings of the right side extended and not overlapping; the neuration is perfect.

Inasmuch as Dr. Scudder states that the figure of *Chrestotes lapidea* is erroneous in part, and elsewhere characterizes the genus as having the scapular vein and its main branch approximated, we shall have to regard the present specimen as excluded from this genus. With *Hemeristia* it therefore agrees in this character, and in the disposition of the main veins, but here the veins are straight and simply connected by transverse cross-veins, and exhibit no trace of reticulation. Thus the present genus is characterized briefly by the angular course of the veins and the prominent reticulation of the cross-veins.

Family *Gerarina* Scudder.

22. **Gerarus danae** Scudder.

Geol. Surv. Ill., Vol. III, p. 566, Fig. 1.

There is in the university collection what we have reason to believe is the type of this species, inasmuch as the strange outline of the body together with the general neuration is as depicted in the figure. However, the shape of the rather large and rounded stone is quite different from that in Dr. Scudder's illustrations. Should this be the type, a slight error has been committed in figuring the termination of the mediastical vein. Toward the tip, this becomes irregular, owing to its flexture at each cross-vein. This might lead one, especially in a poorly preserved specimen, to suppose that the mediastinal terminates in the scapular vein, or, as in *Xenoneura antiquorum* Scudder or *Dictyoneura libelluloides* Gold., that it ends in a cross-vein rectangularly bent, its upper half somewhat the longer. However, in such a case the great length of the mediastinal vein, together with the numerous under-branches of the scapular, would easily lead one to recognize its affinities with this family.

Type. Pal. Coll. No. 9245.

In addition to the twenty-three species here enumerated there is still another specimen exhibiting a wing shaped like that of *Paralogus æschnoides* Scudder, but of which the neuration is obscured.

EXPLANATION OF THE PLATES.[1]

PLATE V.

FIG. 1. *Hadrachne horribilis*, g. et sp. n.
FIG. 2. *Architarbus rotundatus* Scudd.
FIG. 3. *Geraphrynus carbonarius* Scudd.
FIG. 4. *Kustarachne sulcata*, sp. n.
FIG. 5. *Kustarachne exstincta*, sp. n.
FIG. 6. *Dipeltis diplodiscus* Pack.

PLATE VI.

FIG. 1. *Dictyoneura clarinervis*, sp. n.
FIG. 2. *Cheliphlebia extensa*, sp. n.
FIG. 3. *Eucænus mazonus*, sp. n.
FIG. 4. *Eucænus attenuatus*, sp. n.
FIG. 5. *Dieconeura maxima*, sp. n.
FIG. 6. *Petromartus indistinctus*, g. et sp. n.
FIG. 7. *Protodictyon pulchripenne*, g. et sp. n.

PLATE VII.

FIG. 1. *Hadrachne horribilis*, g. et sp. n.
FIG. 2. *Architarbus rotundatus* Scudd.
FIG. 3. *Geraphrynus carbonarius* Scudd.
FIG. 4. *Kustarachne sulcata*, sp. n.
FIG. 5. *Kustarachne exstincta*, sp. n.
FIG. 6. *Dipeltis diplodiscus* Pack.
FIG. 7. *Paolia gurleyi* Scudd.
FIG. 8. *Dictyoneura clarinervis*, sp. n.
FIG. 9. *Cheliphlebia extensa*, sp. n.
FIG. 10. *Eucænus mazonus*, sp. n.
FIG. 11. *Eucænus attenuatus*, sp. n.
FIG. 12. *Petromartus indistinctus*, g. et sp. n.
FIG. 13. *Petromartus indistinctus*, restoration of fore wing. *Md*, mediastinal; *Sc*, scapular; *Em*, externomedian; *Im*, internomedian; *A*, anal.
FIG. 14. *Dieconeura maxima*, sp. n.
FIG. 15. *Dieconeura maxima*, fore wing restored.
FIG. 16. *Dieconeura maxima*, hind wing restored. *Mg*, marginal vein; other letters as in Fig. 13.
FIG. 17. *Protodictyon pulchripenne*, g. et sp. n.

AXEL LEONARD MELANDER.

[1]All figures are natural size.

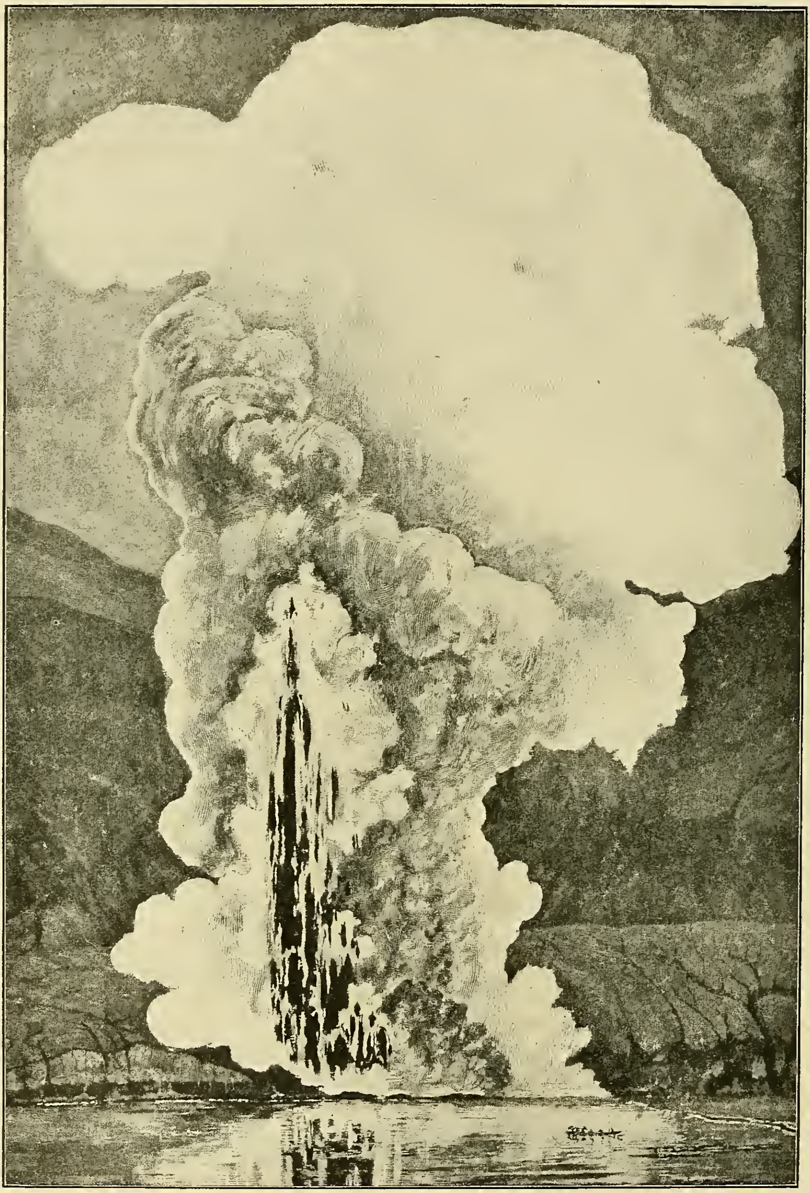
SECONDARY PHENOMENA OF THE WEST INDIAN VOLCANIC ERUPTIONS OF 1902.[1]

A COMPLETE report on the secondary volcanic phenomena of the West Indian eruptions of 1902 should include at least the following topics:

Development of consequent streams upon an initial ash surface.
Stream deflections by volcanic ejecta.
Subsidence of coastal plain.
Elevation of marginal deposits.
Effect of "tidal" or reflex waves.
Results of marine erosion.
Sedimentation of sea deposits.
Eruption within stream valleys.

The latter subject has been selected for this paper, leaving the others for later publication. According to some views I should include also as secondary phenomena the earthy flows of detrital matter which have played an important part in the destruction both of life and property, and have been generally reported as "mud flows." I regard them as, in part at least, of primary volcanic origin and think that the "mud flow" which buried the Guerin sugar works on May 5—two days before the destruction of St. Pierre—was a result of an eruption from the crater of Mount Pelée. After the great eruption of May 7 on St. Vincent, more than half a billion gallons of water had disappeared from the crater lake of La Soufrière, which we found, on reaching the crater's rim on May 31, to have fallen about 800 feet below its former level. The evidence indicates that this volume of water was poured out over the mountain, bearing with it bowlders and "earth." This "earth" was composed of soil washed from slopes, the finer fragments of volcanic ejecta, and comminuted rock which has been commonly referred to as "ash." Mingled with widely varying percentages of water, the mixture was generally termed "mud," and in many instances "lava." In the May 6

[1] Paper read before the American Association for the Advancement of Science, January 2, 1902.



By permission of the "Century Co."

FIG. 1.—Outburst of dust-laden steam at the mouth of the Wallibou river, St. Vincent.

issue of *Les Colonies* (the last save one of this St. Pierre journal), under the headings "La catastrophe de l'Usine Guérin," the "flow" is described as "le débordement de lave." About noon on May 6 — the day before the memorable eruption — the inhabitants of St. Vincent, on both leeward and windward sides of the volcanic cone, saw the paths of the principal rivers flooded with "mountains of steaming waters." On June 24 I saw from its banks the catastrophic rush of earth, and bowlders, and water which plowed through the channel of the Sèche river. This flow took place during one of the heaviest of the minor eruptions of Mount Pelée, which, however, had been preceded by four

FIG. 2.— The Terre Fendue; or outlet to Pelée crater (eruption cloud obscures inner fragmental cone). Taken from the highest spurr of the "St. Pierre" ridge, which trends across the head of the Blanche river, by C. C. Curtis on June 26, 1902.

hours of very heavy rain. Two days later I reached the spur of the "St. Pierre ridge" which trends across the "Terre Fendue," or lip of Pelée's crater. It was possible from this position to see directly into the crater. During a minor outbreak, the channel of the gorge began to send out vapor, while its water both visibly and audibly increased. This I interpreted as erupted water. On May 8, according to M. Déseré, mayor's deputy at Grande Rivière, at 4 A. M.—four hours before the destruction of St. Pierre—a great flood, bearing bowlders up to six feet or more in diameter, came rushing down and buried the lower part of the town some twelve feet, where the stream formerly debouched into the sea. There had been little rain before this flood. Similar floods took place at this village of Grande Rivière on May 11, on June 6—the day of perhaps the heaviest eruption of Pelée on record—and on June 22 (when I was about two miles off the delta of the Grande Rivière, in a sloop, though unaware of such occurrence). Little rain fell on this day. The towns to the southward, situated at the mouths of streams heading on Mount Pelée, were visited by similar catastrophes.

From these accounts it appears that the major eruptions have been accompanied or preceded by "mud flows," and evidence indicates that the waters of the crater lakes have been discharged over the mountain sides. If fragmental material has accompanied these ejections of water, as it has the other eruptions, it is reasonable to assume that much of it would have been carried down into the lower valleys. The fine dust which was observed to be accumulating within the crater of Pelée would be swept down during such a flood, together with much of the fragmental material lying upon the inner cone. Re-ejected material, both coarse and fine, which had fallen within the crater might be either washed down the inner cone and out through the lip, or in a stronger outburst deluged over the upper slopes of the outer cone to be distributed by the summit-heading valleys. Dr. E. O. Hovey has reported these "mud flows" as due to landslides.[1] While this may account possibly for some of the minor occurrences, it can explain with difficulty the great volume of water necessary to convert the

[1] *Bull. Am. Mus. Nat. Hist.*, Vol. XVI.

unconsolidated cover over the bed-rock into a liquid-like torrent moving with great rapidity, and maintaining this state for several miles from its assumed source, especially since the remarkably porous quality of the "ash" cover renders it a very poor water-bearing medium. Some of the small, viscous-flowing mud streams originated in the cutting down of landslide dams behind which stream water had accumulated, as we observed on St. Vincent, but it is difficult to conceive how in the narrow, steep, graded canyons, large bodies of water could be collected sufficient to have caused the greater flows. Drs. Anderson and Flett[1] state that the "crater lake of La Soufrière was probably driven down over the lip of the crater and poured

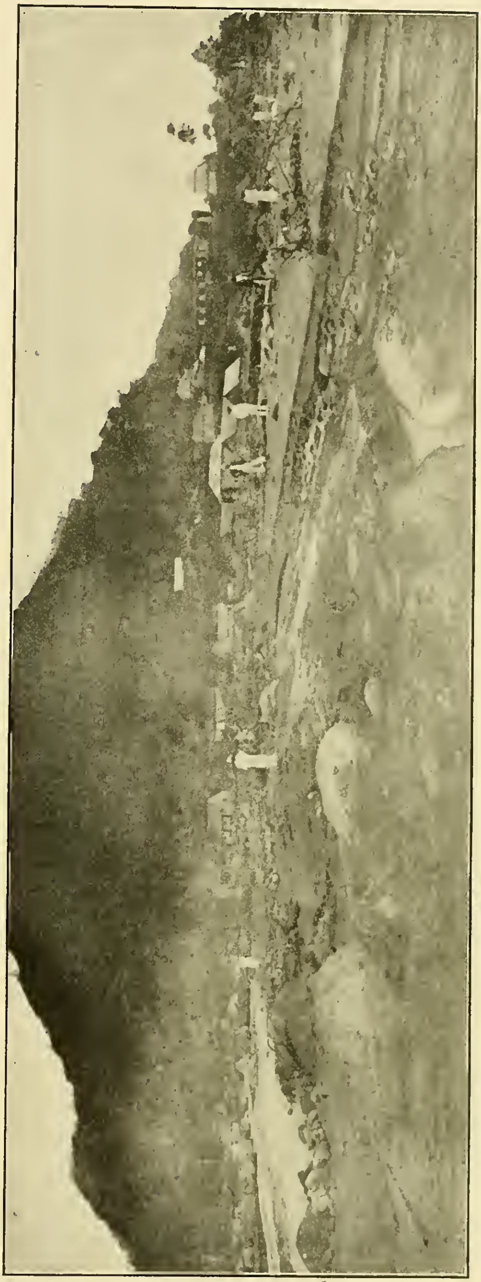


FIG. 3.—Delta of the Grande Rivière. Showing character of flood deposit which destroyed lower portion of the town. Natives standing along former shore line.

[1] *Proc. Royal Soc.*, Vol. XX, p. 426.

down the valleys into the sea." The transporting power of such a flood is tremendous. Professor Angelo Heilprin says of the flood of May 5:[1]

"Hardly had the mid-day hour passed when the gates of the volcano were drawn, and a flood of boiling mud was sent hurling down the mountain side to be flung from it into the sea. In three minutes it had covered its three miles to the ocean. . . . . It is needless to ask whence came the mud; it could plainly be traced to the position of the Soufrière or Étang Sec."

Dr. T. A. Jaggar writes:[2]

This crater [Pelée] ends in a deep gulch west that extends down to the sea. . . . . Apparently it was down this gulch that the mud flood came which overwhelmed the Guérin factory.

M. Parel, Vicar General of Martinique, in his memorable record of the beginning of the disturbances on Mount Pelée,[3] states:

Since the morning [May 5] Rivière Blanche, which for some days had been swelling to disquieting proportions, although there had been no rain, had assumed suddenly the aspect of a menacing and muddy torrent. . . . . At the same time a moving column of vapor was seen in the high valley (see Fig. 2) that extends from the crater. . . . . It was an avalanche of black mud, ejected by the crater, and swollen by successive discharges until it became a rolling mountain, while it was breaking its way through the deep gorge. The moment it approached the delta, its presence was betrayed by the ascending vapors.

This show of vapors indicates the presence of some steam-generating factor, which was probably heated bowlders thrown out of the crater with or previous to the erupted flood, and borne down with it.

These observations indicate that the "mud flows" must be included with the primary volcanic phenomena of eruption as well as with the secondary.

VALLEY ERUPTIONS.

Perhaps no phenomena observed in the recent West Indian eruptions have led to more misinterpretation than the eruptions which were observed within the confines of valleys and canyons.

[1] *Mt. Pelée and the Tragedy of Martinique*, J. B. Lippincott Co.

[2] *Popular Science Monthly*, August, 1902, p. 359.

[3] *Century Magazine*, August, 1902.

Persisting after the great eruptions from the summit craters, they formed a source of intermittent anxiety to the inhabitants left near the borders of devastation, and one of considerable misinterpretation by the early explorers, who saw the voluminous outbursts only at a distance.

From afar these eruptions appeared as occasional outbursts of steam, whose snow-white bulging tops were sometimes mingled with tints of brown or shaded with deeper grayish color; "black mud" was reported to have issued from them; hence the name of "mud craters" was applied by some to the sites of these outbursts. Professor Angelo Heilprin, in his article, "Mount Pelée in its Might,"[1] speaks of "vents of the Falisse river acting as safety valves for Pelée." Professor Heilprin, in an account of his second visit to Martinique,[2] says:

> When my observations were made, I was not near enough to clearly ascertain its features, and relied for my determination largely on the observations of others. A closer examination of the gorge leads me to very strongly doubt the crateral origin of the outbursts—a doubt which has already been expressed by Lacroix and others.

Mr. Robert T. Hill, in his report on the volcanic disturbances in the West Indies[3] has prepared a map on which he locates three "mud craters," each over a mile from the crater of Pelée, and has located a "Soufrière crater" on the Rivière Blanche half way between the summit and the sea.

Of the hundreds of these eruptions from "lower craters" which I saw during the forty-eight days on these islands, one which occurred at the mouth of the Wallibou river, St. Vincent, on May 30, and another in the Sèche river on June 24, both witnessed at close range, may serve as the basis of a description of these phenomena.

While passing the Wallibou river in a dug-out canoe on the afternoon of May 30, a great cloud of vapor suddenly sprang from the stream, accompanied by a cannon-like roar. The column of steam rose to a height estimated at over 3,000 feet, and passed from a straight geyser-like jet into a bulging top ten

[1] *McClure's*, August, 1902.

[2] *Op. cit.*, p. 214. [3] *National Geographical Magazine*, July, 1902.

times its base in width. Now and then black finger-like masses shot up into the curling vapor, were sustained for a minute or more, and then sank back out of view. At other times the jet appeared a solid column of black, during which the steam cloud would change from white to golden tints, and, as the violence increased, to grays. The black jets were composed

Fig. 4.— Delta at Basse Point. Showing encroachment of mud flows

of erupted sand and rock fragments from the stream bed, and the changing color of the steam cloud indicated that some of the finer particles were carried even to its balloon-shaped top. Indeed, this erupted ash soon began to fall upon us until boat and crew alike were completely covered with a snow-like fall of gritty, gray dust. The eruption cloud itself quite simulated those from the crater of Pelée; the straight, black, rigid column at the base, the writhing, twisting puffs of brain-like formed globules with brownish hue above, and the lighter-colored, spreading pine-tree cloud on top which floated off with the trade wind in distinct globes, each indicating a different time of outburst.

It is scarcely a cause for wonder then, that these minor manifestations, with their spectacular appearance, were early regarded as originating from lateral craters connected with the main vents. From the location of these outbursts in stream beds it came to be reported that St. Pierre had probably been destroyed by a lateral crater in the bed of the Blanche river.[9]

sea. Half buried houses in foreground are close to the old shore line.

The particular eruption witnessed in the Wallibou took place about an hour after the beginning of a very heavy tropical rain which sent sand-filled water in sheets down over the sea cliffs and changing valleys. The river, which had maintained a mere showing of water, became a steaming torrent several feet in depth, instigating the explosion.

I was within the valley of the Sèche in the mud flow of June 24, when returning from an ascent to the crater of Pelée from the St. Pierre side, and saw in the bed of the avalanche-swept stream below, which we had just crossed in ankle-deep

[9] A. HEILPRIN, *McClure's*, August, 1902; R. T. HILL, *Century Magazine*, September, 1902; GEORGE KENNON, *Outlook*, Vol. LXXI.

waters, an eruption which threw its column of steam to a height of over half a mile. I found opportunity to visit the sites of both these explosions on the days following, and to examine them closely. From these and numerous other observations, especially in the Rozeau Dry river of St. Vincent, where the phenomena were best developed, it appears that the geyser-like eruptions may be explained as secondary phenomena.

Fig. 5.—Small, viscous mud stream —5 feet wide—flowing by pulsations in canyon north of Precheau.

Mechanics of "ash-geyser eruptions."—The beds of nearly all, if not all, of the rivers which head at the summit craters of La Soufrière and Mount Pelée contain deposits of volcanic ejecta generally known as "ash" in depths from a few inches to one hundred feet or more. This fragmental material ranges from the size of a block 22 by 50 by 24 feet in the Sèche river to impalpable dust. In some instances where the surface is more thickly strewn with bowlders, these rocks have been found to be hot enough to cause cracking of their surfaces, even fumerole-like deposits forming about them. In other places where the stream has deeply intrenched these deposits of volcanic ejecta, it has opened a passage between beds which are hot enough to burn the shoes, and clouds of mingled unconfined steam are given out whenever the hot dust slips into the stream water or the sea.

The mouths of the Blanche, the Sèche, and the Wallibou presented the best examples of these dissected hot-ash beds. When the bed of the stream was dry—its prevailing condition—little indication of this underlying high temperature within the deep stream deposits was apparent, save in the rare instances of hot bowlder surfaces and the mild steaming of the beds from small pits, through which hot vapor was sometimes rising, with the distinct blowing noise of escaping steam. These vents were evidently outlets of underlying heated deposits, which, whenever reached by sufficient water, expressed themselves by the geyser-like eruptions.

Process of eruption.—Over the bed-rock bottoms of the peripheral streams a certain considerable amount of flood-plain deposit

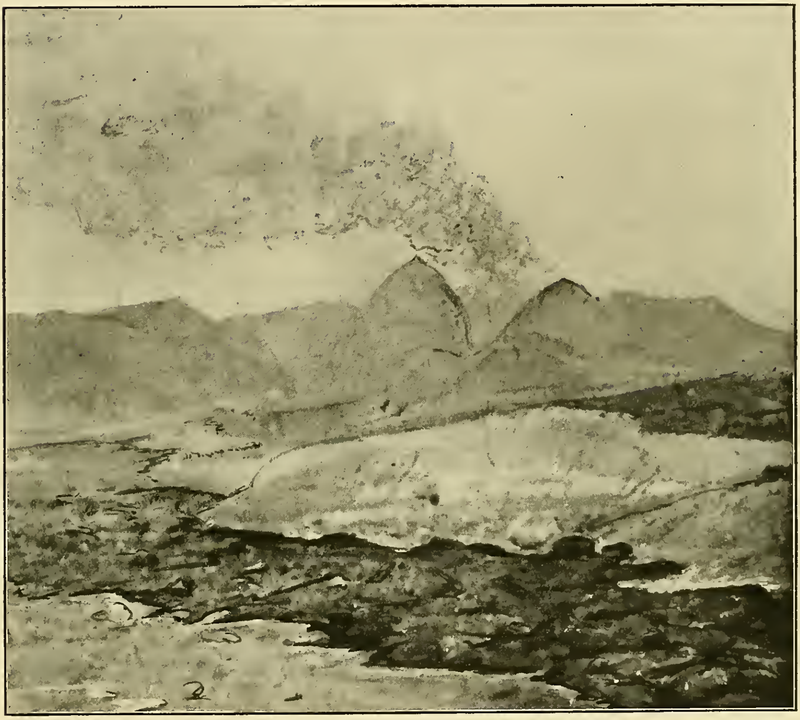


FIG. 6.—Mud flows on Blanche Lake divide.

had taken place before the eruptions. Upon this plain, and well up upon the including valley walls, were deposited hot volcanic ejecta of dust and bowlders. The high temperatures of the latter were maintained, aided by the blanket covering of overlying ash; and by their gravity they had tended to gather in the old river channel, forming loci of concentrated temperatures. Into these heated beds water percolated from above. The vapor generated by contact with the hot rocks increased until it suddenly found vent by eruption through the impounding beds; thus a chimney or vent was formed through which copious supplies of water were poured during the intervals of explosion, to be ejected again from the same pipe.

The instigation of eruption.—On reaching the hot, covered ash beds in sufficient quantities, the water must bring about geyser-like explosions until the underground heat is dissipated. There

FIG. 7.—An ash geyser eruption in the bed of the Wallibou river. Soufrière crater in the distance.

are a number of distinct processes by which this water manages to collect in sufficient quantities to instigate eruption. One is the flooding of the stream channel by a sudden tropical downpour, as observed on May 30; another is that of an eruption flood from the primary crater—as that from Mount Pelée on June 24. Still a third process, one of gradual accumulation, is that which obtains its water supply by the damming of the stream through landslides. I observed this in the Wallibou river at 8 o'clock on the morning of May 30. A portion of the undercut riparian ash banks had fallen, slipping across the channel, and by thus damming the stream caused a lake to form behind this barrier. When its water had reached and covered a certain place near the right bank of the stream, an explosion suddenly took place, continuing with the usual attendant phenomena of "ash-geyser" eruptions. The explosion dug the bank rapidly away, adding the erupted detritus to the dam, which by rising increased the supply of water and the force of the explosions. Eventually the lake overflowed and a channel was cut back which, draining

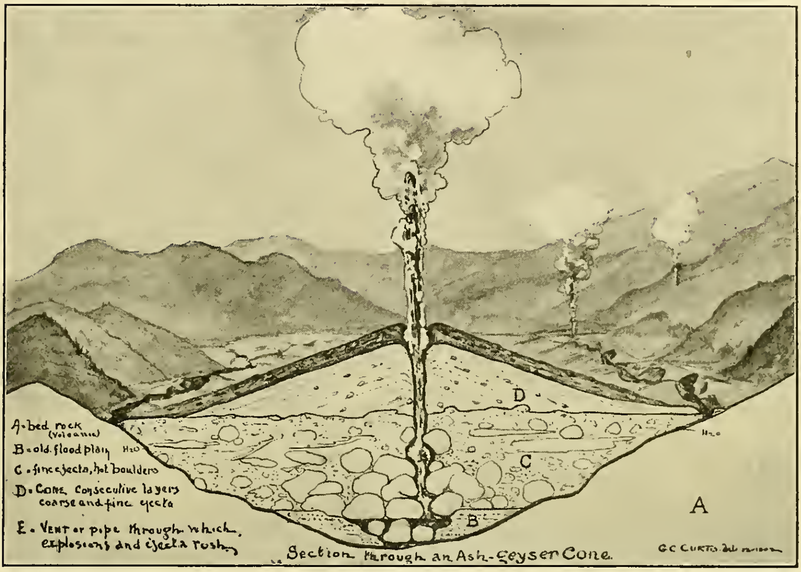


FIG. 8.

it by this outlet, brought a cessation of the eruption. The water may reach the hot-ash bed by filtration through the overlying deposit, or by pouring down the pipe or chimney when the orifice lies submerged.

Description of secondary cones.—The effects of these eruptions within the river courses simulate those of true volcanic craters. Steam rushes up through the overlying beds, carrying with it fragments from below and from the surrounding walls. It throws ejecta, composed of fine and coarse fragments (some were the size of a man's head), to a considerable height (that of a mile being observed), the finer material being doubtless scattered to distances of miles, but the coarse falling within the immediate vicinity of the vent. By gradual accumulation this collection of sand and coarser fragments grows into a pile about the pipe, tending to assume the form of a perfect volcanic fragmental cone with crater falling into the descending pipe, and slopes averaging 25° to 30° (several cones 40 feet in

Fig. 9.—A secondary (or ash geyser) crater in the Rabaka river trenched by stream.

Fig. 10.—A secondary cone—ash geyser cone—partially demolished—Rabaka river. St. Vincent.

height and 160 feet in diameter were observed on both Martinique and St. Vincent).

The accompanying diagram (Fig. 8) represents the structure of the ash-geyser cone.

The ash-geyser, indeed, simulates a miniature volcano both in topographic form and phenomena of eruption. Professor Russell asks:[1] "What is the crucial test by which a true crater may be distinguished from a pseudo-crater?" as he terms these secondary craters. Five characteristics were noted: first, location — the ash-geyser crater occurs persistently within the streams or the deltas; second, composition — the walls are con-

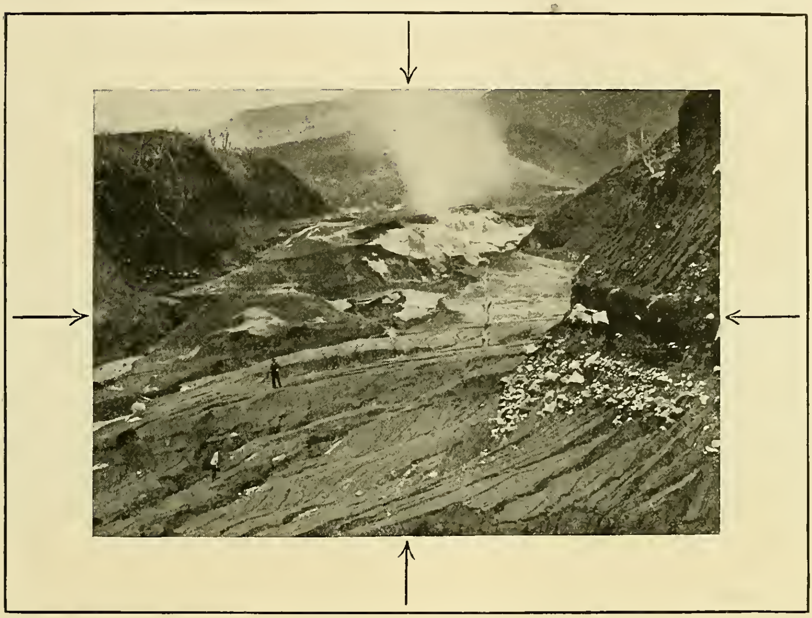


FIG. 11.— Ash cone topography and dissected ash cone lying in the present stream channel — Wallibou river. (Arrows point to cone).

structed entirely of fragmental material and not of old bedrock (the structural layers of the volcanic cone as observed on the rims of the primary craters); third, method of eruption — eruption occurs only in time of water accumulation; fourth, temperature — a relatively low temperature of ejecta; fifth, size — the ash-geyser cone is a small fraction of any true lateral crater observed. I am inclined to account for both the island discovered off the river Blanche on May 23,[2] and which had disappeared on return

[1] *National Geographical Magazine*, Vol XIII, No. 12, p. 416.

[2] R. T. HILL, *Century Magazine*, September, 1902.

to Martinique on June 14, and for the elongated hill of hot bowlders between the 600 and 700 foot level in the Sèche valley,[1] by secondary eruption.

Comparison of ash-geyser cones with other secondary volcanic cones.—These cones, occurring as they do within the valleys and upon

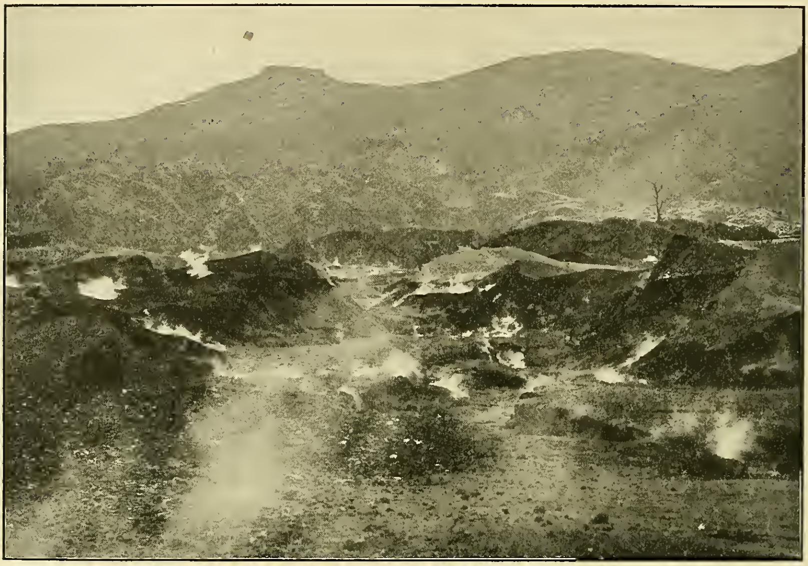


FIG. 12.—Secondary ash cone topography. Rabaka river. Vents slightly "steaming" with mere trickle of water in stream bed.

the "mud lavas," may be compared with those irregular heaps of volcanic scoriae which abound on the tops of some true lava streams, being piled up around each vent or "bocca" which the steam-jets escaping from the lava currents, form at their surfaces. The Vesuvian lavas of 1855 and of 1872 developed such cones on their surfaces.[2]

Ash-cone topography.—I was at first unable to account for the peculiar irregular topography in the channels of the streams soon after the great eruptions. It had the irregular rounded hillock appearance which resembled sand-dune forms. The sug-

[1] HOVEY, *Bull. American Museum*, Vol. XVI, p. 360.

[2] JUDD, *Volcanoes*, p. 101, drawing by Schmidt.

gestion was early offered that a rotary motion of tornadoes which emanated from the summit might account for the mounded topography. I am now persuaded that the rolling character of the stream deposits which doubtless originally had regular flood-plain cross-sections was largely due to this geyser action and to the presence of remnants of these secondary cones. These were left in every stage of demolition by shifting in the vents, by migration of the stream channels, by the degradation of the channel which carried the water surface out of reach of the main vent, or simply by the disappearance of the stream water.

GEO. CARROLL CURTIS.

GLACIATION IN THE BIGHORN MOUNTAINS.[1]

In Vol. IX of this Journal a brief outline of the results of the work done on the glacial formations of the western mountains in 1901 was given. These studies were continued during the past summer. One of the parties, under the immediate charge of the junior author of this note, spent several weeks in the Bighorn mountains of Wyoming. He was assisted by Messrs. W. H. Emmons and F. W. DeWolf, while the senior writer was with the party for about a week at the beginning of the work.

In 1900 Mr. Matthes[2] gave a discriminating description of the cirques and other topographic features in the Bighorn mountains, due to glacial erosion. In the same year Professor W. C. Knight made mention of the former existence of glaciers in the same range.[3] When the party went into the field in 1902, Professor Knight furnished it with some general notes on the geology of the range, and in these notes there was a much fuller statement of the general facts concerning the distribution of glacial drift in these mountains than had hitherto been published by him. These data had been gathered by Professor Knight in the prosecution of his other work.

So far as known to the writers, no detailed study of the drift of these mountains had been attempted previous to their work in 1902, and up to that time the existence of more than one series of glacial formations had not been recognized. The studies of last summer revealed the existence of two series of glacial formations, separated from each other by a relatively long interval of time. A third series of deposits was found, much older than the older of the preceding, which may prove to be of glacial origin, though the evidence now in hand on this point is not regarded as conclusive.

[1] Published by permission of the director of the U. S. Geological Survey.

[2] *Twenty-first Annual Report U. S. Geol. Surv.*, Part II, pp. 173–90.

[3] *A Preliminary Report on the Artesian Basins of Wyoming.* Bull. 45, Wyoming Experiment Station, p. 174.

Existing glaciers.—Five small glaciers, all less than 1 ¼ miles in length, still exist in the mountains in the vicinity of Cloud peak at elevations exceeding 11,200 feet. In view of the fact that the annual snowfall is not great, while the altitude of the range is moderate, the highest point having an altitude of 13,165 feet, the persistence of these glaciers is probably due primarily to the exceptionally deep and narrow cirques in which they are situated, and by whose precipitous walls they are partially sheltered from the sun, and from desiccating winds.

Drift of the last glacial epoch.—The work of the latest series of glaciers in the Bighorns was similar to that which has been described from other ranges in the western mountains. They affected a tract about 45 miles long and 20 miles wide, extending from the head of the South Fork of Tongue river on the north to the head of the southernmost tributary of Clear creek on the south. The glaciers were, for the most part, of the simple valley type, though in many cases the glaciers of several tributary valleys united into one, in the main valley below. Nowhere was there a well-developed ice-cap, though the expanse of ice in some of the valleys was considerable. In length the glaciers varied from 1 to 14 miles, and the largest of them crossed the plateau above which the sharper part of the range rises, but in no case did they reach the plains beyond.

The altitude necessary for the development of glaciers was rather more than 10,000 feet in most of the valleys, but one glacier (South Fork of Tongue river) was developed at an elevation of little more than 9,000 feet. In this case there was a favorable catchment basin on a north slope, protected against warm, drying winds.

About forty-five well-developed cirques are shown on the Cloud peak quadrangle. All of them were occupied by glaciers of the last glacial epoch, and all but two of the late Pleistocene glaciers had their sources in cirques, and were concerned in their formation. The exceptions were the feeble tongues of ice at Dome lake, and at the head of the South Fork of Tongue river.

Not counting the small feeders of larger glaciers, the deposits of twelve distinct glaciers or systems of glaciers were studied. They occur in the following valleys:

		Length.
1.	Four tributaries of the South Fork of Clear creek, the several glaciers uniting into one below	about 6 miles
2.	Little cliff-glacier, south of the South Fork of Clear creek,	" 1 mile
3.	Middle Fork of Clear creek	" 1 "
4.	South branch of the North Fork of Clear creek	" 4 miles
5.	North Fork of Clear creek	" 10 "
6.	South Fork of South Piney creek	" 8 "
7.	North Fork of South Piney creek	" 12 "
8.	East Fork of Big Goose creek	" 9 "
9.	West Fork of Big Goose creek	" 8 "
10.	South Fork of Tongue river	" 6 "
11.	Willett creek	" 3 "
12.	Shell creek	" 14 "

In addition to the above, glacial formations are known in the following valleys, though they were not studied in detail during the past summer:

13. Trapper creek.
14. North Fork of Medicine Lodge creek.
15. South Fork of Medicine Lodge creek.
16. North Fork of Paintrock creek.
17. Middle Fork of Paintrock creek.
18. Buckskin Ed creek.
19. Tensleep creek.

The glaciers of the last glacial epoch made deposits consistent with their various sizes and activities. In general, the lateral and terminal moraines are more conspicuous than the ground moraines, while the amount of drift is slight near the sources of the glaciers, and great below. The lateral moraines are long, sharp ridges, paralleling the sides of the valleys, and have rather even crest-lines, 500–700 feet above the streams. Their proximal ends usually lie against the rocky sides of the glacial canyons at an elevation of about 10,000 feet, while their distal ends merge into the stout terminal moraines. The outer fronts of the terminal moraines frequently rise somewhat abruptly 400 to 500 feet above the valley below, and their surfaces often possess in a notable degree the hummocky topography characteristic of these formations. Valley trains are present below the terminal moraines, but they are not usually very conspicuous.

One of the most striking features of the youngest series of glacial deposits is the extremely fresh appearance of the drift, and the trivial extent of the inroads which weathering and erosion have made on it and on the rock of the canyon walls and *roches moutonnées* within the area where it occurs. The till often shows scarcely a trace of surface oxidation. The numerous lakes in the valleys occupied by the glaciers of the last ice epoch, many of them confined by drift dams in valleys which have steep gradients and copious drainage, are clear indications of the

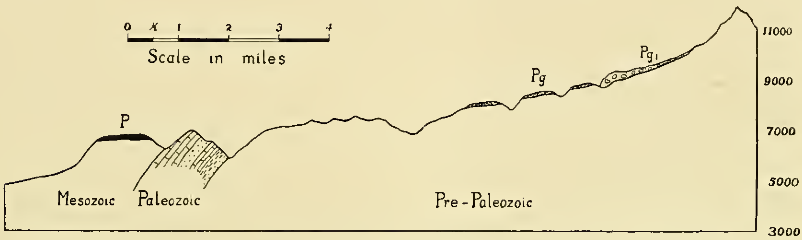


FIG. 1.—Section from near Fort McKinney to the head of the South Fork of Clear creek, showing the distribution of the Pleistocene formations: *P*, Bald mountain beds; *Pg*, drift of the next to the last glacial epoch; Pg_1, drift of the last glacial epoch.

recency of glaciation. The amount of postglacial stream erosion has been slight in most cases. It is at a maximum where the streams cut through the terminal moraines, where V-shaped gorges, 50 to 100 feet deep, have been cut in the till; but inasmuch as a single flood in Piney creek in the spring of 1902 cut a channel 10 to 20 feet deep, these figures must be regarded as small. In addition to the signs of freshness in the drift itself, striæ still remain on exposed surfaces of granite.

Glacial drift antedating the last.—In most of the valleys examined there are bodies of glacial drift outside of the fresh moraines referred to above, and of notably greater age. Their glacial origin is established both by the disposition of the drift in the form of well-defined lateral moraines, and by the finding of striated stones in the fresh exposures.

Their greater age is shown by the topography of the drift, by the physical condition of the material, by its topographic position, and by its patchy distribution (*Pg*, Fig. 1). The details of the topography of this older drift, and in many cases even its larger features, are no longer glacial, but erosional. Any lakes which once existed in its surface seem to have disappeared long before the advent of the glaciers of the last epoch. This is true at any rate of that part of the drift which lies outside the newer drift, the only part now exposed. The surfaces of the *roches moutonnées* within the area of the older drift have been weathered into roughness, many of them being angular crags, while deep valleys have been cut into the drift, and 100 to 500 feet into the underlying crystalline rock. In most cases no traces of terminal moraines were found at the limit of this series of older drift deposits. From their position, such moraines were the first part of the drift to be removed. Portions of old lateral moraines are, however, preserved in some of the valleys, such as that of North Fork of Clear creek, East Fork of Big Goose creek, and at Penrose park. They have suffered considerably from stream erosion, but the even crest-line and ridge-like character are sometimes still distinct.

In general, this body of drift has been rendered notably discontinuous by erosion. The remnants are often so meager that accurate mapping of the outlines of the glaciers which made it is not practicable, though their approximate limits can usually be ascertained. In many places the remnants are restricted to hilltops.

A formation of still older (*glacial ?*) *drift.*—From the foregoing, it is clear that the Bighorn mountains were subjected to two distinct glacial régimes in the Pleistocene period. That there was a still earlier epoch of glaciation is suggested, though not proved, by the data now in hand concerning a series of deposits which antedate the older of the drift formations referred to above. Gravel, some of it containing bowlders, is widespread about the mountains. It covers the dissected plains and caps the hills which rise above them. Most of this gravel is regarded as the work of waters flowing out from the mountains and spreading on the plains. These gravels are of various ages, as their varying topographic positions show, and the oldest antedate, by some considerable period, the glacier deposits of the last two glacial epochs. While most of the gravels seen gave no evidence of being glacial, there is on certain of the hills west of Buffalo, especially on the summit of the mountain locally known as Bald mountain[1] about six miles west southwest of Buffalo, a deposit of unconsolidated material which has something of a

FIG. 2.— Section of the drift on the summit of Bald mountain.

glacial aspect (*P*, Fig. 1). It is made up of bowlders and stones set in a matrix of finer material (Fig. 2).

All the bowlders, so far as seen, are of igneous or metamorphic rock derived from the pre-Cambrian core of the range, the nearest part of which is more than a mile west of the locality in question. Most of them appear to have come from the higher part of the range, some 8 or 10 miles away. This material must have come across the intervening Paleozoic beds,

[1] There is another Bald mountain about 40 miles northwest of Cloud peak (see Bald Mountain quadrangle).

though no Paleozoic material was found in the deposit. This is the more remarkable since some of the gravels at lower levels in the vicinity contain a large proportion of Paleozoic material. The thickness of this body of drift was not determined, but it probably exceeds 100 feet. The plateau surface between Bald mountain and the known glacial drift has not been studied in sufficient detail to affirm that drift is absent from it, but, if present, it is certainly scattering and meager in the region visited.

In connection with the problem of the transportation of this detritus, streams and glaciers are the only agents whose claims need to be considered. Positive evidence in favor of a fluvial origin is absent, so far as known data are concerned, and the existence of numerous bowlders 15 to 25 feet in diameter militates against it, especially as the gradient between the source of the bowlders and their present position is not such as to make their reference to streams seem plausible. The summit of Bald mountain has an elevation of about 7,000 feet, and the (dissected) plateau level of the crystalline schists to the west has an elevation of about 8,500 feet some 10 miles. Bald mountain is, indeed, an isolated remnant of this plateau, the surface of which declines eastward from the base of the high part of the range which rises above it. A gradient of 150 feet or less per mile would be altogether inadequate for the transportation of such bowlders as occur on Bald mountain, by any stream which could have had its origin in this range. If river ice be assumed, the difficulty is somewhat relieved, but by no means eliminated. It is to be recognized, however, that the surface gradient may have changed since the deposit was made.

The general constitution and structure of the material are consistent with its glacial origin, though, except for the great size of some of the bowlders, perhaps not inconsistent with a torrential origin. If the deposit be glacial, the large bowlders present no difficulty, though the absence of Paleozoic material is as difficult of explanation on this hypothesis as on the other. No unequivocal striæ were found on the stones of the deposit, though somewhat careful search was made for them. Numerous stones and bowlders were found the surfaces of which had the appearance of having been glaciated, but none which could be regarded as decisive. The failure of distinct striæ is perhaps not to be wondered at, since most of the material is so deeply weathered that but few of the bowlders retain much of the original surface. Many of the bowlders, indeed, are decayed to their centers, and many more have thick coatings of oxidized material. Furthermore, in the younger glacial drift of the present valleys, these same sorts of rock are striated but rarely.

The drift-like material on Bald mountain is separated from the Paleozoic terranes to the west by a valley 500 feet or more in depth. Farther west, a valley 1,000 feet or more in depth separates the Paleozoic terranes from the crystalline rock, whence the débris in question was derived. Whatever its origin, the drift appears to have reached its present position before these valleys were excavated. Its topographic position therefore, as well as its physical condition, points to its great age, an age which must antedate the older body of certain glacial drift (*Pg*, Fig. 1) by an interval of time greater than that which separates the two formations of known glacial drift.

Deposits which have some similarity to that on Bald mountain have some development elsewhere, but nowhere else was the suggestion of glacial drift so strong as on Bald mountain.

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NOTES ON THE MARINE SEDIMENTS OF EASTERN OREGON.

The marine sediments of eastern Oregon comprise beds ranging from the Carboniferous to the Upper Cretaceous. The Carboniferous and Triassic have been described by Waldemar Lindgren,[1] the Jurassic by Alpheus Hyatt,[2] and the Cretaceous by John C. Merriam,[3] C. A. White,[4] W. M. Gabb,[5] J. S. Diller and T. W. Stanton,[6] and Professor Blake.[7] The present paper is written to demonstrate the Carboniferous age of the limestone of Baker county, and to describe new localities of the Paleozoic and the Mesozoic in eastern Oregon.

The Carboniferous. — Lindgren[8] has described and mapped a great series of metamorphic argillites and limestones in Baker county, which he refers with doubt to the Carboniferous. Fossils are scarce in these rocks, the only ones reported by Lindgren being some round crinoid stems.

In the early eighties some fossiliferous limestone was sent to Professor Condon from Powder river, below Baker City. Professor Condon recognized the fossils as *Producti*, and hence sufficient to prove the Carboniferous age of the Baker county limestone that Lindgren maps as Carboniferous. Recently, through the help of Mr. H. G. Moulton, Mr. N. C. Haskell, Mr. Thomas Burke, and Mr. L. W. Nelson, of Baker City, the position of the

[1] "Gold Belt of the Blue Mountains," *Twenty-second Annual Rept. U. S. Geol. Surv.*, Part II, pp. 577–82, 1902; *Science*, Vol. XIII, pp. 270, 271, 1901.

[2] "Trias and Jura in the Western States," *Bull. Geol. Soc. Am.*, Vol. V, pp. 418–20, 1894.

[3] "Contribution to the Geology of the John Day," *Bull. Dep't Geol., Univ. of Calif.*, Vol. II, No. 9, pp. 280–85.

[4] *Bull. 33, U. S. Geol. Surv.*, p. 19; *Bull. 15*, pp. 31, 8; *Bull. U. S. G. S. Terr.*, Vol. II, p. 359.

[5] *Paleon. Calif.*, Vol. II, pp. 138, 181.

[6] *Bull. Geol. Soc. Am.*, Vol. IV, pp. 214, 452, 453.

[7] *Am. Jour. Science*, 1867, p. 118.

[8] *Twenty-second Annual Rept. U. S. Geol. Surv.*, Part II, p. 578.

limestone has been ascertained and more fossils collected from it. Mr. Nelson writes that he found the fossils *in situ* in limestone east of Big creek, about three miles south of Medical Springs. He says that the limestone extends in a broken line through Tp. 7 S., R's. 41, 42, and that it contains fossils in many places. Lindgren's map shows only Triassic in this vicinity. The fossils were referred to Dr. George H. Girty, to whose kindness the writer is indebted for the following report:

The unfortunate preservation of the material from Oregon is such as to render a nice discrimination of species impossible. Among the *Producti* there appear to be at least three species, one of these a large, comparatively flat, and spreading shell, which cannot be identified. Another group consists of small shells, which can be almost exactly duplicated in *Marginifera splendens* N & P of the Mississippi valley, a species frequently cited as *Productus longispinus*. I have not, however, been able to make out the internal characters distinguishing the genus *Marginifera*. The third group comprises forms more or less closely related to *Productus multistriatus* Meek. All of these specimens are smaller than typical *P. multistriatus*, and some are more coarsely striated. These shells vary so much in these two characters, size, and striation, that I suspect that more than one species is represented. The material, however, will not permit this fact to be satisfactorily determined. Besides the forms mentioned are a *Spirifer* or *Spiriferina* (probably the latter), a *Seminula* not unlike some forms of *S. subtilita* from the Mississippi valley.

The only other place in eastern Oregon in which Paleozoic fossils have been found is on upper Crooked river. The fossils occur in partly crystalline limestone on upper Beaver creek, near the crossing of the Prineville-Izee wagon road. They were discovered by Mr. John Platts and the writer while on a bicycle trip in 1899.

Dr. Girty reports on them as follows:

The following species have been identified:

Zaphrentis sp.

Brachiopod ?

Aviculopecten sp.

Pseudomonotis sp.

The shell referred to as Brachiopod is indeterminable.

The third-mentioned form is probably an *Aviculopecten*, but it belongs to no species with which I am familiar, and certainly not to the common Carboniferous ones.

A species of Zaphrentis seems to be quite common and, as this type of coral is restricted to the Paleozoic, its presence seems to indicate, though broadly, something definite with regard to the age of the beds.

The fourth form, however, is somewhat contradictory. Several paleontologists to whom I have shown it know nothing similar to it in the Paleozoic. I am forced to conclude either that it is something entirely new or that its preservation has obscured its real character. It seems to resemble *Pseudomonotis* more than any other genus I know, but it is quite unlike, in its peculiar surface markings, any members of the genus yet found in this country. *Pseudomonotis*, it should be remarked, is especially distinctive of the Permian period.

On the whole, I am forced to conclude that the fauna indicates Carboniferous, though it may, in fact, be Devonian. Evidence of a more conclusive character is desirable to really establish the age of these beds.[1]

The *Aviculopecten* mentioned by Dr. Girty was not found in the limestone with the other fossils, but in siliceous shales which dipped away from the limestone for at least ten miles eastward to Izee post-office, where the fossil was found. The shales are well exposed along the north side of the south fork of the John Day for several miles below Izee. How far they continue east of Izee I do not know, since we turned north at Izee and passed over basalt most of the distance to Canyon City. All of the rock that was not basalt was on the Canyon City end of the road and either serpentine or coarse-grained igneous rock. The shales on the south fork did not seem as much metamorphosed as the Pitt shales of northern California and would likely yield plenty of fossils. From the fact that they overlie the Paleozoic limestone and dip toward undoubted Jurassic strata twenty-five miles southeast, the shales are possibly Triassic.

The Triassic.—The Triassic was first reported from eastern Oregon by Waldemar Lindgren.[2] From Lindgren's beds near Wallowa Lake, in T. 3 S., R. 44 E., Secs. 9, 10, 14, 15, 35, 36, a great many *Halobiae* have been sent to Professor Condon by Mr. Charles Cambell, Mr. Oglesby, and others. The collections

[1] No "well-defined Carboniferous," nor indeed any Paleozoic but this, has been reported from Crooked river. Lindgren was mistaken in thinking Professor Condon had found such rocks there. (*Twenty-second Ann. Rept. U. S. G. S.*, Part II, p. 579.)

[2] *Twenty-second Ann. Rept. U. S. Geol. Surv.*, Part II, pp. 579–81, 1902; also *Science*, Vol. XIII, pp. 270, 271, 1901.

have not yet been thoroughly studied, but contain probably *Halobia rugosa*, Guembel, aud two undetermined species.

The Jurassic.— Hyatt[1] described fossils from eastern Oregon which he thought came from Beaver creek, a tributary to Crooked river. The specimens are now in the Condon Museum, University of Oregon, and include, according to Hyatt:

Pecten acutiplicatus Meek.
Pholadomya nevadana Gabb.
Pholadomya multilineata Gabb.
Pleuromya concentrica Hyatt.
Cardinia gibbosum (?) Meek.
Rhynchonella sp.

These fossils did not come from Beaver creek, but from Silver river, over thirty miles east of Beaver creek, where they were found by William Day, of Dayville, Ore.

Professor Condon has obtained another collection made at Red Butte, Tp. 19 S., R. 30, about twenty miles north of Burns. This collection was sent to him by Mr. A. H. Huntington, of Baker City. It includes:

Pecten acutiplicatus Meek.
Pholadomya nevadana Gabb.
P. multilineata ? Gabb.
Entolium meeki Hyatt.

The third-mentioned form bears some resemblance to *P. inaequiplicata* Stanton. There are also some undetermined bivalves and ammonites in the collection. The fauna is that of the Hardgrave sandstone of Taylorville.[2]

Though the fossils studied by Hyatt did not come from Crooked river, it is probable that the Jurassic does occur there. In 1862 Professor Condon picked up a few shells on lower Beaver creek that seem to belong to that period. Mr. Stanton says of them:

> The fossils from Beaver creek include a *Gryphea*, two casts of an *Ostrea*, a *Pecten*, and probably two species of *Rhynchonella* related to *R. gnathophora* Meek. I am unable to give specific identification of any of the forms, and they do not give any certain indication of the horizon from which they came.

[1] *Bull. Geol. Soc. Am.*, Vol. V, pp. 401, 418–20.

[2] *Bull. Geol. Soc. Am.*, Vol. V, p. 401.

They are certainly Mesozoic, however, and I think Jurassic rather than Cretaceous.

The Knoxville Cretaceous.— On petrographic and stratigraphic grounds Merriam[1] has recognized the Knoxville and the Chico near Mitchell, Wheeler county. His conclusions are supported by the evidence of the following fossils collected by Professor Condon in 1863 from various places between Mitchell and the John Day:

Olcostophanus sp.
Nautilus texanus (?) Shumard.
Acteonella oviformis Gabb.
Trigonia leana Gabb.

There are also two ammonites, one of them probably *Scaphites*, that the writer cannot classify. The first-mentioned form is a fragment that seems to be closely related to *O. Mutabilis* Stanton, a characteristic Knoxville species.[2] The other three species probably came from the strata that Merriam regarded as Chico. An interesting problem in Cretaceous geography will be solved when it can be proven that the Knoxville is present or absent in eastern Oregon, and it is to be hoped that someone will secure such proof. No *Aucellae* have yet been found there.

The Chico.— The first record of the Chico in eastern Oregon was made by Whitney,[3] who published some fossils collected by Gabb on Crooked river. In the same year Blake[4] described a *Turrilites* and other fossils that Professor Condon had collected at the same place. Since then several writers[5] have referred to the Chico in eastern Oregon, from knowledge that they gained from Professor Condon's Spanish Gulch and Crooked river fossils. Recently Merriam[6] has made large collections at the Spanish Gulch locality.

On upper Beaver creek John Platts and the writer made a

[1] *Bull. Dept. Geol., Univ. of Calif.*, Vol. II, p. 285, 1901.

[2] See Stanton, *Bull. U. S. Geol. Surv.*, No. 133, pp. 17, 18, 27, 77.

[3] *Proc. Cal. Acad. Nat. Sci.*, Vol. III, p. 309, January, 1867.

[4] *Am. Jour. Sci.*, July, 1867, p. 118.

[5] See footnotes on first page of this paper.

[6] *Bull. Dep't Geol., Univ. of Calif.*, Vol. II, pp. 418–20.

hasty collection of fossils, from dark-colored sandstones that were not unlikely the source of the earlier collections. The sandstone contains several beds of conglomerate, composed largely of pebbles of argillite and black chert. It dips gently northwest and rests unconformably upon the Paleozoic limestone mentioned above. Some of the fossils were obtained within a few feet of the limestone, in a conglomerate that contained an occasional pebble of the limestone. We did not have time to learn much about the distribution of the sandstone, but since the road up Crooked river had been entirely through Tertiary sediments and lavas, and the road beyond was through older rocks, it is not likely that the Chico covers much ground. Our collection was referred to Mr. Stanton, to whom we are indebted for the following list of species:

Hemiaster californicus Clark.
Exogyra parasitica Gabb.
Ostrea sp.
Gervillia sp.
Inoceramus sp.
Trigonia evansana Meek.
Homomya concentrica Gabb.
Dentalium stramineum Gabb.
Gyrodes expansa Gabb.
Lunatia sp.
Amauropsis sp.
Anthonya cultriformis Gabb.
Meretrix varians Gabb.
Dosinia elevata Gabb.
Tellina ? sp.
Anatina quadrata Gabb.
Pholadomya sp.
Acteonina californica Gabb.
Tritonium sp.
Fusus sp.
Itruvis sp.
Desmoceras dawsoni Whiteaves.

Mr. Stanton says:

The present collection is interesting from the fact that it contains a considerable number of new species. Nearly all the forms that are only generically determined appear to be undescribed. A larger collection of fossils from this locality, with a description of the beds in which they occur, is very desirable.

It is evident that the same need exists for all the Paleozoic and Mesozoic rocks of eastern Oregon.

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Eugene, Ore.

REED CITY METEORITE.[1]

For the early history of this meteorite I am indebted to Professor Walter B. Barrows, of the Michigan State Agricultural College, and to a clipping from an article written by Professor Barrows in the *M. A. C. Record*, published by the same institution.

This meteorite, according to Professor Barrows's statement, was found by Mr. Ernest Ruppert, a small farmer and junk dealer, on his farm in Osceola county, near Reed City, Mich., while plowing in September, 1895. Later the meteorite was displayed in a hotel window in Reed City, where Professor Barrows saw it in December, 1898, and was told there had been a dispute as to the origin of the specimen, some claiming that it was a meteor from the skies, others that it was a lump of ordinary iron. Professor Barrows saw at a glance from its general character that it was a genuine meteorite and at that time made an unsuccessful effort to obtain it for the college museum. Other attempts were equally unsuccessful, until recently when the iron was purchased by the college.

In January of this year Professor Henry A. Ward, of Chicago, visited Professor Barrows to see if he could not make arrangements to obtain a portion of the mass for the Ward-Coonley Collection of Meteorites now on deposit in the American Museum of Natural History in New York. In consequence of this visit, the mass was sent to Rochester, N. Y., for slicing.

The meteorite before cutting was a semicircular or ham-shaped mass $10 \times 21 \times 26\frac{1}{2}^{cm}$ in its greatest diameters. One side (Fig. 1) has a comparatively smooth convex surface showing no distinct pittings; the opposite side is much more irregular in form, slightly concave, with three prominent and numerous small characteristic pittings. On the upper edge of this face is a hackly fracture oblong in shape $4\frac{1}{2} \times 10^{cm}$ in diameter, where a piece of less than a pound, according to Professor Barrows,

[1] Read before Rochester Academy of Science, March 9, 1903.

was broken off by the finder in an effort to discover what made the "stone" so heavy. The surface of this fracture, like that of the entire mass, is much oxidized, so that the nickeliferous iron is not visible. On one edge there is a large irregular pitting some 10^{cm} long and 5^{cm} deep. The whole mass is of a reddish-

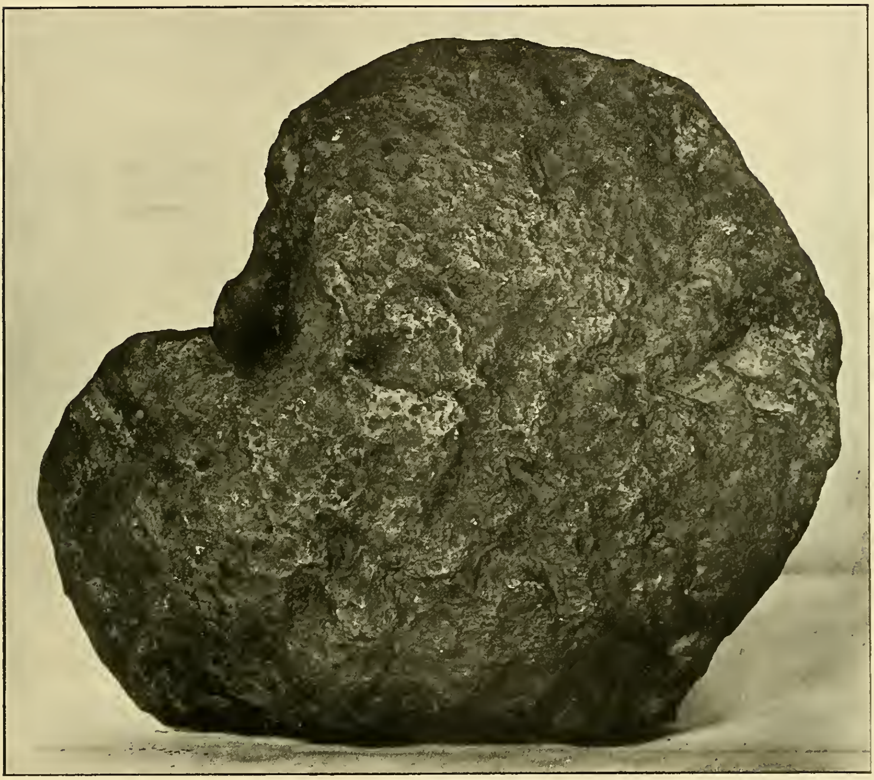

FIG. 1.—Showing convex surface. Three-fifths actual size.

brown hue, intermingled with large irregular patches of an ochre yellow color. On no part of the iron was the true crust observed. Its weight was 43 pounds 11 ounces, or 19.8 kilograms.

Following the directions of Professor Ward, a few cuts were made parallel to the upper left-hand edge (Fig. 1), showing the deep pitting mentioned above, and commencing just within the edge of this pitting. On polishing and etching these cut surfaces, we found that the iron was octahedral in structure, with well-marked Widmanstätten figures. A feature of this iron is the fact that it etches so readily that the Widmanstätten figures were slightly outlined on an ordinary polished surface, without the use of acid or any other solvent.

The etched surfaces havc numerous fissures from ½ to 1½^{mm} in width and from 5 to 65^{mm} in length, partly filled with

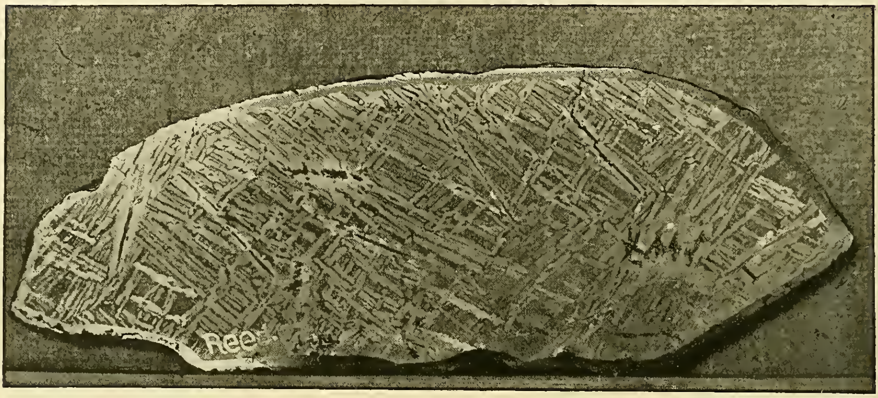

FIG. 2.—Section showing Widmanstätten figures. Three-fifths actual size.

troilite, but mainly with schreibersite. These fissures occur at various angles toward each other, thus breaking to some extent the regularity of the Widmanstätten figures, and are invariably entirely surrounded by kamacite bands. The kamacite bands average from 1½ to 2^{mm} in width, with the broadest bands generally surrounding the schreibersite-filled fissures as seen in Fig. 2. The plessite patches which are quite prominent on the etched surfaces show clearly the alternating layers of kamacite and taenite (so-called Laphamite lines) a feature that was first distinguished in another Michigan iron, that of Grand Rapids. On no section were rounded troilite nodules, so characteristic of iron meteorites, found.

The character of the etched surface of this meteorite in many respects resembles that of Cuernavaca, but the kamacite blades are much broader and longer than in Cuernavaca, thus making the figures much more prominent.

An analysis of this meteorite made for Professor Ward by Professor J. F. Whitfield, of Philadelphia, gave the following results:

Fe. 89.386.
Ni. 8.180.
Specific gravity is 7.6.

From the close proximity of the farm on which this meteorite was found to Reed City we will designate it as the "Reed City Meteorite."

The main mass of this iron was returned to the Michigan Agricultural College, while the smaller end and one slice weighing 2.9 kilograms were added to the Ward-Coonley Collection of Meteorites.

Michigan has to the present time furnished but three meteorites to the scientific world as far as described:

Grand Rapids - - - - -	found 1883
Reed City - - - - -	found 1895
Allegan - - - - - -	fell July 10, 1890

The first two are siderites, the last an aerolite.

H. L. Preston.

Rochester, N. Y.

Reviews.

Report of the Vermont State Geologist, 1901–1902. 190 pages; 62 plates; 2 maps.

This volume seems to mark, in a way, a fresh start in geological work in Vermont, made possible by more adequate provision for the work of the state geologist. The first thirty pages are devoted to a résumé of past geological work in the state, including (1) a sketch of the life of Zadock Thomson, state geologist 1853–56, together with a list of his publications; (2) a list of reports on the geology of Vermont, 1845–1900, with a summary of the scope of each report; (3) a list of other publications bearing on Vermont geology; and (4) a biography of Mr. Augustus Wing (1808–76), an independent investigator who made important contributions to the knowledge of Vermont geology.

Then follows a summary of the metallic products, useful minerals, and building-stones of the state. Mr. George I. Finlay contributes the results of a study of the Barre Granite area, one of the most important granite areas in the country, the workshops at the Barre quarries being the largest of the kind in the world. A detailed petrographical description is given of the granites and their associated rocks.

"The Terranes of Orange County" are discussed by Dr. C. H. Richardson. The slates of Montpelier and Northfield, and those extending north and south from Bradford, which have been regarded as Cambrian, are placed by him in the same horizon with the "Calciferous Mica Schist" of Hitchcock, on stratigraphic grounds. The latter is separated by Richardson into a calcareous member, the Washington limestone, and a non-calcareous member, the Bradford schist. These have been regarded by most geologists as Silurian (Upper Silurian), but are placed by the author, together with the slates, in the Lower Trenton, on the ground of the lithological similarity of the slates with the graptolitic slates of Trenton age at Willard's Mill and Castle Brook, Quebec. The slates are shown to rest unconformably on the Huronian, and so the Cambrian, according to this classification, is absent. A more detailed statement and discussion of the evidence for this important change of correlation would be of interest. It may be noted that in accounting for the break in the outcrop of the slates near Bradford by erosion (necessarily previous to the deposition of the Bradford schists), the writer presumes an erosion interval between the very beds (Washington limestone and the slate) which he classes together (see p. 78 and Plate XIV).

"The Geology of Grand Isle" is the subject of a chapter by Dr. Perkins. This is the largest of the islands of Lake Champlain. The term "Champlainian" is used instead of "Ordovician," and "Beekmantown" instead of "Calciferous," upon grounds of priority. The much-folded and tilted Utica shales, resting on only slightly disturbed Trenton and Chazy beds, afford an excellent example of the different effects which the same orogenic movements may have on strata of different lithologic character and in different stratigraphic positions.

Peculiar concretion-like organic remains in the Chazy are believed to be sponges, and are placed by H. M. Seely in a new genus, Stephochetus. Four new species of this genus are described and figured. A petrographic description of the dikes of Grand Isle is given by H. W. Shirmer, of Columbia University.

The illustrations are numerous and especially good.

E. S. B.

Mineral Resources of the United States. Calendar Year 1901. By David T. Day. United States Geological Survey.

The total value of our mineral production was $1,086,529,521 — a gain of 2.15 per cent. over that of 1900. For the second time it was more than a billion dollars. The twenty-two products whose value exceeded a million dollars each are, in order of their value, as follows: Coal, pig iron, copper, gold, silver (coining value), petroleum, stone (building), natural gas, lead, cement, brick clay, zinc, mineral waters, salt, phosphate rock, limestone (for iron flux), zinc white, clay (other than brick), aluminum, gypsum, quicksilver, and pyrite.

Coal.—The coal product of the United States for the year 1901 was the greatest in the history of the industry, its value being $348,910,464 — an increase of 14 per cent. The tonnage exceeded that of Great Britain and colonies, and was 75 per cent. greater than the output of Germany. The industry gave employment to 485,544 men. There were twenty-eight states and territories producing coal, and twenty-two of them show increased output, the greatest per cent. increase being that of North Dakota. Pennsylvania produced 51 per cent. of all the coal mined. Illinois ranked second with 9.6 per cent. West Virginia, Ohio, Alabama, Indiana, Kentucky, Colorado, and Iowa follow in the order named.

The anthracite product was $112,504,020 — an increase of 31 per cent. over that of the previous year. The average price at the mine was $2.05 per long ton, Pennsylvania producing all of this, though true anthracite has been produced for a number of years in Colorado and New Mexico.

The bituminous product was valued at $236,406,449. Of this the Appalachian field produced 67 per cent.; the central field (Illinois, Indiana, Kentucky), 16 per cent.; the western field (Iowa, Missouri, Kansas), 9 per cent.; the Rocky Mountain field, 6 per cent.; the coast field, 1 per cent.; and the Michigan field, ½ per cent. The average price at the mine was $1.05. The report includes statistics of labor, of accidents, and of the use of mining machinery, given by states.

The product of coke, included under coal, was $44,445,923. It is shown that by the beehive ovens now generally in use $18,000,000 worth of by-products, exclusive of gas, was wasted. Nor is this due to a lack of demand for these products, for we are paying, principally to Germany, $10,000,000 a year for these materials.

Petroleum.—The production of crude petroleum for the year was valued at $66,417,335 — the greatest in the history of the industry. There was a very remarkable increase in the production of Texas and California, a decrease in the Appalachian field, and a small gain in the Lima-Indiana region. The exports of petroleum products were the largest ever recorded, although there was a slight decrease in their value. The development of new pools in Texas, California, and at Boulder, Col., was attended by the organization of 1,478 companies representing a capitalization of $663,283,000. Of these only 556 produced petroleum. Prices varied from $0.28 per barrel in Texas to $7 for the natural lubricating oil of Wyoming. The average price was $0.96. From the results of analyses of the Beaumont petroleum the opinion is that, though it is eminently fitted for a fuel, the present known methods will fail to secure illuminating and lubricating derivatives in sufficient quantity to justify its refinement. The wide distribution and great production of the Texas fields "seem to assure the final result that Texas will in the course of time be at the head of the list of oil-producing states in this country."

New discoveries of oil in California are of far-reaching importance. There practically all of the coal must be imported, coming largely from British Columbia and Australia. This has prevented. San Francisco from becoming a great manufacturing center, but this situation need no longer exist, for sufficient oil at low prices is piped directly to the city from the Kern county district. Like the Texas oil, the California product is low in illuminating and high in heating power, three and one-half barrels being equivalent to a ton of coal. The report includes extensive reviews of the oil production of the world.

Natural gas.—The value of the product was $27,067,500—an increase of 14 per cent. over the previous year. The pressure, however, has continued to decline, necessitating the expense of compression in order to market an increased production from declining fields. A total of 709,921 domestic fires and 5,742 factories and mills were supplied. The increase per cent. in production was greatest in Kansas.

Iron ore.—The production of 28,887,479 long tons was 5 per cent. greater than the production of any previous year and greater than the output of any other country, exceeding that of Germany, our nearest competitor, by more than 50 per cent. Of the twenty-five states mining iron, Minnesota ranked first, Michigan second, and Alabama third. The ores were hematite 93 per cent., magnetite 6 per cent., and carbonate less than 1 per cent. The Mesabi range in Minnesota, owing to the large deposits and the ease of working them, produced 32 per cent. of the total for the United States. About 200 cargo analyses of Lake Superior iron ore are given. The production of pig iron was worth $242,174,000 and exceeded the combined British and German production for the same year.

Gold.—The production for the year was $78,666,700—a decrease of 0.6 per cent. California increased her production over a million dollars and Nevada almost as much, her increase coming largely from the new camp of Tonapah in Nye county. Alaska and Colorado showed a decrease of about a million dollars each. The principal producing states and territories, in order of production, were as follows: Colorado, California, Alaska, South Dakota, Montana, and Arizona. About 85 per cent. of the production came from quartz and the remainder from placer mines.

Silver.—The commercial value of the yield was $33,128,400—about 4 per cent. less than that of the previous year. The greatest gain was in Utah, most of which came from the Park City district. Colorado and Montana showed a material decrease. About 29 per cent. came from quartz mining and the remainder from lead and copper ores.

Copper.—The year's production was valued at $87,300,515—a decrease of 11 per cent. This decrease was due chiefly to the lower prices prevailing, the quantity mined falling off less than 1 per cent. The product of the United States was considerably more than that of all other countries combined. Of this Montana produced 38 per cent., the Lake Superior region 26 per cent., and Arizona 22 per cent. Statistics are given showing the cost of operation and the profits of various mines, with a résumé of the foreign and domestic copper trade.

Lead.—The value of the lead mined in 1901 was $23,280,200, this being something less than that of the preceding year. Idaho stood first in production, Colorado second, and the Mississippi valley districts third. Important developments of lead properties are now going on in southeast Missouri, and it is believed that a material increase of output will follow.

Zinc.—The value of the zinc production was $11,265,760. The quantity mined was the greatest in the history of the industry, being 25 per cent. of the world's production. More than half of this ore came from the Joplin, Mo., district. The features of the year were the removal of smelting properties to the Kansas natural-gas district and a futile attempt to consolidate the smelting interests.

Aluminum.—The Pittsburg Reduction Co. is the sole producer of aluminum in the United States. The value of the product was $1,920,000, this being half the output of the world. As an electrical conductor, aluminum continues to increase in favor. Beauxite, the ore of aluminum, was mined in Georgia, Alabama, and Arkansas. The new field at Beauxite, Ark., is one of great promise.

Quicksilver. — The production of $1,382,305 came chiefly from California, though Texas contributed a small amount. The ores being worked are very lean, and the outlook for increased production is unpromising.

Precious stones.— The production of the United States was $289,-050, while the importation was $22,815,352. The jewelry trade is a very sensitive barometer of the general financial situation, and the great importation of precious stones clearly reflects the remarkable prosperity of the country.

W. H. E.

THE

JOURNAL OF GEOLOGY

APRIL–MAY, 1903

THE MONTEREGIAN HILLS—A CANADIAN PETROGRAPHICAL PROVINCE.

GENERAL STATEMENT.

In the province of Quebec between the enormous expanse of the Laurentian highlands to the northwest, constituting the "Canadian Shield," and the disturbed and folded tract of country to the southeast which marks the Appalachian uplift, there is a great plain underlain by nearly horizontal rocks of Lower Paleozoic age. This plain, while really showing slight differences of level from place to place, seems to the casual observer perfectly flat. Its surface is mantled with a fertile soil consisting of drift redistributed upon its surface by the sea which at the close of glacial times covered it. The uniform expanse of this plain, however, is broken by several isolated hills composed of igneous rocks, which rise abruptly from it and which constitute very striking features of the landscape. It was at the foot of one of these hills rising by the side of the river St. Lawrence, and which he named Mount Royal, that Jacques Cartier on his first visit found the Indian encampment of Hochelaga, whose site is now overspread by the city of Montreal, which has not only grown around the foot of the hill, but has extended up its sides and has reserved its summit as a park.

From the top of Mount Royal the other hills referred to can all be seen rising from the plain to the east, while to the north the plain stretches away unbroken to the foot of the Laurentian country.

As has been remarked by Sir Archibald Geikie:[1]

> The word "mountain" is properly speaking not a scientific term. It includes many forms of ground utterly different from each other in size, shape, structure, and origin. In a really mountainous country the word would be restricted to the loftier masses of ground, while such a word as "hill" would be given to the lesser heights. But in a region of low or gently undulating land, where any conspicuous eminence becomes important, the term "mountain" is lavishly used. In eastern America this habit has been indulged in to such an extent that what are, so to speak, mere hummocks in the general landscape are dignified by the name of mountain.

The hills under consideration, while by no means "mere hummocks," being situated in such a country of low relief, seem to be higher than they really are and are always referred to locally as "mountains."

These mountains, whose positions are shown on the accompanying map (Fig. 1), are eight in number, their names and their height above sea level being as follows:

Mount Royal	769.6 feet
Montarville or Boucherville mountain	Not yet accurately determined
Beloeil	1,437 feet (Leroy)
Rougemont	Not yet accurately determined
Yamaska	Not yet accurately determined
Shefford	1,600 feet (Dresser)
Brome	1,440 feet (Dresser)
Mount Johnson or Monnoir	875 feet

Brome mountain is by far the largest of the group, having an area of 30 square miles. Shefford comes next in size, having an area of rather less than nine square miles, while Mount Johnson, which is very much smaller than any of the others, has an area of only .422 of one square mile.

Of these eight, the first six, as Logan[2] notes, "stand pretty nearly in a straight line," running approximately east and west, Mount Royal being the most westerly, and the others following in the order in which they are enumerated above, until Shefford mountain is reached, which is the most easterly member of the series. The distance from Mount Royal to Shefford is fifty

[1] *Text-Book of Geology.* [2] *Geology of Canada*, p. 9.

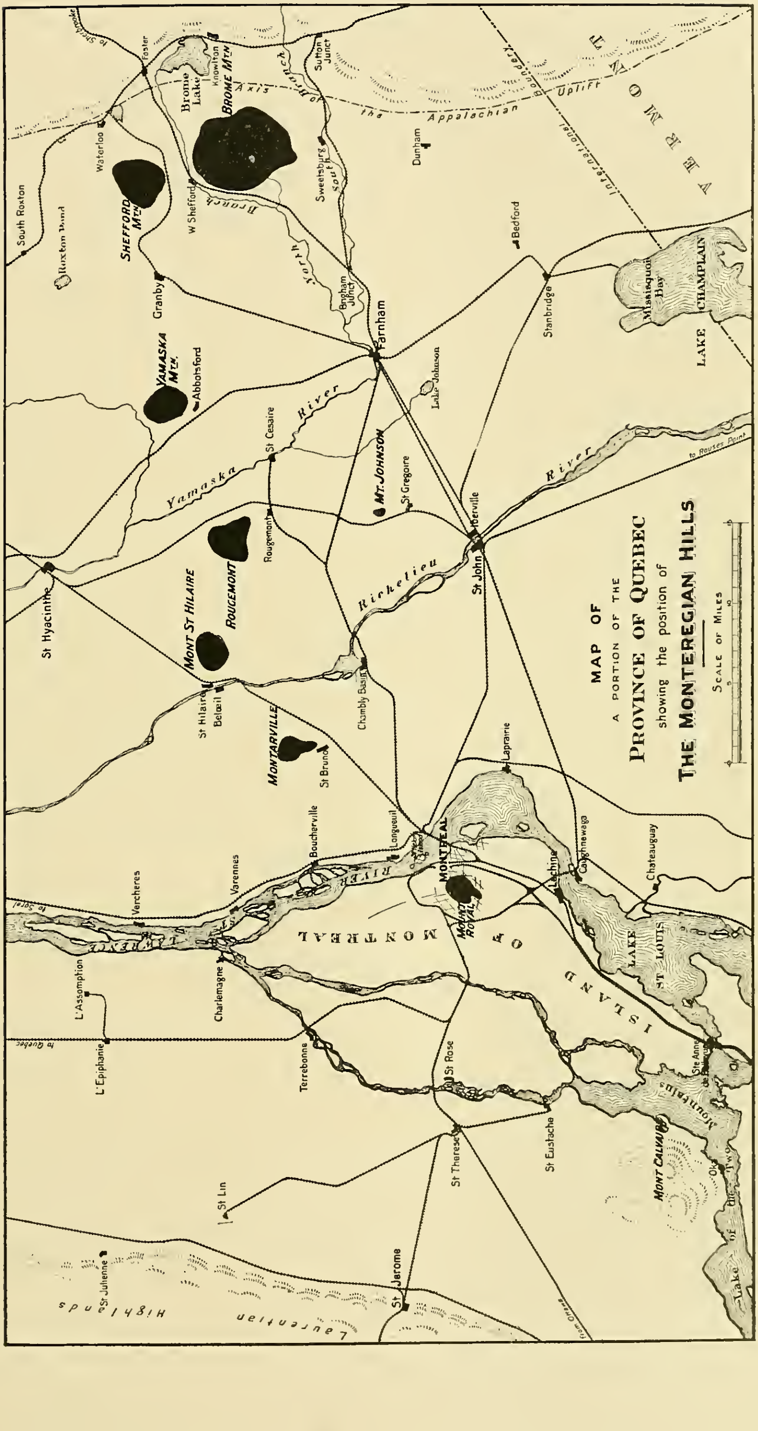
MAP OF
A PORTION OF THE
PROVINCE OF QUEBEC
showing the position of
THE MONTEREGIAN HILLS
SCALE OF MILES
BROME MTN
SHEFFORD MTN
YAMASKA MTN
MT. JOHNSON
ROUGEMONT
MONT ST HILAIRE
MONTARVILLE
MOUNT ROYAL
MONT CALVAIRE
VERMONT
LAKE CHAMPLAIN
Missisquoi Bay
Brome Lake
Yamaska River
Richelieu River
LAKE ST LOUIS
ISLAND OF MONTREAL
Lake of the Two Mountains
Laurentian Highlands
Axis of the Appalachian Uplift
International Boundary
North Branch
South Branch
MONTREAL
St Hyacinthe
Farnham
Granby
Waterloo
Foster
Knowlton
Sutton Junct
Sweetsburg
Dunham
Bedford
Stanbridge
Iberville
St John
Laprairie
Longueuil
Boucherville
Varennes
Vercheres
Chambly Basin
St Bruno
St Hilaire
Belœil
Rougemont
St Cesaire
Abbotsford
St Gregoire
Lachine
Caughnawaga
Chateauguay
Charlemagne
L'Assomption
L'Epiphanie
Terrebonne
St Rose
St Therese
St Eustache
St Lin
St Jerome
St Julienne
Ste Anne
Oka
South Roxton
Roxton Pond
W Shefford
Brigham Junct
Lake Johnson
to Sherbrooke
to Sorel
to Quebec
to Rouses Point
from Ottawa

FIG. I.

miles. Mount Johnson and Brome mountain lie on a line parallel to them, but a short distance to the south, Rougemont being the nearest neighbor to Mount Johnson and Brome mountain being immediately south of Shefford. It is highly probable, in view of this distribution, that these ancient volcanic mountains are, as is usual in such occurrences, arranged along some line or lines of weakness or deep-seated fracture. The "pretty nearly straight line" referred to by Logan on which the first six mountains of the group are situated must be considered either as a single line with a rather sharp curve in the middle, or as made up of two shorter straight lines, each with three mountains, which diverge from one another at an angle of about 30°, Montarville being located at the point of intersection. Mount Johnson and Brome mountain might then be considered as situated on short subsidiary fractures.

Brome and Shefford, however, which are the two largest mountains of the series and which are only separated by a distance of a little over two miles, are probably connected at no great depth below the surface, forming in reality one large mass, while Mount Johnson, like the similar volcanic necks of Fife and Würtemberg, may have no direct connection with any line of fracture. It must be noted, as mentioned by Dresser,[1] that while six of these mountains rise from the horizontal strata of the plain, the two most easterly members of the group, named Shefford and Brome, while still to the west of the axis of the range, lie well within the folded belt of the Appalachians, though, owing to the extensive denudation from which the region has suffered, this folding has had but little influence on the local topography.

No collective name has hitherto been proposed for this remarkable group of hills.[2] From their intimate geological

[1] "On the Petrography of Shefford Mountain," *Amer. Geol.*, October, 1901.

[2] The only instances in which these hills have been referred to as a geographical unit are, so far as can be ascertained, in a paper by STERRY HUNT entitled "On Some Igneous Rocks of Canada," *Am. Jour. Science*, March, 1860, where they are called the Montreal group; and by ELIE DE BEAUMONT, who in a late edition of his *Systèmes des Montagnes* included these hills as one of his systems, under the name of the "Système de Montréal." See PRESTWICH, *Geology, Chemical, Physical and Stratigraphical*, Vol. I, p. 294.

relationship, however, constituting as they do a distinct and remarkable petrographical province, such a name is required. I propose to call them the *Monteregian Hills*, deriving their name from Mount Royal ("Mons Regius"), which may be taken as their type, being as it is the best-known member of the group.

There are certain other hills which have been considered by former workers in the geology of this district to belong to this group. Thus Logan thought that Rigaud Mountain, situated near the margin of the plain, by the river Ottawa, about forty miles west of Mount Royal, was "probably connected with" the series.[1] Ells[2] also included Mont Calvaire, a large, low mass which rises from the plain immediately to the north of the Lake of Two Mountains, near the junction of the Ottawa and the St. Lawrence.

Ells also refers to "the hills on the west side of Memphremagog lake and to the northeast toward the Chaudière river and beyond" as bearing a marked resemblance to the rocks of Mount Royal, Yamaska, etc., and as probably being of the same age.[3]

In a careful study of Rigaud mountain, recently completed by Mr. Leroy,[4] of this university, it is shown that the rocks constituting this mountain are different in character from those of the Monteregian hills, being composed of a reddish hornblende syenite and a quartz-bearing porphyry. These rocks, however, were found to be identical in character and composition with a great area of syenite, cut by porphyry, mentioned by Logan as occupying some forty square miles in the townships of Chatham and Grenville on the margin of the Laurentian plateau, a few miles to the north of Rigaud mountain. Owing to the drift which mantles this district, the actual contact of the igneous rock of Rigaud mountain and the Paleozoic strata of the plain is

[1] *Geology of Canada*, 1863, p. 9.

[2] "Report on a Portion of the Province of Quebec," *Ann. Rept. Geol. Surv. of Canada*, Vol. VII, Part J, 1896.

[3] Eastern Townships Map (Montreal Sheet), *Ann. Rept. Geol. Surv. of Canada*, Vol. VII, Part J.

[4] *Bull. of the American Geological Society*, Vol. XII, 1901.

nowhere visible, so that it is impossible to determine whether the mass of Rigaud mountain cuts through the strata in question, as in the case of the Monteregian hills, or whether it is pre-Paleozoic in age. The same is true of the mass in Chatham and Grenville, the actual contact here also being found by Mr. Leroy to be banked up with drift. The narrow margin of gneiss shown on Logan's map[1] between the Chatham syenite and the Paleozoic is also conjectural, the area being likewise drift-covered. Rigaud mountain is furthermore of a different shape from the mountains east of Montreal, being six miles in length and only two and one-half miles wide; at the eastern end of it, moreover, there is found an occurrence of ordinary Laurentian gneiss. The abrupt and straight southern boundary of the Laurentian plateau along this part of its course probably marks a fault. Ells has noted the existence of other faults in this district, one of which he believes to follow the north side of Rigaud mountain. It is thus highly probable that the ridge known as Rigaud mountain does not belong to the Monteregian hills, but that it is a portion of the Laurentian plateau separated from the main area by faulting and stripped of its original covers of Paleozoic strata by denudation. It is probable that Mont Calvaire, as regarded by Logan, is also an outlying portion of the Laurentian plateau.

The hills on the west side of Lake Memphremagog and to the northeast toward the Chaudière river, referred to by Dr. Ells, so far as is known, are quite different in petrographical character from Mount Royal and the other members of its group. They constitute a chain of hills occupying a tract of country some four miles wide and thirty-five miles in length, in the heart of the Appalachian uplift and following the strike of the Appalachian folding. Many of them, as Owl's Head and Orford mountain, rise to a very considerable height, these peaks having a height of about 2,400 and 2,800 feet respectively; forming, in fact, the highest elevations in this part of Canada. So far as has been ascertained, these mountains are in all cases composed of

[1] Atlas to accompany the *Geology of Canada*, 1863, Map No. 2.

highly altered rocks. Many of them are altered diabases.[1] In other cases the alteration is so far advanced that it is impossible to determine the character of the original rock. Many of them have been completely altered to masses of serpentine. Nepheline-syenites, essexites, and similar rocks have not as yet been found anywhere in this chain of hills. A series of dyke rocks from Lake Memphremagog, examined by Marsters,[2] were found to be chiefly granites and lamprophyres, with one typical camptonite. It would seem therefore, that while our knowledge of these hills is as yet very imperfect, the evidence at our command, so far as it goes, points to them as belonging to a group quite distinct from Mount Royal and its associates. The petrographical province of the Monteregian hills may therefore, in the present state of our knowledge, be said to comprise only the eight mountains enumerated on p. 240, together with the consanguineous dykes which at many points are found cutting the rocks of the surrounding plains.

The first description of these hills was that given by Logan and Hunt in the early years of the Canadian Survey. To Hunt especially we owe a somewhat extended description of the petrography of the group and a number of chemical analyses, more especially of the constituent minerals of certain of the rocks. These descriptions are, however, very general and often very imperfect, as must necessarily have been the case before the introduction of modern petrographical methods. Nor were certain important petrographical relationships observed which have in later times come to be recognized. This early work, however, is of great interest, and in case of three of the mountains almost all the information which we have even at the present time, is derived from those early studies. The results of this work were brought together in the *Geology of Canada*, published by the Geological Survey of Canada in 1863, and are to be found on pp. 655–70. During the thirty years following the appearance of this volume, only three papers containing additional information concerning these rocks appeared. These were by

[1] F. D. ADAMS, *Ann. Rept. Geol. Surv. of Canada*, 1880–81–82, pp. 12–13 A.

[2] *American Geologist*, July, 1895.

Harrington,[1] Lacroix,[2] and the present writer,[3] respectively, all dealing with Mount Royal. In 1896 the "Montreal Sheet" of the *Eastern Townships Map*, prepared by Ells, and embracing the district of the Monteregian hills, was published by the Geological Survey of Canada and accompanied by a geological report on this portion of the province of Quebec. Four years later Principal Dresser of St. Francis College, Richmond, aided by a small grant from the Geological Survey of Canada, made a careful study of Shefford mountain, and a preliminary paper embodying the chief results of his investigations appeared in 1901.[4] Mr. Dresser last summer extended his work to Brome mountain, and has since published a brief description of this occurrence.[5] Mr. O. E. Leroy, of McGill University, is now engaged in a study of Beloeil, and I am indebted to him for the facts concerning the geology of this mountain which are here presented. Montarville, Rougemont, and Yamaska mountains still await detailed study, but it is expected that they also will before long be put in commission.

In the present paper it is proposed first to gather together the more important facts concerning the geology of the Monteregian hills which are scattered throughout these various publications, revising some of the earlier work and embodying the results of later personal studies, and then to describe in some detail one of these hills—Mount Johnson—of which hitherto but little has been known.

PETROGRAPHY OF THE MONTEREGIAN HILLS.

Hunt distinguished four types of igneous rocks as constituents of the Monteregian hills. These he classed as trachyte,

[1] "On Some of the Diorites of Montreal," *Ann. Rept. of the Geol. Surv. of Canada*, 1877–78, 42 G.

[2] "Description des syénites néphélinitiques de Pousac et de Montréal (Canada) et de leurs phénomènes de contact," *Bull. Soc. Géol. de France*, 3e série, tome XVIII, 1890.

[3] "On a Melilite-Bearing Rock (Alnöite) from St. Anne de Bellevue near Montreal, Canada," *Amer. Jour. of Science*, April, 1892.

[4] "On the Petrography of Shefford Mountain," *Amer. Geol.*, October, 1901.

[5] *Summary Report of the Geological Survey Department for 1901*, p. 183.

phonolite, diorite, and dolerite, respectively. In this classification no distinction was made between rocks occurring as dykes and the great igneous intrusions which form the body of the hills; differences in structure resulting from mode of occurrence were not considered, the classification being based upon mineralogical composition alone.

Recent investigations have shown that Hunt's names do not convey an accurate idea of the petrography of these hills, nor do they set forth the interesting relationships of the various rocks composing them. It is necessary for this purpose to adopt a more modern nomenclature, for all the mountains of the group are composed of a family of consanguineous rocks, and taken together they present one of the finest examples of a petrographical province hitherto discovered. They consist, furthermore, of a rather rare class of rocks characterized by a high content of alumina and alkalies, especially soda.

The rocks forming the great intrusions which make up the mass of these mountains belong to two well-characterized types —one light in color, poor in iron-magnesia constituents, and comparatively high in silica; the other dark in color, rich in iron-magnesia constituents, and with a lower content of silica. They may be classed as follows, if Rosenbusch's nomenclature be followed:

1. Alkali-syenite, nepheline-syenite, or sodalite-syenite.
2. Essexite.

The first is an alkali-syenite, always containing a little nepheline, but this mineral in some cases becoming so abundant that the rock passes into a true nepheline-syenite, or, by the replacement of the nepheline by sodalite, into a sodalite-syenite. This in the case of Mount Johnson and Shefford mountain is represented by the variety known as pulaskite; in Brome mountain it is stated by Dresser to resemble Brögger's laurvikite,[1] while in Mount Royal and Beloeil it is a nepheline-syenite. At the latter mountain a sodalite-syenite also occurs in association with the nepheline-syenite. Nepheline-syenite is also known to form part of Yamaska mountain. In addition to the syenite of the

[1] *Summary Report of the Geological Survey of Canada*, 1901, p. 187.

pulaskite variety, Dresser found in Shefford mountain a large development of a distinctly more acid type of the syenite magma, the rock showing occasionally a few grains of quartz. This rock he has classed as nordmarkite. These light-colored syenites, together with certain dykes of bostonite having a general similarity in composition, were the rocks classed by Dr. Hunt as trachytes.

To the essexites belong the dolerites and diorites of Hunt, when he applied these terms to the great igneous intrusions of the mountains and not to mere dykes. They usually contain both hornblende and pyroxene, but the relative proportion of these two minerals varies considerably in the different occurrences. Olivine is sometimes present. Hunt did not recognize the presence of nepheline in these rocks, nor the highly alkaline character of the magma which they represent, and classified them as dolerite or diorite according to the preponderance of pyroxene or hornblende, noticing certain occurrences in which the former rock passed into a pyroxenite or peridotite.

The greater part of Mount Royal is composed of an essexite, usually very basic, the dark-colored constituents forming a very large proportion of the whole rock. This was classed by Hunt as a dolerite, but is almost identical with the essexite of Mount Johnson, which Hunt classes as a diorite. This same rock is stated by Hunt to make up the greater part of Montarville and Rougemont and to form a portion of Yamaska mountain. An examination of thin sections of specimens of the Rougemont rock in the petrographical collection at McGill University shows it to be an essexite, rich in olivine. Dresser has found it to constitute approximately one-half of Shefford mountain and also to form large areas in Brome mountain. It makes up the greater part of Mount Johnson and forms the mass of Beloeil.

It is thus seen that the essexite magma is represented in every one of the eight mountains, and that in six of them at least it is associated with the syenite magma. The remaining two, Montarville and Rougemont, which have not been thoroughly examined as yet, while certainly composed chiefly of essexite, will probably be found, on further study, to present a development of the syenite in some portions of their mass also.

In addition to these bodies of intrusive rock which form the mass of the mountains, great numbers of dykes occur cutting both the surrounding sedimentary strata and the intrusions. These are, of course, especially numerous in and around the mountains themselves, but are also occasionally found far removed from the centers of activity. The relative abundance of these dykes in the vicinity of the several mountains varies greatly. They swarm through the Paleozoic strata about Mount Royal, cutting the limestones in all directions and also traversing, although less frequently, the igneous rock of the main intrusion as well. No less than twenty-nine dykes and flows, belonging to at least four and possibly five separate series, each cutting the preceding set, were mapped by Dr. Harrington some years ago in an excavation measuring 220 yards by 100 yards which was opened up in the Trenton limestone on the flank of Mount Royal during the construction of the Montreal Reservoir extension. Dykes, in fact, abound wherever in the vicinity of Mount Royal the bed-rock is exposed by the removal of the mantle of drift, as for instance at the Mile End Quarries, St. Helen's Island, and in the bed of the St. Lawrence about Point St. Charles when it is exposed at low water. The whole district about the city would present a network of dykes, could the overlying drift be removed.

Dresser mentions dykes as occurring abundantly about Shefford mountain. In Mount Johnson, on the other hand, they are almost entirely absent. Only five dykes could be found after a careful exploration of the whole occurrence, and they were of insignificent dimensions. But very few dykes also occur at Beloeil mountain. A large number of the dyke rocks have been collected from the various occurrences and are now awaiting investigation in the geological department at McGill University. The work on the dykes of Mount Royal is now well advanced and, it is hoped, will be ready for publication shortly. They form a most remarkable series, comprising bostonites, tinguaites, sölvsbergites, camptonites, fourchites, monchiquites, and alnöites. Most, if not all, of the types of dyke rocks which have been described as occurring in association with the alkaline rich magmas of the theralite and nepheline-syenite groups in any part of the world are thus represented. To these dyke rocks belong Hunt's phonolite, which he considered to differ from the trachyte in that it contained a certain proportion of natrolite. The two occurrences which he describes[1] are both from points near Montreal. They are nepheline bearing dykes in an advanced stage of alteration.

As has been mentioned, dyke rocks which from their composition are clearly connected with the intrusions of the Monteregian hills have been found cutting the rocks of the plain at very considerable distances from any of the main centers of activity. Thus, in addition to occurrences at Laprairie, Lachine, Rivière des Prairies, Ste. Anne de Bellevue, St. Paul's Island in the vicinity of Montreal, several dykes and flows of "trachyte" (bostonite) are noted by Hunt and Logan as occurring about Chambly, which is six miles to the south of the line of the Monteregian hills,[2] while the occurrence of a "dolerite" dyke at St. Hyacinth, ten miles north of the line, is mentioned.[3]

A sheet of trap evidently connected with these intrusions also occurs at St. Lin,[4] twenty-four miles north of this line, where it alters the Chazy limestones through which it cuts into a pink marble. It is very much decomposed, but evidently belongs to some variety of the nepheline or melilite dyke rocks above mentioned.[5]

Whether the camptonite and in some cases bostonite dykes, described by several authors from various points in the states of Maine, New Hampshire, and Vermont, adjacent to the Canadian line, and the still more distant occurrences of similar dyke rocks in the state of New York, are connected with the Monteregian hills, is not yet known. There seem to be no intrusions of nepheline-syenite or essexite hitherto discovered with which these southern dykes can be connected in the districts in which they occur. The umptekite intrusion of Red Hill, Molton-

[1] *Geology of Canada*, pp. 659–61.

[2] *Ibid.*, pp. 209 and 657.

[3] *Ibid.*, p. 210.

[4] *Ibid.*, p. 133.

[5] F. D. Adams, "Report of Geology of Laurentian Area to North of Island of Montreal," *Ann. Rept. Geol. Surv. of Canada*, Vol. VIII, J, p. 139, 1896.

boro, N. H., is, however, closely related to the Monteregian pulaskite in character and composition, and may prove to be such a center.

STRUCTURE AND ORIGIN OF THE MONTEREGIAN HILLS.

The question of the mutual relations and relative age of the several rock types constituting these hills presents many points of interest. In the case of Mount Royal the essexite which constitutes the greater part of the mountain was the earliest intrusion. When this had become solid the nepheline-syenite broke through it, sending arms into it and catching up detached fragments of the shattered essexite. The same sequence in time is, according to Dresser, to be seen in Shefford Mountain. The basic essexite here forms the earliest intrusion, and was succeeded by the pulaskite and more acid nordmarkite. Mount Johnson, however, presents the two rocks in an entirely different relation. Here, as will be shown later, there was but a single period of intrusion. For although both rocks are present in the mountain, the essexite forms the central portion of the mass and passes over into pulaskite about the periphery of the neck. The mountain thus consists of essexite in its center, surrounded by a zone of pulaskite, the two rocks passing imperceptibly into one another. Mr. Leroy considers it probable that a similar passage takes place in the case of Beloeil mountain, but it is there difficult accurately to determine the relations of the magmas to one another on account of the covering of drift which obscures the contact.

It is thus evident that the two rock types constituting the Monteregian hills are differentiation products of a single magma, the separated magmas, however, in the case of Mount Royal and Shefford having been erupted in succession instead of simultaneously. In connection with the question of differentiation, another noteworthy fact is that the more easterly mountains contain proportionately more syenite and the western hills a greater proportion of the essexite. The bearing of this fact on the character of the differentiation which took place in the subterranean magma basin can be more profitably discussed at a later date when the precise character and relative extent of the intrusions in Yamaska, Rougemont, and Montarville have been determined.

With regard to the structure of these mountains, it may be noted that Logan, who first examined them, refers to them as "intrusive masses breaking through the surrounding Paleozoic strata."[1] They are thus represented in the geological sections of this district contained in the atlas accompanying his report. Ells refers to them simply as "eruptive mountains."[2] The more detailed studies of Shefford and Brome mountains recently carried out by Dresser, however, have led him to consider these two occurrences as uncovered laccolites. Concerning Shefford mountain he says:

> The sedimentary strata which surround the mountain . . . . are found to wrap around the igneous mass of the mountain, mantling it with a hardened contact zone to a height of 300 to 1,000 feet above the surrounding country, according to the direction of glaciation. Above the latter height the mountain rises upward of 200 feet, the summit being capped by an outlier of Trenton slate about a quarter of a mile in extent. This preserves the cleavage, dip, and strike of the similar rock at either side of the mountain and is penetrated by dykes from the underlying igneous rocks. From these facts, together with the absence of tufaceous material and the general arching of the strata around the mountain, it is inferred that Shefford mountain is an uncovered laccolite rather than the denuded neck of a once active volcano.[3]

In Brome mountain also the presence of outlying masses of the surrounding sedimentary series at high levels lying upon the igneous rock of the intrusion "seem to indicate unmistakably that Brome mountain, like Shefford, is an uncovered laccolite and has never been an active volcano."[4]

Mount Johnson, on the contrary, as will be shown, is a typical neck or plug, representing a portion of the conduit through which the magma rose, to fill laccolites above in strata which have long since been swept away by erosion, or to be poured out at the surface at volcanic vents. This is seen by the fact

[1] *Geology of Canada*, p. 655.

[2] *Ann. Rept. of Geol. Surv. of Canada*, Vol. VII, J, p. 71.

[3] *American Geologist*, October, 1901, p. 204.

[4] *Geol. Surv. of Canada, Summary Rept. for 1901*, p. 187.

that the flat-lying strata all about it are not arched up, but abut sharply against the igneous core of the mountain and are cut off by it. Being shales, they are of course baked to hornstones, but show no signs of upheaval or tilting. The small size and almost circular cross-section of the mountain are a further indication of this origin; and finally there is conclusive proof that there was a vertical or upward movement of molten rock through the pipe. The mountain has been figured by Professor Davis, in his *Physical Geography*, from one of the author's photographs, as a typical example of a volcanic neck.

In a recent paper by Buchan[1] the view was put forward that Mount Royal represents the remnant of a denuded laccolite— on the ground that on one side of the mountain, toward the summit, there is an isolated mass of flat-lying, altered Paleozoic limestone, evidently a part of the sedimentary strata of the plain from which the mountain rises. This alone, however, is not sufficient to establish a laccolitic origin, and opposed to such an explanation is the fact that where the strata of the plain are seen along their immediate contact with the intrusion in many places, especially on the eastern and northern side of the mountain, they abut against the intrusive rock and are cut off by it instead of being uptilted, the igneous core of the mountain rising up precipitously like a wall across the truncated edge of the beds. The occurrences of the flat-lying limestone on the side of the mountain referred to above appear to represent the remnant of certain beds, beneath which a portion of the intrusive mass penetrated, after the manner of a laccolite, on one side of the mass. Their existence does not by any means indicate a laccolitic structure for the mountains as a whole, or that the igneous material did not find a vent at the surface, there developing a volcano. In fact, there is evidence in the existence of a remarkable deposit of a breccia-conglomerate in several places around the mountain that it did develop as a volcano and that the materials constituting the deposit in question were ejected from it. A study of this breccia was undertaken last autumn by one of the geological field parties of McGill University, and a description of it, with a

[1] *Canadian Record of Science*, Vol. VIII (1901), p. 321.

discussion of its origin, is now in press and will appear in the *Canadian Record of Science* within the next few weeks. The other four hills have not as yet been studied in sufficient detail to enable any definite statement concerning their structure to be made.

In the Monteregian hills there are thus intrusions of the nature of laccolites, true necks, and probably also of stocks. The age of the intrusions cannot as yet be definitely determined. They are later than the lower Devonian, for some of the dykes connected with Mount Royal cut limestones which belong to the summit of the upper Silurian, while fragments of limestone which are shown by the fossils which they contain to be referable to the lowest beds of the Devonian, occur as inclusions in the volcanic breccia or agglomerate which is found about the flanks of the same mountain. The deeply eroded character of the mountains, however, shows that they are of early date, and it seems most probable that the intrusion took place somewhere in later Paleozoic times.

Having considered in a general way the character of the Monteregian hills as a whole it may be of interest to look somewhat more closely into the structure and petrographical characters of one member of the group which has recently been studied in some detail, namely Mount Johnson.

MOUNT JOHNSON.

Mount Johnson rises from the plain twenty-two miles east-southeast of the city of Montreal, and six miles northeast of the town of St. Johns on the Richelieu river, and twenty-five miles north of the international boundary. The little village of St. Grègoire is situated near its base. The surrounding country is perfectly flat, forming a fertile and well-tilled agricultural district, the nearest mountain being Rougemont, which lies in a northeasterly direction some nine miles distant. In cross-section Mount Johnson is nearly circular. (Fig. 2.) The igneous plug itself has at the base, immediately above the hornstone collar, a somewhat elliptical outline and measures 3,500 feet by 2,500 feet, the longer axis having a direction N 20° E. This gives the

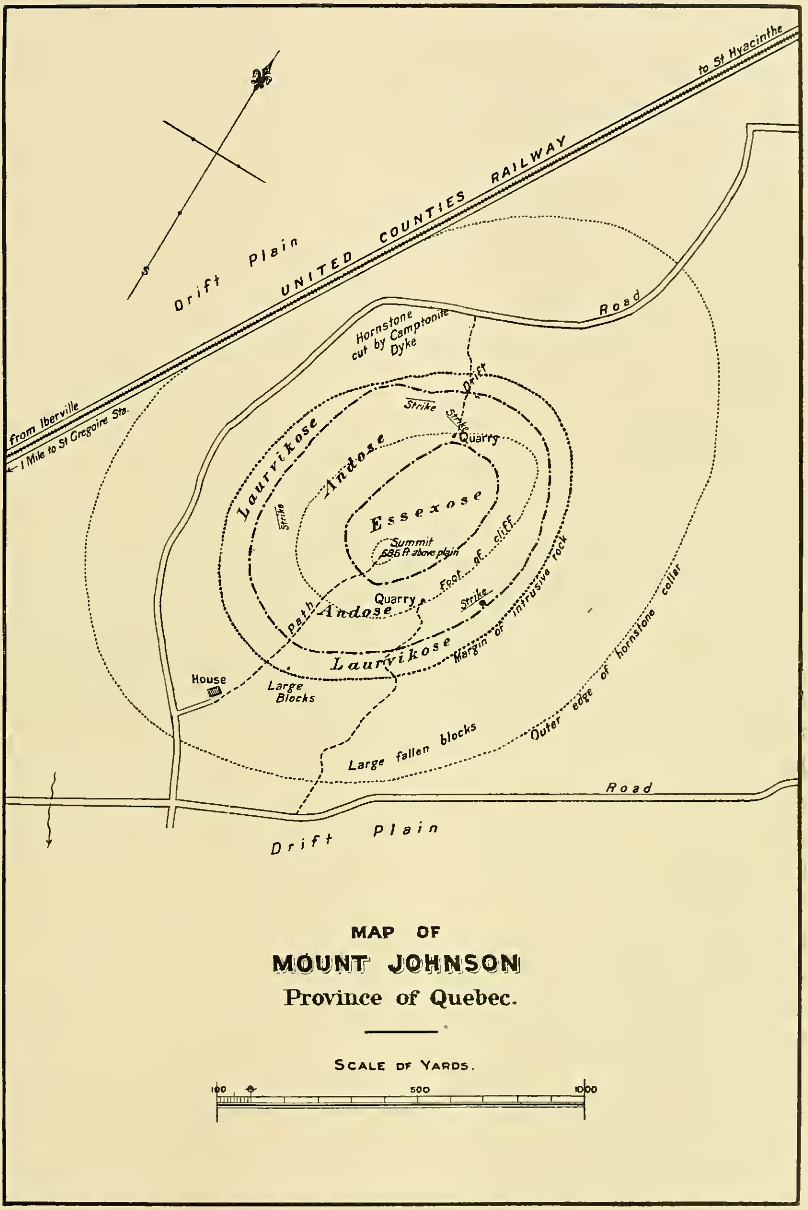
UNITED COUNTIES RAILWAY
to St Hyacinthe
from Iberville
← 1 Mile to St Gregoire Sta.
Drift Plain
Road
Hornstone cut by Camptonite Dyke
Drift
Strike
Strike
Quarry
Laurvikose
Andose
Essexose
Strike
Summit 685 ft above plain
Foot of cliff
Margin of intrusive rock
Quarry
path
Andose
Strike
Laurvikose
House
Large Blocks
Outer edge of hornstone collar
Large fallen blocks
Road
Drift Plain
MAP OF
MOUNT JOHNSON
Province of Quebec.
SCALE OF YARDS.
100
0
500
1000

FIG. 2.

igneous intrusion an area of .422 of a square mile. The mean of a series of closely concordant aneroid readings, corrected by comparison with barometers at the observatory of McGill University at Montreal, shows that the highest point of the mountain is 685 feet above the main street in the village of St. Grègoire opposite the church, that is, above the surrounding plain, or 875 feet above sea-level, the plain here having an elevation above sea-level of 190 feet. It has a somewhat dome-like outline and forms a very striking feature in the landscape. The slope on the southern side is steep, in places precipitous, while to the north it is more gentle. The accompanying photograph (Fig. 3), taken from the railway station near St. Grègoire, which is about a mile and a quarter distant from the mountain in a direction approximately southwest, shows this profile, as well as the little notch near the summit caused by a ravine which passes down the side.

At the foot of the mountain, more especially on its southern, southeastern, and southwestern sides, are numbers of large blocks which have fallen from the steep upper slopes and extend out from the foot; on the southern is a gently sloping, terraced platform of drift which in part buries these great blocks, forming a "tail" probably due to the drift accumulating here on the lee side of the mountain during the ice movements in the glacial age. This drift, however, has been in part at least reassorted by wave-action during the period of depression which in this region followed the glacial age and during which the sea covered the plain to a depth of several hundred feet at least, as shown by the high level terraces with shell banks on the slopes of Mount Royal. On the plain about the mountain no rock exposures are seen. A mantle of drift covers it, and numerous erratic blocks and bowlders are scattered about. These are largely gneisses from the Laurentian highlands, but some of them are plutonic rocks from other hills of the Monteregian group. The plain about Mount Johnson is, however, stated by Ells, who has examined this district, to be underlain "presumably" by rocks of the Utica-Lorraine division of the Lower Silurian.

On ascending the mountain the first rock which is exposed above the drift mantle is a very fine-grained dark hornstone, uniform in character and lying in undisturbed horizontal beds. It can be seen at intervals all around the base of the mountain, forming a sort of collar, and is undoubtedly a shale such as that usually constituting the Utica formation, here however altered by its proximity to the intrusion. This shale wherever seen lies flat and abuts against the igneous rock of the intrusion, being cut sharply off by it, but not tilted or upturned. The upper limit of the shale is shown in the accompanying photograph of the mountain.

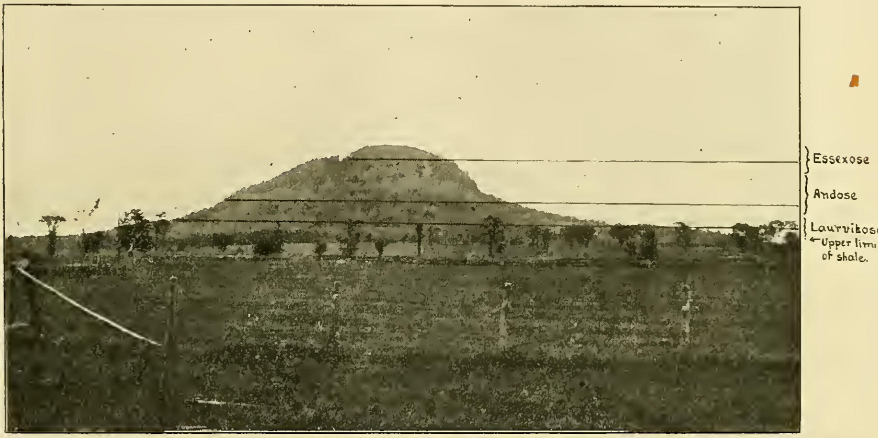

FIG. 3.—Mount Johnson, as seen from the southwest, showing limits of the several rock types composing the mountain.

The mountain above this hornstone collar is made up exclusively of igneous material, which presents a most striking and beautiful instance of differentiation.

Immediately above the hornstone collar, and in contact with it, is a coarse-grained and highly feldspathic syenite, light buff in color, of the pulaskite type. This, as the mountain is scaled, passes rather abruptly into a dark-colored rock with large porphyritic white feldspars, which in its turn loses its porphyritic character and passes into a coarse-grained essexite which constitutes the mass of the hill and which becomes at the summit finer in grain, richer in pyroxene and often holding a little olivine. No sharp lines can be drawn between these several rocks; one passes gradually into the other, the whole constituting one intrusive unit. The approximate limits of these several rock species are shown in the accompanying map (Fig. 2) and photograph (Fig. 3) of the mountain, it being impossible sharply to delimit the several species, seeing that they pass into one another. The mass therefore becomes progressively more basic as we pass from the margin of the intrusion to its center. The two chief rock types are the pulaskite and the essexite which will be separately considered. The essexite, being the more abundant rock and one presenting a greater complexity in mineralogical composition, may be first described.

Essexite.—The rock is dark in color and rather coarse in grain, and although holocrystalline usually presents a more or less marked fluidal arrangement of the constituents. This is especially marked in the zone of transition between the essexite and pulaskite, owing to the presence there of the large feldspar phenocysts which, being arranged with their longer axes parallel to the direction of flow, serve to accentuate this structure. The finer-grained variety forming the summit of the mountain is more massive in character and does not exhibit the fluidal arrangement of constituents. Under the microscope the rock is seen to be composed of the following minerals: hornblende, pyroxene, biotite, olivine, plagioclase, nepheline, sodalite, apatite, magnetite, sphene, and in some cases a very small amount of orthoclase.

There is a marked tendency on the part of all the constituents to assume an idiomorphic development. The long lath-shaped plagioclases and large hornblende individuals have an approximately parallel arrangement, and between these lie the other iron-magnesia constituents with the smaller plagioclase individuals, the nepheline and the other components of the rock. These interstitial constituents do not differ greatly in size from the others and show the same tendency to a parallel arrangement.

Hornblende.—Although almost every thin section of the rock contains not only hornblende, but pyroxene and biotite also, their relative proportion varies considerably. The hornblende is distinctly the most abundant, except in the finer-grained variety forming the summit of the mountain in which it is distinctly subordinate in amount to both pyroxene and mica. It is deep brown in color and is sometimes hypidiomorphic in its development, but often occurs with perfect crystalline form, showing the prismatic and the orthopinacoidal faces. Its extinction is larger than is usual in brown hornblendes, judging from the recorded instances, reaching 20°. It possesses a strong pleochroism as follows:

$\mathfrak{a}$ = pale yellowish-brown.
$\mathfrak{b}$ = deep-brown.
$\mathfrak{c}$ = very deep-brown.
Absorption = $\mathfrak{c} \geqq \mathfrak{b} > \mathfrak{a}$.

It is often twinned parallel to $\infty P \bar{\infty}$ or to a steep orthodome, and sometimes presents a faint zonal structure, marked by a slight difference in extinction of the several zones indicating a slight change in composition as growth proceeded, and occasionally a greenish tint is noticeable about the margin of the individual. It sometimes holds inclusions of magnetite and is often intergrown with the pyroxene. In the essexite from one place on the south side of the mountain, the hornblende was found free from inclusions, and practically free from the pyroxene which is usually so intimately associated with it. From this locality a quantity of the hornblende was obtained in a state of perfect purity through repeated separations by means of Klein's solution, all grains of foreign mineral still remaining being finally removed by picking them out by hand with the aid of a powerful lens. The pure material thus obtained was analyzed by Professor Norton Evans, of the McGill University, every precaution to secure accuracy being observed and especial care being taken to effect a complete separation of the magnesia from the alumina by the repeated precipitation of the latter. The water was estimated by a direct determination. The results of the analysis are given below, together with those of several other hornblendes of similar composition which have been added for purposes of comparison:

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
SiO_2	38.633	39.75	40.15	40.14	41.35	39.16
TiO_2	5.035	5.40	5.21	4.26	4.97	.....
Al_2O_3	11.974	15.00	14.34	14.30	13.48	14.39
Fe_2O_3	3.903	7.86	7.80	7.07	5.14	12.42
FeO	11.523	2.89	4.53	6.27	10.33	5.85
MnO	0.729	.....	.....	0.21	.....	1.50
MgO	10.200	14.16	13.14	11.62	11.44	10.52
CaO	12.807	12.97	11.75	12.00	10.93	11.18
Na_2O	3.139	1.92	2.31	2.22	2.10	2.48
K_2O	1.489	1.61	1.14	1.35	0.62	2.01
H_2O	0.330	.....	.....	.....	0.48	0.39
	99.762	101.56	100.37	99.44	100.84	99.90

No. 1. Hornblende. From the essexite of Mount Johnson, province of Quebec, Canada.

No. 2. Hornblende. From Bohemian Mittelgebirge.

No. 3. Hornblende. From tuff of hornblende basalt, Härtlingen, Nassau.

No. 4. Hornblende. Basalt tuff, Hoheberg, near Giessen.

No. 5. Hornblende. From "hornblende diabase," Gräveneck, near Weilburg.

No. 6. Hornblende. Syntagmatite. Jan Mayen.

Analyses Nos. 2 to 6 are taken from Schneider's paper referred to below.

The hornblende thus belongs to the class of basaltic hornblendes, and not to the barkevikites as might be expected. It contains, however, proportionally more of the iron in a ferrous condition, together with somewhat less alumina and a somewhat larger proportion of alkalies than most basaltic hornblendes. The unusually high extinction for a hornblende of this class which it possesses is probably connected with the high content in ferrous iron, since Schneider [1] has shown that the extinction increases with the increase of iron in this state of oxidation.

Pyroxene.—This mineral occurs intimately associated and often intergrown with the hornblende, both minerals frequently holding many inclusions of magnetite and apatite. It is very pale-greenish in color, with no perceptible pleochroism, but with a marked dispersion of the bisectrices. It is usually hypidiomorphic, but is frequently idiomorphic, showing a distinct cleavage parallel to the pinacoids, but usually none parallel to the prismatic faces. It belongs to the variety of diopside-like

[1] "Zur Kenntniss basaltischer Hornblenden," *Zeitschr. für Kryst.*, 1891, p. 579.

augites which occur in rocks of this class. The extinction is high, reaching 45°.

Biotite.—This is deep-brown and almost identical in color with the hornblende and is strongly pleochroic, $\mathfrak{c}$ yellowish-brown, and $\mathfrak{a}$ deep-brown. It occurs intimately associated with the hornblende and augite, and also frequently as a border around the iron ore. While usually present in comparatively small amount, in the finer-grained essexite forming the summit of the mountain it is much more abundant than the hornblende. In this variety of the essexite both the mica and the hornblende often possess a poikilitic structure owing to the presence of numerous inclusions of plagioclase, which mineral also often penetrates the individuals of biotite and hornblende in the form of well-developed crystals.

Olivine.—This species is found in the finer-grained variety of the essexite at the summit of the mountain, and was also observed in the thin sections from the essexite at one point on the east side of the mountain not far from the summit. It is very pale-green in color and occurs as little grains inclosed in the biotite and pyroxene.

Plagioclase.—The plagioclase in the rock has well-developed, lath-like forms and is, almost without exception, excellently twinned according to the albite law. Twinning according to the carlsbad and pericline laws is also very common, occurring in the same individuals which show the albite twinning. The laths of plagioclase can in a few cases be seen to be distinctly twisted, evidently owing to pressure exerted upon them by other crystals during the consolidation of the rock, since the rock was submitted to no dynamic action subsequent to its crystallization.

As before mentioned, all the plagioclase individuals are not of the same dimensions. There are larger laths associated with the large hornblende crystals, and between these are smaller laths. The two sets are not, however, sufficiently well marked to cause the resulting structure to be classed as porphyritic. The plagioclase in the rock is not all of the same composition, but varies somewhat, even in the same hand specimen, ranging from an extremely acid labradorite to an oligoclase. It, however, is chiefly andesine. Its character was determined by a large number of extinction measurements carried out on the albite twins, as well as by Michel-Lévy's method, which can readily be applied owing to the frequency of carlsbad twinning in association with albite twinning. These determinations were extended and checked by a number of specific-gravity determinations and separations by means of Thoulet's solution. The larger plagioclase individuals were found, in the case of the rock on the northeast side of the mountain 320 feet above the plain, to be somewhat more basic than the smaller crystals, having the composition of a basic andesine, while the latter ranged in character from andesine to oligoclase. In this case no feldspar having a specific gravity of over 2.65 was found to be present in the rock. Again in the rock of one of the quarries on the south side of the mountain, the larger feldspars tested by Michel-Lévy's method were found to have the composition of a very acid labradorite, $Ab_1 An_1$. The results of a separation of the constituents of the rock by Thoulet's solution showed that the feldspar was almost all andesine, although it varied from $Ab_1 An_1$ to an oligoclase. A crystal examined by Mr. Wright in Professor Rosenbusch's laboratory gave on P an extinction of $5°–6°$ and on M about $11°$, showing the feldspar to be on the line between andesine and labradorite. A very small amount of orthoclase was also present, forming a subordinate accessory constituent. That there is a variation in composition even in the same individual of plagioclase is indicated in many cases by marked growth rings with different extinctions in the different rings. The smaller plagioclases, although twinned in the same manner as the larger, usually have the twinning developed in a less striking manner. A certain proportion of the smaller grains are also untwinned, but most of these must be identical in character with the twinned feldspar, since the separations show that, while orthoclase is often present, it occurs in only extremely small amount. Dr. Sterry Hunt gives[1] an analysis of the feldspar from the essexite of Mount Johnson (called by him diorite). This is as follows:

[1] *Geology of Canada*, p. 477.

SiO_2	62.05
Al_2O_3	22.60
Fe_2O_3	.75
CaO	3.96
Na_2O	7.95
K_2O	1.80
Volatile	.80
	99.91

Sp. G. = 2.659.

This feldspar has the specific gravity and general composition of an acid andesine, although the high content of K_2O may possibly indicate the presence of some potash feldspar as an intergrowth.

Nepheline.—This is quite subordinate to the feldspar in amount. It possesses the usual low index of refraction, with extinction parallel to the cleavages, which latter can usually be seen. It is sometimes quite fresh, but at other times is found more or less completely altered to a mineral which occurs as little fibrous bundles, showing strong double refraction and parallel extinction. The fibers usually have a more or less distinctly parallel arrangement. This mineral remains practically unaltered when treated with concentrated hydrochloric acid for twenty minutes, although the nepheline in which it is imbedded is destroyed. It is either muscovite or kaolin. The nepheline is allotriomorphic and occurs chiefly in the corners between the larger crystals of feldspar and other minerals, and is penetrated by them. It is especially abundant in those portions of the rock which are rich in the dark-colored constituents. When occurring in this manner it appears, with the sodalite, to have been the last constituent of the rock to crystallize out. It is usually much more abundant than the sodalite. The nepheline also occurs in places as irregular-shaped lath-like inclusions in the feldspar.

Sodalite is usually, although not invariably, present. It strongly resembles the nepheline in appearance and shows the same alteration product. It is, however, quite isotropic. Like the nepheline, it occurs either in the spaces between the other minerals, cementing them together, or as inclusions in the feldspars.

Apatite.— The abundance of apatite is a distinct feature in this, as in similar rocks occurring elsewhere. It is always present and was the first constituent to crystallize out, being found in the form of perfect hexagonal prisms with double pyramidal terminations imbedded in the iron ore. It also occurs in the sphene as well as in the iron-magnesia constituents, in the nepheline, and also, although much less frequently, in the feldspar. Its large amount is shown by the high percentage of phosphoric acid in the analysis of the rock, 1.23 per cent. Another specimen of the rock in which the phosphoric acid was determined by Dr. B. J. Harrington gave 1.01 per cent. These figures represent 2.79 per cent. and 2.35 per cent. of apatite, respectively. It is usually somewhat turbid from the presence of minute dust-like inclusions.

Magnetite occurs chiefly inclosed in the iron-magnesia constituents, but is occasionally found in the feldspar. It is black, opaque, and highly magnetic, and is usually allotriomorphic, but occasionally presents an approximation to definite crystalline outline. As shown by the calculation of the analysis of the rock, this iron ore contains a considerable percentage of titanic acid.

Sphene is not found in more than one-half of the specimens examined. When present it is not very abundant and usually occurs as well-defined wedge-shaped crystals, often of considerable size.

In the accompanying table analyses are given of the normal essexite which forms the greater part of Mount Johnson, and of the finer-grained olivine-bearing variety of the same rock found at the summit of the mountain. For purposes of comparison there is presented in the same table the analysis of the essexite from Shefford mountain, which belongs to the same Monteregian province, together with analyses of the original essexite from Salem, Mass., and of allied rocks from two other localities. A partial analysis of the transitional rock between the essexite and the pulaskite of Mount Johnson is also given.

For the analysis of the Mount Johnson essexite (No. 1) as well as for that of the associated pulaskite, which is given below, I am indebted to Professor Norton-Evans, while the analysis of the olivine-bearing variety of the essexite (No. 2) was made for me by Mr. M. F. Connor. The methods recommended by Hillebrand and employed in the very accurate, analytical work carried out in the laboratory of the United States Geological Survey were followed by both analysts and every precaution was taken to insure accuracy.

	I	II	III	IV	V	VI
SiO_2	48.85	48.69	53.15	46.99	47.67	50.40
TiO_2	2.47	2.71	1.52	2.92	....	1.17
Al_2O_3	19.38	17.91	17.64	17.94	18 22	....
Fe_2O_3	4.29	3.09	3.10	2.56	3.65	5.58
FeO	4.94	6.41	4.65	7.56	3.85	
$NiO + CoO$	not det.	0.05	not det.	not det.	....	not det.
MnO	0.19	0.15	0.46	trace	0.28	0.77
MgO	2.00	3.06	2.94	3.22	6.35	....
CaO	7.98	7.30	5.66	7.85	8.03	6.77
BaO	....	0.08	0.13	none	....	....
Na_2O	5.44	5.95	5.00	6.35	4.93	6.24
K_2O	1.91	2.56	3.10	2.62	2.97	2.56
P_2O_5	1.23	1.11	0.65	0.94	....	0.09
Cl	not det.	not det.	0.07	....	....	....
H_2O	0.68	0.95	1.10	0.65	3.82	....
Total	99.36	100.02	99.84	99.60	100.15	

I. Normal essexite (andose), Mount Johnson, Quebec.

II. Olivine-bearing essexite (essexose), Mount Johnson, Quebec.

III. Essexite (akerose), Shefford mountain, Quebec, (*American Geologist*, 1901, p. 201), (with $CO_2$0.39 and $SO_3$0.28).

IV. Essexite (essexose), Salem Neck, Salem, Mass. (Washington, JOUR. GEOL., 1899, p. 57).

V. Theralite, Elbow Creek, Crazy mountains, Montana.

VI. Rock forming transition from essexite to pulaskite, Mount Johnson, Quebec. (Partial analysis. The iron present is all calculated as FeO.)

The analyses (Nos. 1 and 2) of the two varieties of the essexite from Mount Johnson can be readily calculated out so as to show the quantitative mineralogical composition of the rocks.

The calculation of the *mode*[1]—or relative proportion of the minerals actually present gives the following result:

[1] *Quantitative Classification of Igneous Rocks* (*C. I. P. W.*) (University of Chicago Press, 1903), p. 147.

	Essexite (Analysis 1) Mount Johnson		Olivine–Essexite (Analysis 2) Mount Johnson	
Albite	36.75	66.45	29.14	54.79
Anorthite	20.23		13.11	
Orthoclase	9.47		12.54	
Nepheline	3.99	4.77	11.12	11.90
Kaolin	.78		.78	
Pyroxene		6.29		12.22
Hornblende		7.05		2.30
Biotite		2.04		4.08
Olivine		none		2.84
Magnetite	5.68	9.53	3.94	8.41
Ilmenite	3.85		4.47	
Apatite		2.68		2.59
Water (hygr.)		.58		.85
		99.39		99.98

In the case of No. 1 the percentage mineralogical composition given expresses exactly the chemical composition of the rock, except that it requires 0.06 per cent. of FeO in excess of that shown in the analysis. In No. 2 the agreement is complete.

The calculation further demonstrates that the plagioclase in the case of No. 1 is a trifle more basic, and in the case of No. 2 a little more acid, than $Ab_2 An_1$, which as has been stated, is shown by the optical character and by the specific gravity of the feldspar to represent its average composition in these rocks. The amount of orthoclase recognized in thin sections also appears as mentioned in the description of the rock. The nepheline is in places somewhat altered to a mineral resembling kaolin. The small percentage of kaolin shown by the calculation has therefore been added to the nepheline in extending the table.

In order to fix the position of these rocks in the excellent system of classification recently elaborated by Messrs. Cross, Iddings, Pirsson, and Washington, and to determine the name which should be given to these rocks, if their precise character is to be designated, it is necessary to calculate their *norms*. These have been found to be as follows:

	No. 1			No. 2		
Albite		35.63	69.82		28.62	57.90
Anorthite		23.07			14.23	
Orthoclase		11.12			15.05	
Nepheline			5.40			11.83
Diopside	$34CaO.\ SiO_2$ — 3.94		7.56	$53\ CaO.\ SiO_2$ — 6.15		12.03
	$7FeO.\ SiO_2$ — .92			$18\ FeO.\ SiO_2$ — 2.38		
	$27MgO.\ SiO_2$ — 2.70			$35\ MgO.\ SiO_2$ — 3.50		
Olivine	$6\ FeO.\ \frac{1}{2}\ SiO_2$ — .61		2.22	$21\ FeO.\ \frac{1}{2}\ SiO_2$ — 2.14		5.08
	$23\ MgO.\ \frac{1}{2}\ SiO_2$ — 1.61			$42\ MgO.\ \frac{1}{2}SiO_2$ — 2.94		
Magnetite			6.26			4.41
Ilmenite			4.71			5.01
Apatite			2.68			2.59
Water			.68			.95
				BaO=.08, Excess FeO=.07		.15
			99.33			99.95

No. 1 thus takes the following position in the classification in question:

Class II, dosalane.
Order 5, germanare.
Rang 3, andase.
Subrang 4, andose (grad = polmitic).

Its precise designation would be *nepheline-bearing grano-andose* or in some cases *nepheline-bearing tracho-andose*.

No. 2, however, belongs to the next order and is domalkalic. Its position is as follows:

Class II, dosalane.
Order 6, norgare.
Rang 2, essexase.
Subrang 4, essexose (grad = prepolic).

It would therefore be termed a *nepheline-bearing grano-essexose*. It is therefore seen that the essexite from the central portion of Mount Johnson (No. 2) is practically identical in character and composition with the essexite of the original locality at Salem, Mass. (Analysis IV), while the outer andose is poorer in nepheline and has a somewhat larger proportion of lime as compared with the alkalies.

The proportions of the several minerals present in thin sections of the specimens analyzed were then determined by the system of diametral measurements proposed by Rosiwal.[1] In

[1] *Verhd. K. K. Geol. Reichsanst.* (Wien, 1898), p. 143.

each case over 500 average diameters were measured instead of 100, which latter number Rosiwal considers to be sufficient. The measurements were, however, confined to a small number of thin sections, namely two in the case of No. 1, and four in the case of No. 2, it being considered advisable to use only sections cut from the actual specimen from which the material for analysis was taken. The results obtained were as follows:

	No. 1	No. 2
Feldspar	63.77 per cent.	64.06 per cent.
Nepheline	6.12 "	6.16 "
Pyroxene	9.26 "	13.60 "
Hornblende	8.06 "	1.29 "
Biotite	2.11 "	4.07 "
Olivine	.....	1.40 "
Iron Ore	8.56 "	8.10 "
Apatite	2.12 "	1.29 "
	100.00 "	99.97 "

In the case of No. 1 the results are substantially the same as the calculated *mode* except that there is about 3 per cent. more pyroxene and a correspondingly smaller proportion of feldspar. This relatively high proportion of pyroxene is unusual, the examination of thin sections of the rock for various parts of the mountain showing that, as has been stated above, and as is shown also by the calculation of the *mode* of this specimen, there is usually a preponderance of hornblende over pyroxene. In the case of No. 2 the chief difference between the values measured and the calculated *mode* lies in the relatively higher proportion of feldspar and lower proportion of nepheline in the former. In this rock, however, it is very difficult to distinguish the nepheline from the feldspar in every case. These discrepancies indicate that in applying Rosiwal's method to comparatively coarse-grained rocks such as these, especially if there be any tendency to irregularity in composition a considerable number of thin sections should be employed in order to obtain a true average of the rock as a whole.

For purposes of comparison the analysis of the essexite from Shefford mountain (No. III) has been reduced to its normative form and the position of the rock in the Quantitative classification determined. It is found to be as follows:

Class II, dosalane.
Order 5, germanare.
Rang 3, monzonase.
Subrang 4, akerose (grad = polmitic).

It thus, in composition, occupies, in a manner, a middle place between the essexose and andose of Mount Johnson.

THE PULASKITE.—This soda-syenite which, as above mentioned, forms the outer zone of the mountain, girdling the essexite, is less abundant than the latter and differs greatly from it in appearance. This difference is due chiefly to the fact that it is much lighter in color, being pale-yellow or buff instead of dark-gray, the lighter color being due to the very small proportion of iron-magnesia constituents present and the marked preponderance of the feldspars. The rock also has a more massive structure, the fluidal arrangement of the constituents often met with in the essexite being absent, and it weathers in a somewhat different manner. It possesses, moreover, a species of porphyritic structure, owing to the development of the feldspar in two forms: first, as stout prisms, up to 10^{mm} in diameter, which are light-gray in color and very abundant; and, secondly, in the form of smaller laths of a yellow or buff color which, in association with the iron-magnesia and other constituents, form a sort of groundmass in the rock.

The constituent minerals of the rock are biotite, hornblende, (pyroxene), soda-orthoclase, nepheline, sodalite, apatite, magnetite, and sphene. The darker constituents are identical in character with those occurring in the essexite, and therefore do not require to be described again. Not only are they as a class much less abundant in this pulaskite, but the mica here preponderates, being the prevailing iron-magnesia constituent, while the hornblende is much less abundant and the pyroxene is entirely absent. It may be noted, however, that the hornblende sometimes possesses the greenish tint referred to as occasionally seen about the borders of the hornblende individuals in the essexite, indicating probably that, the pulaskite magma being richer in soda, the hornblende crystallizing out of it has a tendency to take up this element more abundantly.

The feldspar in the pulaskite, as has been mentioned, occurs in part as stout prisms and in part as smaller laths. The latter usually have a somewhat cloudy appearance under the microscope, probably owing to incipient alteration. The larger feldspars are what is commonly described as soda-orthoclase. When examined under the microscope they are seen to be composed of very minute intergrowths of two, and in some cases perhaps even of three, different feldspars — causing them to present between crossed nicols a mottled appearance. These several feldspars have somewhat different indices of refraction, and frequently under a high power, where two are present, one of them can be seen to possess a very minute polysynthetic twinning, while the other is untwinned. The relative proportion of the several feldspars present differs in different grains. The individuals as a whole occasionally present the form of carlsbad twins but usually have the appearance of simple crystals, and Professor Rosenbusch, to whom sections of the work were submitted, considers the feldspars composing them to be microcline, and in part microcline-microperthite, with probably some anorthoclase.

The specific gravity of these phenocrysts was determined in the case of two hand specimens of the pulaskite from different parts of the mountain. In the first of these three specimens of the feldspar were found to have specific gravities of 2.62, 2.609, and 2.603, respectively; while in the second, five specimens of the feldspar were selected and found to have specific gravities lying between orthoclase and albite, which bears out the results of their microscopic study.

The smaller lath-shaped feldspars, although more frequently composed of a single species, often show an intergrowth of two feldspars, as described in the case of the phenocrysts. Separations of the constituents of several species of the rock by means of Thoulet's solution show that these smaller feldspars have a somewhat lower specific gravity than the phenocrysts. Thus, while the specific gravity of the phenocrysts lies between 2.591, and 2.62, that of the smaller feldspars is between 2.591 and 2.56; that is to say, the smaller feldspars approach more nearly to pure orthoclase in composition. They consist chiefly of minute intergrowths of orthoclase with albite, or of either of these with microcline or anorthoclase. No lime-soda feldspar could be recognized in any specimen of the rock.

Nepheline and sodalite.—These minerals are quite subordinate in amount, although they are seen in nearly every thin section. Both minerals present the same characters and occur in the same way as in the essexite, lying chiefly in the corners between the other constituents being penetrated by the latter, but also occurring as inclusions in the feldspar. They are, as a general rule, much altered to the same decomposition product seen in nephe-

	VII	VIII	IX	X	XI	XII
SiO_2	57.44	59.96	65.43	56.45	59.01	60.03
TiO_2	1.97	0.66	0.16	0.29	0.81	.....
Al_2O_3	19.43	19.12	16.96	20.08	18.18	20.76
Fe_2O_3	1.69	1.85	1.55	1.31	1.63	4.01
FeO	2.70	1.73	1.53	4.39	3.65	0.75
MnO	0.25	0.49	0.40	0.09	0.03	trace
MgO	1.16	0.65	0.22	0.63	1.05	0.80
CaO	2.66	2.24	1.36	2.14	2.40	2.62
BaO	not det.	.12	none	.....	.08	.....
Na_2O	6.48	6.98	5.95	5.61	7.03	5.96
K_2O	4.28	4.91	5.36	7.13	5.34	5.48
P_2O_5	0.60	0.14	0.02	0.13	trace	0.07
SO_3	not det.	0.08	0.06	.....	.....	.....
Cl	trace	0.14	0.04	0.43	0.12	.....
H_2O	1.03	1.10	0.82	1.51	0.50	0.59
	99.69	100.17	99.86	100.19	99.98	101.07

VII. Pulaskite (laurvikose), Mount Johnson, Quebec.

VIII. Pulaskite (laurvikose), Shefford mountain, Quebec. (*American Geologist*, 1901, p. 211.)

IX. Nordmarkite (nordmarkose), Shefford mountain, Quebec. (*Ibid.*, 1901, p. 209.)

X. Sodalite syenite, Square Butte, Montana (differentiation product of shonkinite).

XI. Umptekite, Red Hill, Moltonboro, New Hampshire.

XII. Pulaskite, Fourche mountain, Arkansas (original locality).

line in the essexite and which is, as has been mentioned, either kaolin or muscovite. Probably both are present.

Apatite is present in considerable amount and in the form of perfect crystals, occurring chiefly in the mica, hornblende, and sphene.

The *iron ore* and *sphene* present the same characters as in the case of the essexite, but the latter mineral is relatively more abundant than in that rock.

An analysis of this pulaskite is given in the accompanying table together with analysis of the pulaskite and the nordmarkite of Shefford mountain described by Dresser. Analysis of three allied rocks from other localities are added for purposes of comparison.

The *mode* of the Mount Johnson pulaskite (No. VII), calculated from the analysis given above, is as follows:

Albite - - - -	48.73	74.03
Anorthite - - - -	3.06	
Orthoclase and microcline	22.24	
Nepheline - - - -		2.56
Kaolin - - - - -		4.96
Hornblende - - - -		5.08
Biotite - - - - -		6.29
Magnetite - - - -	1.86	2.77
Ilmenite - - - - -	0.91	
Sphene - - - - -		2.35
Apatite - - - - -		1.34
Water (hygroscopic) - - -		0.30
		99.68

This proportion of the various minerals expresses exactly the chemical composition of the rock as presented by the analysis, except that a very small excess of silica, amounting to 0.06 per cent., is required.

The calculation shows clearly the fact, ascertained by the study of the thin sections of the rock, that a considerable percentage of sphene is present, a mineral which does not occur at all in the essexite.

The anorthite is probably in combination with the other feldspathic constituents in the form of anorthoclase. The calculation also brings out clearly a point already mentioned, namely, that in this rock the nepheline is much more highly altered than in the essexite, as shown by the amount of kaolin present. This kaolin, however, is not entirely derived from the alteration of the nepheline, but appears as a haze all through the smaller feldspars, and hence in the extension of the results should be assigned in part to the nepheline and in part to the feldspar. It is of course impossible to measure the amount of kaolin present by Rosiwal's method, occurring as it does distributed through the sections in the form of extremely minute individuals. If, however, the amount of nepheline given by the Rosiwal measurement be correct, namely 4.40 per cent.—and this of course includes both the unaltered mineral and that filled with decomposition products—then 1.84 per cent. of the kaolin has been derived from the alteration of the nepheline. There will thus remain 3.12 per cent. of the kaolin which has been derived from and measured up with the feldspar. If this amount be added to the feldspar found by calculation, it will increase the proportion present to 77.15 per cent., which is within 0.09 per cent. of the percentage of feldspar obtained by the Rosiwal measurement.

The *norm* of the pulaskite is found to be as follows:

Albite		50.30	85.61
Anorthite		9.73	
Orthoclase		25.58	
Nepheline			2.56
Olivine	$2MgO.SiO_2$	2.03	2.54
	$2FeO.SiO_2$	0.51	
Corundum			0.41
Magnetite			2.55
Ilmenite			3.80
Apatite			1.34
Water			1.03
			99.84

Its position is, therefore, as follows:

Class I, persalane.
Order 5, canadare.
Rang 2, pulaskase.
Subrang 4, laurvikose.

It should thus be termed a *grano-laurvikose* or possibly, in view of its somewhat porphyritic structure, a *granophyro-laurvikose*. The proportions of the several minerals present, or *mode*, as determined by Rosiwal's method were as follows:

Feldspar	77.24	per cent.
Nepheline	4.40	"
Hornblende	5.37	"
Biotite	7.08	"
Iron ore	1.81	"
Sphene	3.29	"
Apatite	.81	"
	100.00	

For purposes of comparison the analysis of the pulaskite (No. VIII) and of the nordmarkite (No. IX) of Shefford mountain were calculated into their respective *norms* and the position of these rocks in the new system of classification determined. The pulaskite (No. VIII) is found to have the following position:

Class I, persalane.
Order 5, canadare.
Rang 2, pulaskase.
Subrang 4, laurvikose.

The nordmarkite (No. IX), however is peralkalic and must be classified as follows:

Class I, persalane.
Order 5, canadare.
Rang 1, nordmarkase.
Subrang 4, nordmarkose.

It, however, lies just on the line between nordmarkose and phlegrose, and might thus be best termed a nordmarkose-phlegrose.

It is thus seen that the rocks from Mount Johnson and from Shefford mountain which, following Rosenbusch's classification, have been called pulaskite, and which in this new scheme of classification are pulaskase, are almost identical in composition with one another and with the Norwegian laurvikite, and the nordmarkite of Shefford mountain is very close in composition to the nordmarkose of the original Scandinavian locality.

Diagrams showing the composition of these several rocks are presented in Fig. 4.

The transitional rock.—As has been mentioned, there intervenes in Mount Johnson between the pulaskite border and the central mass of essexite a transitional zone consisting of a rock which is dark in color and thus resembles the essexite, but which is characterized by the presence of large porphyritic feldspars sometimes as much as two inches in length, of peculiar form scattered through it and often arranged with their larger axes in the same direction, thus giving a fluidal appearance to the rock. This rock contains a large proportion of the same iron-magnesia minerals, more especially the hornblende, found in the essexite, and passes over gradually into this rock. Its passage into the pulaskite is rather more abrupt and is marked chiefly by the almost entire disappearance of the dark-colored constituents above mentioned. There is, however, a continuous transition or passage from the pulaskite through this intermediate rock into the inner essexite of the mountain.

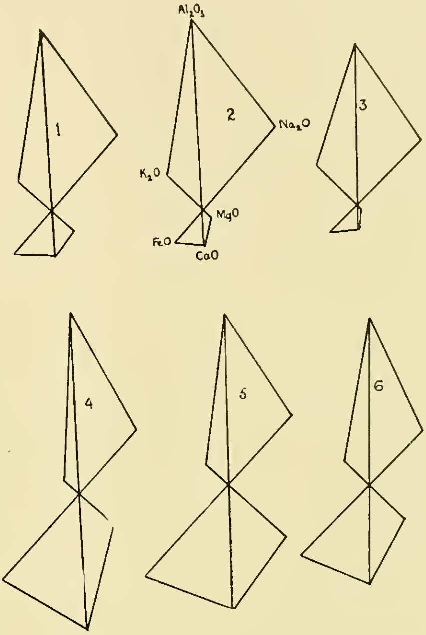

Fig. 4.—Diagrammatic representation of the chemical composition of the several rocks described.

No. 1. Laurvikose — Mount Johnson.
No. 2. Laurvikose — Shefford mountain.
No. 3. Nordmarkose—Shefford mountain.
No. 4. Andose — Mount Johnson.
No. 5. Essexose — Mount Johnson.
No. 6. Andose — Shefford mountain.

This transitional rock is composed of the same minerals as the essexite with the exception of the feldspar, which consists in part of the soda-orthoclase characteristic of the pulaskite, and in part of the plagioclase (in this case oligoclase) which forms the feldspathic element of the essexite. It is thus in mineralogical composition intermediate between these two rocks, although, as above mentioned, being rich in the dark-colored constituents, it more closely resembles the latter.

The large feldspars have frequently a peculiar crystalline form giving to the mineral, when broken across, a perfect hexagonal outline. The six faces represented in this form are apparently T, L, and M. The crystals hold many little inclusions of pyroxene, biotite, hornblende, magnetite, sphene, and nepheline, often regularly arranged so as to give a zonal structure to the feldspar individual. The specific gravity of twelve small fragments of the feldspar of these large crystals, collected from a locality on the southern side of the mountain and as free as possible from all inclusions, was determined. The specific gravity of nine of these lay between 2.59 and 2.607, while that of the other three was between 2.625 and 2.628. This shows the feldspar in the former case to be identical with that of the pulaskite, while in the latter three the specific gravity lies between that of albite and oligoclase. The somewhat greater specific gravity in this case may be due in part to inclusions of other minerals. A separation of the constituents of the rock shows, however, that, as above mentioned, a considerable amount of oligoclase is really present. The feldspar individuals, both great and small, usually show in thin sections the mottled character due to the intergrowth of different species, described in the pulaskite. A partial analysis of a specimen of this intermediate rock, from the south side of the mountain, is given in the accompanying table of analyses (No. VI), on page 265. As will be seen, in chemical composition as well as in mineralogical character, it occupies a position intermediate between the essexite and the pulaskite, occurring on either side of it, thus representing an intermediate zone in which the differentation was not quite completed. It is, however, much more nearly allied to the essexite, being alkalicalcic and dosodic, and although in the absence of a complete analysis or detailed measurements its position in the new classification cannot be determined with absolute certainty, there is very little doubt that it also, like the essexite adjacent to it, is an andose.

Dykes.—A feature in connection with Mount Johnson, and one possibly connected with its somewhat peculiar structure, is the almost entire absence of dykes. These were found only in two places, and in both cases the dykes were small in size. The first of these localities is on the northeastern margin of the intrusion, where the dyke occurs in association with and probably cutting the hornstone. It was found as large angular blocks in the heavy maple bush which here covers the slope of the mountain, but is undoubtedly in place in the immediate vicinity. The rock is very dark gray in color and very fine in grain, and belongs to the camptonites. It has a porphyritic structure, the very numerous phenocrysts consisting of hornblende and pyroxene. The hornblende phenocrysts are deep-brown in color and strongly pleochroic, the mineral being the same basaltic hornblende described in the essexite. The pyroxene of the phenocrysts is pale purplish in color and shows a marked dispersion of the bisectrices. Both minerals have very perfect crystalline forms. The plagioclase of the rock is very basic in character, as shown by its high extension. The rock resembles very closely certain occurrences found on Mount Royal. The size of this dyke is not known, but it probably has not a width of more than a foot or two. The other dykes occur on the southeastern slope of the mountain by the side of the road leading down from the quarries here. At this locality there are four small dykes, the largest only a foot in width, cutting the essexite. These are all very fine in grain and much decomposed, but represent two varieties of rock. Two of the smallest are composed of a camptonite consisting of a groundmass of brownish hornblende and plagioclase, with lath-shaped plagioclase phenocrysts. The other two dykes consist of a rusty weathering rock, made up of feldspar laths and a mass of pseudomorphs of limonite after some prismatic mineral, probably either ægerin or arfvedsonite. Professor Rosenbusch considers it to be a highly altered tinguaite or sölvsbergite, probably the latter.

The several dykes, while small and unimportant in themselves, are of interest in that they present the petrographical types regularly associated with the alkaline rich intrusions of the class represented in Mount Johnson.

The Structure of Mount Johnson.—The structure of the mountain and the character of the rocks composing it also throw some light on the question as to where the differentiation took place. In course of conversation with the foreman of one of the quarries in the essexite on the flank of the mountain, the writer was informed by him that Mount Johnson consisted of three layers of horizontal rock; a fine-grained one on top, below which

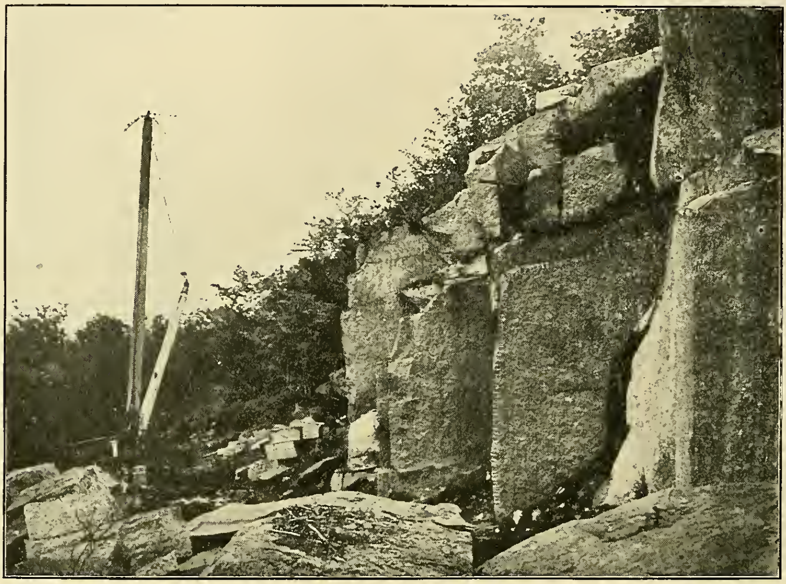

Fig. 5.—Quarry in andose, Mount Johnson, showing vertical flow structure on right.

was the coarser-grained rock of the quarry, and beneath this a spotted variety. Each of these layers, he considered, went through the mountain horizontally and could be seen outcropping at their respective levels on every side. The three rocks referred to were, as will be recognized, the fine-grained essexose, the andose, and the transitional rock below the latter, respectively. The pulaskite zone he had not noticed, it being at the base of the mountain and in many places more or less covered with fallen blocks and talus. If this were the true interpretation of the structure, the mountain would have to be considered as the remnant of a laccolite which had been intruded between the horizontal Silurian strata and which had subsequently been almost entirely removed by peripheral denudation. This has been shown to be the true explanation of the origin of some of the occurrences, formerly supposed to be intrusive stocks, in the western portion of the United States, and it was at first considered as a possible explanation of the origin of Mount Johnson. A careful examination of the mountain, however, shows that such an explanation of its origin is untenable, and that it is a true neck, due to the filling up of a nearly circular perforation in the horizontal strata of the plain, by an upward moving magma.

The evidence of this is to be found in the direction of the banding or fluidal arrangement of the crystals in the essexite already referred to and shown in Fig. 5. This fluidal arrangement is seen in most large exposures of the essexite and with especial distinctness in the great faces of this rock exposed in the quarries on the mountain side, and it is always vertical, showing that the movement of the rock was upward through the pipe, and not outward and horizontally over the pulaskite, as it would have been in the case of a laccolite. Furthermore, in several cases when the fluidal arrangement is very distinct and has a somewhat banded character, as shown in Fig. 6, due to the alternation of somewhat more feldspathic portions of the rock with others richer in iron-magnesia constituents, a strike can be made out on horizontal surfaces, and this strike curves around the mountain, following its marginal outline, as shown in the map, Fig. 2.

It is thus clear that Mount Johnson is a neck in its most typical form. A cross-section of the mountain is shown in Fig. 7. The opening occupied by the intrusion was in all probability formed by the perforation of the horizontal shales at this point by the explosive action of the steam and vapors preceding the eruption proper, as it presents exactly the features reproduced by Daubrée in his highly suggestive experiments on the penetrating action of exploding gases. It is, in fact, what he terms a *diatrème*.

Des perforations aussi remarkables, tant par leurs formes que par les communications qu'elles ont établies avec les profondeurs du sol, constituent, parmi les cassures terrestres, un type assez nettement charactérisé pour mériter d'être distingué par une dénomination précise et cosmopolite. Le nom de diatrème rapelle l'origine probable de ces trouées naturelles, véritables *tunnels verticaux*, qui se rattachent souvent, comme un incident particulier, aux cassures linéaires, diaclases et paraclases.[1]

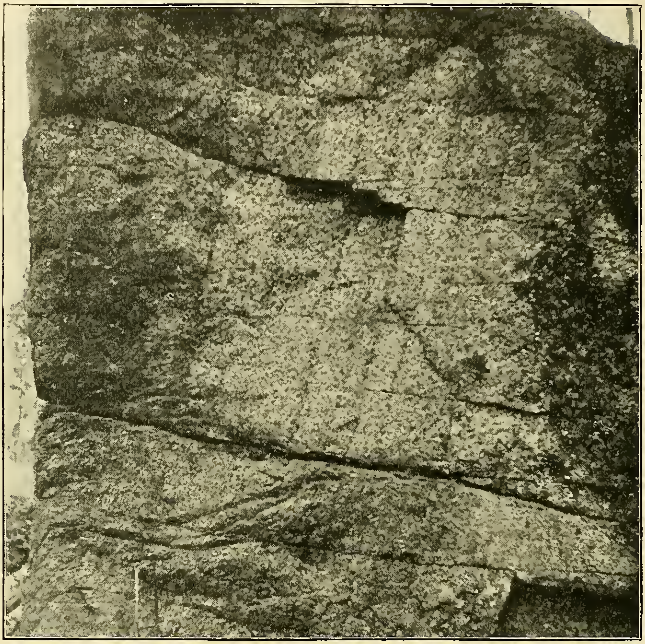

FIG. 6.— Andose in quarry on Mount Johnson, showing vertical flow structure.

The occurrence is one which presents a close resemblance to the remarkable volcanic necks recently described by Sir Archibald Geikie[2] in East Fife, and also to those described by Branco,[3] in Würtemberg. Mount Johnson, however, is a neck occurring

[1] "Recherches expérimentales sur le rôle possible des gaz à hautes températures doués de très fortes pressions, etc.," *Bull. de la Soc. Géol. de France*, 3e série, tome XIX (1891), p. 328.

[2] *The Volcanic Necks of East Fife.* Glasgow: Hedderwich & Sons.

[3] *Schwabens 125 Vulcan-Embryonen und deren tufferfüllte Ausbruchsröhren das grösste Gebiet ehemaliger Maare auf der Erde.* Tübingen, 1894.

in an area which has undergone much more extensive denudation since the time of the intrusion than in the cases above mentioned, and as a consequence of this the fragmental material which fills some, although not all of the necks referred to above, has been entirely swept away.

In view of the fact, then, that Mount Johnson is a neck or pipe of comparatively small sectional area, in which the differentiation is very complete, but in which the magma did not remain at rest, but was not long prior to final consolidation,

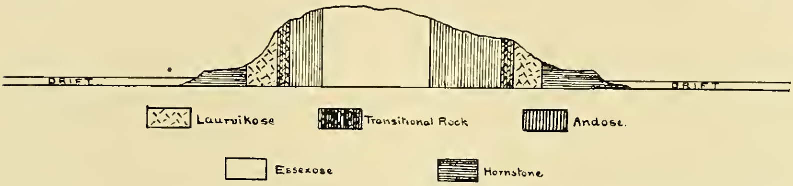

FIG. 7.— Diagrammatic cross-section of Mount Johnson, showing the relation of the several rock types.

moving upward, it seems improbable that the marked differentiation of the magma into the several varieties described in this paper took place while the magma was in the pipe itself. The evidence points rather to the differentiation of the mass having already taken place in the reservoir of molten rock beneath, which was tapped by the pipe. If this be the case, it would seem that the upper and more acid portion of the magma, represented by the lighter pulaskite, had collected in the upper portion of the reservoir, and that the essexite formed a lower, more basic, and heavier stratum or part. When the passage to the surface was opened up, the pulaskite would first rise in it and, after a more or less long-continued flow, being followed by the essexite, would be pressed toward the circumference of the pipe, the more basic rock occupying the central portion of the passage, and the most basic variety, originally lower, would be found in the central axis of the neck. The fact that, while the essexite forms the mass of the intrusion, there is a zone of pulaskite about it, would seem to indicate that there had not been at this center of volcanic activity any very protracted outpouring of the essexite, since, had this been the case, it would seem probable that the pipe would have in time been cleared of the earlier pulaskite magma.

The interesting question of the succession of the eruption of the several magmas in this petrographical province, as well as the causes of their differentiation, can be more profitably discussed when the other centers of eruption have been more thoroughly studied. It is interesting to note the cumulative evidence in favor of differentiation as an explanation of the origin of these and similar groups of rocks, arising not only from the repeated association of the various members of the group at many centers in a single area like that described in the present paper, but also at centers widely separated from one another in different parts of the world. The occurrences described by Ramsay[1] in the Kola peninsula may be especially noted in this connection as closely allied to those of the Monteregian hills, a soda-syenite (umptekite) occurring about the margin of an intrusion of the nepheline-syenite which constitutes the *massive*, while theralite is also found as a differentiation product of the same intrusion.

The author desires to acknowledge his indebtedness in connection with this investigation to Miss Rosalind Watson, of Victoria, B. C., who, when a student at this university began the study of Mount Johnson; also to Professor Rosenbusch, Professor Iddings, and Professor C. H. McLeod for valuable aid during the course of the work.

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[1] *Das Nephelinsyenitgebiet auf der Halbinsel Kola.* Fennia 11, No. 2. Helsingfors, 1894.

FORAMINIFERAL OOZE IN THE COALMEASURES OF IOWA.

Last summer the writer gathered a number of specimens of the marls, shales, sandstones, and limestones from the Missourian stage of the coalmeasures in Fremont and Mills counties in Iowa. It was desired to study more closely their mechanical structure. A number of the samples were cut and polished, and many were crushed and washed, and the fragments separated by means of a series of sieves, and then examined under the lens and the microscope. In the course of this work several minute fossils were observed that would otherwise have escaped my attention. Among such were various apparently chitinous denticles and plates of brown color, some resembling in form the jaws of Nereidavus, described from the Devonian, and other forms, more frequent, resembling fragments of the radulæ of gasteropods.

More frequent still were several kinds of foraminifera, such as an Endothyra, a Textularia, and an Ammodiscus. The delicate tests of these little animals were found to be quite generally distributed through the whole section of the Missourian in these two counties, excepting arenaceous strata. In rocks which had been leached and weathered they were not to be found. Such frail shells are evidently the first to suffer from oxidation and leaching.

The upper part of one ledge of limestone was found to be really an indurated ooze composed almost wholly of the shells of an Ammodiscus. It consisted of microscopic tubes, irregularly curved and twisted. The rock might be described as consisting of a feltwork of such tubes, with the interstices filled with transparent compact calcareous material. This ledge is in the upper part of the main quarry rock in the bluffs in section 16 in Lyons township in Mills county. It was also noted in the same position in these ledges in the bluffs, six miles farther south, in section 14, Scott township, in Fremont county. It has a thickness varying from two to six inches. Evidently it was originally a foraminiferal ooze, which has later been indurated by the infiltration and deposition of a strong calcareous matrix.

The occurrence of such an ooze in the rocks of this age in Iowa, in close association with great numbers of *Fusulina cylindrica*, is interesting as showing the luxuriance of the foraminiferal fauna of the time, and also as furnishing an additional item for consideration in correlating the uppermost members of the Carboniferous of America with those of Europe, where the same forms occur at about the same level in the geological scale. A full account of the other fossils of these beds will be published in the next volume of the annual reports of the Iowa Geological Survey. They represent the uppermost strata of the coal-measures in the state. It may not be amiss in this connection to record the fact that the author some years ago observed related, if not identical, foraminifera in the higher strata of the coal-measures at La Salle in Illinois.

Some of the material from Iowa was forwarded to Professor E. Schellwien, of Königsberg, Germany, for exact identification, and I take the liberty to quote from his reply as follows:

> Das zugesandte stück kalk enthält ganz besonders häufig die kleinen schälchen von Ammodisciden und zwar einmal von *Ammodiscus* s. str., dann aber noch häufiger von unregelmässig aufgerollten formen von *Ammodiscus*, welche ähnlich gestaltet sind, wie *Am. inversus* und die ebenso wie dieser zur untergattung *Psammophis* gehören. Derartige formen sind bisher nur im Obercarbon (höhere schichten desselben) gefunden. . . . . Derselbe kalk enthält ausserdem eíne kleine *Endothyra*, welche ebenfalls am ehesten mit einer vorwiegend im Obercarbon beobachteten aber auch im Untercarbon auftretenden art, *Endothyra parva* Möll., übereinstimmt.

J. A. UDDEN.

THE VARIATION OF GLACIERS. VIII.[1]

THE following is a summary of the Sixth Annual Report of the International Committee on Glaciers:[2]

REPORT OF GLACIERS FOR 1901.

Swiss Alps.—Of the ninety-four glaciers which have been observed by the Swiss Foresters all, with one exception, are retreating. We have no reason to think that the other sixty-eight known glaciers which have not been specially observed are doing differently. The only glacier advancing in 1901 was the Boveyre, in the Valais. Its advance, which has amounted to one hundred and eight meters in ten years, is the result of a large avalanche which fell upon the glacier and so increased its thickness as to permit a considerable increase in length before the ice melted. A few glaciers show a hesitancy in their retreat, but this does not alter the statement that the Swiss glaciers are receding.[3]

Eastern Alps.—The greater number of the fifty-five glaciers observed are retreating. A small number, however, are advancing. The most remarkable of all these is the Vernagt glacier, in the Oetzthal, which has continued its remarkable advance and has gained fifty meters since 1900. Its velocity has increased at the same time from 210 to 250 meters a year. No glacier of the Alps within the last fifty years has shown so remarkable a growth.

The independence of neighboring glaciers with regard to their advance or retreat is sometimes characteristic even of different parts of the same glacier. For instance: Presena glacier, in the Adamello group, has three tongues; in 1901 the central was sensibly longer than in 1895; the other two, on the contrary,

[1] The earlier reports appeared in the JOUR. GEOL., Vol. III, pp. 278–88; Vol. V, pp. 378–83; Vol. VI, pp. 473–6; Vol. VII, pp. 217–25; Vol. VIII, pp. 154–9; Vol. IX, pp. 250–54; Vol. X, pp. 313–17.

[2] *Archives des sciences phys. et nat.*, Geneva, Vol. XII (1902), pp. 282–302.

[3] Report of Professor Forel and M. Muret.

were much shorter. The Gaisbergferner in the Oetzthal also exhibits certain peculiarities; the right half was advancing up to 1895, but has since then retreated; whereas the left half was retreating from 1894 until two years ago (with the exception of one year, 1898–99), and is now advancing.[1]

Italian Alps.—All the glaciers observed in the Italian Alps are retreating. On the south side of Monte Rosa a few small glaciers have disappeared altogether. A historical study of the two following glacier show these variations:

Macugnaga glacier: Advance, 1780; retreat, ?; great advance, 1820; retreat, 1820–45; advance, 1845–60; retreat, 1860–81; advance, 1881–93; retreat, 1893—.

Lys glacier: Advance, end of seventeenth century; retreat, ?; advance, 1820; retreat, 1820–52; advance, 1852–59; retreat, 1859–84; advance, 1884–89; retreat, 1889—.[2]

French Alps.—The only observations made of the French glaciers are in the groups of the Pelvoux and of the Chambeyron, in Dauphiné, where all the glaciers observed are in retreat. The glacier Blanc, which has lately been advancing, has joined the general retreat. The Marinet glaciers, the most southerly in the French Alps, are decreasing very remarkably. In general the glaciers of Dauphiné are retreating strongly, with the probability that before long some of them will entirely disappear.[3]

Scandinavian Alps.—One glacier in the mountains north of Kvikkjökle, in Lapland, retreated ten meters from 1900 to 1901. This may be due to the extraordinary heat of last summer, when the maximum temperature of Kvikkjökle was above 60° F. The Suotes glacier, on the other hand, has advanced fifteen to twenty meters since 1896.[4]

Caucasus.—All the glaciers which have been visited are retreating, with the exception of the Devdorak, which is advan-

[1] Report of Professor Richter. These peculiarities are undoubtedly the result of the different parts of these glaciers being fed from different reservoirs.

An excellent historical study of the literature of moraines has been made by Dr. August Böhm, with references to the original sources of information. *Abhand. d. K. K. Geograph. Gesells. in Wien*, 1901, Vol. III, No. 4.

[2] Report of Professor Porro. [3] Report of M. Kilian. [4] Report of M. Svenonius.

cing. Stations have been fixed for the future study of a number of glaciers, and many new glaciers not heretofore known have been discovered.

Nova Zembla.—Colonel Wilkizky has discovered a number of large glaciers on the eastern side of the northern island, which reach the sea and form icebergs.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1902.[1]

The ice shaken from Muir glacier by the earthquake in September, 1899, still prevents steamers from approaching the glacier. Last summer one of the steamers succeeded in going to within four miles of the glacier, and the captain reports that a new face can now be seen over the floating ice. From his descriptions and the sketch he made it appears that the new face is about a mile and a half back of its former position; and the nunatak bounding Morse glacier on the north is now washed by the inlet (*Davidson*). It is probable also that Dirt glacier has been separated from Muir.

Explorations in the Copper river basin lead to the conclusion that the maximum glaciation of this region was far more extensive than has hitherto been recognized. It seems that the Wrangell and the Alaskan mountains were the centers of a great ice-sheet which flowed southward well up into the Chugach mountains; and that the latter range also supported a continuous sheet of ice on the southern flanks[2] (*Schrader* and *Spencer*).

According to Indian tradition, Miles and Childs glaciers, which lie on opposite sides of the Copper river, were formerly united, and the river flowed under them. Between 1894 and 1898 the southern side of Miles glacier retreated five or six miles, and the Childs glacier five or six hundred yards. Between 1894 and 1902 Valdez glacier and Shoup glacier, near by, retreated about a mile; the latter was at the water's edge in 1884[3] (*Abercrombie*).

[1] A synopsis of this report will appear in the Eighth Annual Report of the International Committee. The report on the glaciers of the United States for 1900 was given in this JOURNAL, Vol. X, pp. 316, 317.

[2] "The Copper River District, Alaska," *Twenty-second Ann. Rept. U.S. Geol. Surv.* A map accompanies the report and shows the location of many large glaciers, but no information is given regarding their present variations.

[3] The Copper River Exploring Expedition, 1899.

There are no reports of the glaciers of Mount Hood and Mount Adams, but there was a greater snow-fall on Adams in 1902 than in 1901; and even in 1901 the snow lasted very late, being still in the timber in the middle of August (*Rusk*).

A dozen small glaciers about the heads of Kern and King rivers in the Sierra Nevada mountains of California have receded slightly in the last few years (*Muir*). The snow-fall in these mountains has been below the average for some years (*Le Conte*).

In the Rocky mountains of Colorado also the snow-fall for the past three years has been deficient and the summer melting excessive. As a consequence Arapahoe glacier is rapidly retreating, as shown by masses of débris-covered ice in advance of, and disconnected from, the glacier. Also a recently deposited moraine which stands about forty feet above the present level of the ice is so extremely fresh that the fine gravel and mud have been scarcely affected by the rain. Professor Fenneman thinks the ice was level with it within a year, which indicates a melting down of forty feet in that time. Photographs taken in former years show this moraine standing above the ice; so that, if the conclusion drawn above is correct, the Arapahoe glacier has experienced unusually violent fluctuations within the past few years. This small glacier, with an area of about a quarter square mile only, apparently exhibits the phenomena of the blue bands and stratification extremely well[1] (*Fenneman*).

A number of glaciers in northern Montana have been visited and mapped during the past summer. They are the remnants of much larger glaciers; only one or two have areas approaching three square miles. They appear in general to occupy shelves on the mountain sides and are broader than they are long. So far as could be observed, their moraines show that they are shrinking (*F. E. Matthes, by permission of the director of the U. S. Geological Survey*).

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April 8, 1903.

[1] "The Arapahoe Glacier in 1902," this JOURNAL, Vol. X (1902), pp. 839–51.

THE PRE-POTSDAM PENEPLAIN OF THE PRE-CAMBRIAN OF NORTH-CENTRAL WISCONSIN.

THE region of central and northern Wisconsin consists principally of various igneous and sedimentary rocks of pre-Cambrian age surrounded and overlapped on the southeast, south, and southwest by nearly horizontal beds of Paleozoic sedimentaries having a slight dip downward and away from the central core of the pre-Cambrian. The highest portion of the pre-Cambrian region is the divide between the waters of Lake Michigan and the Mississippi river on the south and of Lake Superior on the north. This divide lies from fifteen to thirty miles south of Lake Superior and trends in a direction slightly north of east into northern Michigan. The surface of the pre-Cambrian is gently sloping, with a more gentle inclination to the south than to the north.

The present paper describes the physiography of the southward-sloping portion of the pre-Cambrian area and particularly that part in central Wisconsin[1] in Taylor, Lincoln, Marathon, Portage, Wood, Clark, and Jackson counties which is adjacent to the Paleozoic area. A part of this section of the state is either free from drift or very sparingly covered with drift of one or more of the earlier glacial epochs, and is thus better adapted than other portions of the Lake Superior region for a study of the older non-glacial features of the land surface. The physiography of this area, including also the post-Cambrian of the southern part of the state, has been referred to by Professor Van Hise[2] in a brief description of a base-level in central Wisconsin, a reference to which is again made in a later part of this paper.

Surface feature of the pre-Cambrian.— If one should climb the hill immediately northwest of Wausau and look eastward across

[1] See Plate I, *Atlas of the Geology of Wisconsin*, 1881, or Plate I, *Bull. IV, Wis. Geol. and Nat. Hist. Surv.*

[2] *Science*, Vol. IV (1896), pp. 57–9.

the narrow valley of the Wisconsin to the flat-topped uplands, ridges, and valleys beyond, he would see that the uplands rise approximately to his own elevation and form an even crest-line along the horizon. If he should look northward, the even sky-line would be seen to rise gently but persistently to the northeast. Looking to the west, the even crests of the hills are seen to return to an elevation equal to his own. However, if he should turn to the south, Rib hill and the adjoining Mosinee hills, six

FIG. 1.—View looking east across the Wisconsin valley to the even-summited upland of the dissected peneplain. At Wausau.

miles southwest of Wausau, would rise before him and obstruct his view of the even sky-line which swings away beyond and falls not only far below the summit of Rib hill, but also much below his own position. The even-summit surface of the main upland area is the most striking feature of the landscape and at once suggests an ancient plain sloping upward to the north, below which the Wisconsin river and its tributaries have sculptured their valleys, and above which project a few isolated pointed ridges and hills like Rib hill and the Mosinee hills.

Rock structure of the pre-Cambrian.—If the observer should now descend the upland and note the character of the rocks exposed along the valley sides and on the flat-topped uplands of the vicinity, he would see a wide variety of massive and schistose igneous rocks alternating with formations of metamorphic sedimentaries. Wherever the rocks are exposed, their schistosity and bedding are seen to be dipping steeply at various angles, and along the valley bottoms the streams flow over their upturned edges. Hand specimens chipped from ledges show rock crumplings on a minute scale; and the dipping beds of hillsides are the remnants of large rock folds that once roofed

FIG. 2.—View looking west across the valley of the Little Rib river, showing the even upland of the dissected peneplain. Seven miles northwest of Wausau.

over broad spaces from a few hundred to a thousand feet across. Everywhere the rocks stand on edge and are folded and crumpled, and reveal a structure like that seen in the Alps, the Alleghanies, or the Rocky mountains.

While the rocks of the pre-Cambrian area have typical mountain structures, there is nothing in the present land surface to suggest mountain topography. The dipping beds and schists stop abruptly at the even sky-line formed by the crests of the flat-topped hills. There is thus an entire lack of sympathy, a striking unconformity, between the gently sloping summits of this main upland area and the internal structure of the rocks. This indifference of surface form to internal structure could be developed in only one way; namely, by the process of degradation of a pre-existing mountainous region.

Discordance of land surface and rock structure of other regions like that of this pre-Cambrian area has been so adequately explained and so generally accepted by geologists for the last two or three decades, as the resultant of long-continued erosion, that it seems reasonable to conclude at once that the sloping, flat-topped uplands about Wausau are the remnants of what was

FIG. 3.—View of the beveled pre-Cambrian rocks on the west side of the Wisconsin river one mile south of Stevens Point. This is at the border of the sandstone and crystalline districts, and here the level of the river practically coincides with the level of the ancient peneplain. The view shows decomposed gneiss overlain by the river sand and gravel, the sandstone and residual clay having been eroded. On the opposite bank of the river sandstone caps residual clay, the latter grading down into the partly decomposed gneiss.

formerly a nearly level land surface due to the wearing down by erosion of a once mountainous region to an approximate plain. The mountain folds of the pre-Cambrian have been cut off by erosion at the even sky-line of the area, just as the fibers of a great tree are cut across at the even surface of its sawed stump. The complete degradation of the mountains was not accomplished, as is evidenced by such isolated hills as Rib hill and the Mosinee hills which project above the flat-topped uplands, and hence the region must have been, not a plain, but a peneplain of erosion.

In retrospect, the pre-Cambrian area was once a mountainous region. Subsequently the mountainous area was worn down by erosion to a peneplain, and must necessarily have been near sea-level. At a much later period the peneplain was uplifted to its present elevation, and again subjected to a period of erosion which is continued into the present time. Out of this ancient plain of erosion the present valleys about Wausau are seen to be in process of construction, and hence the region may be described as a dissected peneplain.

Present slope of the peneplain.—Since the topography of a considerable portion of this region has recently been mapped, the elevation of a part of the peneplain is definitely known. At Wausau the elevation of the dissected peneplain represented by the summits of the even-crested uplands is approximately 1,420 feet above the sea. About twenty miles north of Wausau, in the vicinity of Merrill, it is between 1,550 and 1,600 feet above sea-level. North of Merrill the thick drift of the Wisconsin Epoch is present, and the exact elevation of the pre-Cambrian is not known; but the slope upward to the north, so far as known, is about the same as it is between Wausau and Merrill. Going south of Wausau about twenty miles to the vicinity of the boundary of Marathon and Portage counties, the slope gradually descends to an elevation of about 1,200 feet, and twenty miles still farther south, in the vicinity of Grand Rapids, at the border of the Potsdam sandstone, the plain is 1,000 feet above the sea. The descent of the peneplain from seven miles north of Merrill to Grand Rapids, a distance of about sixty miles, where elevations are definitely known, is between 550 and 600 feet.

Valleys in the dissected peneplain.—The Wisconsin river from Merrill to Grand Rapids has carved a U-shaped valley with steep sides and variable width in the dissected peneplain. North of Merrill in the region of thick drift the valley is either post-glacial or much modified by glacial deposition. That part of the valley between Merrill and Wausau in the area of old thin drift has a depth of 200 to 300 feet (see Plate I, Fig. 1). The

Wisconsin valley gradually grows shallower toward the south, so that at twenty miles south of Wausau the valley bottom is only about 100 feet below the peneplain, and twenty miles still farther south, at Grand Rapids, the valley has no depth in the pre-Cambrian, but is on a level with the more rapidly descending slope of the peneplain. The branch rivers of the Wisconsin, such as the Big Rib, Big Eau Pleine, and Little Eau Pleine on hte west, and the Pine, Trap, and Eau Claire on the east, are

FIG. 4.—View of the dissected peneplain looking northwest one mile northwest of Wausau. The even sky-line in the distance is the ancient peneplain out of which the intervening valley of the Little Rib river has been sculptured.

U-shaped for about one-quarter to one-third of their distance from the Wisconsin, and then pass into narrow V-shaped valleys, and finally into broad V-shaped valleys near the flat-topped uplands. North of the branch rivers just named the drift is very thick and the side valleys, like the Wisconsin, are either wholly post-glacial or much modified by glacial action. South of these branch rivers the side valleys, like the valley of the Wisconsin, gradually grow shallower until their floors coincide with the level of the peneplain.

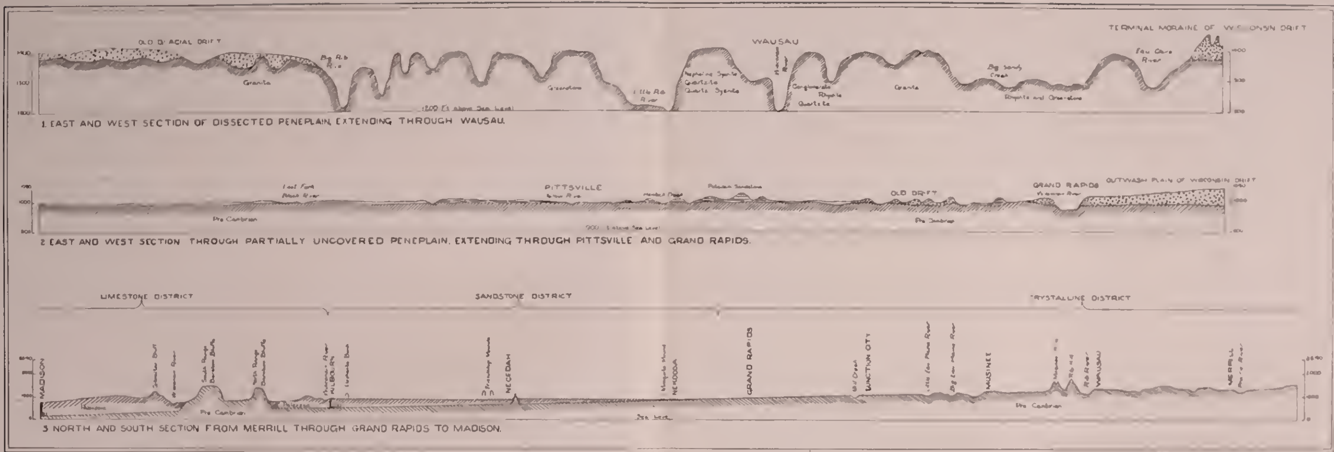
The undissected portion of the peneplain.—As one goes south from the vicinity of Wausau, the dissection of the peneplain gradually grows less, and the Wisconsin valley, and also the side valleys, as already stated, gradually grow shallower, until their floors coincide with the level of the peneplain (compare Plate I, Figs. 1 and 2). Cappings of erosion remnants of Potsdam sandstone begin to appear in the slightly dissected peneplain in northern Wood and Portage counties, and become quite numerous about Grand Rapids at the border of the continuous sandstone district. For some distance into the sandstone district south of Grand Rapids, at the rapids of Grand Rapids, Port Edwards, and Nekoosa, the Wisconsin river has exposed crystalline rock, showing the latter in the river bottom and the overlying, nearly horizontal Potsdam sandstone outcropping above it in thin patches along the river bank, whence the sandstone extends in low ridgy exposures dotting the low plain of the surrounding sandstone district. The dissected peneplain about Wausau thus gradually changes to the undissected peneplain about Grand Rapids, where it is covered with thin sandstone outliers, and for some distance into the sandstone district the pre-Cambrian rocks are seen only in the river bottom, the adjacent flat-lying land being covered with Potsdam sandstone.

West of the Wisconsin river are the Yellow and Black rivers, which also lie athwart the pre-Cambrian and Cambrian districts. The Yellow in its upper course flows through the region of thick drift covering a few sandstone outliers. A short distance south of Marshfield the thick drift ceases, and from here as far south as Dexterville, a distance of twenty miles, the Yellow has exposed the pre-Cambrian in the river-bed, showing at numerous places thin cappings of the sandstone lying above it along the river bank. The descent of the pre-Cambrian surface along the Yellow river is approximately between 11 and 12 feet per mile. The Black river above Neillsville also lies in the region of thick drift and sandstone outliers, but south of Neillsville to Black River Falls—a distance of twenty-two miles—through the low plain of the thin drift area the Black shows almost continuous crystalline rocks in the river bottom, with sandstone cappings above them along the bank. The rate of descent of the crystalline area along the Black river from Neillsville, with an elevation of

996 feet, to Black River Falls, with an elevation of 812 feet, is about 9 feet per mile.

Slope of the sandstone district.— The sandstone district of south-central Wisconsin south of the vicinity of Grand Rapids and between the resistant Cambrian area on the north and the region of hard limestone rocks of the southern part of the state is pre-eminently a broad valley bottom plain dotted here and there with isolated peaks and mounds of sandstone. While there is considerable alluvial wash in the flat-lying sandstone district, the main features of the area, the broad plain and isolated peaks, are due to long-continued erosion. As stated by Salisbury and Atwood[1] for the vicinity of Camp Douglas: "Here the broad plain, extending in some directions as far as the eye can reach, is as low as it could be reduced by the streams which developed it." The sandstone district is therefore a graded valley plain sloping upward to the north, and isolated mounds and peaks are the disappearing remnants of divides of an earlier, less eroded sandstone region. From data of elevations along the various railroads extending across the sandstone district it is found that the slope of the valley plain is upward to the north at the rate of about 2 feet per mile. The slope upward from Kilbourn City to Grand Rapids across the entire width, north and south, of the sandstone district is only about 100 feet in about 55 miles, and thus 2 feet per mile may reasonably be considered an average slope for the sandstone district (see Plate I, Fig. 3). As already stated, from the vicinity of Merrill to Grand Rapids the southward pitch of the peneplain slope of the main pre-Cambrian area is 550 feet in 55 miles. The downward slope of the sandstone district from Grand Rapids to Kilbourn City is only about 100 feet for an equal distance of 55 miles. Thus there is an abrupt change of slope in the main land surface at the border of the sandstone and crystalline districts. The surface of the dissected plateau north of Grand Rapids is therefore not continuous in slope with the surface of the sandstone district south of Grand Rapids. On the other hand, as already shown, the beveled surface of the pre-Cambrian continues south-

[1] *Bull. V, Wis. Geol. and Nat. Hist. Survey*, p. 51.



1. EAST AND WEST SECTION OF DISSECTED PENEPLAIN EXTENDING THROUGH WAUSAU.

2. EAST AND WEST SECTION THROUGH PARTIALLY UNCOVERED PENEPLAIN, EXTENDING THROUGH PITTSVILLE AND GRAND RAPIDS.

3. NORTH AND SOUTH SECTION FROM MERRILL THROUGH GRAND RAPIDS TO MADISON.

ward along the beds of the Wisconsin, Yellow, and Black rivers, beneath the Potsdam sandstone, in a plain sloping southward with a pitch the same as that of the peneplain farther north.

The age of the peneplain.—The deeply dissected peneplain about Wausau thus passes into the slightly dissected peneplain, covered with isolated sandstone remnants, in northern Wood and Portage counties, and at Grand Rapids, Pittsville, and Neillsville it is seen to slip under the Potsdam sandstone and become a buried peneplain (see Plate I, Fig. 3). Hence we must conclude that this peneplain was made in pre-Potsdam time.

Monadnocks in the dissected peneplain.—In our view at Wausau it was noted that certain hills and ridges project above the flat-topped uplands of the pre-Cambrian area. These are the Mosinee hills and Hardwood hill, which are conical, and Rib hill, a sharp ridge. The above-named hills consist for the most part of very coarse resistant quartzite, and for this reason they were not worn down during the general degradation of the surrounding area. These monadnocks, with their pointed crests, are in marked contrast with the flat tops of the uplands forming the peneplain. They are the remnants of a land surface older than the even-crested hills, and are typical monadnocks like Mount Monadnock of New Hampshire, which bears a similar relation to the peneplain of erosion of southern New England. Rib hill, the most prominent of these monadnocks, has a elevation of 1,942 feet above the sea and of 500 feet above the surrounding dissected peneplain. Its summit reaches over 700 feet above the alluvial plain of the Rib and Wisconsin rivers lying at its base, and it has the distinction of being one of the highest hills in the state.

Monadnocks in the slightly dissected peneplain.—About thirty-five miles southwest of Wausau at Arpin, in central Wood county, is Powers bluff, consisting of fine-grained quartzite and chert, whose elevation is not known, but which apparently reaches about 300 feet above the surrounding area of the slightly dissected peneplain. This bluff stands in the midst of isolated thin sandstone remnants lying upon the surrounding crystalline plain, and wrapped about its base are patches of Potsdam conglomerate. Powers bluff bears the same relation to the surrounding slightly dissected peneplain that Rib hill bears to the deeply dissected peneplain about Wausau. In adjacent parts of Wood county, and also in Jackson county, there are monadnocks of massive resistant granite, some of which rise from 50 to 100 feet above the general slope of the pre-Cambrian plain.

From the foregoing it has been concluded that the pre-Cambrian land was a worn-down country, a peneplain of erosion, before the Potsdam sandstone was deposited upon it, and that later it was elevated, and through the work of erosion is in the process of being uncovered and dissected. The evidence upon which the pre-Potsdam age of the crystalline peneplain is based, is the uniformity in slope of the dissected and buried portions of the pre-Cambrian land. Ordinarily such evidence as this would be deemed conclusive, and it may be so considered in this instance; but, besides the evidence of the uniformity in slope, which may be considered physiographic, there are other geological evidences in the partially uncovered portions of the pre-Cambrian area which also point clearly, it is believed, to the pre-Potsdam age of the peneplain.

Residual clay at the surface of the pre-Cambrian.— Lying at the contact of the gently sloping pre-Cambrian and the Potsdam, apparently everywhere except about the pre-Cambrian monadnocks, is a widespread formation of partly decomposed crystalline rock and clay. The clay occurs not only at the edge of the sandstone outliers and along the river banks at the margin of the sandstone district, but, as shown by a number of well-borings, it is also at various distances from these now exposed places and beneath a widely variable thickness of sandstone. The clay varies considerably in thickness, but generally has a depth of 10 to 20 feet, though in places it is known to reach the unusual thickness of 40 feet. It occurs in such abundance that it has been used quite extensively for many years for making brick, and is outlined on Dr. E. R. Buckley's map[1] of the clay deposits of Wisconsin and shown to be distributed along the boundary of the crystalline and sandstone district. It contains

[1] *Bull. VII, Wis. Geol. and Nat. Hist. Surv.*, Plate I.

no evidence of sedimentation, and hence could not have been deposited by water. On the other hand, as pointed out by Irving a number of years ago,[1] there is every evidence, as shown by correspondence in structure and composition, as well as by gradation downward into the hard rock beneath, that the clay

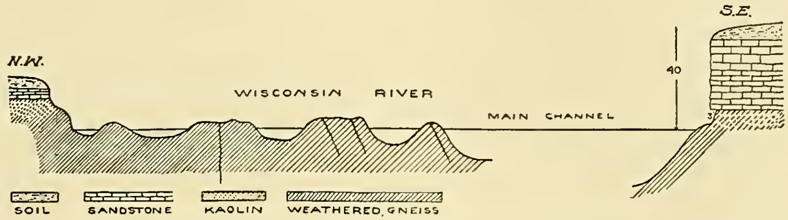


FIG. 5.—Section across the Wisconsin river valley near Grand Rapids. (After Irving.)

formation had its origin in the weathering and decomposition of the crystalline rocks. It was Irving's belief that the clay, though confined to the pre-Cambrian region, having more or less of a sandstone covering and often occurring beneath a few layers at least of sandstone—which fully agrees with the writer's defi-

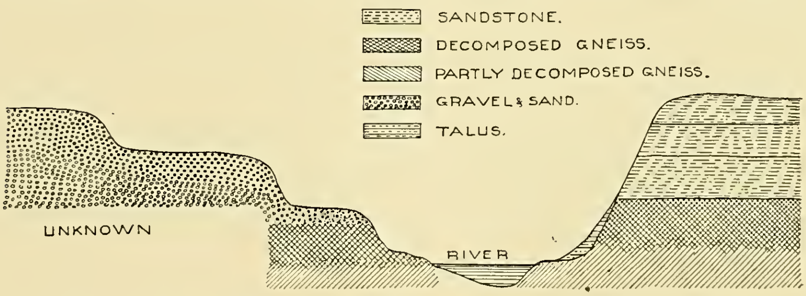


FIG. 6.—Ideal section across the Black river at Halcyon showing the shale or partly decomposed gneiss. (After Buckley.)

nition of the area—had nevertheless been formed subsequent to the deposition of the Potsdam sandstone which covers it, instead of antecedent, as believed by the writer.

In the two sections, after Irving and Buckley (Figs. 5 and 6), the position of the clay beneath the sandstone is clearly shown.

[1] *Trans. Wis. Acad. of Sci.*, Vol. II, pp. 13-17; and *Geol. of Wis.*, Vol. II, p. 468.

Immediately south of the Wisconsin Central Railway bridge at Stevens Point on the west side of the Wisconsin river relations similar to those appearing in the above sections are shown. At this place is 10 or 12 feet of decomposed pre-Cambrian rock, overlain by sandstone, along the river bank, while 40 feet west of the river is a well showing 4 feet of sandstone overlying 12 feet of clay, and 100 feet still farther west, on the west side of the wagon road, on higher ground, is a well showing 12 feet of sandstone and below this 12 feet of the kaolinized pre-Cambrian rock overlying hard crystalline rock. Similar thicknesses of the clay formation were noted beneath the sandstone mounds in which the sandstone quarries are located, on the west side of the river at Stevens Point. An instance of a sandstone mound overlying the clay is shown in the diagram (Fig. 8). About a mile north of Stevens Point is located the Langenberg brickyard, the source of the clay here used being a thickness of 15 to 20 feet of the decomposed pre-Cambrian schists. This clay bed is about a mile and a half from the Wisconsin river and is not overlain with sandstone, though the latter formation lies at a higher level, forming a low broad hill one-fourth of a mile to the north.

It seems hardly necessary to multiply instances of the occurrence of a variable thickness of decomposed pre-Cambrian lying beneath an equally variable thickness of the Potsdam sandstone. The relations shown in the above sections are found wherever the sandstone and pre-Cambrian occur, whether it be along the river banks or in the well sections through the sandstone far from the streams.

As already stated, it was Irving's belief that the clays were formed *after* the deposition of the sandstone, two possible explanations[1] being offered by him: one, that the clays were formed by processes of weathering during the existing cycle of erosion, but mainly in pre-glacial times; and the other, that "surface waters, percolating through the porous sandstone—in ancient times much thicker than now—have formed natural watercourses along the junction between it and the less easily penetrable

[1] *Geol. of Wis.*, Vol. II, p. 464.

crystalline rocks, and have thus exerted an unusual disintegrating action; whilst the sandstone itself has subsequently acted as a preserver of the kaolinized rock from the ordinary eroding

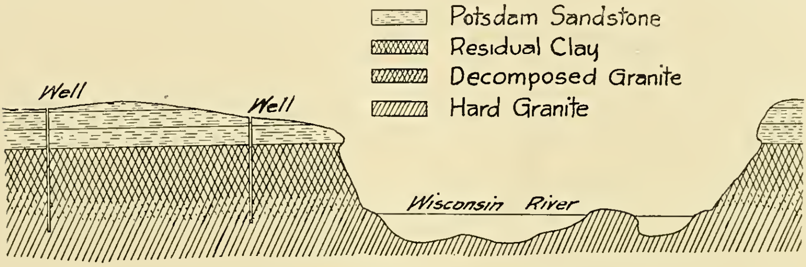


FIG. 7.—Section across the Wisconsin river at Stevens Point.

agencies." It seems hardly necessary to enter into the details of the explanations offered by Irving[1] and accepted by Buckley[2] for the post-Potsdam development of these clay deposits. It is purposed to present in a later publication a fuller discussion[3] of the

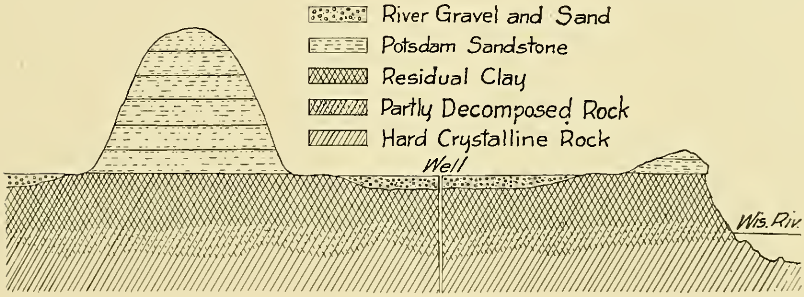


FIG. 8.—Section on west side of Wisconsin river at Stevens Point.

clay and associated formations. It should be borne in mind that the evidence of the peneplain character of the pre-Cambrian land of central Wisconsin before the deposition of the Potsdam sandstone, which is believed to be a fact of great significance in

[1] *Ibid.*, pp. 463, 464.

[2] *Bull. VII, Wis. Geol. and Nat. Hist. Surv.*, p. 217; also discussion before Wis. Acad. of Sci., December, 1901.

[3] A report on the geology of north-central Wisconsin, *Wis. Geol. and Nat. Hist. Surv.*

connection with the origin of the clay, was unknown to Irving. Indeed, the idea of peneplains or base-levels of erosion had hardly been promulgated at the time of his writing in 1876. While it is probable that the processes suggested by Irving may have operated to some extent in the development of the clay formation, it is not thought that either or both combined could have been important factors. It is believed by the writer that the wide-spread occurrence of the thick deposit of clay as a subjacent formation of the Potsdam sandstone obviously points to its origin and its presence there before the sandstone was deposited upon it. This view is entirely in harmony with and strongly supported by what has already been stated concerning the geographic evidence of the peneplain character of the pre-Cambrian land in pre-Potsdam time; for if the pre-Cambrian land surface were degraded to the near level of the sea, it is very evident that the conditions for deep weathering and decomposition of the surface would prevail over large portions of the plain. In the process of degradation of the pre-Cambrian, the less resistant rocks would first be cut down to the limit of slope below which the streams could not longer transport the loose material from the surface, and at this stage of the degradation, when erosion would cease, the most favorable conditions for chemical metamorphism would prevail, and the weathering and decomposition of the rock into clay would be likely to extend even to depths below the level of the sea. In fact, we could hardly expect the degrading of a land area consisting mainly of the silicate minerals like the pre-Cambrian rocks, to the near level of the sea without considerable weathering of the flat-lying surface. Hence the position of the clay beneath the sandstone, in view of the peneplain character of the pre-Cambrian land in pre-Potsdam time, obviously points, it is believed, to its development there before the deposition of the Potsdam formation.

Distribution of Potsdam conglomerate.— About the isolated sandstone outliers upon the slightly dissected peneplain, and along the crystalline rapids in the border of the sandstone district there is a general absence of conglomerate, or even a semblance of coarse sediment, at the base of the Potsdam sandstone. In the various wells also that penetrate the sandstone to the crystalline rock the clay formation generally occurs and conglomerate is rarely or never found. On the other hand, about the monadnocks in the peneplain, such as Powers bluff, which stand well within the region of outlying sandstone remnants, and about the low mounds of ferruginous schist in the vicinity of Black River Falls, there is a variable thickness of conglomerate, as would be expected. The conglomerate about the monadnocks generally, if not always, contains pebbles representing simply the quartz rock or massive granite forming the monadnocks which it lies against, and in this respect the Potsdam conglomerate is in marked contrast with the Huronian conglomerates of the region with their generally complex variety of pebbles.

Relative distribution of the pre-Potsdam clay and Potsdam conglomerate.—The distribution of the clay upon the gently sloping pre-Cambrian, as shown along the pre-Cambrian rock rapids in the border of the sandstone district, and also about and beneath the erosion remnants of sandstone upon the slightly dissected peneplain, has already been described. The occurrence of the simple conglomerate about the resistant rocks of the monadnocks is very obviously because sufficiently steep slopes existed at these places for the continuation of erosion long after the surrounding softer rocks had been reduced to a grade too low for erosion. The development of the conglomerate was very probably due to the monadnocks serving as barriers for the accumulation of coarse sediments by the waves of the Potsdam sea, in combination with stream action down the gorges and ravines of the monadnocks.

Thus the widespread occurrence of the blanket of residual clay on the gently sloping crystalline area, indicating the deep weathering of the pre-Cambrian land before the deposition of the Potsdam sandstone, as well as the distribution of Potsdam conglomerate only about the isolated monadnocks, is completely in harmony with the geographic evidence of the peneplain character of the pre-Cambrian land, and may therefore be considered as additional proof of the pre-Potsdam age of the peneplain.

Value of residual clays as evidence of unconformity.—True basal conglomerates have been quite generally used for many years by geologists as evidence of unconformity. The occurrence of residual clays or soils as evidence of unconformity has, so far as known to the writer, been used only in connection with the determining of the stratigraphy of the various Pleistocene deposits. If the explanation of the origin and age of the thick residual clays here described be the true one, and if old soils can be used as evidence of unconformity between the comparatively recent deposits of the Pleistocene series, then it seems to the writer that residual clays and soils between other unconformable series should occur, and that the presence of such residual deposits may be used as important criteria for establishing the unconformity of rock formations throughout other parts of the geological column. As formations indicating unconformity, basal conglomerates would belong to the first formation of the upper series, whereas the residual clays would be closely related to the lower series, but originating during a part or the whole of the hiatus between the deposition of the lower and the upper series. Basal conglomerates and residual clays would not likely be found in contact, but the former would be expected to be found covering hilly land surfaces and rocky coast lines, whereas the latter would be found on gentler slopes, where the forces of erosion were relatively inactive or *nil.* The fairly uniform and widespread occurrence of thick residual clays might well be considered as strong evidence of the base-leveled condition of the land floor upon which the overlying series was deposited; but isolated occurrences of such residual deposits should only be considered as an evidence of unconformity, for such isolated deposits are found at the present day in process of development in places protected from erosion, at all elevations above the sea. The full meaning of weathered zones in the stratigraphic column can therefore be understood only when considered with the associated geological phenomena.

The peneplain made by sub-aërial erosion.—Peneplains may be cut out of land areas by sub-aërial erosion—the work of rains and streams; by marine erosion—the work of sea-waves beating against a coast line; and by a combination of these processes.

In Great Britain it was formerly believed that only sea-waves could accomplish the work of reducing land areas to the near level of the sea. But the presence of the residual clay formations beneath the sandstone, indicating the deep weathering and decomposition of the pre-Cambrian surface before the Potsdam formation was deposited upon it, and the occurrence of simple conglomerate about the isolated monadnocks obviously indicate that the region must have been flat-lying near to sea-level a long time before the encroachment of the Potsdam sea. Hence the sea-waves could have had little or nothing to do with the leveling of the pre-Cambrian to a peneplain, for the degradation was accomplished mainly by sub-aërial erosion long before the sea was present.

The time of the construction of the peneplain and the deep weathering of its surface.—The period of the uplift of the pre-Cambrian horizon and the construction of the peneplain of central Wisconsin, and the deep weathering and decomposition of the surface, must have occupied a long period, even as time is reckoned in geological chronology. This period is certainly somewhere between the age of the youngest rocks of the peneplain, the Upper Huronian, and the age of the sandstone overlying them, the Upper Cambrian. It seems very probable that pre-Cambrian rocks younger than the Upper Huronian, the Keweenawan, may also be included in this old peneplain on the south slope of the crystalline district, for they are abundant in the adjoining pre-Cambrian area on the north slope along the shore of Lake Superior. It seems, therefore, that this period of erosion represents the whole of the Lower and Middle Cambrian periods, and that it may also have reached back some distance into pre-Cambrian time. The physical geography of the pre-Cambrian land at the close of pre-Cambrian time and at the beginning of Cambrian time here depicted for central Wisconsin is strikingly favorable for the conditions governing the concentration of much of the abundant iron ores[1] in other parts of the pre-Cambrian area of the Lake Superior region. These ore deposits are viewed by

[1] "The Iron-Ore Deposits of the Lake Superior Region." *Twenty-first Ann. Rept. U. S. Geol. Surv.*, 1901, Part III, p. 330.

Van Hise as products of weathering, thus having an origin somewhat similar to these residual clays, but formed a short distance below the land surface, being "regarded as the result of the work of descending waters combined with progressive denudation."

Probable slope of the buried pre-Cambrian.—It will at once be seen by the reader that, if, as believed by the writer on the evidence here presented, the pre-Cambrian land of north-central Wisconsin is an old peneplain of erosion formed in the period preceding the deposition of the Potsdam sandstone, it is extremely probable that this peneplain has a wide extension beyond the border of the area here described. It is not the purpose of the writer, however, to present in this paper the various evidences for the belief in the wide extension of the pre-Potsdam peneplain over the pre-Cambrian land. It might be of interest, however, to point out as briefly as possible the general slope of the surface of the pre-Cambrian beneath the adjacent area of the Paleozoic rocks. It may be sufficient to state that fifty-five miles south of Grand Rapids, at Kilbourn City, as shown in Plate I, Fig. 3, the pre-Cambrian surface is struck at a depth of 385 feet, or 515 feet above sea-level. About thirty-five miles farther south, at Madison, the pre-Cambrian occurs at a depth of 810 feet, or 70 feet above sea-level. In the wells at both Kilbourn City and Madison the pre-Cambrian rock struck was called a shale, and it is apparently very similar to the decomposed clayey schists about Grand Rapids. Furthermore, no conglomerate was found at the base of the sandstone. From Grand Rapids to Madison, therefore, a distance of about ninety miles, the surface of the pre-Cambrian descends from an elevation of 1,000 feet to 70 feet above the sea, and thus the slope of the buried pre-Cambrian surface to the south continues in a remarkable manner at the same rate of descent, about ten feet per mile, that is exhibited by the uncovered and dissected peneplain between Merrill and Grand Rapids (see Plate I, Fig. 3). Between Grand Rapids and Kilbourn City is the Necedah pre-Cambrian quartzite bluff with an elevation of 1,080 feet, and between Kilbourn City and Madison are the Baraboo pre-Cambrian quartzite bluffs, whose highest points reach an elevation of 1,600 feet. Surrounding the Baraboo quartzite are great thicknesses of the Potsdam conglomerate. The Necedah quartzite probably attained an approximate elevation of 280 feet and the Baraboo quartzite ranges an elevation of 1,200 to 1,400 feet above the surrounding pre-Cambrian plain. These two elevations of the pre-Cambrian surface consist of hard resistant rock and bear a similar relation, it is believed, to the surrounding buried pre-Cambrian that the Powers bluff and Rib hill quartzite monadnocks bear to the slightly dissected and deeply dissected portions of the peneplain farther north.

Southeast of the pre-Cambrian area and also southwest there is a much steeper slope to the pre-Cambrian surface, as indicated by the artesian wells at Oshkosh and La Crosse. To the southeast are the pre-Cambrian outliers of rhyolite and granite along the Fox river, which are believed to have been monadnocks in the pre-Cambrian plain.

The uplifting and consequent folding of the region which has produced the present slope of the uncovered pre-Cambrian in central Wisconsin, as well as its buried portion farther south, is outside the scope of the present paper. Briefly stated, however, as generally accepted,[1] there is a broad anticlinal extending southward from central Wisconsin into Illinois, with a corresponding synclinal depression extending under Michigan on the east and a similar one under Iowa on the west. The uniform slope of the buried pre-Cambrian at Kilbourn City and Madison and the uncovered peneplain about Wausau is thus along the anticlinal. It is believed that the buried pre-Cambrian to the east at Oshkosh and to the west at La Crosse also had a common peneplain slope, in Potsdam time, with the now exposed portion of the pre-Cambrian, and that the greater rate of descent in these directions at the present time is to be explained as the corresponding synclinals formed in the pre-Cambrian since the beginning of Potsdam time.

Contemporaneous erosion of the pre-Cambrian and post-Cambrian rocks.—The main features of the pre-Cambrian peneplain area

[1] T. C. Chamberlin, *Geol. of Wis.*, Vol. IV, p. 424.

and the sandstone district south of the pre-Cambrian area have already been pointed out. The sandstone district is apparently a graded valley plain sloping upward to the north, and the isolated mounds are disappearing remnants of the divides of an early and less eroded sandstone region. In the sandstone district the main surface feature is the plain of the valley bottom with an entire absence of the valley sides, but as one follows north along the Wisconsin river into the pre-Cambrian area, valley sides are seen to close in upon the river, the Wisconsin valley becomes narrow and is carved deeper and deeper into the peneplain toward the north. The slope of the valley plain of the sandstone district from Kilbourn City to Grand Rapids, as shown in Plate I, Fig. 3, is upward to the north at the rate of about two feet per mile; but in the pre-Cambrian district the narrow valley bottom of the Wisconsin river rises from Grand Rapids, with an elevation of 1,000 feet, to Merrill, with an elevation of 1,250 feet, as indicated in the same figure, thus showing a rate of ascent of about four and one-half feet per mile in the dissected peneplain. Throughout the course of the Wisconsin river in the pre-Cambrian district there are numerous rapids. From Nekoosa to Stevens Point across the border of the sandstone district there is a series of almost continuous rapids where the river flows southward, there being no rapids in the westward course of the river flowing parallel to the border of the two districts. North of Stevens Point the rapids are not so numerous, though extensive rapids occur at intervals of ten to twenty miles, as at Mosinee, Wausau, and Merrill. The broad valley plain of the sandstone district thus assumes a steeper gradient as it changes to the narrow Wisconsin valley, with numerous rapids, in the dissected peneplain. It is believed that the steeper gradient and narrowness of the valley of the Wisconsin, and likewise of the other valleys in the pre-Cambrian area, as compared with the same and similarly related valleys in the sandstone area, are fully explained by the greater resistance to erosion of the crystalline rock than of the sandstone; and if this be true, it would follow that the degradation of the sandstone district and the dissection of the pre-Cambrian peneplain were very probably contemporaneous. The dissection of the pre-Cambrian peneplain about Wausau, the uncovering of the buried peneplain about Grand Rapids, and the degradation of the sandstone district, it is believed, have thus gone on hand-in-hand under the same period of sub-aërial erosion, and all phases of this work of erosion may be seen as one travels from the dissected pre-Cambrian peneplain to the broad river plain of the sandstone district.

Former extension of the Potsdam.— How far to the north over the pre-Cambrian land the Potsdam sandstone was once distributed is not now known. Isolated remnants of the sandstone have been found by the writer within nine miles southeast of Wausau and four miles southwest of Medford, which are points much nearer the center of the pre-Cambrian area of Wisconsin than it was formerly supposed the sandstone occurred.[1] These sandstone remnants far within the general pre-Cambrian area are hard, resistant, consolidated rocks, which would seem to indicate that the beds now remaining were once covered over with a considerable thickness of sandstone in order to be thus consolidated. It seems not unlikely, therefore, that a great part of the ancient peneplain of the pre-Cambrian land, perhaps the whole of it, was once covered with the sandstone formation and that the sandstone has since been removed by erosion.

When Van Hise[2] wrote his brief sketch on the base-level features of this region, it was his belief that the sloping sky-line of the dissected peneplain of the district about Wausau was continuous with the tops of certain sandstone buttes in the Potsdam district, and probably with the limestone uplands of southern Wisconsin, and that, though the pre-Cambrian land may have been degraded to a low slope before the deposition of the Potsdam formation, it had later been degraded, perhaps in Cretaceous time, to form a continuous peneplain across the Paleozoic and pre-Cambrian formations. It is the thesis of the present paper that the clear-cut peneplain of the pre-Cambrian region is buried beneath the surrounding Potsdam sandstone, and therefore lies at the base of the sandstone buttes in the sandstone district and

[1] Plate I, *Atlas of the Geology of Wisconsin*, 1881.

[2] *Science*, Vol. IV (1896), pp. 57–9.

not at their tops. Professor Van Hise has since intimated his belief in the probability of the principal conclusion concerning the age of the peneplain as here presented. Whether the tops of the buttes in the sandstone district represent a Cretaceous or any other post-Paleozoic peneplain I shall not discuss. But in the pre-Cambrian region studied, although this part of the continent must have been near sea-level several times since Potsdam time, there appears to be no evidence for the belief in the degradation of the pre-Cambrian rocks to a peneplain later than the period immediately previous to the deposition of the Potsdam sandstone.

SUMMARY.

In the pre-Cambrian area of north-central Wisconsin the main feature of the land surface is the even-summited, flat-topped upland area forming an even sky-line sloping upward to the north and having the appearance of a plain or plateau below which lie the valleys of the region and above which rise a few pointed hills and ridges. The rocks of the pre-Cambrian area are of various kinds of igneous formations and metamorphic sedimentaries, which are much folded and crumpled and have a typical mountain structure. The schistosity and bedding of the various formations dip in all directions, and the formations are cut off abruptly at the even sky-line of the main upland area. The indifference of surface form to internal structure shown in the plain-like feature of the upland area and the mountain structure of the rocks, can be explained in only one way: by the degradation or wearing down by erosion of a once mountainous region to an approximate plain. Hence it is concluded that the even summits of the main upland area of the pre-Cambrian district represent the surface of an old peneplain of erosion. The pointed hills and ridges consisting of hard resistant quartzite, like the Mosinee hills and Rib hill, were not worn down to the level of the surrounding flat-topped uplands consisting of softer rocks, and these stood up as monadnocks in the peneplain.

The slope of the peneplain, as shown by the elevations of the flat-topped uplands is downward to the south at the rate of ten feet per mile. The slope of the plain of the sandstone district south of the peneplain is only two feet per mile; and hence there is a distinct unconformity in the slope of the two districts. The dissection of the peneplain about Wausau is considerable, the valleys having a depth of 200 to 300 feet. Going southward toward the sandstone district, the dissection gradually grows less, and the valley bottoms in the pre-Cambrian gradually rise nearer and nearer to the level of the peneplain. At Grand Rapids, at the border of the sandstone district, the Wisconsin valley bottom is even with the peneplain, showing the sandstone along the river banks and the beveled pre-Cambrian in the river bottom. At Grand Rapids the slope of the peneplain to the north is seen to be uniform, not with the more gentle slope of the sandstone district to the south, but with the less gentle slope of the pre-Cambrian surface in the Wisconsin river bottom. Thus it is shown that the deeply dissected peneplain about Wausau changes to the slightly dissected peneplain covered with isolated sandstone remnants immediately north of Grand Rapids, and at Grand Rapids and also at Pittsville on the Yellow river and Neillsville on the Black river the peneplain is seen to dip under the Potsdam sandstone and become a buried peneplain. It is therefore concluded that the peneplain of the pre-Cambrian area is older than the sandstone; that is, it is of pre-Potsdam age.

A further evidence of the pre-Potsdam age of the peneplain is believed to be shown by the occurrence of thick deposits of clay lying beneath the Potsdam sandstone. The clay is not of sedimentary origin, but is decomposed pre-Cambrian rock, and generally has a thickness of 10 to 20 feet, sometimes attaining a thickness of 40 feet. The residual character of the clay and its widespread distribution beneath a variable thickness of sandstone, it is believed, point to its origin before the deposition of the overlying Potsdam sandstone, at a time when the pre-Cambrian land was so flat-lying, that is, so near base-level, that conditions were favorable for the deep weathering and decomposition of the pre-Cambrian surface without removal by erosion. The absence of conglomerate at the base of the Potsdam, with the exception of the conglomerate beds about the monadnocks, which are in their simple character in marked contrast with the complex variety of pebbles found in the pre-Cambrian conglomerates, is pointed out as significant evidence in full accord with all the other indications pointing to the pre-Potsdam age of the peneplain. The occurrence of the thick deposits of residual clay beneath the Potsdam sandstone, indicating the deep weathering of the crystalline rocks without erosion, and thus the approximate base-leveled condition of the pre-Cambrian land a long time before the encroachment of the Potsdam sea, is adduced as significant evidence pointing to the degradation of the pre-Cambrian land to a peneplain by sub-aërial erosion and not by submarine erosion. The occurrence of the deposits of residual clay at the surface of the pre-Cambrian rocks suggests the probability that similar residual deposits may be found between other unconformable series, and that such residual deposits may be used as evidence of unconformity in other parts of the geological column just as the old soils and weathered zones in the Pleistocene deposits are used for determining the stratigraphy of the glacial formations.

The probable wide extension of the peneplain over other portions of the pre-Cambrian area is suggested, and the continuation of the peneplain slope beneath the surrounding Paleozoic to the south is pointed out. The degrading of the sandstone district to a broad valley plain, the uncovering of the pre-Potsdam peneplain at Grand Rapids at the border of the crystalline and sandstone districts, and the deep dissecting of the uncovered peneplain farther north, about Wausau, are pointed out as contemporaneous processes, this work being continued through a long period into the present time. The probability of the former extension of the Potsdam sandstone over a large part of the peneplain of the pre-Cambrian area, if not the whole of it, is suggested.

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EXPLANATION OF PLATE I.

Fig. 1.—Profile extending approximately east and west through the deeply dissected peneplain at Wausau. The uplands rise to the same level to an elevation of about 1,400 feet representing the surface of the peneplain.

The larger stream valleys about Wausau have been carved in the peneplain to a depth of about 200 feet.

Fig. 2.— Profile extending approximately east and west through Grand Rapids and Pittsville forty miles south of Wausau at the border of the pre-Cambrian and sandstone districts. Here the pre-Cambrian is covered with remnants of the Potsdam sandstone, and the valley bottoms are broad and shallow, and have no depth in the peneplain.

Fig. 3.—Profile extending north and south through the pre-Cambrian and Paleozoic areas, from Merrill and Wausau through Grand Rapids to Madison. The elevation of the dissected peneplain at Merrill is 1,550 feet, of the partly uncovered peneplain at Grand Rapids about 1,000 feet. The buried peneplain has an elevation of 500 feet at Kilbourn and 70 feet at Madison. The dissected peneplain, the slightly dissected peneplain, and the buried peneplain have essentially a continuous and uniform slope downward to the south. Rib hill and the Mosinee hills are monadnocks in the dissected peneplain, and the Necedah and Baraboo quartzite bluffs are monadnocks in the buried peneplain. Mosquito mound, the Friendship mounds, and Elephant's Back are mounds of Potsdam sandstone in the valley-bottom plain of the sandstone district.

NOTE ON THE ACTION OF FROST ON SOIL.

THE action of frost in altering the surface of the soil was well shown during the period of cold weather which prevailed over the Puget Sound region from February 10 to 18, 1903. During this time heavy white frosts formed every night, the temperature falling as low as 24° Fahrenheit, and ice formed three inches thick in open water. In the direct rays of the sun the surface thawed daily, but in shaded places the melting that took place was slight. The ground was not frozen at the beginning of the period mentioned.

The first night's frost had its usual effect of raising the surface of loose ground, which was well illustrated in gravelly soil. A layer of ice consisting of vertical prisms five-eighths of an inch long formed during the night at a depth of about three-eighths of an inch below the surface, thus raising the overlying material without otherwise disturbing it. The cold of the following night produced a similar layer of ice almost an inch thick below the first one, raising the latter along with its load of sand and gravel. A slight thaw took place on the day after the second cold night, the second day of observation. Specimens taken from shady spots early on the following day showed three layers of frost (Figs. 1 and 2), of which the top one had melted down unevenly, being almost destroyed in some places. The larger pebbles, absorbing and radiating a great amount of heat during the day, had settled through the ice to depths varying with their weight and shape.

After six nights the laminated structure presented the appearance shown in Figs. 3 and 4. In some cases the line of division between adjacent layers is difficult to locate in the figure, although it could be found in the specimens. The fifth and sixth nights were not quite so cold as those preceding, and it is to be noted that they yielded crystals of shorter growth, about three-eighths of an inch in length. By the eighth day all the layers

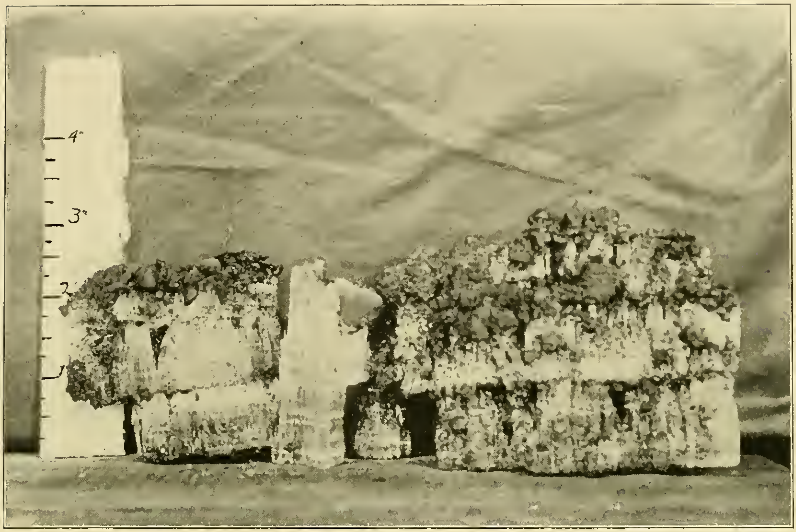

FIG. 1.

FIG. 2.

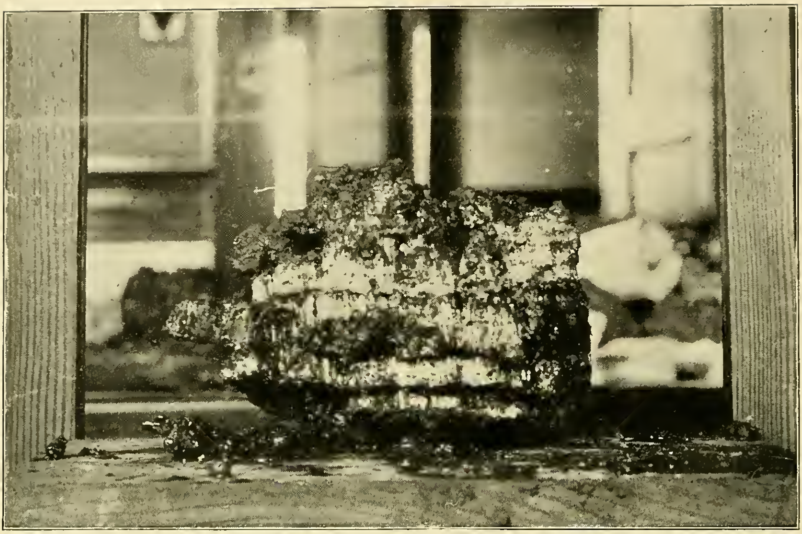

FIG. 3.

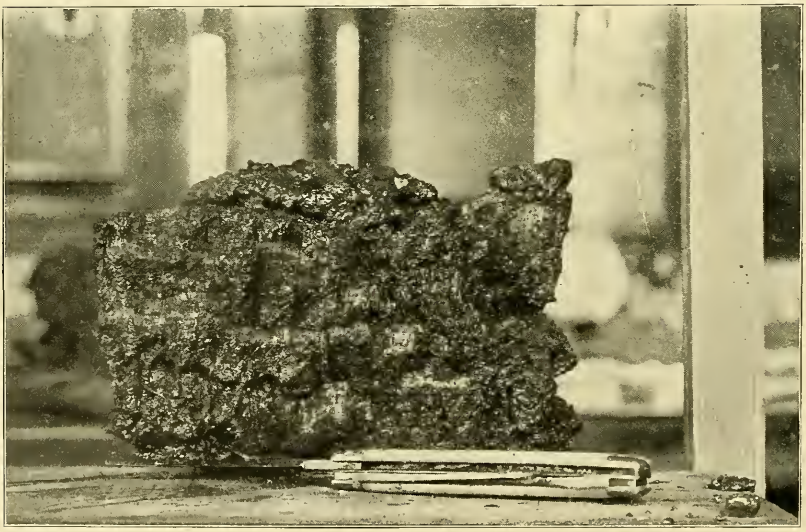

FIG. 4.

had shrunk by melting to such an extent that the total height of the eight layers was less than three inches, and the separate layers could be distinguished only in a few places.

The following conditions prevailed and seem to have controlled the formation of these many-storied frost-forms: (1) ground which was not frozen and which was readily permeable to moisture; (2) freezing temperature at night; (3) mild thawing in the daytime; and (4) considerable moisture in the soil.

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UNIVERSITY OF WASHINGTON, SEATTLE,
February 20, 1903.

NEW TERM FOR THE UPPER CAMBRIAN SERIES.

During a recent revision of the classification of Cambrian formations, in connection with the nomenclature and classification to be used in the geologic atlas of the United States, it became apparent that the term "Potsdam" or "Potsdamic" could no longer be retained as the series name to include the various formations referred to the Upper Cambrian. It was used in this sense by me in 1891,[1] but this usage has led to confusion, owing to the term "Potsdam" being retained for the well-known Upper Cambrian sandstone about the Adirondack mountains. In order to avoid further confusion, the term *Saratogian* is now proposed to include the various formations composing the Upper Cambrian series, leaving the term "Potsdam" restricted to its original application, the Potsdam sandstone. We shall then have the terms "Georgian" (Lower Cambrian), "Acadian" (Middle Cambrian), and "Saratogian" (Upper Cambrian) for the three series of formations of the Cambrian system.

The type locality of the Saratogian is north and west of Saratoga Springs, N. Y. The section has, at the base, about 200 feet of evenly bedded, compact, grayish to yellowish colored sandstone, that rests unconformably against or upon spurs or ridges of pre-Cambrian gneiss. At a locality three miles north of Saratoga Springs the sandstone is about 40 feet in thickness; it is overlain by an oölitic limestone, 30 feet, and a dark gray, evenly bedded limestone 50 feet in thickness. In this latter limestone the following fauna occurs :

Cryptozoa proliferum.	*Billingsia saratogensis.*
Obolus (*Lingulepis*) *acuminatus.*	*Matthevia variabilis.*
Platyceras minutissimum.	*Dikelocephalus hartti.*
Platyceras hoyti.	*Dikelocephalus speciosus.*
Metoptoma cornutiforme.	*Ptychoparia calcifera.*
Metoptoma simplex.	(*A.*) *saratogensis.*

[1] *Bull. U. S. Geol. Surv.*, No. 81, p. 360.

The Calciferous formation of the New York section rests conformably on the Upper Cambrian limestone.

The formations now referred to the Saratogian are as follows:

Type.—Sandstones and limestones of the south side of the Adirondacks, Saratoga county, N. Y., containing the Upper Cambrian fauna.

Correlated.—Upper part of Cambrian limestones of Dutchess county, N. Y., and an unknown portion of the limestones of the "Marble Belt" of western Vermont.

Upper part of shales of Tennessee (Knox), state of Georgia, and Alabama (Connasauga), and the lower part of the Knox dolomite.

Upper part of the sandstones of the upper Mississippi valley (St. Croix), Upper Cambrian limestones of South Dakota, Wyoming, Montana, and Colorado.

Upper calcareous beds of the Cambrian of northern Arizona (Tonto) and central Texas (Katemcy).

Upper Cambrian limestones and shales of Nevada (Hamburg), Idaho, and Montana (Gallatin).

Black shales of the upper portion of the New Brunswick and Cape Breton Island Cambrian sections.

Upper Cambrian shales and sandstones of Conception Bay, Newfoundland (Belle Isle).

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THE

JOURNAL OF GEOLOGY

MAY–JUNE, 1903

THE CORRELATION AND RECONSTRUCTION OF RECESSIONAL ICE BORDERS IN BERKSHIRE COUNTY, MASSACHUSETTS.[1]

PRELIMINARY STATEMENT.

THE studies which form the basis of this paper were made chiefly in connection with the mapping of the surficial geology of the Housatonic quadrangle, which comprises the southern two-thirds of Berkshire county and lies mainly in western Massachusetts, but partly also in New York and Connecticut. The southern half of the Taconic quadrangle, comprising the northern third of Berkshire county and an equal area in New York, is also included. This presentation of some of the results is offered by permission of Professor T. C. Chamberlin, under whose direction the studies were made.

One of the most important things brought out by the study of this area relates to the retreat of the ice-sheet, or, rather, to the retreat of its frontal edge or margin, across Berkshire county. As is well known from the extensive studies of Chamberlin,[2] Leverett,[3] and others in the states west of New York, the retreat

[1] An abstract of this paper was presented before Section E of the A. A. A. S. at Washington, January 2, 1903.

[2] T. C. CHAMBERLIN, "Preliminary Paper on the Terminal Moraine of the Second Glacial Epoch," *Third Ann. Rep. U. S. Geol. Surv.*, 1883.

[3] FRANK LEVERETT, "The Illinois Glacial Lobe," Monograph XXXVIII, *U. S. Geol. Surv.*, 1899.

of the ice-front in that region was not by an even, steady movement giving a uniform rate of recession, but by oscillations in which there were many alternating episodes of relatively rapid retreat and less marked readvance separated by times of halting, when the ice-front remained for some time in a stationary state. These minor oscillations with repeated haltings characterized the whole of the main movement of retreat of the last ice-sheet in the West. Each halt was the occasion of the building of a frontal or marginal moraine, and the drift of the Wisconsin epoch is nearly everywhere marked by a numerous series of these *recessional* moraines.

HISTORICAL.

In the East the ice-sheet was long thought to have had a different habit, and to have made no recessional moraines like those of the West. The two great marginal moraines extending westward along the coast from Cape Cod and Nantucket Island, and converging toward the west end of Long Island, have been known for many years.[1] The extension of one of these as the so-called "terminal moraine" of H. Carvill Lewis, having a general course west-northwest across New Jersey and Pennsylvania, is also well known.[2] These, however, are not recessional moraines, but the frontal deposits of the grand climax, when the ice-front rested after the general advance and before the general retreat.

Leverett has mapped the recessional moraines of the extreme western portion of New York and of the northwestern part of Pennsylvania, and he has also mapped in detail the morainic deposits of the Olean and Salamanca quadrangles in western New York. The folios to which these belong have not yet been published, but a map of the Olean quadrangle has been issued

[1] WARREN UPHAM, "Terminal Moraines of the North American Ice Sheet," *Am. Jour. Sci.*, III, Vol. XVIII (1879), pp. 81–92, 197–209.

[2] GEORGE H. COOK, "On the Southern Limit of the Last Glacial Drift Across New Jersey and the Adjacent Parts of New York and Pennsylvania," *Am. Inst. Min. Eng. Trans.*, Vol. VI (1879), pp. 467–520; H. CARVILL LEWIS, "Report on Terminal Moraine Across Pennsylvania and Western New York," *Second Geol. Surv. of Penn.*, *Rept. Z.*, 1884.

as a pocket map with Leverett's second monograph.[1] With these exceptions, the recessional moraines of Pennsylvania and New York have been recognized in only a few places and in short and scattered fragments. Salisbury has mapped a few fragments of recessional moraines which cross northern New Jersey.[2]

Essentially the same statement applies to New England. Emerson has identified a number of positions of the ice-front in central Massachusetts in places where it served as the retaining barrier for temporary glacial lakes or for the building of terraces of sand and gravel.[3] Woodworth has mapped two recessional halts on the western end of Long Island back of the great terminal moraine, and has made out the position of several consecutive ice-fronts by sand plains in the vicinity of Narragansett Bay.[4] Grabau has done the same in southeastern Massachusetts in the study of Lake Bouvé.[5] Crosby has found one or two morainic fragments and the positions of several ice barriers for lakes in northeastern Massachusetts.[6]

While these observations have added much to our knowledge, no considerable consecutive series of halts has been made out through them, nor has the course of the ice-front at any particular halt been traced continuously across the country for scores

[1] FRANK LEVERETT, "Glacial Formations and Drainage Features of the Erie and Ohio Basins," Monograph XLI, *U. S. Geol. Surv.*, 1902.

[2] R. D. SALISBURY, "Glacial Geology," *Geol. Surv. of New Jersey*, Vol. V (1902); also, "Pleistocene Formations," *New York City Folio, U. S. Geol. Surv.*, Folio No. 83, 1902.

[3] B. K. EMERSON, "Pleistocene," *Holyoke Folio, U. S. Geol. Surv.*, Folio No. 50, 1898; also, "Geology of Old Hampshire County, Massachusetts," Monograph XXIX, *U. S. Geol. Surv.*, 1900; also, "Geology of Eastern Berkshire County, Massachusetts," *U. S. Geol. Surv.*, Bull. No. 159, 1899.

[4] J. B. WOODWORTH, "The Retreat of the Ice Sheet in the Narragansett Bay Region," *Am. Geol.*, Vol. XVIII (1896), pp. 150–68; also, "Pleistocene Geology of Portions of Nassau of Queens County and Borough," *N. Y. State Mus. Bull.* No. 48, 1901.

[5] A. W. GRABAU, "Lake Bouvé, an Extinct Glacial Lake in the Southern Part of the Boston Basin," *Boston Soc. Nat. Hist., Occ. Papers*, Vol. IV, Part 3 (1900), pp. 601–94.

[6] W. O. CROSBY, "Geological History of the Nashua Valley during the Tertiary and Quaternary Periods," *Tech. Quart.*, Vol. XII (1899), pp. 288–324.

of miles, as is common in the West. Indeed, few if any have been traced as far as ten miles. Nor has any method of correlating the moraine fragments been worked out by which the individual ice borders may be plausibly reconstructed across the rugged country of New England. Because a distinct series of recessional moraines has not thus far been found in the East, the impression has prevailed in some minds that the ice-sheet may not have had the oscillations and halts that it did in the West. But this opinion has been held in spite of the suggestive significance of the fragmentary evidences just mentioned. The recent studies in Berkshire county have disclosed the fact that, at least within its boundaries, and in much of the country contiguous to it, the recessional halts did take place with usual regularity, and that fragmentary moraines were built along the several lines on which the ice-front rested. It is more the object of the present paper to show in particular what results bearing on the manner of the retreat of the ice-front have been attained by these studies.

TOPOGRAPHY.

The topography of Berkshire county is a rugged and varied one. The development of the present relief and its drainage systems has been almost entirely the work of subaërial agencies. Rain and frost and streams like those now there have done the work. Glacial erosion has been very slight. The development of the relief has followed the distribution of the harder and softer rocks, and lines of weakness in the former. The harder members are the mountains and uplands of today, while the valleys follow mainly the lines of the softer strata. The quartzite and gneiss of the Green mountain range, the various gneisses of Hoosic mountain and the plateau to the south, the Berkshire and Greylock schists of Greylock mountain, and the Berkshire schist of Mount Washington and the Taconic range constitute the principal areas of the harder rocks, and they are all areas of high relief, while the Stockbridge limestone and a few other less extensive, but relatively soft, strata lie chiefly in the valleys, and have determined their place and extent.

Although the Berkshires are a mountainous region the mountains are relatively small and low. The extremes of relief range from about 565 feet above sea level on the Hoosic river north of Williamstown, and about 650 feet on the Housatonic river below Ashley Falls, to 3,505 feet on Greylock mountain and 2,624 feet on Mount Everett, otherwise known as the Dome of Mount Washington. The two principal rivers are the Housatonic, flowing south, and the Hoosic, flowing north and northwest. Their valleys are the principal valleys of the county and are united as one trough across a col about three miles northeast of Pittsfield. The altitude of this col is about 1,120 feet above tide. Some of the main sources of the Hoosic are near the col, but the Housatonic, coming from the east, receives branches of some size from the north and west near Pittsfield. The extensive area of Stockbridge limestone stretching south from the vicinity of Pontoosuc lake three miles north of Pittsfield gives rise to the broadest valley of the county. Its usual breadth is from four to six or seven miles, but for twenty miles south-southwest of Pittsfield it is broken by isolated faulted mountains, and between these from Glendale to Housatonic the river flows through a narrow gorge-like valley.

Mount Washington, which is the highest point of the southern Berkshires, rises in considerable part above 2,000 feet. Excepting this, the higher lands in the southern and southeastern Berkshires commonly reach an altitude but little above 1,600 to 1,800 feet. The plateau of the southeastern part, however, is trenched by the deep, narrow valleys of the Westfield and Farmington rivers and their branches.

In the northern third of the county the reliefs become greater. Excepting in the vicinity of Williamstown, the Hoosic valley is seldom more than a mile wide in its lower levels. South of Williamstown a considerable area of limestone develops a broader lowland along Green river, and where this merges with the Hoosic valley it has the effect of broadening the latter.

The mountain masses bounding the Hoosic valley are considerably higher than those to the south. A large part of the Greylock mass rises above 2,000 feet, as does also the main crest of Hoosac mountain, East mountain, the Taconic range, and the southern end of the Green mountain range. In these ranges heights of 2,400 to 2,600 feet are quite common.

GENERAL ICE MOVEMENTS.

From their studies of striæ and bowlder transportation the earlier geologists, E. Hitchcock,[1] L. Agassiz,[2] and others, found that the ice-sheet moved across Berkshire county in a south-easterly direction, along the Hudson river in a southerly direction, and on the slope west of the river in a southwesterly direction, showing thus a wide southward spreading of the ice from the axis of the Hudson valley. This spreading of striæ characterizes the valley through its whole length from south to north. Such an arrangement of striæ shows that the valley was occupied at all stages of retreat by a great glacier lobe which projected far south from the general line of the ice-front and spread away laterally over the country both to the east and west of the river. Berkshire county was therefore overrun by ice from the Hudson valley lobe and may be said to lie within the territory of its retreating eastern limb. The recent studies fully confirm this conclusion from other evidences also, such as the alinement of drumlin axes, the position of stoss-side smoothing of the hills, and still more and with independent conclusiveness from recessional moraines and border drainage. It is found that in retreating from southeast to northwest diagonally across the county the ice-front halted fourteen times; that is to say, the east limb of the Hudson lobe oscillated or wavered that many times in retreating about fifty miles.

[1] E. HITCHCOCK, "On a Singular Case of the Dispersion of Blocks of Stone at the Drift Period in Berkshire County, Massachusetts," *Am. Jour. Sci.*, Vol. XLVII (1844); and Vol. XLIX (1845); also, "Illustrations of Surface Geology," *Smithsonian Contrib.*, Vol. IX (1857, and second edition, Amherst, 1860.) C. H. HITCHCOCK, "On the Marks of Ancient Glaciers on the Green Mountain Range in Massachusetts and Vermont," *A. A. A. S., Proc.*, Vol. XIII (1860), pp. 329–35.

[2] L. AGASSIZ, "Glacial Scratches in Berkshire and Wachusett Ranges, Massachusetts," and "Observations on a Set of Bowlders in Berkshire County, Massachusetts," *Boston Soc. Nat. Hist. Proc.* Vol. XIV (1872). Other early papers on the Richmond bowlder trains are by H. D. and W. B. ROGERS, *Boston Soc. Nat. Hist.*, Vol. V (1847), pp. 310–30, and by E. DESOR, *ibid.*, Vol. II (1848). But the most exhaustive paper is by E. R. BENTON, *Harvard Mus. Comp. Zool. Bull.*, Vol. V (1878).

GENERAL RELATIONS OF THE RETREATING ICE-FRONT TO THE LARGER LAND RELIEFS.

It is interesting to note the general relations of the larger features of the land relief to the receding ice-front; for, according as the ice-front retreated across them in one direction or another, the recessional history of the region was one thing or another very different thing. The earlier investigators found that the general direction of ice-movement was about S. 30° to 40° E. It is a general principle that the direction of ice-movement at any point near the ice-front is about normal to the margin, so that in this case the general trend of the ice-border was presumably northeast and southwest, and remained so during its retreat across the county.

The southeastern part of the county is occupied by the high plateau already referred to. While the ice-front was retreating across this area, the Westfield and Farmington rivers drained the waters freely away from the ice-front. But when the retreat had reached the western edge of the plateau, the ice-sheet obstructed the drainage of several relatively small valleys and caused the formation of temporary lakes. When it rested in the Housatonic valley, the ice-front had free drainage to the south in every position but one. From the bend south of East Lee to that west of Glendale the river flows west. During one of its halts the ice obstructed the passage at Glendale, so that the valley to the east was occupied by a lake of considerable size. West of the Taconic range in Canaan and New Lebanon in New York, more lakes were produced at a later stage in the westwardly draining valleys of that region.

But the largest lake in the Berkshires was that which was held in the Hoosic valley. The Hoosic river flows north as far as North Adams, and thence west and northwest. Throughout its whole course in Massachusetts and Vermont, and for some distance in New York, the retreating ice-sheet obstructed the normal direction of flow. The consequence was that this valley with its principal branches — the valleys of Green river and the Little Hoosic — was filled first with independent lakes, which later merged into one long, irregularly shaped body that filled the whole valley up to the contour of about 1,110 or 1,120 feet, according as one or another of two outlets was active. Geographical considerations, which ought to control wherever possible, would suggest Lake Hoosic as the most appropriate name for this body of water. Professor T. Nelson Dale, who has described certain features which he attributes to this lake, has called it Lake Bascom in published notices. But I shall use the geographical name as being decidedly better. One of the effects of Lake Hoosic was to obliterate and render unrecognizable the deposits of the ice-front where its halts rested in the northern, deeper part. This greatly increased the difficulty of distinguishing the successive halts in that part of the area.

If the ice-front had retreated from northwest to southeast, instead of in the opposite direction, the Hoosic would have been the valley of free drainage with valley trains of gravel, and the Housatonic, Westfield, and Farmington valleys would have had the lakes with deltas. The fact that, excepting in one small part where there are deltas, the Housatonic has only valley trains, and that the Westfield and Farmington have the same, while the Hoosic valley has deltas and lake clays, but no valley trains, accords well with the evidence of striæ and bowlder transportation, showing that the ice-front did in fact retreat in a general direction from southeast to northwest.

EVIDENCES BY WHICH THE RECESSIONAL HALTING PLACES OF THE ICE-FRONT WERE DETERMINED.

While the general retreat was going on across this region, the ice-front halted many times and formed a series of recessional moraines corresponding in a general way with the recessional moraines of the Great-Lake lobes in the West, except that they are very fragmentary and relatively faint and slender. The successive individuals are also on the average more closely spaced, the average interval between the halts in Berkshire county being about three and one-half miles, and they are all intensely sinuous in their courses.

There are, however, other classes of deposits which assist very materially in determining the place of the ice-border.

Besides (1) the moraines just mentioned, which are purely ice-laid sediments, there are (2) kames, eskers, and the like, which were made by the joint action of the ice and running water, and which may generally be relied upon as good supplementary evidence; and (3) eroded river channels along the border of the ice, outwash gravel fans, valley gravel trains, deltas, etc.

Excepting for the small isolated kames which occur in sporadic fashion, kames, and especially kame clusters, are essentially ice-border phenomena and are substantially equivalent to marginal morainic deposits. They nearly always occur at or very near the margin of the ice and are very commonly associated with moraines.

Eskers are not quite so closely related to the ice-front, and yet they are generally valuable aids; for, although they may extend for miles back, they nearly always take on a characteristic modification of development where they emerge from the ice. At such places they often take the form of a small kame cluster or delta, or sometimes an outwash fan. When an esker persists during several recessional halts, it generally shows one or another of these modifications at each place where the ice-front halted, although its ridge may be typically developed in the intervals. A good example of this sort may be seen in the great esker which runs south from North Adams to Berkshire.

Deposits of the third class often show the place of the ice-front in situations where there are no contiguous recognizable morainic deposits. In the Berkshires especially this class of evidence has been invaluable. Eroded river beds along the border of the ice are traceable for long distances only where the ice-front rested against a long unbroken mountain flank, as of the Green mountain range or of Hoosac mountain. But there are many places where shorter fragments of river beds are well developed. The streams that made them were not large, as a rule, but they are often very clearly cut in situations where their occurrence would be altogether impossible without the immediate presence of the ice-front to serve as one of the retaining banks. These fragments often occur on hillsides and steep valley slopes, and in other situations where the morainic deposits are absent or are so lacking in the usual characters of moraines as to be not surely recognized when taken by themselves. The occurrence of an old river bed at the upper limit of a hillside belt of bowldery till which has no particular morainic expression makes a combination as surely indicative of the presence of the ice-border as if it were a well-developed moraine. One of the most remarkable river beds of this kind runs along the flank of Dry hill between Hartsville and New Marlboro.

Outwash gravel fans also occur occasionally in such a way as to mark the place of the ice-front where no certain morainic deposits are discoverable. A small deposit of this kind in front of a faint moraine occurs near the base of Mount Washington west of Sheffield.

There are several moraine-headed gravel trains in the Housatonic and other freely drained valleys. These show the halting places of the ice-front quite clearly and may be safely relied upon. The gravel trains which head at Housatonic and at State Line and at Pittsfield are good examples.

Deltas occurring in association with moraines, and sometimes also with kames, are also valuable adjuncts to interpretation. The magnificent terrace at Lenoxdale combines moraine and kame with delta.

SOME DESCRIPTIVE DETAILS OF MORAINES AND BORDER DRAINAGE.

A brief description of a few of the better examples of moraines and border drainage will now be given. The morainic deposits associated with the ice-front may be divided into three or possibly into four classes:

1. *Frontal or marginal moraines, resembling those of the Great-Lake lobes in the West.*—These are ridges of bowldery till in which clay is a relatively large constituent. They have usually a swell-and-sag topography, but also more or less knob-and-basin development. In the West this type of moraine is most characteristically developed on a plain country along the straight or gently curving margin of a great lobe. There is but one typical and strongly developed example of this class in Berkshire county. This fragment runs three miles southeast from Pittsfield.

It is about a mile broad, has a beautifully undulating surface, the higher swells reaching an altitude of sixty feet above the surrounding plain. Clay is a large factor in its composition, and it originally carried a great number of bowlders on its surface. It is built out across an open part of the Housatonic valley and was made by an ice-tongue which came from the north out of the Hoosic valley. The fact that this tongue deployed upon an open plain caused it to expand as it advanced, and no doubt gave its moraine the character described rather than that of the next class of deposits, which is much more common in the Berkshires. There are moraines of this type, but not so well formed, west of Hoosick Falls, N. Y., and there is a small fragment of similar character three-fourths of a mile north of Ashley Falls.

2. *Terminal moraines of ice-tongues.*—This class of moraines is the best developed and the most common type in the Berkshires, but it has both advantages and disadvantages as a means of tracing the ice-borders. It is always fragmentary and limited in extent, being confined in its best developments to the terminal parts of sharply pointed tongues in relatively deep and narrow valleys. On the other hand, excepting the first class, it is the most easily and most certainly recognizable form of moraine. These deposits are as a rule much coarser in composition than either of the other three classes. Clay is usually a relatively small constituent, and knob-and-basin topography is the common form of expression. In many respects they resemble kames in the forms they take, and many of them might well be mistaken for such if their composition and the circumstances of their occurrence were left out of account. They nearly always contain a large percentage of gravel, and in this, too, they remotely resemble kames. But as a rule they contain some clay and a very large proportion of the coarser sediments, sometimes being composed mainly of cobbles and bowlders, with only a filling of gravel and sandy clay. Not infrequently small bodies of stratified sand and gravel occur in them. They may be distinguished from kames, however, by the fact that their best development occurs in narrow valleys where there was free drainage from the ice, while typical kames occur where there was more or less local

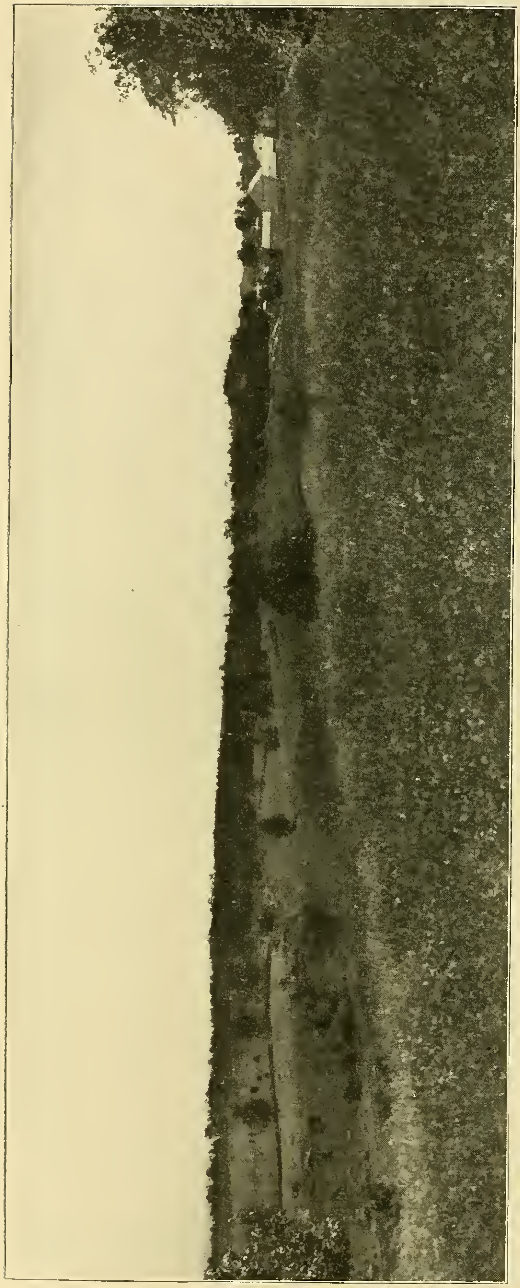


FIG. 1.—Looking southeast, one mile south of Cummington, Mass. Knolls of terminal moraine in middle ground.

ponding of the water. They are generally much coarser in composition than typical kames, and as a rule their knobs are lower and their basins shallower.

One of the best terminal moraines found is on the east side of the Farmington river, one mile north of Riverton, Conn. Besides the usual topography and coarse composition of terminal deposits, this one is thickly covered with huge blocks. Another, nearly as fine, was made at the next halt and is partly deposited on a low rock terrace below Hanging mountain, two miles south of New Boston, Mass.

Fig. 1 shows a well-developed terminal moraine one mile south of Cummington, Mass. Its topography is shown in the middle ground and is very characteristic, the wave-like knolls ranging from ten to fifteen feet in height, with sags and occasional shallow basins between. A broken esker leads to this moraine from the direction of Cummington. The deposit is about a mile wide from north to south. On its outer southward slope there are a few knolls of coarser composition and a small gravel train heads at the moraine. This moraine appears to have blocked the original valley of Westfield river, which formerly went directly south from Cummington, but now goes around to the east through a narrower valley past Swift River.

Fig. 2 is two miles north of Stamford, Vt., and shows a remarkably fine specimen of the deposits of an ice-tongue. The rounded knolls to the right and left below the higher hills are mainly morainic, and are twenty to thirty-five feet or more

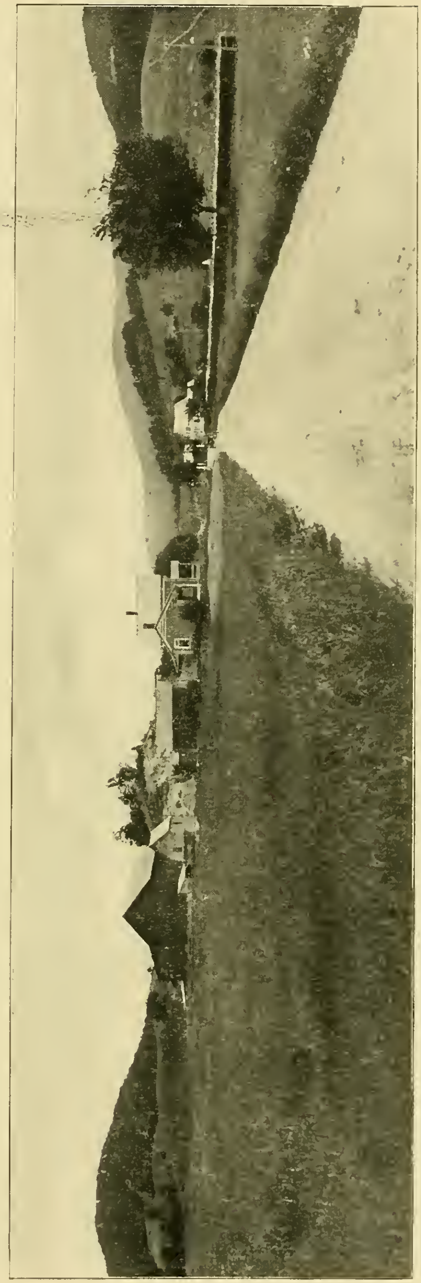


Fig. 2.—Looking north, two miles north of Stamford, Vt. Morainic knolls on right and left; end of esker between house and barn.

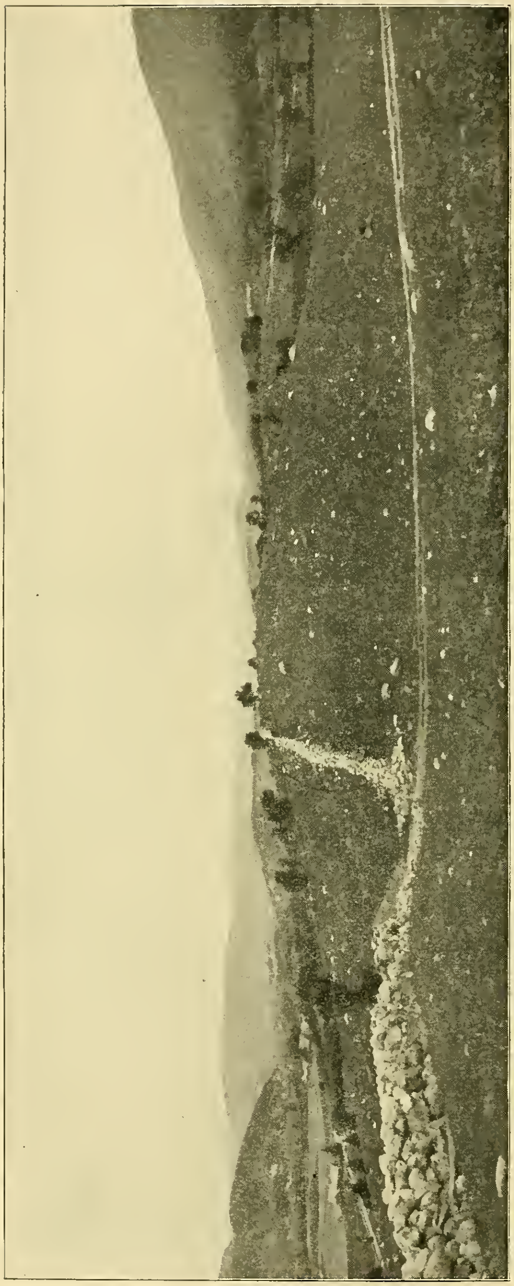


FIG. 3.—Looking north, two miles south of North Adams, Mass.

in height. The knoll seen between the house and barn is the outer end of an esker and is composed of fine stratified sand. This ice-tongue came from the north and ended in a lake in water probably fifty to one hundred feet deep. The deposits of this moraine are strongly developed for nearly two miles farther north.

Fig. 3 is south of North Adams. The stony knolls in the immediate foreground are part of a fringe of morainic knolls deposited on the outer edge of the great terrace along the base of Hoosac mountain. These knolls partake somewhat of the character of kames in their composition, but are nevertheless ice-border deposits. The body of the great terrace upon which this moraine rests is composed of limestone.

3. *Lateral moraines of ice-tongues.*—This class is probably much more extensive, measured along the sinuous length of ice-borders, than all the others put together. But, with a few marked exceptions, it is extremely difficult to recognize with certainty. It is also extremely whimsical in its occurrence. In many situations where one would expect to find it there is no sign of it, while in other places it may be splendidly developed where one would not expect it.

The principal difficulty in recognizing this type of moraine with certainty is its lack of distinctive characters. The place and manner of its occurrence and its association with other border features are the principal guides to its recognition. As would be expected, lateral moraines generally occur on hillsides or the sides of valleys, and often where they are steep. In surface expression and in composition they appear to differ in no important respect from the relatively smooth and featureless stony till of the ground moraine. Sometimes low knolls of coarser composition, and frequently small kames with more or less gravel and sand, are associated with their upper edges, but seldom enter into their composition as an important quantity. Sometimes the mass of drift composing them forms a thick bank —ten or twenty feet, or even more—and their recognition is easy. But oftener it is thin, and their recognition is then difficult or impossible. They are most easily recognized when associated with strong border drainage. Where such a moraine is banked up on a valley side and a river of some volume flowed along the side of the tongue, the bed of the stream puts a very sharp upper limit to the heavier belt of drift, which is then readily recognized as a *submarginal* deposit of the ice. Usually, too, the hillside above the river bed is bare or only thinly coated with drift. Occasionally these moraines are distinct where border drainage was absent or too slight for recognition, their upper limit being determined as before by a line dividing a heavy bank of drift below from a thinly coated surface above. Where border drainage was very strong, a ridge of coarse detritus was sometimes built along the edge of the ice and left there upon its retreat as a distinct narrow ridge forming the outer bank of the river bed. A beautiful example of this kind occurs on the west slope of Dry hill between Hartsville and New Marlboro. There are three of these river beds at this locality, with vertical intervals of fifteen or twenty feet. The lower one is the most

FIG. 4.—Looking southwest across old channel, two miles south of Hartsville, Mass.

strongly developed and has an outer morainic ridge or bank like a parapet or levee running, with occasional breaks, for two miles or more. It runs along the hillside half a mile east of the Konkapot river and about 130 feet above it. Fig. 4 is a view from the hillside looking southwest across this river bed, which is here about 200 feet wide. The meadow and the cornfield are on the floor of the channel, beyond which the stony parapet ridge may be seen rising ten feet or more above the channel floor. This type of lateral moraine, however, is rarely seen, the more common type being the smooth submarginal form.

Fig. 5 shows a well-defined lateral moraine on the southwest flank of East mountain about three miles northeast of Hancock, Mass. The heavy bank of till rises conspicuously to a certain level above which the drift coating over the rock is thin. The fresh gulley recently cut by a rivulet shows the composition of the mass. The end of this tongue was on the right at Brodie pass.

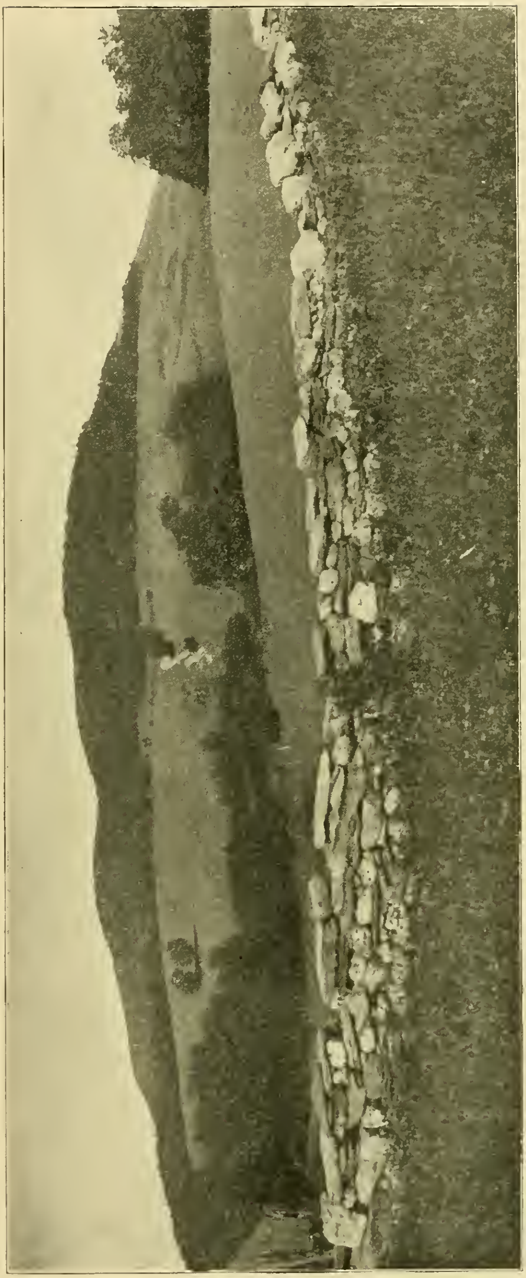


FIG. 5.—Looking northeast, three miles northeast of Hancock, Mass.

Fig. 6 is in the valley of Deerfield river near the mouth of Dunbar brook about two miles below Monroe Bridge. This is a remarkable locality. The mountain wall on the left rises over 1,000 feet from the river, in one

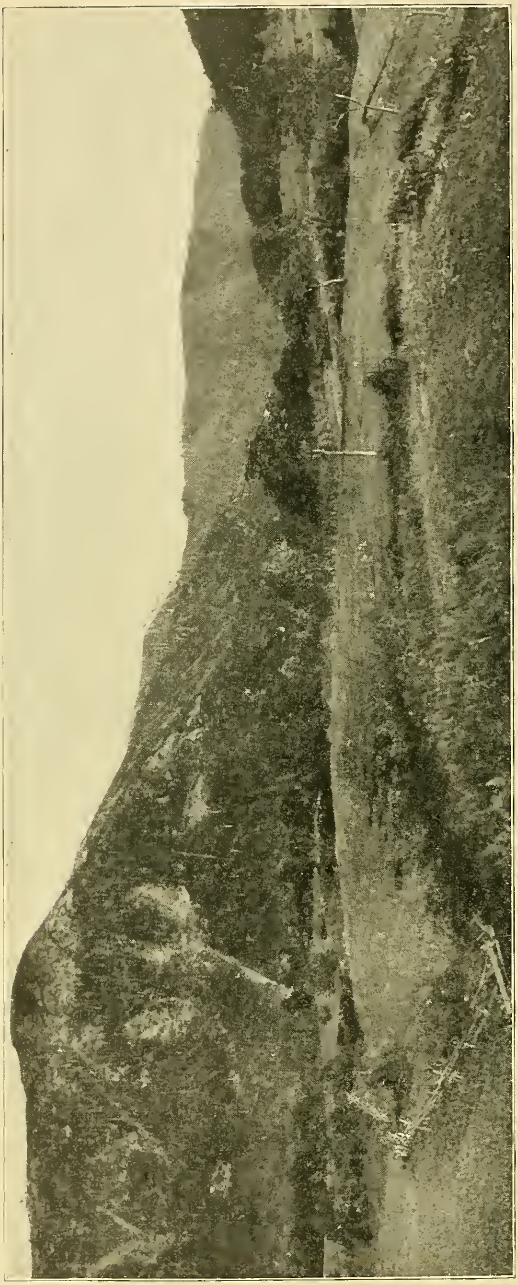


Fig. 6.—Looking south in valley of Deerfield river, two miles south of Monroe Bridge, Mass.

place rising nearly 900 feet in one-sixth of a mile, thus giving a slope of forty-five degrees. Two moraines are seen here in one view. The near foreground in the center is the outer end of an esker which turns to the left and then to the south at sharp angles. This esker seems to come out of the ravine of Dunbar brook, and appears to have belonged to a narrow ice-tongue which emerged from that ravine into the Deerfield valley whence it spread in the shape of an anchor with a short prong up and a longer one down the Deerfield. The hummocky ground under the hill at the right is full of knobs and basins, and is a part of the terminal deposit of this tongue. On the lower shoulder of the hill at the left and to the right of the tracks of the snow slides there hangs a fragment of gravelly morainic deposit about 300 feet above the river and belonging to this moraine. A little farther down at a lower level there are heavy morainic deposits continuous with it. These and the hanging fragment are better shown in Fig. 7. It may be noticed in Fig. 6 that the forest

FIG. 7.—Detail of hanging fragment of moraine shown in Fig. 6.

extends up the hillside to a certain line near the top, perhaps 200 feet from the summit, and that the snow slides begin at this same line. Above this line the rock is practically bare, but below it there is a coating of till which supports the forest. The upper limit of the snow slides marks the limit of the ice during the halt next preceding the time of the Dunbar ice-tongue, and the till coating where the several slides occur may be regarded as a thin lateral submarginal moraine. The end of the tongue at this halt was near Zoar.

There are many other good examples of lateral moraines, especially along the west slope of Hoosac mountain and on the hills north of Williamstown. The latter, however, are very much modified by the strong border drainage that was associated with them. On this account they show a much greater proportion of coarse sediment than usual and also a more varied topography.

(4) *Stoss moraines.*—These are moraines that are banked up on the stoss-side of hills or mountains which stood in sharp re-entrant angles of the ice-front. They have the same general character as the lateral moraines described above, and might perhaps be included with them. Like them they are distinctly submarginal and very smooth in expression and seldom well developed. They differ, however, from the lateral moraines somewhat in the manner of their occurrence and in their associations. Only a few good examples were seen, and none of these appeared to have border drainage associated with them nor any deposits of sand or gravel. The best example of this class was found on the north slope of Miles mountain, a mile and a half southwest of Ashley Falls. The north slope of this mountain is covered with a heavy coating of bowldery till up to about 300 feet above the river, but here the till suddenly grows thin.

All through the Berkshires the normal action of the glacier on the steeper stoss-slopes of mountains was to rub them hard and sweep them clean of all loose materials. Following this rule, the steeper stoss-slopes of the mountains are usually bare or only very thinly coated with drift. The drift sheet of the valleys usually rises somewhat upon their lower flanks, but this cannot be counted as a marginal deposit. However, where a high stoss-slope which would normally be swept bare is found to carry a heavy bank of bowldery till up to a certain height, above which the hill is mostly bare, the explanation seems to be that the bank of till was deposited just under the edge of the ice when the ice-front rested there and was depositing, and hence not sweeping heavily up the slope and over the hill. Stoss-slopes are swept bare most effectively when situated under the ice at some distance back from the edge and when the ice mass is moving freely over the tops of the hills. On Day mountain, which rises south of Dalton, there is a similar deposit.

We have seen in Fig. 4 a good illustration of the work of border drainage. The stream which made this channel was larger than most border streams within the Housatonic quadrangle, for it was the outlet of a temporary lake which filled the Monterey valley and drained a considerable area of land and ice lying to the northwest. None other equal to this was found, but there are good records of border drainage along the base of Peru hill east of Hinsdale; three miles directly south of Tolland; south of Mill River and from New Marlboro south and southwest; along the hill east of Sheffield; north of Salisbury and northeast of Hillsdale, N. Y. West of the quadrangle splendid lines of border drainage run southwest from Brainard, from East Chatham, and from near Spencertown.

In the Taconic quadrangle, so far as investigated, border drainage was found particularly strong where the ice-front rested against the Green mountains between Bennington, Vt., and Williamstown, Mass. It is strong also between North Adams and Cheshire along the flank of Hoosac mountain.

But some of the finest examples of border drainage are those associated with the later outlets of Lake Hoosic. As soon as the retreating ice-front withdrew from the north end of the Rensselaer Grit plateau, Lake Hoosic found lower levels of discharge in that vicinity. At four or five successive halts the outlet river found a new and lower course to the southwest along the front of the ice, and in each position it made a well-defined channel, and built a sandy delta each time where it struck the level of the Hudson estuary.

INTERPOLATION BETWEEN MORAINE FRAGMENTS.

The study of the ice-border in certain localities, where either border drainage or the lateral as well as the terminal moraines were traceable, has furnished the basis of a rule for interpolating re-entrant angles around hills and mountains from one terminal deposit to another. One of the best examples showing this relation may be seen in the Housatonic valley south of Pittsfield. The apex of this tongue rested at Lenoxdale, and at this place there is a very conspicuous terminal deposit. A small amount of bowldery till rises upon the flank of the hill along the east side, but the deposit is mainly a combination of kame and delta. The Housatonic river has found a way around the west side of the deposit. At the north end is a very tumultuous pebbly kame deposit, with pronounced knob-and-basin structure, while to the south the undulations fade away upon a level gravelly surface which terminates in an abrupt bluff at something more than a mile. The bluff has been made more steep by recent erosion. Toward the south the terrace is composed of stratified fine sand, except about fifteen feet at the top, which is coarse gravel. Two or three kames rise as sharp cones forty feet above the delta. One is shaped like a mesa, but narrows into a short but well-developed esker at the north. This tongue projected into Lake Housatonic, and it was in the water of this glacial lake that the delta and kames were made.

The Housatonic valley in this part is bounded on the east by the plateau front and on the west by Lenox mountain. Five miles north of Lenoxdale the plateau front turns to the east and Lenox mountain comes to an abrupt end. The ice-tongue evidently projected between these stolid sentinels. On the east side there appear to be no prominent features marking the ice-border. But on the west side the edge of the ice along the side of the tongue is prettily marked by a small lake and by the channel of its outlet, and in one place by morainic sediments. Two miles and a half north of Lenox and west of the main road there is a slight ridging up of the till into the form of a moraine. To the west this originally extended across the expanded portion of a ravine, coming out of Lenox mountain at the southwest. When the ice stood here it held a small lake in the ravine, and there are some small kames made by a stream which entered this lake from the ice. Eastward and southward, passing three-fourths of a mile east of Lenox, is a small but well defined old river bed which holds its course along the eastward slope nearly down to Laurel lake. Just east of Lenox it branches and takes a lower route a quarter to half a mile farther east and runs about parallel to the same destination. The two branches of the channel represent two positions of the ice-front during this halt.

The Yokun river drains the ravine, and the little lake may be known as Yokun glacial lake. It is near 1,350 feet above sea-level, while the top of the terrace at Lenoxdale is close to 1,020 feet. The base of the terrace is about 960 feet, and this is taken as the basis of measurement. The distance is about four miles from the central part of the terrace to the nearest part of the Yokun glacial lake. Hence the rate of slope along the side of this ice-tongue was nearly 100 feet per mile.

Several other tongues within the area studied afforded similar evidence, but generally the rate of slope indicated was slightly greater, between 100 and 110 feet in a mile. This rate was used as the basis for interpolating from the ends of tongues up to the re-entrant angles at their sides, and has seemed to give satisfactory results. The rate of slope is a little greater where tongues are very narrow, and a little less where they are broad. The average slope along the side of the Hudson lobe, regardless of the tongues and re-entrants, is something between twenty-five and thirty feet per mile.

In the Olean[1] and Salamanca quadrangles Leverett found the side slopes of tongues which reach down the ravines to the Allegheny river to vary between 100 and 130 feet per mile, or slightly steeper than those here reported for the Berkshire region.

Salisbury found the slope at the ice-front at Baraboo, Wis., to be 320 feet per mile. Other estimates of slope quoted by him are for the surface of the ice at points some distance back from its edge, where the slope is always less than at the front.[2]

THE CONTINUOUS AND SEPARATE INDIVIDUALITY OF THE RECESSIONAL ICE BORDERS.

The remains of the ice-borders in the Berkshires are mostly so faint and so fragmentary, and the fragments are so scattered about in the valleys and on the hillsides, with so little appearance of order or arrangement, that a map showing these features alone is unintelligible; it appears for the most part like a mere

[1] Pocket map in Monograph XLI, *U. S. Geol. Surv.*

[2] "Glacial Geology," *Geol. Surv., New Jersey*, Vol. V, pp. 41–3.

aggregation of spots, without any scheme of orderly arrangement, as shown in Fig. 8. This appearance arises not only from the fragmentary character of the evidences, but is greatly increased by two other causes—by the shortness of the average interval between the successive halting places, and by the extreme sinuosity of the ice-front at every halt. If the successive halting places had been farther apart, say fifteen or twenty miles on the average, instead of three and one-half, the continuity of the successive ice-borders would have been more apparent; for each one would have stood out as a recognizable continuous individual, inspite of the fact that it was represented only by a sinuous line of fragments.

In order to see the true relations in the Berkshires it is necessary to revert briefly to some of the larger elements of the situation. The Hudson valley was occupied by a great glacier lobe, low and sharply pointed at the south, but rising to higher and higher levels to the northeast along its eastern border until it overtopped the highest summits of the Berkshires. It was the ice of this lobe that overspread Berkshire county, and it was its retreating eastern limb or margin which made the recessional moraines. Each time the ice-front halted it fitted itself to the rugged topography with which it happened to be in contact at that time, projecting a series of tongues in the valleys and forming high re-entrant angles on the intervening hills. Thus the border of the Hudson valley lobe was made intensely serrate by the ruggedness of the local topography, and it was this that gave the course of the ice-border so many sinuosities and determined the peculiar distribution of its associated deposits. When the Hudson lobe began a movement of retreat, its border drew back all along the line until it reached the place of the next halt; then it halted all along the line, and whenever it advanced it proceeded in the same manner. There is no reason to believe that different parts of the margin of the lobe had dissynchronous movements, such as would be the case if one part retreated while another remained stationary or while still another advanced. Everything we know tends to the conclusion that the movement at all points was synchronous or in unison along the entire side of the lobe.

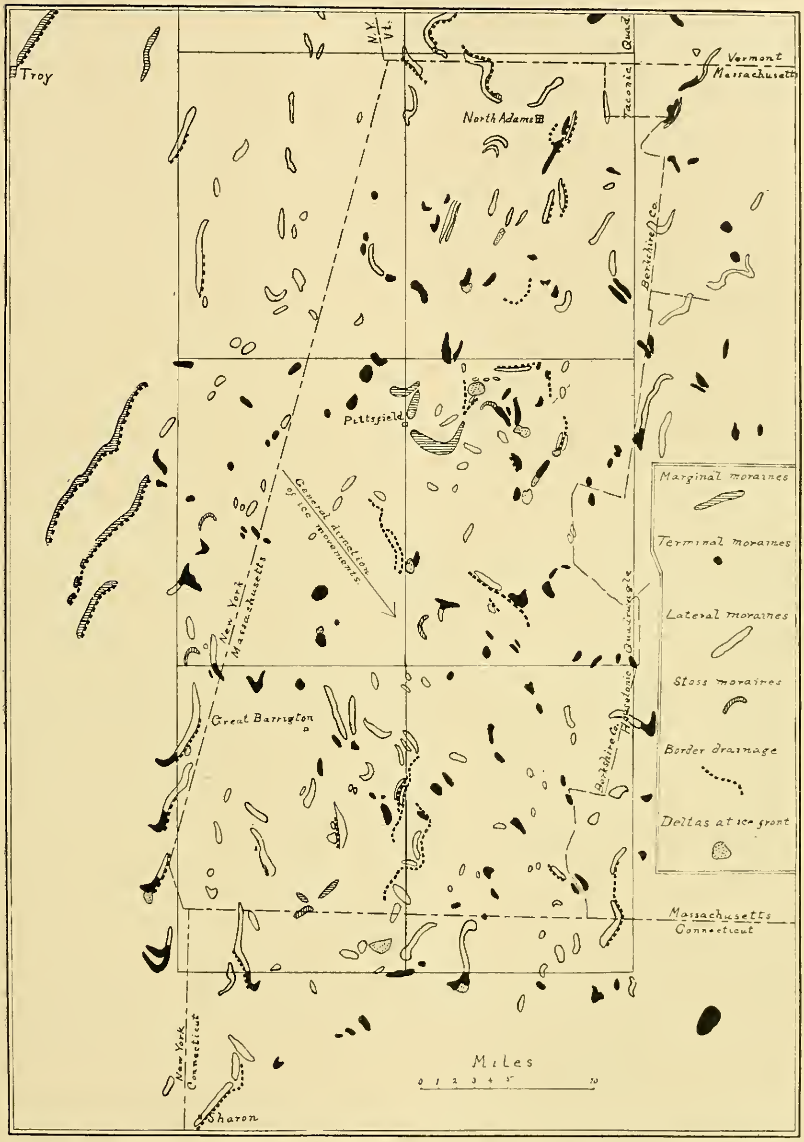


FIG. 8.—This map shows the distribution of morainic and border drainage features without any interpolation. When drawn upon the topographic contour maps, their relations to topography are brought out, and their distribution and arrangement are more intelligible. All moraine fragments which seemed uncertain in their relations to the ice-front are represented on the map as lateral.

These considerations disclose the true relation of the Berkshire ice-tongues to the Hudson lobe. They were absolutely dependent upon that lobe for all their movements, and they reflected its conditions in the most intimate way. They were all parts of the lobe itself and constituted a mere fringe along its border. If Berkshire county had been an even plain, either flat or gently inclined, the border of the lobe would have crossed it in straight lines, and the recessional moraines would have been straight and parallel. There would be no reason, then, to suppose dissynchronous movements at different points on the line. The rugged topography has not altered this relation. It produced a fringe of ice-tongues, but those tongues had no dissynchronous movements among themselves. They all advanced at one time, they all retreated at one time, and they all halted at one time.

The conclusion to be drawn from these considerations is that the ice-border at each halt rested on a line which was distinct and separate from the line of the halt that preceded it; so that if perfectly continuous moraines had been made along the entire margin at each halt, these moraines would now be separate and distinct individuals, extremely sinuous, but still roughly parallel and *without any overlappings*. Local differences of climate may have produced some slight dissynchronism of movements, and glacial erosion may have added a little to the same result, but the effects attributable to these causes appear to be so small as to be well within the ordinary width of the moraines. Sometimes moraines are a mile and one-half to two miles wide, and they are then generally composed of three or four secondary ridges more or less distinct, suggesting waverings or changes in the position of the ice-front during the halt. Border drainage channels often show the same waverings. But whether these very slight waverings were due to general or local causes is not yet clear.

Alpine glaciers, on the other hand, show widely dissynchronous movements.[1] While one advances, another retreats, and

[1] H. A. Reid, "Variations of Glaciers," reports in several recent volumes of the Journal of Geology.

still others may be at a standstill. The cause of this lack of unison in movements is found in the fact that Alpine glaciers are fed from separate snow-fields. Their gathering grounds are on the high flanks of mountain peaks or ranges, and each glacier has its own basin, or cirque, in which its snow accumulates. The varying conditions of snowfall in individual storms, and in different months and years and periods of years, furnish abundant reason for their individual peculiarities and dissynchronous movements.

But although their forms often bore some resemblance to Alpine glaciers, the ice-tongues of the Berkshires were not of the Alpine type. They were not fed by independent snow-fields, but were all simple offshoots from one ice-mass — the Hudson valley lobe. They were all fed from one source, and whatever affected that source affected them all alike. There appears to be ample reason, therefore, for believing that the recessional halts in the Berkshires were separate individuals without overlappings.

But while these conclusions may be safely applied to the Berkshires, and would probably be applicable in other regions where the relations were equally simple, it is not intended to imply that they would be a safe guide everywhere. There is much reason to believe that the great lobes, like the Hudson valley and Lake Ontario lobes, had movements somewhat dissynchronous, so that as between two such lobes the principle of correlation here suggested might not apply.

In the Berkshires, however, this seems to be the one thing needed. It seems to furnish the only possible basis of correlation by which the fragments of the recessional moraines can be connected together and the ice-borders reconstructed as they actually existed. With one or two ice-borders clearly made out in continuous form for a sufficient distance to show their general trend, with branching and interlacing series of terminal deposits made by ice-tongues at consecutive halts in the main valleys, and with a moderate amount of interpolation between adjacent fragments applied according to rule as given above, it becomes possible to reconstruct in continuous form all of the recessional ice-borders of Berkshire county. Of course, the certainty of correlation and reconstruction varies in different localities according as it is necessary to use more or less interpolation. For example, across Mount Washington the course of the ice-borders is almost wholly interpolated. The few fragments of moraine found on the mountain are so far from those in the surrounding valleys that their connections must remain uncertain. These lines, however, are not drawn by mere guess, but as closely by rule as possible, and are projected from points of observation in the valleys near by. The terminal deposits in the valleys on both sides of the mountain are mostly well developed and form an excellent basis for correlation. About the same amount of interpolation was used on Greylock mountain. The lines across Hoosac mountain are somewhat less certain, but they are based on excellent data in the valleys on both sides. The Green mountains, the northern part of the Taconic range, and the Rensselaer Grit plateau have not yet been sufficiently studied for mapping. In the rest of the area interpolation is used in less degree and is generally simple, and reconstruction of the ice-fronts is correspondingly easier.

THE BECKET AND LENOXDALE MORAINES.

Where ice-borders are represented by moraine fragments scattered in such disorderly fashion, it is fortunate to find two or three sections of some length in which the evidence for continuity is complete. Such sections establish the general trend of the ice-border and form excellent bases for the correlation of other less clearly connected fragments of near-by earlier and later borders. The second moraine, as shown on Figs. 9 and 10, is substantially continuous from Tolland to Colebrook, only a very little interpolation being required to complete the line between these places. There are a number of other sections of similar length, the continuity of which is quite clear. But besides these there are two longer sections, which in their combined length reach entirely across the Housatonic quadrangle from southwest to northeast. These are the Becket and Lenoxdale moraines, parts of the sixth and eighth, as shown in Figs. 9 and 10.

Beginning at a point about three miles northeast of Tyringham, the Becket moraine is readily recognizable as a continuous line for a distance of twenty-five miles, or to a point two or three miles northeast of Plainfield. The continuity of this line is evident simply from the closeness of the moraine fragments of which it is made up, and from its distinct separateness and lack of confusion with the fragments of other earlier and later moraines. The line of fragments stands out quite clearly as a unit in Fig. 8, where no interpolation is employed.

The other section is part of the Lenoxdale moraine. This one has much larger tongues and re-entrants, and might at first seem an unlikely case for clearly established continuity. But its relation to Lake Housatonic fixes the contemporaneity of two of its most widely separated tongues. As we have seen above, the great kame-and-delta terrace at Lenoxdale was built in a lake. If there had been no obstruction in the narrow valley of the Housatonic river below Glendale, the water would have passed out by that course as it does now, and there would have been no lake. There is another great kame-moraine deposit, with some delta gravel, at Glendale, showing conclusively that the ice-border stood there also in a lake. More than this, at the Konkapot col, three miles east of Great Barrington, there is the head of a well-marked eroded river bed which was the outlet of the lake in question, and this outlet is at an altitude of about 1,000 feet above the sea level—about the same as the top of the fine sand in the Lenoxdale delta. There is also a beautifully cuspate lake delta at East Lee at the same level, and the highest part of the Glendale deposit stands at about the same. It seems plain, therefore, that the ice-tongues at Lenoxdale and Glendale stood in their places at the same time, and that there was between these tongues a deep, wide re-entrant around Lenox mountain. From Glendale to Hillsdale, N. Y., the closeness of the moraine fragments and their distinct separateness from the fragments of earlier and later lines leave no doubt of the continuity of the Lenoxdale ice-front. This section also is about twenty-five miles long.

The Becket and Lenoxdale moraines are roughly parallel, and between their ends, which lap past each other, there are fragments of another moraine at East Lee and Washington. Supposing the successive moraines to be distinct individuals, as stated above, the correlation of fragments of other moraines with either of these continuous sections has the same significance as though they were correlated with the same point in a single series. These relations furnish the basis for reconstructing the several recessional ice-borders.

BRANCHING AND INTERLACING SERIES OF TERMINAL MORAINES.

With the aid of two or three ice-borders made out clearly as continuous units for distances of twenty or twenty-five miles, like those just mentioned above, it becomes possible to reconstruct other near-by ice-borders whose continuity is not so clear when taken by themselves. This can be accomplished by the correlation of branching and interlacing series of terminal moraines in their relation to the identified continuous lines.

The most favorable condition for the formation of a complete series of moraines that shall make a perfect record of the successive recessional halts occurs where a deep, narrow valley drains directly away from the receding ice-front and keeps this relation during many successive halts. This is the relation of the Farmington valley. From its head near East Lee it cuts through the plateau a few miles to the east, then turns to the south, and passes out of the county and out of the Housatonic quadrangle near the southeast corner. The earliest ice-border which rested within the area of the Housatonic quadrangle crossed the extreme southeast corner a mile west of West Hartland. It was a re-entrant angle of the ice-front and is a faintly developed feature, but it is here designated as No. 1 of the series. Counting up the moraines in the Farmington valley, beginning with the one north of Riverton as No. 2, we find that the deposit at West Becket on the line of the Becket moraine is the sixth, the one east of East Lee the seventh, the one at Lenoxdale the eighth, and the one at Pittsfield the ninth. The moraines of this series are distinct, well-formed individuals, and would be readily recognized by any experienced observer. A careful

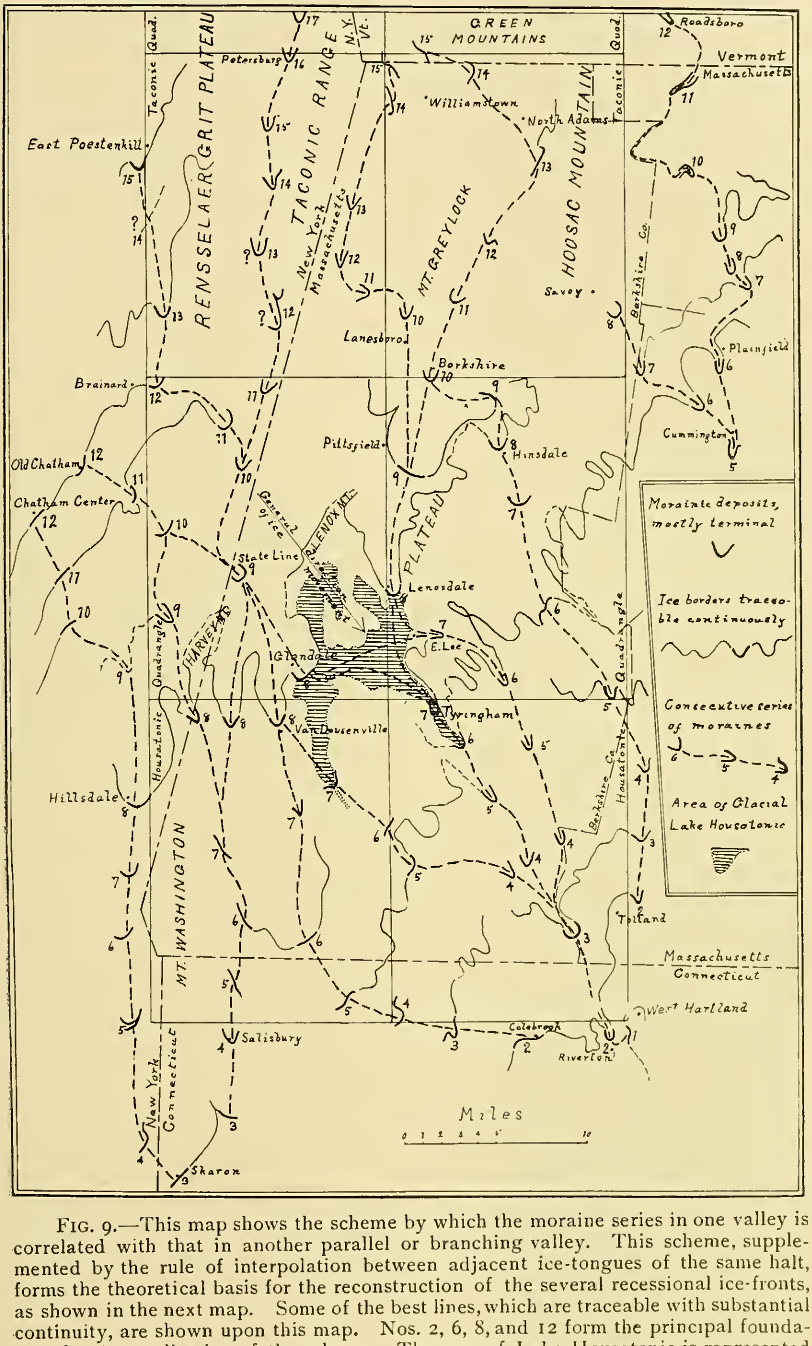


FIG. 9.—This map shows the scheme by which the moraine series in one valley is correlated with that in another parallel or branching valley. This scheme, supplemented by the rule of interpolation between adjacent ice-tongues of the same halt, forms the theoretical basis for the reconstruction of the several recessional ice-fronts, as shown in the next map. Some of the best lines, which are traceable with substantial continuity, are shown upon this map. Nos. 2, 6, 8, and 12 form the principal foundation for the application of the scheme. The area of Lake Housatonic is represented in order to show the contemporaneity of the Lenoxdale and Glendale ice-tongues.

study of the valleys in which these tongues lie shows further that there are no other recognizable terminal deposits in them. The deposits at Cold Spring and at North Otis show some complexity, because they are spread up and down the valley a little more than usual, in each case showing earlier and later phases of deposition which are one to two miles apart. But a little experience enables one to recognize the fact that deposits like these are due to the waverings of one halt.

South of East Lee the deep Tyringham valley comes in from the southeast. Over the col at its head it is continuous with the valley of Clam river, which joins the Farmington at New Boston. Counting the moraines up the valley again from Riverton by way of Clam river, we find the deposit at Tyringham to be the seventh or the same as that at East Lee, with the eighth at Lenoxdale as before. Here we have a branching series in which the first two are common, but north of the second one two parallel branches run up to the seventh. The branches diverge so little that they are not over four miles apart at any point. In a simple branching series like this it can hardly be doubted that the two deposits which stand as No. 4 in each series belong together as parts of one halt line, and the two deposits marked No. 5 as parts of a different later line, No. 6 as parts of still another line, and No. 7 as parts of still another. At Lenoxdale the two branches reunite as one.

From New Boston another series may be followed more to the west past Montville, New Marlboro, Hartsville, and the Konkapot col to Van Deusenville, where again is found the Lenoxdale moraine, which is the eighth of the series. This series, however, is not quite so good as either of the others, for it does not lie in a single trough or in a pair of head-joined valleys, like the other two, but crosses the hills from the Farmington valley to the Housatonic.

The moraine north of Riverton is easily recognized as part of a line which runs westward to Colebrook. Beginning at this place as No. 2, another series may be followed northwest to Van Deusenville as before, but by a different route through Norfolk, West Norfolk, East Canaan, Ashley Falls, and the hillside southeast of Great Barrington. Part of this series is somewhat less distinct than the preceding, but still is clear enough, and here we have four branching series of six terminating in No. 8, which is well determined as a continuous line.

In order to get the best possible basis for carrying the ice-borders by interpolation across Mount Washington, it was necessary to extend investigations some distance to the south beyond the limits of the quadrangle. The Housatonic valley passes close along the base of the mountain on the east, and the Copake valley along its west side in New York. In the latter valley there is a fine series of terminal deposits, which may be counted from the north, beginning with the Lenoxdale moraine at Hillsdale as No. 8. The seventh, then, is at Copake Furnace, the sixth at Boston Corners, the fifth about two miles north of Millerton, the fourth at Indian Lake, and the third at Sharon, Conn. This is as far as this series has been made out, but it is as strong and distinct as the series in the Farmington valley. At Sharon, and for three miles northeast, there is a well-defined moraine running along the edge of a bench near the northwest base of a mountain ridge extending in the same direction. The ridge is east of the moraine, and between the two there is a well-defined abandoned river bed averaging about an eighth of a mile wide. Beardsley pond lies in the course of this channel. The east side of the moraine facing the river bed is gravelly and sandy most of the way. At a point about three miles northeast of Sharon the river bed seems to have an abrupt beginning on the brow of a low ridge, overlooking Beaslick pond to the north 100 feet lower. There is no sign of such a river bed in that direction. The moraine turns to the north a mile south of the pond and changes its character, becoming a heavy till ridge of smooth form with very little sand or gravel. East of this ridge, and separated from it by the sharp depression in which Beaslick brook flows, is another heavy, smooth till ridge of precisely similar character. These ridges are about eighty feet above the adjacent low ground, but may not be wholly composed of drift. North of the pond these ridges are nearly parallel, but at the pond they diverge and turn away in opposite directions. The eastern one turns off to the east and is soon lost on the hill above Salmon creek, while the western one follows the bench to Sharon as described.

The relations here are highly significant and afford a strong basis of correlation around the two sides of Mount Washington; for evidently the large river, which seems to start so abruptly where the two moraines diverge, came from the northwest along a crease or depression in the ice. The ice-sheet advancing down the Copake valley on the west side of Mount Washington pressed eastward over the relatively low ground north of Sharon and west of Lakeville, and met the ice coming down the Housatonic valley on the east side of the mountain. A moraine along the southeast flank of Mount Washington north of Lakeville appears to belong to this same halt and indicates that a large portion, probably nearly one-half of the mountain, remained at that time uncovered as a nunatak. All of the drainage of the nunatak and of as much of the adjacent ice-field as sloped toward it found its way of escape along the crease between the two lobes and thence down the old river bed past Sharon. Since the ice has disappeared, the bed of the river in the ice-crease has gone, and no trace of it remains. This is why we find the river bed appearing suddenly where it emerged from the crease.

The significant fact which this relation establishes is this, viz., that the two moraines which diverge from the crease belong to the ice-border of one and the same halt. This enables us to say that if the Sharon moraine is No. 3, in a series numbered down from Hillsdale, then the east moraine at the crease is the same number counting down the Housatonic from Van Deusenville. Part of the latter series is not so strong as that between Sharon and Hillsdale, for the moraines in the Housatonic valley are mostly faint and weak. Still, well-developed small fragments may be seen at Salisbury for No. 4, west of Chapinville for No. 5, near Ashley Falls for No. 6, and on the mountain flank southeast of Great Barrington for No. 7. It would be hard to think of a more beautiful correlation between two series than that which is furnished by the peculiar relations of the Sharon glacial river.

There is another series of terminal deposits east of the Farmington valley almost as fine as those of the Farmington and Copake valleys. From the moraine north of Riverton the lateral moraine and border drainage is quite clear most of the way along the valley side north to Tolland, where the ice-border turned to the east. Starting with the deposits near Tolland as No. 2, there is a well-defined series running to the north past North Blandford, Becket, Washington, and Hinsdale to the moraine north of Dalton, which is the ninth in the series and the same as the Pittsfield moraine. The deposits at Tolland are rather faint, but all the other members of this series are well developed.

Passing out of Berkshire county into New York we may extend the series from the Lenoxdale moraine to the northwest corner of the Housatonic quadrangle. This may be done by following the series of terminal deposits from Van Deusenville as No. 8 past State Line, and thence north and west past Lebanon Center to moraine No. 12 east of Brainard. From here the series may be extended north to No. 15 at East Poestenkill. Outside of the quadrangle a series may be followed from No. 8 at Hillsdale to No. 12 at Chatham Center. Or, another good line runs from No. 8 south of Green River past Austerlitz to No. 12 at Old Chatham.

From the Pittsfield-Dalton moraine (No. 9) the series may be extended northward by two routes so as to surround Mount Greylock. One line runs through Berkshire, Cheshire, Adams, and North Adams to two lateral moraines northeast and north of Williamstown, the last one being No. 15 in the series. The first four are terminal deposits. Berkshire village is just north of the col between the Housatonic and Hoosic valleys, and the terminal deposits there and all those along the Hoosic river north of there, were laid down in the water of Lake Hoosic. From North Adams down, the lake was so deep that the terminal deposits are unrecognizable, and the positions of the tongues have been determined mainly by lateral deposits and border drainage features on the flank of the Green mountain range at and above the level of the lake. At Williamstown the lake was 500 feet deep. The conditions along the flank of the Green mountains favored the making of a strong record of glacial border deposits at every halt. The drainage features especially are very pronounced, and their value for determining the recessional series is almost equal to the terminal deposits of deep valleys with free drainage.

The other series running north from Pittsfield passes by way of Lanesboro and the Hancock valley to two lateral moraines on the flank of the Taconic range west and northwest of Williamstown, the last one being No. 15 as in the other series. Some of the individual deposits of this series are not so strong as those of the series through North Adams.

One of the best series found is that which extends northward in the Lebanon and Berlin valleys along the west side of the Taconic range, but the study of these valleys is not yet completed. Beginning with the tongue at State Line as No. 9, the series runs directly north past Lebanon Springs, Stephentown, and Berlin to No. 17 near North Petersburg, the last four being formed in a deep lake. Four more well-developed moraines lie west of Hoosick Falls. No. 20 passes Johnsonville and enters the city of Troy from the northeast, and No. 21 crosses the Hoosic river three or four miles below Johnsonville, but it is not known whether or not this last one touches the area of the Taconic quadrangle.

Going back now to the country bordering the east side of Berkshire county, we find the Becket moraine (No. 6) extending northeast to Plainfield. The splendid terminal moraine a few miles to the south, near Cummington, seems to belong to No. 5. From this point two series may be traced — one to the northwest up the Westfield river to Savoy, and the other directly north past Plainfield and down the east branch of the Chickley river to the Deerfield at Zoar (No. 10). On account of its depth and narrowness, the deposits in the Deerfield valley are unusually strong and clear, and the series quite easily made out. From Zoar the series may be followed past Monroe Bridge and Readsboro, whence one branch goes northwest past Hartwellville to Woodford on the top of the Green mountain range, while another longer series follows up the Deerfield past Davis Bridge, Searsburg, and Somerset to a point about three miles northeast of the northeast corner of the Taconic quadrangle, where No. 16 is found, about four miles south of Grout's mill.

Among these branching and interlacing series of terminal deposits there are several courses by which a complete series may be followed continuously across the county and across the two quadrangles from southeast to northwest. The Farmington-Housatonic-Hoosic series covers the whole interval, and shows that between the southeast and northwest corners of the county the ice-front halted fourteen times, while in crossing the two quadrangles it halted twenty or twenty-one times, the uncertainty depending on the unfinished work at the northwest corner of the Taconic quadrangle.

Along the west side of the two quadrangles on the less rugged slope to the Hudson the recessional moraines can readily be traced as continuous individuals. They run here in lines more nearly straight, the border drainage was strong, and the series as a whole can be made out with a completeness not possible within the limits of Berkshire county. However, so far as the several interlacing series of fragments in the mountain valleys are complete, they may be regarded as safe counters for the enumeration of the recessional series, and if, as assumed above, the several ice-borders of the recession are separate and distinct individuals without overlappings, then the series may be regarded as complete, provided there have been no errors or omissions in observation. In order that there might be the least possible chance of such errors or omissions, the counts have been confined as far as possible to the valley deposits; for in Berkshire county the morainic deposits are concentrated in the valleys and are nearly always more strongly developed there than elsewhere. A series of terminal deposits like any of the stronger ones mentioned above is in fact a series of accentuated points in the recessional moraines. When series do not follow valleys, but cross hills and mountain ridges, they are not by themselves so reliable. Such in part are the two lines from Colebrook and New Boston to Van Deusenville. But where they occur as supplementary lines between clearly defined valley series they may have considerable corroberative value.

In the interlacing series shown in Fig. 9 a considerable number of the morainic deposits and other ice-border features have not been used, as may be seen by comparison with Fig. 8. When these are all studied in their relation to the several members of the interlacing series, it is found that, with two or three unimportant exceptions, they all fall into line in one or another of the several halting places of the ice-front. Beginning at the southwest with any particular member of the Copake valley series, as for instance No. 6, and going northeast across the interlacing series and noting each deposit numbered 6, the course thus marked out will represent roughly one halt of the ice-front. Then by carefully studying the topography between tongue deposits in adjacent valley series, and allowing for its influence upon the motion of the ice, and making use of all intervening ice-border phenomena as shown in Fig. 8, a fairly accurate restoration of the ice-front at that halt can be made. In doing this the rule outlined above for interpolating around re-entrant angles on mountains or other features with high relief should be followed faithfully. That is to say, in order to restore the ice-front across a mountain ridge between the terminal deposits of two ice-tongues, the tongues having average dimensions for the Berkshire region, allowance should be made for a slope of 100 to 110 feet per mile along the side of the tongue from its point up to the re-entrant angles on its sides.

These are the methods by which the remarkably sinuous ice-borders of Berkshire county have been restored, as shown in Fig. 10. The mean course of any one of them represents the general course of the border of the Hudson valley lobe at that halt. These mean lines are bent from a direct course only by the larger features of topography, such as Mount Washington and the higher ranges to the north. In each one of the sinuous lines represented every point projecting away from the ice-field (generally toward the southeast) is an ice-tongue of more or less pronounced development, and every point projecting back toward the ice-field is a re-entrant angle.

In constructing these lines I have made them continuous where they represent ice-border features actually observed, and

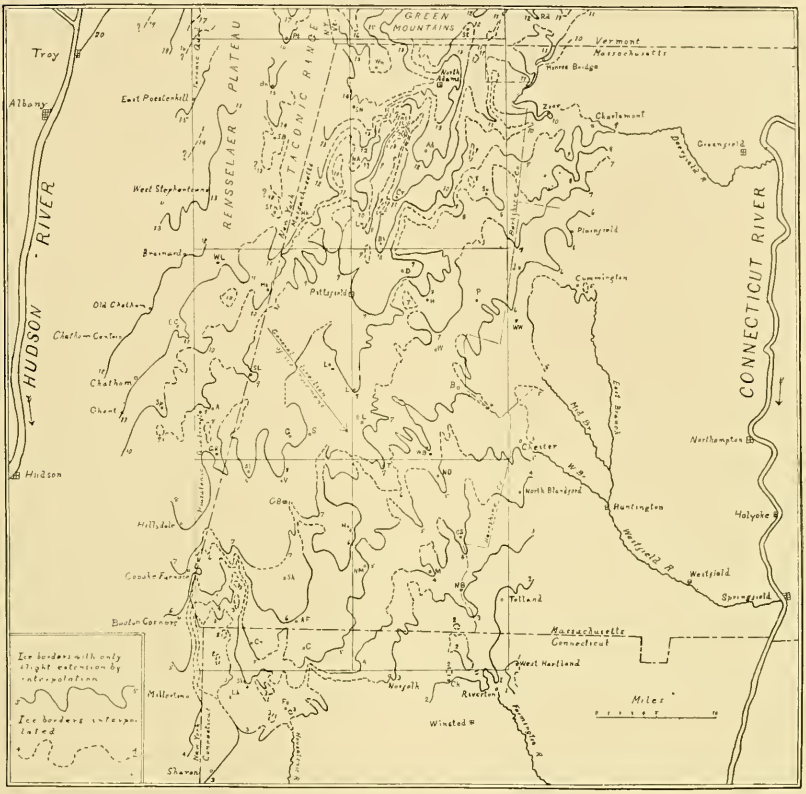


FIG. 10.—This map shows the final results of a reconstruction of the recessional ice-borders by the method set forth in this paper. Parts of the Hudson and Connecticut rivers are included in order to show the general relations of the ice-borders to these two great valleys.

In Connecticut, C = Canaan, Ck = Colebrook, Cn = Chapinville, Fv = Falls Village, Lk = Lakeville, and Sb = Salisbury.

In New York, A = Austerlitz, Bn = Berlin, EC = East Chatham, GR = Green River, Mt = Mt. Lebanon, Pt = Petersburg, SB = South Berlin, Sp = Spencertown, Stn = Stephentown, and WL = West Lebanon.

In Vermont, Rd = Readsboro and St = Stamford.

In Massachusetts, Ad = Adams, AF = Ashley Falls, Al = Alford, B = Becket, Bk = Berkshire, Cr = Cheshire, CS = Cold Spring, D = Dalton, EL = East Lee, G = Glendale, GB = Great Barrington, H = Hinsdale, Hk = Hancock, Hv = Hartsville, J = Jordansville, L = Lenoxdale, Ln = Lanesboro, Lx = Lenox, M = Montville, NA = New Ashford, NB = New Boston, NM = New Marlboro, NO = North Otis, P = Peru, S = Stockbridge, Sh = Sheffield, SL = State Line, Sv = Savoy, SW = South Williamstown, T = Tyringham, V = Van Deusenville, W = Washington, WB = West Beket, Wn = Williamstown, and WW = West Worthington.

I have extended them beyond these features by interpolation for a short distance, which may be defined as interpolation to the first degree. By this I mean that degree or amount of interpolation which any cautious and experienced observer would make without hesitation. Geologists who study the indurated rocks, especially in a drift-covered region, are continually driven to interpolate between outcrops. Where the distance is not great and the relations appear to be simple, such interpolation is regarded as a matter of no great difficulty, seldom involving serious risk of error, and requiring no very critical weighing of the phenomena for its application. It is like interpolating the course of a brook through a wood lot or a thicket when the places of its entrance and exit are known and the general relations are seen to be simple. Of course, many small errors will inevitably arise from such interpolation, but they seldom affect the larger elements of the problem in hand. The first degree of interpolation goes but a little way beyond what we can actually see. Where the restoration of the ice-borders in Fig. 10 has been accomplished by the use of interpolation which involves more uncertainty than the first degree, as here defined, I have drawn them as broken lines. Of course, the limit of the first degree of interpolation is an arbitrary one, but I have endeav ored to keep on the safe side. The higher mountain areas, like Mount Washington, showed very few recognizable ice-border features and the course of the ice-borders across these areas is drawn almost wholly by interpolation. In general, therefore, the margin of error is much larger here than in the lower areas. Nevertheless, an effort was made to minimize such errors by carrying the studies over all the contiguous low ground, even where some of this extended outside of the quadrangles.

CONCLUSION.

If these studies have been guided by right methods and the interpretations made on a foundation of correct principles, we seem justified in concluding that the ice-border which retreated to the northwest across Berkshire county was the eastern edge or limb of the Hudson valley lobe ; that the positions occupied by the ice-border at its successive recessional halts were distinct individuals without overlappings; that by the faintness of the moraines and other border phenomena, the halts may be judged to have been of relatively short duration, although when we consider the number of halts which occurred within the interval of fifty miles it can hardly be said that the retreat of the ice-front was rapid, or that it was a sudden dissolution with great floods, as pictured by Dana[1] and others.

That this ice was Hudson ice and came over the Berkshires from the central axis of the Hudson valley seems to be indicated further by the fact that within the area of the two quadrangles studied no stones or bowlders were found which might be suspected of coming from Canada or from the Adirondacks. It seems that the Adirondack ice never crossed to the east side of the Hudson-Champlain trough, and further that any bowlders which may have started from Canada down the axis of this trough found it impossible to keep the line of that axis far enough to reach the Berkshires. The continual divergence of the ice to one side or the other of the axis appears to have sidetracked all the Canadians before they got so far south. The same fact seems to account in part for the very local derivation of nearly all the drift in the Berkshires. Exceedingly little came from points as far north as Whitehall, N. Y. The great spreading ice-stream which moved down the Champlain-Hudson trough domineered those valleys through every stage of the glacial invasion and was never diverted from its course.

In his recent admirable report on the glacial geology of New Jersey, Salisbury observes that "the edge of the ice might have halted in one place and not at another at the same time. Moraines of recession are therefore sometimes not traceable for long distances."[2]

[1] J. D. Dana, "The Flood of the Connecticut River Valley from the Melting of the Quaternary Glacier," *Am. Jour. Sci.*, III, Vol. XXIII (1882), pp. 87–97, 179–202, 360–73; Vol. XXIV, pp. 98–104. C. H. Hitchcock, "The Glacial Floods of the Connecticut River Valley," *A. A. A. S., Proc.*, Vol. XIII (1883). Warren Upham, "A Review of the Quaternary Era, with Special Reference to the Deposits of Flooded Rivers," *Am. Jour. Sci.*, III, Vol. XLI (1891).

[2] "Glacial Geology," *Geology of New Jersey*, Vol. V, p. 89.

The entire glaciated area of New Jersey falls within the domain of the Hudson lobe, and its relation to that lobe is precisely the same as that of Berkshire county, Mass., except that the former lies on the west limb of the lobe and near the extreme limit of glaciation. If the principles used for Berkshire county are valid, they ought to be equally valid for the west slope of the Hudson valley, including northern New Jersey. We have seen above that a discontinuous character in the recessional moraines is not necessarily due to dissynchronous oscillations of the ice-front, and that, at least in the Berkshires, there are ways in which the continuity of the successive ice-fronts can be demonstrated, despite the extremely fragmentary character of the morainic deposits.

FRANK BURSLEY TAYLOR.

FORT WAYNE, IND.,
May 7, 1903.

THE UPPER RED BEDS OF THE BLACK HILLS.

CONTENTS.

INTRODUCTION.

THIS paper describes the upper red beds of the Black hills and inquires into the origin of their color.

The red beds of the Black hills are composed of from five to six hundred feet of red sandstones and shales with gypsum in the upper part and a bed of limestone toward the base. This limestone enables a threefold division of the rocks.[1] The Opeche formation at the base of the series consists of a hundred feet of unfossiliferous red shaly sandstones. These lower red beds lie apparently conformably upon vari-colored calcareous sandstones of Carboniferous age, the line of division being an abrupt change in color. Separating the upper and lower red beds, and lying conformably between them, is the Minnekahta limestone, which is purplish-gray in color, about forty feet thick, persistent in its occurrence, and contains Permian fossils. The upper red beds average four hundred feet in thickness, and are composed of unfossiliferous red sandy shales and interbedded gypsum unconformably overlain by more somber-colored rocks of Jurassic age. These upper red beds, named the Spearfish formation, are the subject of this paper.

[1] N. H. DARTON, "Geology and Water Resources of the Southern Black Hills," *Twenty-first Annual Report U. S. Geological Survey*, Part IV (1901), pp. 513–19.

DESCRIPTION.

General description.— The accompanying map shows the Spearfish formation girdling the Black hills in a crude ellipse, one axis of which is about eighty miles and the other forty. The width of outcrop varies considerably, but averages two miles. The greatest areal extent is in the vicinity of Sundance, where the formation is eight miles wide; near Cascade Springs the

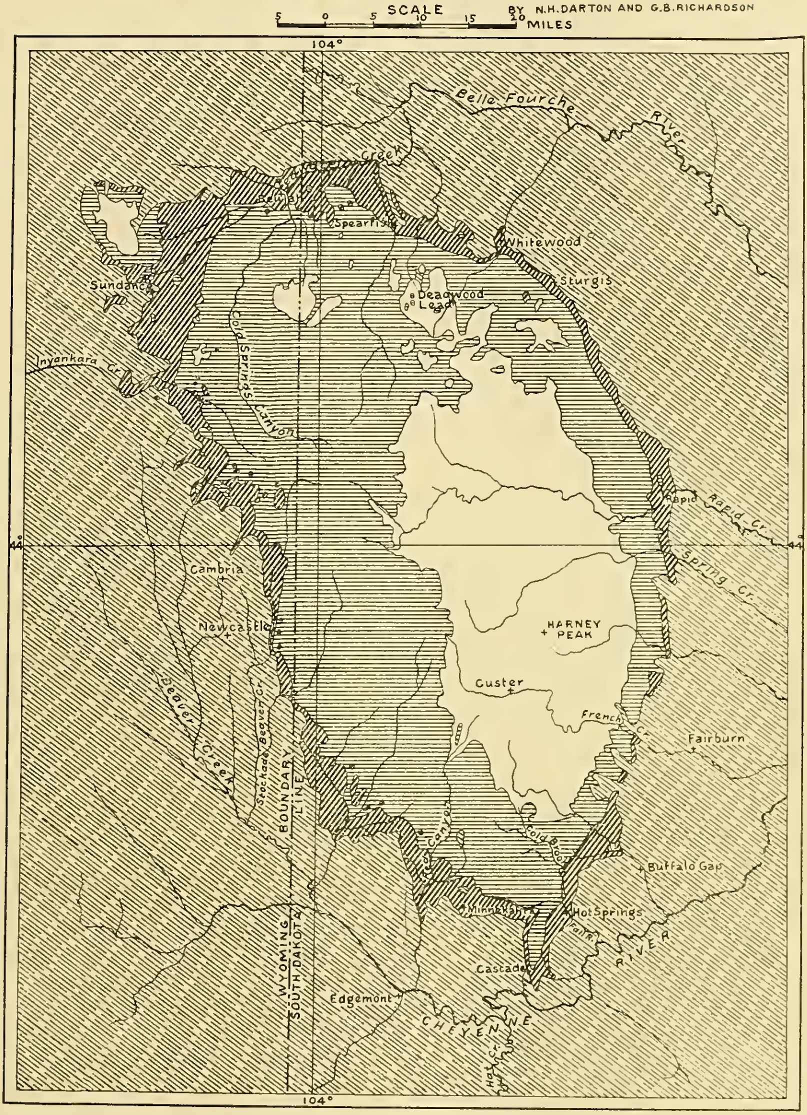
Red Butte, northeast of Cambria, Wyoming. Spearfish red beds capped by 30-foot bed of gypsum.

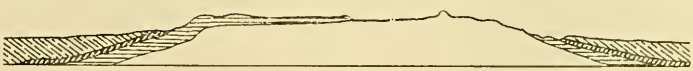
width, because of the steep dip there, diminishes to less than a thousand feet.

Structurally these rocks conform to the contiguous sedimentary formations by dipping on all sides from the central mass of the Black hills. This general dome structure, however, is varied by subsidiary folding. At the inner limit of the upper red beds, toward the center of the hills, the underlying purple limestone slopes upward, and the line of contact, where the softer red

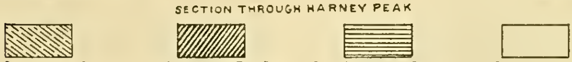
MAP OF THE UPPER RED BEDS OF THE BLACK HILLS

BY N.H. DARTON AND G.B. RICHARDSON





SECTION THROUGH HARNEY PEAK



rocks have been eroded from the surface of the limestone, is extremely irregular. The outer limit of the formation is emphasized by an escarpment formed by Jurassic and Cretaceous sandstones.

Streams coming from the high central area of the Black hills generally flow directly across the red beds, yet occasional creeks, like Red Water in the vicinity of Beulah, flow for some distance parallel to the strike of the red rocks before leaving them. The divides, however, are low and the general appearance of the Spearfish formation is that of a valley. This red valley is very conspicuous. No timber and very little vegetation are supported by the underlying rocks. Erosion has cut gullies in the shales and has exposed prominent gypsum-capped buttes, while the color contrasts of the rich red rocks and pure white gypsum form striking effects.

Details of stratigraphy.—The stratigraphy of the Spearfish formation is shown in detail by the following:

COLUMNAR SECTIONS.

(The heavy lines mark respectively the upper and lower contacts of the Spearfish red beds.)

I. ONE MILE UP COLD BROOK FROM HOT SPRINGS.

	Feet.	Inches.
Upper contact covered.		
Gypsum	10	
Red sandy shale	3	
Massive white gypsum	3	
Fine red shale	15	
White gypsum	..	9
Red clayey sandstone	8	
White gypsum	..	8
Red clayey sandstone	15	
Massive mottled gypsum (red sandy clay admixture)	35	
Red sandy shale with interlacing veins of gypsum 1 inch to $\frac{1}{16}$ inch thick	3	
Massive white gypsum	3	
Green-drab shale	1	3
Chocolate-brown hackley shale	5	
White gypsum	4	
Hard light-red clayey sandstone	..	8
Green shale	..	¼
Hackly brown sandy shale with a 3-inch streak of green clay	15	

	Feet.	Inches.
Covered to lower contact.		
At contact red, clayey sandstone with minute specks of glistening quartz.		
Purple limestone (Permian).		

II. THREE-FOURTHS OF A MILE UP COLD BROOK FROM HOT SPRINGS.

	Feet.	Inches.
Massive buff sandstone (Jurassic).		
Rather coarse dark brick-red sandstone with few streaks of green clay - - - - - - - - - - -	20+	
Concealed.		
Mottled gypsum (admixture of red clay) - - - - - -	4	
Reddish sands with thin green streaks - - - - -	..	8
White gypsum - - - - - - - - -	..	2
Rather coherent bright red sandy shale with few small green specks - - - - - - - - - -	25+	
Concealed.		
Red sandy clay.		
(Abrupt change.)		
Massive pure white gypsum - - - - - - -	18	
Light red clayey sandstone with network of wafer-thin gypsum veins - - - - - - - - - - -	10	
Massive white gypsum - - - - - - - -	8	
Red sandy clay - - - - - - - - -	2	
Massive white gypsum - - - - - - - -	20	
Red sandy clay - - - - - - - - -	40+	
Lower contact covered.		

III. HEAD OF SHEPS CANYON, EAST OF CASCADE SPRINGS.

	Feet.	Inches.
Massive yellowish sandstone with few small basal pebbles of quartz (Jurassic) - - - - - - - -	30–40	
Erosional unconformity.		
Massive chocolate-brown, sandy shale - - - - -	30+	
Dark brown-red clayey sandstone with green clay streaks, not continuous, and thin interlacing gypsum veins - - -	30+	

IV. CANYON NORTHEAST OF CASCADE SPRINGS.

	Feet.	Inches.
Alternating red sandy shales and gypsum of undetermined thickness.		
Hard red clayey sandstone with green streaks - - - - -	..	8
Red clayey sandstone with thin partings 2-inch ± of pure white gypsum - - - - - - - - - -	10	
Red sandy shale - - - - - - - - -	10±	
Pure white massive gypsum - - - - - - -	3	6

	Feet.	Inches.
Purple limestone (Permian)	30+	

V. ONE-HALF MILE SOUTH OF CASCADE SPRINGS.

	Feet.	Inches.
Covered to upper contact.		
Red shales.		
White gypsum	5	
Red sandy shale	20	
White gypsum	20	
Red sandy shale	15	
White gypsum	5	
Red sandy shale	100	
Covered.		
Light red sandy clay.		
White gypsum	20	
Red sandy shale	40	
Mottled gypsum (white gypsum with red clay admixtures)	20	
Red sandy shale.		
Gypsum	3	
Red sandy shale.		
Concealed	100±	
Gypsum.		
Purple limestone (Permian).		

VI. AT CASCADE SPRINGS.

	Feet.	Inches.
Upper contact covered.		
Red sandy shale	15+	
Mottled gypsum (red clay admixture)	10	
Bright red sandy shale	5	
Gypsum	2	
Red sandy shale	3	
Gypsum	10	
Red sandy shale	10	
Gypsum	20	
Red sandy shale	10	
White gypsum with few thin partings of red sandy shale	40	
Red clayey sandstone	20	
Gypsum	20	
Hackly red clayey sandstone	10	
Massive white gypsum	8	
Hard red clayey sandstone	..	6
Red sandy shale	20	
Lower contact covered.		

VII. ONE MILE NORTHWEST OF MINNEKAHTA.

		Feet.	Inches.
Jurassic	Fissile green-drab shale	50±	
	Friable white sandstone	25	
Contact covered.			

	Feet.	Inches.
Chocolate-brown clayey sandstone with patches of green clay	10+	
Concealed.		
Light red sandy shale with some small green specks and streaks	10+	
Chocolate-brown mudstone	4	
Brown-red clayey sandstone with 5′ bed of gypsum and some green streaks	20	
Red sandy shales with some green streaks	30	
Light brick-red clayey sandstone with network of thin gypsum veins	60	
Impure red-stained gypsum	12	
Red sandy shale	..	6
Pure white gypsum	..	2
Red sandy shale	..	1
Green shale	..	½
Red sandy shale with network of gypsum veins	50	
Massive white gypsum	5	
Red sandy shale with network of gypsum veins	15	
Massive white gypsum	20	
Red sandy shale with gypsum veins	5	
Massive white gypsum	3	
Red sandy shale	6	
Massive white gypsum	1	
Red sandy shale with gypsum veins	10	
Mottled gypsum (admixture of red clay)	20	
Brick-red sandy shale	110	
Purple limestone (Permian)	50	

VIII. FOUR MILES WEST OF MINNEKAHTA.

Massive, friable sandstone, red superficially; white within. (Jurassic).

Undulating contact — sharp change.

Hard chocolate-brown sandy clay.

IX. ONE-HALF MILE NORTHEAST OF X.

		Feet.
Jurassic	Massive fine-grained sandstone; superficially stained red — paler to white within	30–40
	Shale and thin-bedded drab-green sandstone	15–20
	Buff sandstone.	
	Massive white sandstone superficially red.	

		Feet.	Inches.
	Hard chocolate-colored shale with streaks of green.		

X. ONE-HALF MILE EAST OF XI.

		Feet.	Inches.
Jurassic	Drab shale	50	
	Buff sandstone	5	
	Drab shale		6
	Yellowish sandstone	15	
	Light red sandstone.		
	Dark red shale	40	
	Red clayey sandstone with thin beds of gypsum	25	

XI. ONE-HALF MILE FARTHER UP RED CANYON FROM XII.

		Feet.	Inches.
Jurassic	Fine white sandstone	15+	
	Drab-green fissile shale	50	
	Friable buff sandstone	5	
	Brick-red sandstone	15	
	Chocolate-brown shaly sandstone	3	
	Green sandy shale		3
	Fissile chocolate-brown shale	15+	

XII. WHERE RED CANYON LEAVES THE RED BEDS.

		Feet.	Inches.
Jurassic	Drab sandstone	10	
	Green shale	8	
	Drab sandstone	1	
	Dark-green shale and thin drab sandstone	20	
	Chocolate-brown shale with fine specks of glistening quartz	10+	

XIII. WEST OF FANNY PEAK.

	Feet.	Inches.
Red shale	100	
Gypsum	15	
Red clayey sandstone	100	
Gypsum mottled with streaks and spots of red and purple clay	30	
Red shale	100	
Gypsum	5	
Red shale with network of gypsum veins; thin-bedded at base with no gypsum and thin streaks of green clay	80	
Purple limestone (Permian)	10+	

XIV. RECORD OF WELL AT CAMBRIA, WYO.

		Feet.	Inches.
Jurassic	Drab shale	60	
	Gray and pink shale	4	

	Feet.	Inches.
Gypsum	8	
Light red shale	237	
Gypsum	7	
Red shale	58	
Gypsum	4	
Red shale with some gypsum	78	
Gypsum	12	
Red shale	88	
Purple limestone (Permian)	42	

XV. SEVEN MILES SOUTH OF SUNDANCE.

	Feet.	Inches.
Drab sandy shales (Jurassic)	10+	
Chocolate-brown sandy shale	10+	
Streak of green clay	..	2
Chocolate-brown sandy shale with few green streaks	3	
Green clay		¼
Red sandy shale	3	
Green streak.		
Red sandy shale	1	
Green streak.		
Concealed.		

XVI. ONE MILE NORTHWEST OF SUNDANCE.

	Feet.	Inches.
Covered to top.		
Red sandy shale.		
Impure gypsum	8	
Red sandy shale with network of gypsum veins	20	
Massive white gypsum	2	
Red sandy shale	5	
White gypsum	1	
(These two gypsum beds are connected by a vein of gypsum 2 inches thick with branches.)		
Chocolate-brown sandy shale	3	
White gypsum	1	
Red sandy shale with small specks of green clay	5	
Concealed		
Purple limestone (Permian).		

XVII. SEVEN AND ONE-QUARTER MILES NORTHWEST OF SUNDANCE.

		Feet.	Inches.
Jurassic	Fissile drab-green shales	40	
Jurassic	Buff, friable sandstone	10	
Jurassic	Gray-green mudstone	6	
Jurassic	Thin-bedded buff clay sandstone	3	

	Feet.	Inches.
Red sandy clay	20+	
(In places the change from red to buff sediments is abrupt and plane. In others there is an intermingling of red and buff. In one place a pocket 2 inches deep and 4 inches wide in the red clay is filled with buff sandstone and a few rounded quartz pebbles varying in size from pin-heads to peas.)		

XVIII. TWO MILES NORTHWEST OF BEULAH.

		Feet.	Inches.
Jurassic	Massive buff sandstone	5	
	Drab shale	..	2
	Light brown friable sandstone	15	
	Fissile green-drab shale	60	
	12 feet from bottom 1-inch bed of marl rich in Jurassic fossils.		
	White sandstone, with pebbles of smooth, rounded quartz from size of peas down	3	

	Feet.	Inches.
Undulating surface of contact.		
Chocolate-brown sandy shale	20	
Gray-drab clayey sandstone	3	
Dark brick-red sandy shale	5	
Gray-drab clay	..	2
Brick-red sandy shale	35	
Streak of green clay	..	2
Red sandy shale with few streaks of green	30	
Persistent bed of green clay	..	6
Red sandy shale	25	
Streak of green clay	..	2
Red sandy shale	4	
Green clay	..	5
Red sandy shale	10	
Green clay	..	1
Red sandy shale	15	
Green clay	..	2
Red sandy shale, occasional streaks of green clay	50	
Mottled gypsum (red clay admixture)	10	
Red sandy shale.		
Concealed.		
Red sandy shale.		
Massive white gypsum	4	
Red sandy shale	10	
White gypsum	2	
Red sandy shale with veins of gypsum	15	
Bedded gypsum.		

	Feet.	Inches
Purple limestone (Permian).		

XIX. NORTHEAST OF SPEARFISH ; VALLEY NEXT EAST OF LOOKOUT PEAK.

	Feet.	Inches
Green shale (Jurassic)	10+	
Massive white gypsum	2	
Clayey sandstone	12	
Massive white gypsum	20	
Red sandy shale with few green streaks	50	
Gypsum	..	2
Red sandy shale	..	½
Green clay	..	½
Chocolate-brown sandy shale, few gypsum veins	20	
Green clay	..	1
Red sandy shale	2	
Gypsum	..	2
Red sandy shale	8	
More massive sandy shale	..	3
Chocolate-brown sandy shale with streaks of green	1	
Thin-bedded red sandy shale with specks of green	10	
Chocolate-brown sandy shale with network of gypsum veins paper-thick to 4 inches.		
Covered.		

XX. ONE AND ONE-HALF MILE WEST OF WHITEWOOD.

Section generally covered. Impure gypsum exposed toward the middle of red clays. Uniform dips of 28° and upper and lower contacts give thickness here of 450 feet for the Spearfish red beds.

These sections show that the upper red beds of the Black hills consist of about four hundred feet of red sandy shales with interstratified beds of gypsum. The shales are generally homogeneous in color, composition, and texture, but subordinate variations are caused by small green streaks and spots. The gypsum beds are irregularly distributed in lenses throughout the formation. Adjacent to the beds of gypsum frequently the red shales are traversed by interlacing gypsum veins. No fossils have been found in the Spearfish formation.

The red beds are characteristically red, the shade varying from chocolate-brown and dark red to light red ; the usual tint is a uniform dark brick-red. The unaided eye sees in a hand specimen a fine-textured arenaceous red shale, with occasional minute glistening particles of quartz and muscovite. The rock crumbles between the fingers to a fine powder, which with water can be readily molded; breathed upon, it gives the characteristic clay odor. The rock has no pronounced structure. It is coherent, yet easily friable, and breaks unevenly, with a tendency to a hackly fracture. Bedding planes are feebly developed and usually cannot be distinguished. Occasionally, though, when sand admixture becomes so prominent as to produce a clayey sandstone, thin flaky bedding planes become distinct.

Streaks and spots of green in the midst of the red shales form local variations. The green streaks seldom are continuous, but occur irregularly, often with uneven and wavy surfaces of contact with the red rocks. In places the green streaks follow small joint planes. The size of the streaks varies from a small fraction of an inch to three or four inches in thickness. The green spots are irregularly distributed and roughly spheroidal in shape; usually of about the diameter of a pin-head, they sometimes reach half an inch in diameter. In composition the green differs from the red shale by being poorer in iron and having a higher ratio of ferrous oxide. An analysis of adjacent green and red shale gave:

Green Shale.		Red Shale.	
Fe_2O_3	1.85 per cent.	Fe_2O_3	4.61 per cent.
FeO	1.04 "	FeO	1.24 "

Beds of gypsum occur at different horizons throughout the extent of the Spearfish formation, the greatest development being toward the middle of the series. Longitudinally no individual bed can be traced far. The thickness of the gypsum varies from a fraction of an inch to a maximum of about forty feet. Generally the gypsum is remarkably pure and the color a clear white. Occasionally admixtures of red clay produce a mottled appearance.

The following is an analysis of a sample of pure white gypsum collected near Cascade Springs:[1]

[1] By Mr. George Steiger.

SiO_2	0.10
Al_2O_3	0.12
CaO	32.44
MgO	0.33
H_2O	20.80
SO_3	45.45
CO_2	0.85
	100.09

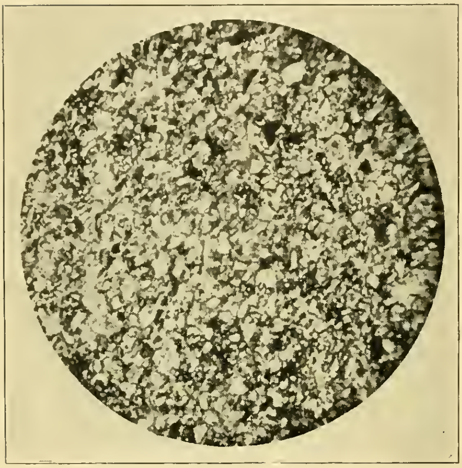
Gypsum also occurs, forming interlacing networks of veins in the red sediments. The veins can be traced directly to adjacent beds of gypsum, and range from paper thinness to two or three inches. Frequently vein structure, crystals oriented perpendicular to the walls, occurs and sometimes two periods of formation of crystals are evident.

The red beds rest on the underlying purple limestone everywhere conformably. There is no indication of a period of exposure of the limestone to subaërial influences, but there is a sharp contrast in the character of the sediments. Massive limestone generally is followed abruptly by red shales; though in places—sections IV, V, and XVIII—gypsum immediately overlies the limestone.

In contrast to the uniformity of the lower contact, the transition from the upper red beds to the Jurassic is variable. The change does not occur in the red beds themselves, but rather marks the beginning of the Jurassic. The upper contact is locally an undulating, gently eroded surface; frequently, however, the contact is plane and apparently conformable. The upper contact is occasionally marked by pebbles of quartz varying in size from pin-heads to peas (section XVII). In one instance (section XIX) gypsum was found at the extreme top of the formation. The most pronounced change, though, is that of color. The uniform chocolate-brown shales of the upper Spearfish are succeeded by green shales or buff sandstones.

Microscopic characters.—Under the microscope the red shale is seen to be composed of minute white particles with irregular outlines coated by, and frequently including, an amorphous brown-red pigment. Quartz is the chief constituent, besides which the white minerals are muscovite, calcite, magnesite, kaolin, gypsum, and feldspar. Some magnetite and ilmenite and occasional fragments of chlorite, are also present.

No systematic arrangement of the minerals occurs, the texture being characteristically sedimentary. The individuals are all minute; few are over 0.1^{mm} in cross-section, and the average is about 0.04^{mm}.



Magnified 50 diameters. ×56

Magnified 136 diameters. ×136

Microphotographs of thin sections of the spearfish red beds.

The quartz grains vary in size from 0.03 to 0.06^{mm} in cross-section. The particles are angular to subangular, seldom well-rounded. Some of the contours are so irregular, though smooth, as to suggest corrosion. Many of the quartz grains are perfectly clear and transparent, while others contain inclusions. Slender prisms of rutile are included in a few of the quartz grains, while others contain fluid inclusions. These do not contain red pigment and probably are original minerals derived from the disintegration of the parent rocks. Other quartz grains contain numerous inclusions of the red pigment and doubtless this quartz is secondary, being formed in the presence of iron oxide.

Muscovite is present in small clear rods, averaging 0.1^{mm} long by 0.006^{mm} wide. Sericite occurs sparingly in irregular patches averaging 0.06 or 0.07^{mm} in cross-section and consisting of minute fibrous plates.

Carbonates occur scattered throughout the slides in rhombs that average about 0.03^{mm} in cross-section and in small irregular particles.

The presence of kaolin is suggested under the microscope by dull white flakes of irregular outline and of low refraction and birefringence. Bits of red pigment are frequently included. And the presence of kaolin is probable from chemical tests. The color was discharged from a piece of red clay by digestion in hydrochloric acid. The resulting gray powder was examined under the microscope, and white flakes of low double refraction were isolated, excluding quartz as far as possible. These flakes reacted for aluminum and water before the blowpipe.

Feldspars are very sparingly present. Some clouded fragments seem to be decomposed orthoclase. A few irregular areas of microperthite of fibrous appearance are also present. And very rarely bits of decomposed plagioclase occur.

Gypsum and dolomite, or magnesite, were not determined under the microscope, but their presence is shown by chemical analysis.

Amorphous red pigment is prominent in the slides. It irregularly coats and spots the minerals, and is included in some. The inclusions seem to be restricted to quartz and kaolin. This pigment constitutes the chief interstitial substance. It does not occur in continuous vein-like impregnations, nor does it form bands or local accumulations.

Analysis shows that the red pigment is iron oxide and that probably it is completely anhydrous. Sample No. 54, in which the complete analysis shows 2.84 per cent. of combined water, was treated with hot hydrochloric acid until all of the iron was dissolved. The residue was found to contain 1.90 per cent. of combined water, leaving 0.94 per cent. available for the hydrous minerals which hydrochloric acid would attack. Gypsum, and possibly an iron hydrate, are the only ones that the acid would decompose. Calculating the amount of gypsum from the amount of SO_3, it is found that 4.8 per cent. of the rock is gypsum. This requires 1 per cent. of water, which practically is the amount available. No water, therefore, is left for combination with the iron. It is true this calculation is but an approximation, but it appears evident that the red pigment is either anhydrous or nearly so.

Chemical analysis.—Two specimens of the Spearfish formation were analyzed by Mr. George Steiger, of the U. S. Geological Survey, with the following results:

	Red Sandy Shale from East of Newcastle. No. 54.	Red Sandy Shale from East of Spearfish. No. 55.
SiO_2	56.20	58.32
TiO_2	0.77	0.48
Al_2O_3	11.50	8.59
Fe_2O_3	3.64	2.04
FeO	0.65	0.18
MnO	0.10	0.07
CaO	5.83	8.45
BaO	none	none
MgO	4.23	3.65
K_2O	3.74	2.71
Na_2O	0.98	0.72
Water 100 –	1.61	0.52
Water 100 +	2.84	1.40
P_2O_5	0.12	0 05
SO_3	2.26	0.43
CO_2	5.72	12.08
Cl	trace	strong trace
	100.19	99.69

The elements are so distributed that an exact determination of the relative abundance of the minerals in the rocks analyzed is impossible. Estimates based on the analyses and on the appearance under the microscope give the following approximate mineral composition of average red shale:

Quartz	41	per cent.
Muscovite	20	"
Kaolin	10	"
Calcite	9	"
Magnesite	8	"
Feldspars	5	"
Hematite	3	"
Gypsum	2	"
Magnetite, ilmenite, chlorite	2	"
	100	

The analyses show traces of chlorine. Probably this is present as common salt, which, in spite of its solubility, may represent salt deposited in the red beds during their formation. No beds of rock salt have been found in the red beds of the Black hills, but a local accumulation is suggested by a salt spring in the red beds about three miles northeast of Cambria, Wyo. An analysis of this water by Mr. Steiger showed:

	Grams per Liter.
CaO	1.960
MgO	.448
K_2O	none
Na_2O	27.334
SO_3	3.556
Cl	31.479
Br	none
I	none
	64.787
Less O=Cl	7.094
	57.693

=51.582 grams of NaCl per liter.

DISCUSSION.

Red beds in general are well known to be colored by ferric hydrate or ferric oxide, but conditions that determine the formation and deposition of red pigment are various. Red beds have accumulated at different times and in different localities, under different conditions. This study was undertaken with the purpose of seeking evidence for the origin of the color of the red beds of the Black hills.

The history of these rocks is intimately connected with the history of the entire series of red beds of the central West, and a complete treatment of the subject is impossible without the accumulation of more facts, concerning the general geology of the Rocky mountains and adjacent regions, than are now known. Nevertheless the red beds of the Black hills constitute an isolated mass, and it is thought that an inquiry into the cause of their color, based on their description, will not be inappropriate.

Theories for the origin of the color of red beds.—One of the most obvious origins of red rocks is that they are formed by the disintegration and resedimentation of pre-existing red beds. This explanation, however, does not strike at the root of the matter, and in accounting for the color of such extensive masses of red beds as those in the western states is not applicable. For the rocks under consideration an explanation is demanded of the formation of original red beds. The following are the most important theories that have been advanced:

1. Water containing iron in solution percolating through rocks may have the iron precipitated as hydrate by contact with oxygen-bearing waters, or by other means. The hydrate thus formed subsequently may become dehydrated to the more stable red hydrate or to the anhydride. John W. Judd[1] in this way, explained the red color of the Northampton sands.

1 *a*. A variation of this method is the precipitation as iron carbonate of the iron contained in percolating waters by replacement of calcium carbonate with which the waters may come in contact. Oxidation may later convert the carbonate to the red iron oxide.[2] C. H. Smyth considers this one of the ways by which the red Clinton ores were formed.

2. Again, iron-bearing minerals in rocks on a land area may be decomposed by acidulated surface waters and the iron taken into solution as bicarbonate and transported to a body of water in which sediments are being deposited. Contact with air would convert the bicarbonate to ferric hydrate, which would be precipitated among the accumulating sediments.[3] Subsequent changes would dehydrate the iron precipitate to a stable red pigment. By this process bog iron ores are now accumulating. This explanation often has been appealed to in accounting for the color of red rocks. A. C. Ramsay[4] advocated such an origin for the color of the New Red sandstone. Also Henry Newton[5] applied this explanation, as his interpretation of the

[1] *Geological Magazine*, Vol. VI, p. 221.

[2] *Ibid.*, p. 487.

[3] Also some algæ have the power of precipitating ferric hydrate from certain iron solutions.—R. Brauns, *Chemische Mineralogie*, 1896, p. 383.

[4] *Quarterly Journal of the Geological Society*, Vol. XVII, p. 241.

[5] Henry Newton, *Geology of the Black Hills of Dakota*, 1880, p. 138.

origin of the color of the red beds of the Black hills. In this way C. H. Smyth[1] accounts for the origin of some of the Clinton ores. And W. Spring[2] in his recent paper on the color of red beds accepts this theory and devotes his attention to details of how dehydration may take place after the iron has been precipitated as hydrate.

Another theory is that the color of red rocks may be caused by the sedimentation of a residual red soil. A. W. McKay[3] thus explained the color of the red sandstone of Nova Scotia. And I. C. Russell[4] has elaborated this theory and has applied it to the explanation of the color of the rocks of the Newark system.

3*a*. A variation in this process may occur when the iron in the soil, which furnishes the sediments of red beds, is not completely changed to the red ferric hydrate or to the anhydride previous to sedimentation. In such a case the soil would have a mottled color due to different stages of hydration of the disseminated iron compounds. Such mottled material may become uniformly red by dehydration of the disseminated iron subsequent to or during sedimentation.

J. D. Dana appealed to such a possibility in criticising Russell's widespread application of the theory of original deposition of red beds as such. Dana regarded conditions attending the consolidation of the rocks sufficient to cause the dehydration necessary to produce the uniform red. In the case of the rocks of the Newark system he considered the influence of the associated trap dykes, by virtue of their raising the temperature of interstitial water, potent to change to the anhydrous red oxide any limonite present about the individual rock particles.[5]

Dehydration may occur also during the process of sedimenta-

[1] C. H. Smyth, *American Journal of Science*, Vol. XLIII (1892), p. 487.

[2] W. Spring, *Recueil des travaux chimiques des Pays-Bas et de la Belgique*, Vol. XVII (1898), No. 2, p. 202.

[3] *Report British Assoc. Adv. Sci.*, Thirty-fifth Meeting (Birmingham, 1865), Part II, p. 67.

[4] *Bulletin 52, U. S. Geological Survey*, 1888.

[5] *American Journal of Science*, Vol. XXXIX (1890), p. 319.

tion. W. Spring[1] recently has shown that the presence of a salt in water produces on a hydrate an effect comparable to that of an elevation of temperature, and on this fact as a basis he would account for the color of red beds. Accepting the theory that red rocks are formed by the precipitation from solution of ferric hydrate about the individual particles of a deposit in an area of sedimentation, Spring maintains that red beds were formed in estuaries or in saline lakes, where the presence of dissolved salts would bring about the dehydration of the precipitated ferric hydrate necessary to produce the red pigment. The dehydrating effect of salt water is an important contribution, but whether the pigment of red beds was deposited from solution or as mechanical detritus is an independent subject, and one which must be settled by the study of any particular red formation.

Application of theories.— Let us now examine the evidence presented by the red beds of the Black hills, in connection with the requirements of these theories.

The first, providing for the deposition of the coloring matter by precipitation from percolating water subsequent to the formation of the rock, clearly is inapplicable. There are no available rocks which could supply sufficient iron in solution, neither is there any apparent reason why the pigment, if thus deposited, was limited to its present extent. Moreover, the uniform distribution of the coloring matter throughout the red beds in minute quantity, instead of in irregular or local accumulations, is difficult to explain by this theory. The coating of iron oxide about grains of quartz offers no suggestion that the pigment is a product of replacement. And the great extent of these red rocks seems to preclude the subsequent origin of the pigment.

The second theory — that the coating of pigment about the rock particles was precipitated from solution during sedimentation — is that which has been most generally appealed to in explanation of the color of red beds. The facts that such an

[1] W. Spring, *Recueil des travaux chimiques des Pays-Bas et de la Belgique*, Vol. XVII, No. 2 (1898), p. 202.

explanation accounts for the red coating of the individual particles, and that it is difficult to disprove, are in its favor. Nevertheless, while it cannot be maintained that no ferric hydrate was precipitated from solution among the accumulating sediments under consideration, yet the evidence is that such was not the principal source of the pigment.

It will be shown presently that the climate during the sedimentation of the red beds probably was arid. Under such conditions vegetation would be scant, and surface waters would not be heavily charged with solvents. Conditions then were not specially favorable for rock decay, nor for the transportation of iron in solution to the area of deposition during red-bed time. Besides, if such were the origin of the pigment, local accumulations of it would be expected as in the case of those Clinton ores for which such an origin is accepted, and in the case of bog ores now forming. On the contrary, in none of the rocks examined microscopically does the thickness of the pigment amount to half a millimeter, and usually it is much thinner. The exact equilibrium required for the chemical precipitation of ferric hydrate to be just sufficient to coat each sedimentary particle, no more nor less, is extremely improbable.

Then there is the theory, emphasized by Russell, that red beds may be formed by the sedimentation of a residual red soil, and the evidence seems to be in favor of such an origin for the red beds of the Black hills.

It is a familiar fact that under suitable conditions rocks which contain iron-bearing minerals weather to a red clay. In the process of rock disintegration and decomposition the iron-bearing minerals alter easily. Ferrous iron—in biotite, hornblende, and pyroxene, for example—becomes oxidized and hydrated to limonite, which dehydrates and passes through stages corresponding to göthite and turgite, to the stable red hematite.[1] A late stage of residual soil, from a variety of parent rocks, consists of the stable minerals quartz, kaolin, and muscovite, traces of original rock constituents in various stages

[1] W. O. Crosby, *American Geologist*, Vol. VIII (1891), p. 72; G. P. Merrill, *Rocks, Rock Weathering and Soils*, 1897, p. 299.

of alteration, and red pigment indiscriminately distributed among the individual soil particles. Instances of residual red soils are numerous. Notable occurrences are: the soils of the Piedmont plateau of the southern Appalachians, the terra rossa of Europe, the laterite of India and the red soil of the valley of the Amazon.

Streams coursing over lands mantled with residual red soil transport it to areas of deposition, and thus tend to cause the sedimentation of red rocks. In many instances, however, in regions where red soils are abundant the red material washed from the land turns brown, and often greenish or bluish, before final deposition among accumulating sediments. For instance, in the Piedmont plateau region of the southern Appalachians red detritus in the streams generally becomes decolorized to the more somber tints of ferrous compounds, because of the deoxidizing influence of abundant decomposing organic matter in the water. But such destruction of the red color of detrital material so as to prevent the actual deposition and accumulation of red sediment is not universal. Thus enough of the red material brought down by the Amazon escapes deoxidation, so that vast deposits of red rocks are now accumulating along the coast of Brazil.[1] And it is probable that under more favorable conditions red rocks would accumulate more generally than now occurs. Such conditions would be the greater prevalence of areas covered with residual red soil and the absence of much organic matter in the waters concerned with the transportation and deposition of the red material.

In the case of the red beds of the Black hills it seems probable that unusually favorable conditions did exist both for the formation of a parent residual soil and for its accumulation as red sediment.

The geography of the Rocky mountain and adjacent regions in red-bed time[2] remains to be worked out. Still it is generally

[1] John Murray, *Challenger*, *Reports Deep Sea Deposits*, 1891, p. 234.

[2] The age of the red beds of the Black hills, considered as an entire series, is not satisfactorily known, because no fossils have been found in the upper and lower formations. The intermediate limestone, however, carries fossils which indicate it to be Permian, but whether the lower red beds are in part Carboniferous or whether the upper are partly Triassic there is no direct evidence.

agreed that during the accumulation of the red beds of the central West a shallow mediterranean sea, whose outlines are very imperfectly known, existed west of the Mississippi and east of the great basin extending northward from Texas almost into Canada. In the midst of this sea the Rocky mountain province formed a group of islands.[1] Stratigraphic evidence renders it probable that different conditions prevailed simultaneously in different parts of the sea and that different conditions prevailed at different times in the same area. But insufficient facts have been accumulated to warrant a detailed statement of conditions that existed during the deposition of the red beds.

The Black hills area was covered by this body of water. The red beds there everywhere succeed the underlying Carboniferous rocks, with no signs of an interval of erosion. There is no evidence of thinning as the red beds approach the center of the hills, nor of off-shore conditions. Moreover, the dips carry these rocks over the highest points of the hills. The Black hills did not supply the sediments under consideration.

For the source of these red beds we must look to the land masses that were contiguous to the Black hills in red-bed times. These were an area of Algonkian rocks to the north and northeast, the lately uplifted Carboniferous limestone to the southeast, and the Rocky mountain area to the southwest and west.

That the limestone furnished sediments to the accumulating red beds in the Black hills cannot be denied, for the relatively insoluble constituents of limestone often form a residual red clay. Yet it is not likely that this was a prominent source. Of the areas named probably the limestone was the farthest away from the Black hills. Furthermore, the abundant quartz and mica in the red beds, and the presence of feldspar, magnetite, and ilmenite, point to a source from crystalline rocks rather than from limestone.

The extent of the Algonkian rock area is very indefinitely known, and it is doubtful whether this area contributed to the red beds of the Black hills. In this general region there was an

[1] S. F. EMMONS, *Bull. Geol. Soc. Amer.*, Vol. I (1890), p. 245; R. C. HILLS, *Proc. Colorado Scientific Soc.*, Vol. III (1888–90), p. 362.

extensive land area which may have been such from Cambrian down to Cretaceous time, but during red-bed deposition the respective limits of water and land are unknown. At Sioux Falls, S. D., there is an exposure of the Algonkian, the Sioux quartzite, which artesian-well borings show to have a considerable extent below the Cretaceous. The Sioux quartzite is a red rock which could have furnished red sediments. Microscopic study, however, renders it unlikely that this formation contributed to any considerable extent to the Spearfish formation. A characteristic feature of the Sioux quartzite is that it is composed of rounded quartz grains, the outlines of which are delicately traced by circlets of iron oxide imbedded in a matrix of interstitial silica crystallized in conformity with the nucleal quartz.[1] The red beds under consideration show no trace of this siliceous rim, which would be expected were the rocks derived from the Sioux quartzite.

The Rocky mountain region, however, was an available source of sediments for the red beds of the Black hills. During red-bed time this area was flanked by the deposition of red sediments whose constituents can be directly traced to such an origin.[2] And although the eastward extent of these red beds toward the Black hills is now deeply hidden by overlying rocks, so that actual stratigraphic connection has not been traced between the red beds contiguous to the Rocky mountains and those of the Black hills, yet such connection seems probable. Wells that have been put down deep enough east of the Rockies invariably have penetrated these red rocks. And the diminution in thickness of red-bed sediments from about three thousand feet adjacent to the mountains to five hundred feet in the Black hills, with an accompanying decrease in fineness of materials strongly suggests that the red beds of the Black hills are continuous with those of the eastern slope of the Rocky mountains.

The unusually favorable conditions, referred to above, for the

[1] S. W. BEYER, *Iowa Geol.*, Vol. VI (1897), p. 102.

[2] A. C. SPENCER, "Geology of the Rico Mountains," *Twenty-first Annual Report, U. S. Geological Survey* (1900), Part II, p. 68; G. K. GILBERT, *Pueblo Folio, U. S. Geological Survey*, 1897.

accumulation of a parent residual red soil and for its deposition as red sediment in the Black hills area were climatic.

It is generally believed that the Carboniferous climate in the present temperate zone was warm and moist. Under such influences the rocks of the Rocky mountain region, which general region is believed to have been land since the Cambrian,[1] were subjected to very favorable conditions for extensive decomposition and for the formation of a mantle of residual red soil. And because of the considerable decomposition the continued formation of red soil coincident with the removal of surface accumulations to supply red-bed sediments was facilitated.

It has been noted, however, that many regions which are now covered with residual red soil do not contribute red material to areas of sedimentation, because the red color is destroyed by deoxidation before or during deposition. But in the case of the red beds under consideration there is reason to believe that this deoxidizing influence was unimportant.

A relatively arid climate in many regions is known to have followed the warm and moist Carboniferous. That this was true in the red-bed region of the central West is testified to by the presence of beds of rock salt and gypsum. In the Black hills, though no beds of salt have been found in the red beds, yet the salt spring near Cambria suggests a local deposit; and interbedded gypsum is abundant.

There can be little doubt that the gypsum of these red beds was accumulated by precipitation from concentrated water containing calcium sulphate in solution. The "bar theory" of Ochsenius[2] clears the difficulty of conceiving how thick beds of chemically precipitated matter can be accumulated; and all the field relations of the gypsum point to such an origin. There is no indication that the gypsum is the result of the action of sulphuric acid on limestone. The bedded character of the gypsum interstratified with detrital sediments, the general occurrence of the gypsum in lenses, the frequent presence of layers of red sand and clay in beds of impure gypsum and of thin layers of

[1] Emmons and Hills, *op. cit.*

[2] *Zeitschrift für praktische Geologie*, 1893, p. 189.

gypsum among the red sediments, besides the presence of gypsum disseminated throughout the red sediments, as shown by the rock analyses, lead to the conclusion that the gypsum was deposited as a chemical precipitate contemporaneously with the detrital sediments. Such an origin demands a somewhat arid climate.[1]

Now, an arid climate, sufficient to cause the precipitation of beds of gypsum tends to cause the preservation of the color of red sediments. Being unfavorable for the existence of abundant life in inland waters, such a climate minimizes the prevalence of deoxidizing influences incident to the presence of organisms. In this connection the general absence of fossils in the red beds is noteworthy.

With such favorable conditions for the accumulation of a red soil and for its deposition as the red beds of the Black hills let us look now for direct evidence bearing on the origin of the color furnished by the composition of the rocks under consideration.

The chemical composition of the red beds of the Black hills is essentially that of a residual red clay, notwithstanding the abundance of carbonates and sulphates. These unusual constituents were not of detrital origin, but were caused by conditions of sedimentation.

The gypsum already has been referred to, and considering the general paucity of life in the water in which these red beds were accumulated and the salinity of this water, the calcium and magnesium carbonates, which are disseminated throughout the red beds, appear to have been formed as chemical precipitates instead of having had a more direct organic origin. The presence of crystals of these carbonates means that they were deposited from solution. Their widespread and uniform dissemination, and the absence of veins and local accumulations, implies original deposition with the detrital sediments rather than subsequent introduction from percolating water. A secondary derivation from decomposition subsequent to sedimentation is

[1] The succession of a genial Carboniferous climate by post-Carboniferous arid conditions is emphasized by CHAMBERLIN, JOUR. GEOL., Vol. V, p. 678.

not borne out by the presence of associated, partly decomposed minerals.

Excluding these adventitious constituents, the analyses show the red beds of the Black hills to be composed essentially of silica, alumina, ferric oxide, potash, and water. These are characteristic components of residual soils, the corresponding mineralogical composition being the stable species, quartz, muscovite, kaolin, and the red pigment with occasional bits of decomposed feldspar.

The result of microscopic examination also shows the similarity of these red beds with residual red clay. Some of the quartz grains have intricate contours, as if etched by alkalies derived from decomposing feldspar. The disposition of the pigment as a coating to the individual rock particles is like that in residual red soils. And the inclusion of the red pigment in secondary quartz and kaolin is significant.

This inclusion implies the formation of the including minerals in the presence of the red pigment. It is not probable that these minerals were formed in the area of deposition when the sediments were accumulating so as to receive inclusions of iron precipitated from solution ; nor is it a likely assumption that much decomposition took place subsequent to the formation of the red beds, and that the secondary minerals received inclusions of iron from percolating solutions. There is but little undecomposed material in the red beds, whereas considerable remains would be expected did alteration take place after sedimentation. The composition of the red beds is essentially of stable minerals, but some of the quartz and all the kaolin are products derived from decomposition. On the land area where the parent red soil of the red beds was accumulating, it is to be expected that in the intimate association of the constituents, iron oxide became included in the secondary minerals that were formed as decomposition products. Such inclusions are common in residual red clay in the District of Columbia.

It seems probable therefore that the dominant factor in the production of the color of the red beds of the Black hills was a residual red soil on the land mass which supplied the sediments.

But inasmuch as favorable conditions for dehydration existed in the area of deposition, it must not be asserted that the color of the red beds of the Black hills was entirely formed in the parent soil, and that none of the color was formed during sedimentation.

W. O. Crosby has called attention to the effect of exposure of iron-bearing sediments in shallow-water areas of deposition upon the production of red pigment.[1] This action depends on the dehydration of hydrated iron compounds and is a further operation of the influences which have been emphasized as the effective cause in the production of a residual red soil.

Another factor in the production of red pigment from hydrated iron compounds is the dehydrating effect of salt water discovered by W. Spring.[2] Because the red beds of the Black hills were deposited in concentrated waters, this influence operated and may have been important.

The presumption is, however, under the favorable climatic conditions and from analogy with the homogeneous red tint of many present residual red soils, that before the soil particles were actually deposited they had become completely red. But the possibility of these two causes having acted must not be forgotten. And, too, the fact must be borne in mind that the dehydration of ferric hydrates tends to go on under ordinary conditions without any unusual cause.[3] So that it is unnecessary to assume the action of further dehydrating agencies than those operating on the land which supplied the residual soil.

Whether a change in the pigment occurred subsequent to deposition, as suggested by Dana,[4] should be considered, inasmuch as the Black hills have been subjected to igneous intrusions. There are, however, in the central west province, red beds — similar to those in the Black hills and apparently genetically connected with them — which are not associated with

[1] W. O. Crosby, *Proc. Boston Soc. Nat. Hist.*, Vol. XXIII (1888), p. 509.

[2] *Op. cit.*

[3] This has been repeatedly demonstrated by experiment: Wittstein, *Vierteljahresschrift für Pharmacie*, Vol. I (1852), p. 275; Davies, *Jour. Chem. Soc. of London*, Vol. XIX (1866), p. 69; Van Bemmeln, *Recueil des travaux chimiques des Pays-Bas et de la Belgique*, Vol. VII (1888), p. 106.

[4] *Op. cit.*

igneous rocks. Moreover, if the igneous rocks of the Black hills exerted a dehydrating influence sufficient to change the red beds from a possibly mottled previous condition to their present uniform color, such influence surely would have dehydrated the varicolored iron pigments in the underlying Carboniferous sandstone. This, however, did not occur, and the suggestion of Dana is not applicable in the Black hills.

Green variations.—The occurrence of green variations in red beds has caused some[1] discussion. In the case of true green beds among sediments derived in general from red soils, it seems likely that such green beds were either deposited from a locally different source than the red material, or that they represent red sediments which were deoxidized in the area of deposition. But small green spots and streaks, which constitute the general occurrence of green material in the Spearfish formation, can best be explained by considering them to have been developed subsequent to deposition.

These variations can be accounted for by the influence of occasional bits of organic matter present in the sediments. Such decomposing organisms reduced the ferric iron of the red pigment to a soluble form that was removed in solution, and green spots and streaks remained. In spite of the lack of more evidence of organic remains in the red beds, these green variations are difficult to explain in any other way. The irregular distribution of the green patches, their occasionally following cracks in the rocks, and their similarity in composition to the adjacent red clay, from which they differ only in containing less iron, point to this explanation.

George B. Richardson.

[1] George Maw, *Quarterly Journal Geological Society of London*, Vol. XXIV, p. 351; T. N. Dale and W. T. Hildebrand, *Nineteenth Annual Report United States Geological Survey*, Part III, p. 255.

NEW OR LITTLE-KNOWN VERTEBRATES FROM THE PERMIAN OF TEXAS.

In 1880 Cope gave the first description and figure of the scapula of *Eryops*.[1] He had at the time only the lower portion of the scapula with the co-ossified coracoid, bearing the cotylus for the humerus. Later, in 1888,[2] he published a figure of the shoulder-girdle with the clavicles and interclavicle in place. As in the first specimen, the distal end of the scapula was missing, but there was a small fragment of a distinct bone joining the upper edge of the scapula, which he regarded as possibly a portion of the scapula, but was uncertain as to its exact position. In 1899, Broili[3] described a skeleton of *Eryops* in which he identified the fragment mentioned in Cope's description as the epiclavicle or cleithrum. In 1898[4] the author mentioned the presence of a cleithrum on the distal end of a scapula which was regarded at the time as reptilian. The element is indicated by a small fragment of the bone, which is attached by strong rugose grooves and ridges to the scapula. The specimen (No. 76) of the collection of the University of Chicago, probably belongs in the genus *Eryops*, but to a species distinct from *megacephalus*. It is shown in Fig. 1. It is the third scapula described below.

In looking over the collection of the Chicago University I find a nearly perfect scapula of *Eryops* (No. 182), with a complete cleithrum in position. The bones have been badly broken, but are little distorted and differ so much from the type species that I refer them to a new species under the name *Eryops latus*. The general outline of the bones is shown in Fig. 2. The scapula differs from that of *Eryops megacephalus* in the relatively greater breadth of the coracoidal region and the straightness of the antero-internal edge. The cleithrum is a queerly shaped bone;

[1] *Proc. Am. Phil. Soc.*, Vol. XIX, p. 51, 1880.

[2] *Trans. Am. Phil. Soc.*, Vol. XVI, p. 362, 1888.

[3] *Paleontographica*, Vol. XLVI, p. 61, 1899.

[4] *Am. Nat.*, Vol. XXXII, p. 70, 1898.

the posterior end is thin and greatly expanded so that it overlaps the upper portion of the distal end of the scapula and is closely applied to it as a thin scale; it is convex outwardly. The anterior two-thirds of the bone is rounded and rod-like. It lies close to the upper edge of the scapula, but is to be described as applied to it rather than being articulated with it, for where the bone is broken away the edge of the scapula is smooth and complete. The edges of the rod-like portion of the cleithrum were evidently extended as narrow and very thin wings. The anterior edge is sharp and marked with rugosities where it joined the clavicle, as indicated in Cope's figure. Broken fragments of the clavicle were found with the scapula and show that the anterior face of the proximal portion was marked with very deep and rugose striations and ridges. The evidence of the cleithrum afforded by this specimen makes our knowledge of the shoulder-girdle of *Eryops* complete.

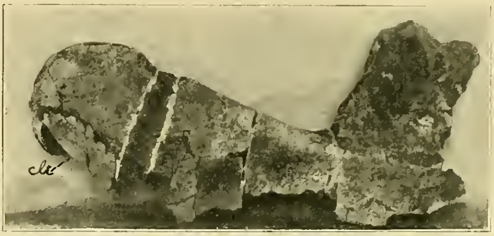


FIG. 1.—Scapula of *Eryops sf.*, showing attachment of cleithrum. *clt.* Left side.

MEASUREMENTS OF E. LATUS.

Breadth across epicoracoid region	.182 m
Breadth opposite center of face for humerus	.079
Width of scapula at middle	.073
Greatest length scapula	.371
Greatest length of cleithrum	.237

In the process of investigating this scapula it becomes very evident that a close similarity existed, superficially, between the scapula of *Eryops* and that of the Pelycosaurian reptiles, and this led to a search for points that might be used in their separation. Baur says that there is no ossified coracoid in the Stegocephali and that the cleithrum does not occur in the reptiles, *Pareiasaurus* excepted. Williston mentions the presence of scapula, coracoid and pre[epi]coracoid in *Eryops*, but says that they are so closely united that the sutures are indistinguishable.

Broili describes a scapula and coracoid in the same genus, but evidently regards as coracoid the bone usually described as epicoracoid, leaving the part here described as coracoid absent or cartilaginous. Cope speaks of the coracoid as distinctly recognizable, but figures no suture and describes the epicoracoid as probably present but not recognizable. There thus seems to be considerable difference of opinion regarding the presence of the coracoid. From considerations cited below it seems to me that the coracoid was cartilaginous, but if so the anterior end of the scapula assumed a strikingly similar form to the coracoid of the reptiles, sheltering the whole of the humeral cotylus, which in the reptiles is shared between the coracoid and scapula.

FIG. 2.—Scapula, epicoracoid, and epiclavicle of *Eryops latus*, showing the complete cleithrum. *clt.* Left side.

In *Eryöps* the antero-internal edge of the bone is thickened and shows the previous attachment of a thick plate of cartilage. This mark of cartilaginous attachment extends around the anterior end of the bone from the anterior end of the face for the humerus to about the end of the anterior fourth of the upper edge, where it terminates in a small but decided angle at the point where the clavicle touched the scapula. Both the cartilaginous edge and the angulation seem to be diagnostic characters of importance, for in the reptiles they are absent. The coracoid of the Pelycosaurs has a sharp beak-like process and the anterior edge is free from cartilage. The edge of the epicoracoid is thin and the cartilage was either absent or small. In the Pelycosaurs the coracoid is always distinctly separated from the scapula by suture, and is apt to be a separate fragment in the specimen. In *Eryops*, the cotylus for the humerus is deeper and the anterior and posterior edges are raised so that the cavity is almost a semicircle; in the reptiles the cavity is shallower and more widely open. The articular face of the cotylus differs in the two. In *Eryops* it is about equal in width at the two ends, but is abruptly wider a little anterior to the middle point; in the reptiles the two ends are the wider and the middle portion is of equal width.

FIG. 3.—Scapula, coracoid, and epicoracoid of a diadected reptile. Right side.

A second scapula, No. 186 of the collection, differs from any heretofore seen by me in its shortness and relatively great width. As it has a free coracoid, no trace of an episcapula, and a very narrow face for cartilage on the anterior edge of the epicoracoid, it is regarded as reptilian, and its robust character shows that it belongs to some genus of the Diadectidae. It so probably belongs to a species already named that I have given it no new name here, leaving its identification to future discoveries. Fig. 3 gives the best idea of its general form. Notable, in comparison with the other scapula, is the great width of the anterior edge and the great width of the median portion, which is as wide as any part of the anterior edge. At its posterior two-thirds the bone narrows rapidly and terminates in a thin blade, which shows the marks of cartilaginous attachment on its distal and upper edges. There are two foramina in the bone in much the same position as in *Eryops*, and both open into a large pit on the inner surface of the bone. The anterior foramen opens on the outer face in a deep pit located just anterior to the prominent edge of the upper portion of the humeral cotylus, instead of somewhat farther out upon the epicoracoid, as in *Eryops*. The scapular and epicoracoidal portions meet at the suture in an angle of about 80°, as shown in the figure by the lighting of the photograph. Just distad to the cotylus in all the scapulae there is a triangular space into which opens the second of the two foramina; this portion of the bone is thickened and its edge is rounded. In *Eryops* this triangular space is marked by a deep pit and the foramen pierces the bottom of it. In the scapula under description the space is flat and the foramen enters at the apex of the triangle, which is toward the distal end of the bone. The space is marked with a V-shaped rugose line near its anterior end; no such line occurs in *Eryops*.

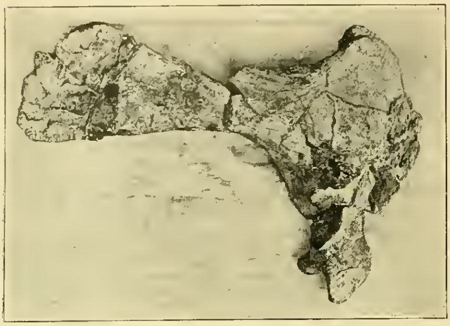


FIG. 4.—Scapula, coracoid, and epicoracoid of *Embolophorus dollovianus*. With clavicle in position. Right side.

Length of scapula No. 186 - - - - - -	.257 m
Width at cotylus for humerus - - - - - -	.190
Width of distal end - - - - - - - -	.066

The third of the scapulae, No. 76, while distinctly amphibian, presents many reptilian characters. As shown in Fig. 4, it has a distinct cleithrum firmly attached to the distal end of the scapula, and there is no evidence of a bony coracoid; on the other hand there is no evidence of cartilaginous attachment on the coracoidal and epicoracoidal edges. The anterior foramen is located in a pit on the anterior edge of the upper extremity of the cotylus, and in this respect is much more similar to the reptiles than to the amphibians. The triangular space distad to the cotylus is filled and marked by a V-shaped rugosity, as in the Diadectid scapula.

FIG. 5.—Dorsal spine of *Zatrachys crucifer*. From behind.

In *Dimetrodon* and *Embolophorus* the anterior foramen opens close to the strongly projecting upper edge of the cotylus;

there is no triangular area, and the posterior foramen opens on the summit of a ridge directly posterior to the elevated edge of the cotylus. Fig. 4 shows the scapula of the right side of *Embolophorus dollovianus*, with the almost perfect clavicle in its normal position.

At this point may be noted a peculiar relation which exists between the scapulae of the American and the African reptiles. In Clepsydropsidae there is no trace of the attachment of the clavicle to the scapulae, except in the problematical facet figured by Cope as possibly forming an articulation for the clavicle. In the Dicynodonts and the Theriodonts there is a distinct process on the scapulae for the clavicle, and this exists even in *Pareiasaurus* where the epiclavicle is still present. In *Cynognathus* this process has developed into a strong scapular spine which occupies the upper edge of the scapula nearly in the same position as is the scapular spine of the Monotremes.

Zatrachys crucifer. sp. nov.

A single neural spine, No. 171 of the Chicago collection, indicates a new form which I have referred to a new species of the genus *Zatrachys* Cope. As shown in Fig. 5, the spine has a cruciform shape with a sharp upper portion and short lateral processes. The posterior zygapophyses are preserved and are relatively small. The upper faces of the lateral processes and the apex of the spine are pitted by a deeply marked rugosity so that the whole upper surface of the spine is excavated by deep pits of a size and depth seen before only in the larger amphibians, *Eryops*, and *Cricotus*. The lower surfaces of the later processes and the sides of the base of the spine are smooth. The anterior and posterior edges of the apex are free from the deep pits and are marked by a narrow space of striations showing that the spine was overlapped by the edges of some other element; it is evident from the shape of the spine that this could not have been the edges of the adjacent spine, but must have been an extra element intercalated between the spines, probably one of the dermal ossifications such as occur along the spine of *Pareiasaurus*. The nearest approach to this condition is found in the rugose expanded apices of *Zatrachys apicalis* Cope, and so I have referred this specimen to that genus until further information may be obtained. Fig. 5. The fragment is .054^{m} in height and .058^{m} across the lateral processes.

DIADECTIDAE.

The family Diadectidae is known so far from the skull, teeth, vertebrae, pelvis, clavicle, and interclavicle; to this we may add the scapulae, if the specimen described above belongs, as assumed, to this family. The separation of genera and species has been done almost entirely upon the characters of the teeth and skull, so that it has been impossible to determine accurately the position of isolated bones. A specimen in the Chicago collection (No. 62) makes it possible to add a description of the caudal vertebrae, some of the bones of the limb and foot, and especially the presence of an unsuspected structure, *i. e.*, dermal plates overlying the ribs and corresponding to them in number. This last structure is shown in two separate fragments; the largest shows five ribs in place and the plates covering them. It is impossible to say which side the fragment is from. The ribs are quite stout and show a large medullary cavity. The plates are large and thin. Their edges are broken away so that their size cannot be determined. The plates lie one over the other like shingles. The plate at one end has the end broken and turned down. Near this is a separate fragment which may be either a portion broken off from the edge of the plate or a distinct marginal plate. The approximate width of each of the plates is .033^{m} and the length of the fragment is about .160^{m}.

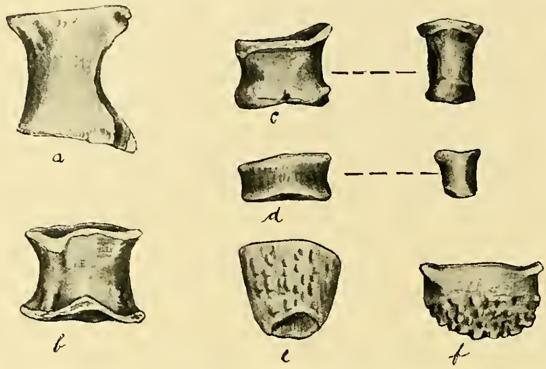
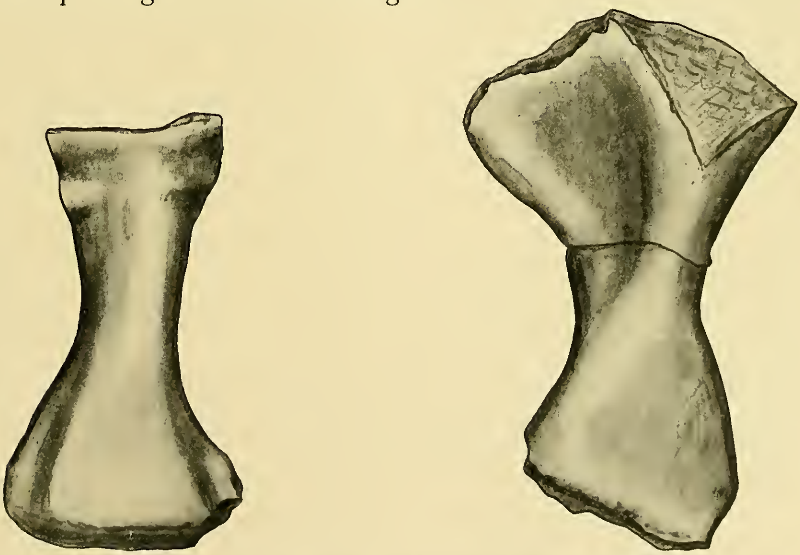


FIG. 6.—Foot bones of a diadected reptile; *a* and *b* metacarpals (?); *c*, *d*, *e*, phalanges found united; *f*, another terminal phalange.

The limb bones consist of the lower end of a humerus, two bones of the fore limb and a fragment of the carpus (?) with the distal end of a bone of the forearm (?) attached. Besides these there are several phalanges, some in connected series. The phalanges and metacarpals (?) are remarkably short and strong and the terminal phalange was covered with a very stout claw bearing out the suggestion made by Cope that the animals were fossorial in habit. Unfortunately there are not more than three phalanges united in any one fragment, and there are six terminal phalanges altogether, so that it is impossible to state the exact number of phalanges in the digits, but it is probable that the usual reptilian formula was present. The phalanges are shown in Fig. 6.

FIGS. 7.—Lower end of humerus of a diadected reptile. Left side.



FIGS. 8 and 9.—Limb bones of same specimen as Figs. 6 and 7.

The bones of the limb are stout and short. The humerus is very imperfect, only the lower portion being preserved, but it indicates a very stout bone, and the lower end is strikingly similar to that of *Eryops;* the head for the radius is very large and is located almost entirely on the anterior side of the bone ; just posterior to it is a strong descending process that reaches below the lower end of the bone. Fig. 7. There is a distinct ectepicondylar process on the outer side of the bone. There is no entepicondylar foramen visible, but the bone is broken below where this should appear. The two other limb bones are shown in Figs. 8 and 9.

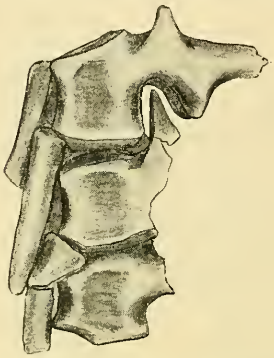


FIG. 10.—Caudal vertebræ from same specimen as that shown in Figs. 6–9.

The caudal vertebræ differ markedly from the typical dorsals. The centra are as high as long and the neural spine is as high as the length of the centrum. The centrum is not broader than long and is deeply amphicœlous. There are well-developed anterior and posterior zygapophyses, but no trace of zygosphene or zygantrum. The lower side of the vertebræ is marked by the exceptionally strong and elongated chevron bones ; they are attached between two adjacent vertebræ, and there is a strong face on the lower edge of the posterior surface of the preceding vertebra for the attachment of the head of the chevron. The caudals with chevrons are shown in Fig. 10.

MEASUREMENTS.

Length of the longest limb bone	.106^{m}
Width of the complete end	.065
Length of the shortest limb bone	.087
Width of its widest end	.047
Width of its shortest end	.036
Length of three caudals	.061
Height of the first from the base of centrum to top of spine	.044
Horizontal diameter of centrum of first	.012
Vertical diameter of centrum of first	.019
Length of a complete chevron	.031

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NOTES ON THE GEOLOGY OF MOUNT KEARSARGE, NEW HAMPSHIRE.

Mount Kearsarge[1] or Pequawket is a mountain of medium height in the southern part of the White mountains of New Hampshire. It is situated a few miles north of North Conway, partly in the town of Bartlett and partly in the town of Chatham. It rises 3,260 feet above the sea, and 2,700[2] feet above the neighboring valley of the Saco river; and includes, as a spur on its southwestern slope, Mount Bartlett. The latter rises 2,630 feet above the sea. These two mountains cannot be separated in a geological study of this mountain mass.

The rock making up the base of these mountains is what Hitchcock has called the Conway granite. On the south slope of Kearsarge this granite is found up to the level of 1,300 feet; on the southwest and west slopes of Bartlett, up to 1,000 or 1,100 feet; on the northwest slope of Kearsarge, up to 1,800 feet; and on the northeast slope of Kearsarge, up to the 2,500 foot level.[3] This granite also makes up the base of Moat mountain, on the opposite side of the Saco river, and is found on the north slope of this mountain in the course of Cedar brook up to the 900 foot level. It is found, in addition, over a broad area around, and is quarried in a number of places. The large quarry in the side of the mountain at Redstone, three miles southeast of North Conway, is in this granite.

The Conway granite[4] is reddish in color, is coarse in crystalline texture, is without foliation or granulation, and is very massive, being cut by few joints either vertically or horizontally. In the quarry at Redstone the distance between the joints is very noticeable. The first joint from the surface, when I was there,

[1] Geological section of this mountain is represented on the second sheet of the geological map of New Hampshire in the atlas accompanying *Geology of New Hampshire.*

[2] Taken from the topographic map of the *U. S. Geol. Surv.*

[3] Determined by means of an aneroid.

[4] Described in *Geology of New Hampshire,* Vol. II, p. 142.

was three feet down; the second, four or five feet below the first; and the third, twenty-five feet or more below the second. In working the rock it is necessary to cut the rock horizontally as well as vertically. The size of the blocks that may be taken out is limited only by the strength of the derricks. The few joints seen were parallel with the side of the mountain, indicating, as the mountain has been produced by erosion, that these joints are due to causes acting since the formation of the mountain.

The orthoclase of the Conway granite is of a reddish tint, and is so abundant as to give its color to the rock. This feldspar occurs in coarse particles an inch or so through, which frequently show Carlsbad twinning. These particles do not present the definite outline of crystals, and do not give a porphyritic appearance. In addition, there is a white feldspar much less abundant, and distributed irregularly, and also in irregularly shaped cleavage particles much smaller than those of the orthoclase. This is a triclinic feldspar, and is twinned according to the albite law.

The quartz is generally distributed in irregular granular masses varying in size from one-half inch to one inch through. It is of a decided smoky-gray color, and, in contrast with the red feldspar, gives a mottled appearance to the rock surface. The quartz masses frequently inclose grains of both the red and white feldspar. There is also quartz distributed in finer particles inclosed in the orthoclase, and entirely separated from the coarser granular masses. These second quartz particles are generally anhedra, but somewhat frequently show distinctly the angles and faces of crystals. This clearly indicates that not all of the quartz crystallized last in this granite, but that a part crystallized before, or along with, the feldspar.

The biotite of the granite is small in quantity, of full black color, and occurs in small, foliated particles rarely more than one-sixteenth of an inch in length or width. It is generally distributed with the coarser granular quartz masses, though some finer scales are inclosed in the feldspar.

In addition the rocks contain a little magnetite.

The specific gravity of the granite is 2.624, and its composition is shown in the following analysis:[1]

SiO_2	73.01
Al_2O_3	13.73
Fe_2O_3	0.44
FeO	1.48
MnO	0.09
CaO	0.94
MgO	0.01
K_2O	5.62
Na_2O	3.50
Loss at 110°C	.05
Loss over blast	.18
	99.05

The weathering of this granite is very characteristic. Every bowlder in the fields has partly or entirely crumbled to a barren ring of gravelly débris. This débris consists of loose, angular, rusty particles varying in size from those an inch through down to fine powder. The particles consist, as far as can be seen, of orthoclase and quartz. The former, during the disintegration, loses its luster and bright flesh-red color, and assumes a dirty rusty color; it does not, however, become covered with a fine powdery coating of kaolin, but is divided into little cleavage blocks by many cracks along the cleavage planes. The angular quartz grains are thrown out by the breaking of the feldspar, and the anhedra and quartz crystals may be found among the particles of the crumbling rock.

The mica is generally decayed, and has changed from a black to a brownish, bronzy, or brassy color. Secondary epidote is frequently seen with the decaying biotite. The triclinic feldspar is rarely seen in the disintegrated particles of this granite.

The analysis of a fair sample of some of the coarser of these particles afforded:

[1] Other determinations were not made. The methods given in Bulletins 148 and 176, *U. S. Geol. Surv.*, were closely followed.

SiO_2	70.18
Al_2O_3	15.13
Fe_2O_3	00.68
FeO	1.54
MnO	0.13
CaO	0.84
Na_2O	2.67
K_2O	8.93
Loss at 110°C.	0.10
Loss over blast	0.22
	100.42

The disintegration of the rock is both chemical and mechanical. The triclinic feldspar and the mica are the first minerals to decay. The frost and mechanical agents then act between the minerals and along the planes of cleavage in the orthoclase, prying apart the minerals and crumbling the rock. The coarseness of the texture probably materially aids these agents in their work. The comparatively rapid disintegration of this granite does not specially recommend it as a building stone, though the somewhat numerous quarries in it indicate a considerable use of it for that purpose.

Within the Conway granite are found inclusions of an earlier granite. The rock of these inclusions is of a light gray color, of a medium-fine, granular texture, and is perfectly massive, without banding, foliation, or parallel arrangement of the minerals. The feldspar is white and glassy, and is partly triclinic. The quartz is finely granular and slightly smoky, and forms with the feldspar an intimate mixture. The black biotite is so abundant as to give a gray color to the whole rock.

Generally, on the different sides of Kearsarge, as well as on the sides of Bartlett, there is found above the Conway granite a granite-porphyry. In this the feldspar phenocrysts measure about one-fourth inch through. These feldspars are orthoclase, and are in part reddish throughout, and in part reddish on the borders with a white center. The outline of the phenocrysts is generally rounded rather than angular. The quartz, of a smoky color, occurs in part in distinct particles, one-sixteenth to one-eighth inch through, sometimes showing crystal forms. The groundmass of the granite-porphyry consists of a fine granular mixture of reddish feldspar, smoky quartz, and black mica, together with, in some places, fine black hornblende and a little magnetite. Iron pyrites is occasionally seen.

The granite-porphyry does not weather and crumble so rapidly as does the Conway granite; neither does it form any such

FIG. 1.—Just left of the center of the picture is shown an inclusion of finely-grained gray granite in the coarse Conway granite. Inclusion 3–4 feet in diameter.

gravelly débris. It is but a few feet, fifty or so, in thickness on the south side of Kearsarge, and on some sides of the mountain was not observed at all, either because entirely absent or because covered. There is a like granite-porphyry in the bed of Cedar brook on the north side of Moat mountain, where there is exposed an excellent section.

Above this granite-porphyry in Mount Kearsarge, or above the Conway granite where the porphyry does not occur, the rock is a quartz-porphyry. This latter rock varies in color from a red to a dark gray. The gray is the prevailing color, while red is more characteristic of the porphyry nearer the granite. The porphyry is massive and without foliation, and is cut by many joints into quite small, irregular, sharply angular blocks.

The quartz is very noticeable. It is smoky in hue, and occurs generally in distinct rounded anhedra one-sixteenth to one-eighth inch through. Now and then among these anhedra may be found a bipyramidal quartz crystal. On the east slope of the mountain, at about the 2,000 foot level, was found a gray quartz-porphyry abounding in quartz crystals, so that every broken surface and every weathered surface presented many of the little projecting pyramids, and the six-sided tapering cavities from which crystals had been broken. The porphyry abounding in quartz crystals is at a considerable distance from the granite beneath.

In the porphyritic phases having the finer-grained groundmass there are orthoclase phenocrysts, but in the coarser-grained varieties the intercrystallizing feldspars constitute the groundmass about the quartz particles with only a trace of the finely grained mixture.

Different specimens of the porphyry afforded on analysis the following results: [1]

	I.	II.
SiO_2	78.37	75.38
Al_2O_3	10.85	11.85
Fe_2O_3	1.33	1.78
FeO	0.44	0.88
MnO	0.06	0.10
CaO	0.40	0.33
MgO	0.00	0.00
Na_2O	2.68	3.68
K_2O	5.52	5.37
Loss at 110°C.	0.04	0.15
Loss at red heat	0.59	0.50
	100.28	100.02

[1] Other determinations were not made. Methods given in Bulletins 148 and 176, *U. S. Geol. Surv.*, were carefully followed.

	III.	IV.
SiO_2	72.25	73.33
Al_2O_3	13.40	12.95
Fe_2O_3	1.10	0.98
FeO	1.53	1.66
MnO	0.11	0.13
CaO	0.74	0.98
MgO	0.00	0.00
Na_2O	4.27	3.46
K_2O	5.56	5.61
Loss at 110°C.	0.10	0.11
Loss at red heat	0.31	0.30
	99.37	99.51

I. Coarse quartz-porphyry, red in color, finely granular groundmass small in quantity and distributed among the coarser red feldspars; from the 1,350 foot elevation near the phyllite, on south slope of Mount Kearsarge. Specific gravity 2.614.

II. Bluish-gray quartz-porphyry, groundmass fine, of bluish-gray color, inclosing anhedra of quartz and phenocrysts of red feldspar. From 1,550 foot elevation, south slope, Mount Kearsarge, near phyllite. Specific gravity 2.62.

III. Dark gray quartz-porphyry; from top of Mount Kearsarge. Specific gravity 2.643.

IV. Dark gray quartz-porphyry, abounding in quartz crystals; from eastern slope at about 2,000 foot elevation. Specific gravity 2.64.

With these analyses of the porphyry, together with that of the Conway granite before us, we may consider the relation of the porphyry to the granite. It has been pointed out that there is generally in Mount Kearsarge and Mount Bartlett between the porphyry and granite a granite-porphyry. The best place to study the relation of these rocks in Mount Kearsarge is on the southern slope in the trail. Though the rock surface is not exposed as much as might be desired, nevertheless it is possible to observe a reasonably well defined gradation from Conway granite into the granite-porphyry, and then from the latter into the quartz-porphyry.

But this gradation may be more clearly and easily seen in the bed of Cedar brook in the lower part of Moat mountain.

Beginning at the 900 foot contour in the brook bed, there appears what is clearly the Conway granite, though possibly a little finer in texture than the granite farther down the stream. Ascending the brook bed a few feet, the rock begins to be slightly porphyritic, and at the same time contains less biotite. There may be distinguished in this phase the beginning of a finer-grained groundmass. Then 150 feet up the brook bed, only 20 feet or so higher vertically, the surface of the ledge being exposed all the way, may be found the granite-porphyry. Its resemblance to the preceding is very close, yet the fine groundmass of a light gray color is clearly defined, inclosing the distinct feldspars, one-half to three-fourths inch through, and the blebs of smoky quartz, together with the black foliated masses, one-eighth inch or less through, of biotite. The biotite is noticeably less in quantity than in the granite beneath.

This gradual variation and gradation may be easily traced until, at the 1,100 foot level, the rock is a quartz-porphyry, the biotite appearing not at all, or now and then only in traces, and the rock, aside from this, identical with the quartz-porphyry higher in the mountain.

The quartz-porphyry of these mountains has thus far been spoken of as if it were a simple and pure porphyry. While the prevailing rock in the upper part of the mountain is the porphyry, this always contains irregular, angular fragments of other rocks, so that it is difficult to obtain a hand specimen that does not show one or more of these inclosed fragments. In places the rock fragments are so abundant as to make up the larger part of the ledge, constituting a breccia with the porphyry as the cement. Such a breccia may be seen on the south slope of Kearsarge at the 2,000 foot level, and continues to appear up to the 2,150 foot level. The fragments constituting the breccia vary in size from a fraction of an inch up to two feet or more in diameter. Those most frequently seen are of phyllite.

There is a large mass of this phyllite in the southern slope of Mount Kearsarge, which is crossed by the mountain trail at the 1,425 foot level. From this trail the phyllite area may be traced easterly and southeasterly to the first brook on the mountain side. The phyllite constitutes a mass in the south side of the mountain about one-fourth mile in length and 100 feet thick.

The phyllite is of a dark gray or slate color, of slightly greasy feel, and is very thinly laminated. The surfaces of the laminæ show a fine, delicate crinkling which is seen on a cross-section to be due to the beginning of a new structure almost at right angles to the lamination. The new structure is produced partly by a very fine faulting and partly by the compression of

FIG. 2.— The breccia in Mt. Kearsarge — the surface of a ledge.

minute folds. There are beds of finely grained, light gray quartzite in the phyllite. They show that the present structure is parallel to the original bedding of the clay. There also appear on the laminæ minute dark spots, longer than wide, and pointed in shape, which are the beginnings of crystals, probably, of andalusite.

The phyllite mass has suffered extreme brecciation, being in large part a mass of simply indurated fragments. In part there is a peculiar regularity displayed in the brecciation. The breaking followed certain straight zones, only a few inches thick, within which the rock was shattered, and the fragments now occupy every conceivable position, while the rock between, several feet in thickness, is not broken, is not even folded. Why the rock yielded so completely through these zones with so little disturbance to the intervening rock is difficult to understand. Near the border of the large phyllite mass the fragments separated somewhat, and the unsolidified porphyry flowed in and crystallized, making the border into a porphyry-breccia. Some of this is well exposed at the side of the trail on the south slope, and is shown in the illustration.

In addition to the phyllite, there are, inclosed in the quartz-porphyry, fragments of gray quartzite, of glassy quartz, and of quartz-porphyry. The quartz-porphyry in fragments closely resembles, frequently, the quartz-porphyry inclosing them.

In Moat mountain the quartz-porphyry contains a smaller number of fragments. Among these are those of glassy quartz, of rusty mica-schist, of quartz-mica-schist, of quartz-porphyry, of quartzite, of biotite-gneiss, of muscovite-granite, and of a dark gray, rusty rock, probably a basic eruptive. In addition to these small fragments, there is a large mass of phyllite, identical with the Kearsarge phyllite and completely brecciated, making up a large part of the top of Moat. The fragments of this breccia vary in size from those that are very small up to those a foot across. Some of these fragments contain andalusite crystals.

CONCLUSIONS.

1. The Conway granite, the granite-porphyry, and the quartz-porphyries, including probably those found in fragments, were formed by the solidification of a single magma.

The sedimentary rocks of this area, together with the underlying crystallines, were profoundly and thoroughly shattered, presumably by a disturbance associated with the coming of this magma into its present position.

2. The shattered condition of the phyllite affords a means of estimating the greatest depth at which this magma could have solidified. Included, as the shattered phyllite was in the molten magma, the latter was not at a depth greater than that of the zone of fracture for the phyllite.

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WORCESTER, MASS.

THE STOKES COLLECTION OF ANTARCTIC FOSSILS.

Mr. F. W. Stokes, artist to the late Belgian Antarctic expedition, collected in February, 1902, a few specimens of fossils upon the Antarctic continent at Admiralty Inlet, Louis Philippe Land, south of South America. These fossils are the first which have ever been brought back by any of the expeditions to the far south, and great praise is due Mr. Stokes for affording this means of identification for the first time, of the age of sedimentary strata upon Antarctica. The collection is not large, containing scarcely more than a dozen specimens, but a sufficient number of species have been recognized to determine somewhat definitely the age of the strata containing them, and to permit of important conclusions as to the faunal geography of Upper Cretaceous time. In the study of the collection the writer is indebted to Dr. T. W. Stanton, of Washington, for valuable suggestions.

The specimens were all collected from a talus slope. Most of them occur in concretionary nodules of a very dense, fine-grained brown sandstone, but the two specimens of Hamites are from a coarser-grained glauconitic sandstone which is reddish in color upon its weathered surfaces. The most perfect specimens of *Tubulostium callosum* occur completely weathered out, but the same species also occurs in the brown sandstone nodules. The original stratigraphic position of all the specimens was probably approximately at the same horizon.

As might be expected, several of the species prove to be undescribed forms and are here described for the first time. The species recognized are as follows :

Lucina? townsendi White.
Lagena ? antarctica, n. sp.
Tubulostium callosum Stol.
Olcostephanus antarctica, n. sp.
Haploceras? sp. undet.
Hamites elatior Forbes ?

Hamites, sp. undet.
Glyphaea stokesi, n. sp.

The presence of the ammonites at once marks the fauna as of Mesozoic age, and the presence of such uncoiled forms as Hamites stamps it at once as Cretaceous. In an examination of the fauna for the purpose of making a closer correlation and to determine the relationships of the fauna with the Cretaceous faunas of other portions of the earth, it is found that these relationships point in two directions. The three species, *Tubulostium callosum*, *Lagena? antarctica* and *Olcostephanus antarctica*, seem to connect the fauna with the Middle or Upper Cretaceous faunas of southern India. The first of these is a peculiar little gastropod which is specifically identical with one originally described from the Utatur formation of southern India. The second species, *Lagena? antarctica*, is most closely related to *L. secans* Stol. from the Ariyalur formation of the same region, and the third, *Olcostephanus antarctica*, most closely resembles *Ammonites madrasinus* Stol., also from the Ariyalur beds of India. In the correlation of these deposits in India, the Ariyalur formation has been referred to the Upper Cretaceous by the Indian geologists, while the Utatur beds are placed in the Middle Cretaceous. The weight of the evidence afforded by the antarctic fossils, therefore, leans about equally towards the correlation of the beds containing them with the Middle or with the Upper Cretaceous beds of India, which would naturally lead to giving them a place in about the middle of the series.

In addition to these three species which establish the relationship of the Antarctic fauna with that of southern India, there are two species, *Lucina? townsendi* and *Hamites elatior* which are identified with forms which have been described by White from islands in the Straits of Magellan, thus establishing the connection of the fauna with that of the continent of South America. The specimens of *Tubulostium callosum* also, are somewhat closely allied to a species described by Stanton[1] as *T. pupoides* from the Cretaceous beds of Patagonia.

The evidence afforded by the specimens in the Stokes collec-

[1] Rep. Princeton Univ. Exped. to Patagonia, Vol. IV, Pt. I, p. 30.

tion seems to establish the relationship of this Antarctic fauna with the Middle or Upper Cretaceous faunas of southern India on the one hand and on the other hand with the Cretaceous faunas of southern South America, and it is believed that the evidence is sufficient to demonstrate the existence of a shallow water connection between these three regions in later Cretaceous time, possibly by way of Australia.

DESCRIPTION OF SPECIES.

MOLLUSCA.

PELECYPODA.

Lucina? townsendi White. Plate I, Figs. 2–3.

1890. *Lucina? townsendi* White. *Proc. U. S. Nat. Mus.*, Vol. XIII, p. 14. Pl. III, Figs. 1–2.

Description.—Shell attaining a length of 70^{mm} in the larger of the two specimens in the collection, subovate in outline, moderately convex, the greatest convexity being one-fourth the total height of the shell below the beaks, the hinge-line arcuate, about two-thirds the total length of the shell. Anterior margin rounded in outline, passing imperceptibly into the more gently rounded ventral margin; posterior margin rather sharply rounded below and in the casts sinuate above. In the internal casts the postero-dorsal surface is rather abruptly depressed, this depression being bounded internally by a slight sinuous, rounded ridge. The adductor muscle impressions are subequal, of rather large size, the posterior ones included almost wholly within the depressed portion of the valve and its bounding ridge, the anterior ones just below the anterior extremity of the hinge-line. Surface markings of the exterior of the valves poorly preserved, apparently consisting of somewhat irregular growth lines only; the surface of the casts marked in the lower third of the valves by more or less irregular and rather obscure, flattened, radiating ribs which become obsolete before reaching the ventral margin.

The dimensions of the smaller and better preserved of the two specimens are: length, 43^{mm}; height, 38^{mm}; thickness through both valves, 22^{mm}. The dimensions of the larger example are: length, 70^{mm}; height, 56^{mm}; thickness through both valves, 42^{mm}.

—Walker Museum Pal. Coll. No. 9707–9708.

Remarks.—The generic reference of these shells cannot be made with certainty because the hinge-characters are not well preserved in either specimen. On the right valve of the smaller specimen, however, near the anterior extremity of the hinge-line, several processes are exhibited which seem to resemble the teeth of the genus Trigonarca. The species seems to be identical, however, with White's *Lucina? townsendi*, described from islands in the Straits of Magellan, and in the absence of any definite proof to the contrary his generic identification is allowed to stand.

GASTROPODA.

Lagena? antarctica, n. sp. Plate I, Figs. 4, 5.

Description. — Shell rather small, fusiform, with about four volutions, the periphery forming a sharp revolving keel. Spire elevated, its height but little less than that of the outer volution. From the revolving keel the surface of each volution slopes abruptly to the suture below, the upper surface of the volution has a much longer concave slope to the suture above. The outer slope of the last volution drops abruptly from the periphery, is then concave for a short distance and then continues in a nearly straight or slightly convex line to near the anterior extremity of the shell where it is again concave.

Surface of shell marked by fine lines of growth which bend backward in passing from the suture to the peripheral keel.

The dimensions of the only specimen observed are: total height 19.5^{mm}, diameter of last volution on the periphery 11^{mm}.

—Walker Museum, Pal. Coll. No. 9713.

Remarks.—This species is established upon a single specimen which preserves the mould of the exterior and a cast of the interior of the shell. It is a rather unusual form of gasteropod shell in Cretaceous faunas and agrees most closely with a species described as *L. secans* Stol., from the Upper Cretaceous of southern India. The antarctic species[1] here described may be distinguished from the Indian species by the absence of the angular revolving rib upon the outer volution below the peripheral keel. In other respects the two species are much alike.

Tubulostium callosum Stol. Plate I, Figs. 6–17.

1898. *Tubulostium callosum* Stoliczka. *Pal. Ind.*, "Cret. Faun. of S. Ind., Gasteropoda," p. 241. Pl. XVII, Figs. 26–32.

Description. — Shell sinistral, thick and rugose, more or less nearly discoidal in form, sometimes with a low spire, aperture circular, entire. Volutions exceedingly irregular, apparently three or four in number, the inner ones being eroded in all specimens observed so that their number, cannot be accurately determined. The peripheral portion of the shell is much thickened, the thickened portion being divided into three strong, more or less irregular revolving ribs; the shell is also marked by conspicuous, irregular lines of growth.

The dimensions of the best preserved specimen are: maximum diameter 17^{mm}, height of outer volution 8^{mm}, diameter of aperture 3^{mm}.

—Walker Museum Pal. Coll. No. 9711.

Remarks. — This little shell has been identified with a south Indian species although none of the Indian specimens which have been illustrated are as nearly discoid in form as some of the Antarctic ones. The Indian specimens, so far as illustrated at least, agree most closely with Fig. 17 upon the accompanying Plate I. The four specimens here illustrated show a regular gradation from the more discoid to the more heliciform shells, and without doubt all are members of a single species.

[1] *Pal. Ind.*, "Cret. Faun. of S. India Gasteropoda," p. 138, pl. 11, f. 20.

All of the Antarctic specimens are sinistral; in the original description the species is said to be usually sinistral, but some of the Indian specimens are dextrally coiled and in a larger collection from Antarctica both forms of shell would doubtless be discovered. The species is also somewhat closely allied to *T. pupoides* Stanton, from the Cretaceous beds of Patagonia.

CEPHALOPODA.

Olcostephanus antarctica, n. sp. Plate II, Figs. 1–2.

Description.—Shell discoid, compressed, dorsum regularly rounded, the aperture two-thirds as broad as high. Umbilicus of moderate size with nearly vertical sides, leaving about three-eighths of the inner whorls exposed. Surface of whorls marked by sharply elevated transverse ribs which are continuous uninterruptedly across the dorsum, their crests being from two to three millimeters apart; most of these ribs originate in a row of tubercles upon the edge of the umbilicus, each tubercle giving rise to two or three ribs, but between the ribs originating in this way there are others which start on the edge of the umbilicus between the bases of the tubercles. The crest of each rib is surmounted by a row of small, low, tubercles about two millimeters apart.

The maximum diameter of the type specimen is 68^{mm}, the height of the aperture 30^{mm}, and the width of the aperture 20^{mm}.

—Walker Museum Pall. Coll. No. 9706.

Remarks.—This type of Ammonite shell, with strong lateral ribs which usually originate in fascicles from nodes on the border of the umbilicus and continue uninterruptedly across the dorsum, is uncommon in the Cretaceous faunas of North America, where it is recognized only in beds of Neocomian or Lower Cretaceous age on the Pacific coast. In Europe the genus is restricted to the Upper Jurassic and Lower Cretaceous. The antarctic species here described, however, is not closely similar to any of the American or European species of the genus, but is allied to several species of Ammonites (*A. kaliki* Stoliczka, *A. madrasinus* Stoliczka, and *A. bhawani* Stoliczka),[1] from the Middle Cretaceous beds of Southern India, all of which should probably be referred to the genus Olcostephanus. *O. antarctica* may be distinguished from all of the Indian species, however, by the line of low tubercles which surmounts each one of the lateral ribs of the shell.

Haploceras? sp. undet. Plate II, Fig. 5.

A single distorted and imperfect specimen of a cephalopod with all the inner whorls destroyed, may be referred to the genus *Haploceras* with a query. The surface of the shell is smooth, the dorsum rounded, with the lateral surfaces gently convex and rounding rather abruptly into the umbilicus which is of moderate size. So far as can be determined the margin of the aperture is continuous, not being produced forward on the sides and on the dorsum, but the specimen is not in a condition to show the form of the aperture with certainty. None of the sutures are preserved.

[1] *Pal. Ind.*, "Foss. Ceph. of Cret. of S. India."

The dimensions of the specimen are: maximum diameter 34^{mm}, height of aperture 17^{mm}, width of aperture 14^{mm}.

—Walker Museum, Pal. Coll. No. 9712.

Hamites elatior Forbes? Plate II, Fig. 3.

1890. *Hamites elatior* Forbes? White, *Proc. U. S. Nat. Mus.*, Vol. XIII, p. 13. Pl. II, Figs. 1–2.

Two specimens in the collection may be referred provisionally to the genus Hamites. One of these is a fragmentary cast of the straight portion of an individual whose diameter must have been about 60^{mm}. On this specimen the annular ridges are closer together than on the other one, the intervals ranging from 3 to 4^{mm}, and on one side the annulations exhibit a shallow sinuosity. The specimen seems to possess all of the essential characters of *H. elatior* Forbes? as identified by White from the Straits of Magellan and is therefore so identified. — Walker Museum, Pal. Coll. No. 9709.

Hamites sp. undet. Plate II, Fig. 4.

The second specimen referred to Hamites is a portion of the impression of the exterior of a very large individual, which, judging from the curvature of the fragment at hand, must have had a diameter of 80^{mm} or more. It is a part of the straight portion of the shell with the crests of the annulations about 6.5^{mm} apart. The raised annular ridges are not symmetrical, the slope on one side being more abrupt than on the other.

—Walker Museum, Pal. Coll. No. 9710.

ARTHROPODA.

MALACOSTRACA.

Decapoda.

Glyphaea stokesi, n. sp. Plate I, Fig. 1.

Description.— Cephalothorax highest toward the front, somewhat flattened both dorsally and laterally, with a short, sharply pointed rostrum. Anterior margin sinuate between the rostrum and the base of the antennae, it rounds regularly into the gently convex ventral margin. From a little in front of the middle of the ventral margin of the lateral surface of the cephalothorax a a conspicuous rounded furrow is directed obliquely upward and backward, crossing the flattened dorsal surface transversely at about one-third of the total length of the cephalothorax from its posterior extremity; from the same point of origin at the ventral margin another furrow describes a sigmoidal curve first forward, then upward and nearly vertical, and then forward and nearly horizontal again, becoming less and less sharply defined to the anterior margin just above the base of the antennae; from this sigmoidal furrow there are two shorter and less well defined furrows directed obliquely downward and forward towards the antero-ventral margin. At the posterior extremity of the cephalothorax a transverse furrow extends across the dorsal surface close to and parallel with the margin. Between the two principal furrows upon the lateral surface of the cephalothorax, and just above their

1

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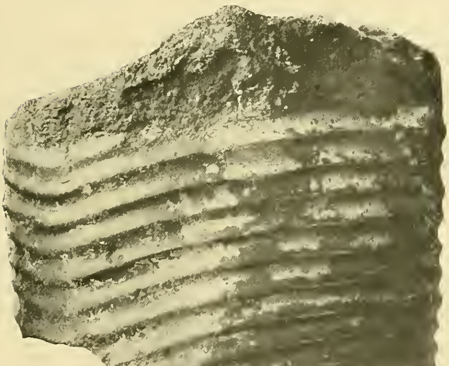

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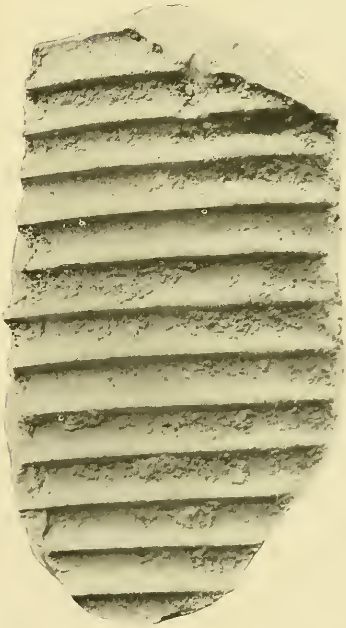

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point of origin, there is a subcircular, depressed-convex, node-like elevation, and between the two shorter furrows which are directed obliquely downward and forward from the sigmoidal furrow is another similar subelliptical elevation. Just back of the base of the antennae is a rather sharp, keel-like ridge reaching backward to the first of the short oblique furrows. Back of the base of the rostrum, upon the dorsal side of the cephalothorax there are two small, sharply pointed tubercles upon each side of the median line ; the anterior one is the larger and is situated almost directly in front of the smaller posterior one.

Abdomen consisting of six segments and a strong telson posteriorly, altogether being as long or longer than the cephalothorax.

The dimensions of the type specimen are : extreme length of cephalothorax 32^{mm}, greatest height 14^{mm}, length of rostrum 4^{mm}.

—Walker Museum, Pal. Coll. No. 9705.

Remarks. — This species is represented in the collection by a single specimen which exhibits in good condition one side of the cephalothorax up to the dorsal median line, with the segments of the abdomen and the telson attached but imperfectly preserved and recurved along the ventral side. Fragments of the legs and the basal joint of one of the antennae are also preserved but not in such a condition as to admit of description. The specimen represents a species which is quite distinct from any of those previously described from the Cretaceous.

EXPLANATION OF PLATES

PLATE I.

FIG. 1. *Glyphaea stokesi,* n. sp. Lateral view of the type specimen.

FIGS. 2–3. *Lucina ? townsendi* White. 2. Laterial view of the right valve of a small specimen. 3. A larger, less perfect specimen believed to belong to the same species.

FIGS. 4–5. *Lagena ? antarctica,* n. sp. 4. Lateral view of a wax cast taken from a natural mould of the exterior. 5. The natural cast of the interior of the shell.

FIGS. 6–17. *Tubulostium cullosum.* Stol. Three views each of four different specimens.

PLATE II.

FIGS. 1–2. *Olcostephanus antarctica,* n. sp. 1. Lateral view of the type specimen. In part an internal cast and in part an impression of the exterior. 2. Lateral view of a wax cast taken from the natural mould of the exterior. Same specimen as Fig. 1.

FIG. 3. *Hamites elatior* Forbes ? Lateral view of an imperfect cast of the interior.

FIG. 4. *Hamites* sp. undet. Lateral view of a plaster cast taken from the natural mould of the exterior.

FIG. 5 *Haploceras ?* sp. undet. Lateral view of the only specimen observed.

STUART WELLER.

Reviews

SUMMARY OF THE LITERATURE OF NORTH AMERICAN PLEISTOCENE GEOLOGY. 1901 AND 1902.

FRANK LEVERETT.

In the two years covered by this summary there have been published in the neighborhood of 150 papers and reports (a few of which the reviewer has been unable to obtain), which either wholly or in part discuss features or problems of North American Pleistocene geology. About forty papers pertain to the Dominion of Canada, and half as many to Alaska and the Cordilleran part of the United States, while nearly every state which falls within the limits of glaciation has had notice in from one to fifteen papers. Iowa appears to lead the states in number of papers published, though New York is but little behind, and Massachusetts, Michigan, Indiana, and Wisconsin have a good showing. New Jersey has been favored by the appearance of a voluminous report on glacial geology, while Ohio and parts of neighboring states are embraced in a monograph by the United States Geological Survey dealing entirely with the glacial formations and drainage features. Kansas and Minnesota have had a little notoriety in connection with the question of glacial man. A large number of papers have been brief contributions to magazines or to the bulletins, transactions, and proceedings of scientific societies or academies which deal usually with a small territory or a single subject. The official reports published by the state, United States, and Canadian surveys which contain matter on Pleistocene geology also in most cases give a large share of attention to the geology of the older rock formations. In such cases this review is confined to the Pleistocene portion. Inasmuch as each area has to some extent problems of its own, it has seemed advisable to group the papers areally. There is also a group composed of papers of a general nature.

THE CORDILLERAN REGION IN CANADA.

BROCK, R. W. *The Boundary Creek District, British Columbia.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 49–67, 1902.

The area examined was confined to the Grand Forks and Kettle River mining divisions of the boundary district. Glaciation is discussed mainly on p. 57. None of the mountains are of sufficient altitude to support glaciers now, but glacial phenomena due to the Cordilleran ice-field are everywhere strikingly evident. The average direction of striation when uninfluenced by local causes is about S, 30° E. Drift "terraces" are numerous at all altitudes, up to 2,000 feet above the valleys. Since glaciation the surface oxidation and weathering has been very slight.

DALY, R. A. *Geology of the Region Adjoining the Western Part of the International Boundary.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 37–49, 1902.

The area discussed embraces a tract eighty miles from west to east and ten miles in width on the north side of the international boundary from the Gulf of Georgia eastward. The glacial geology is mainly treated on pp. 41–5, and embraces a brief discussion of glacial erosion and denudation, cirques, mountain tarns, and small lakes, river terraces, and deltas. A morainal dam which holds in Chilliwack lake is also described. This lake stands 1,850 feet above the sea, and the granite walls rise steeply 3,000 to 4,500 feet higher, with truncated spurs between tributary gulches that indicate a large amount of glacial erosion.

GWILLIM, J. C. *Glaciation in the Atlin District, British Columbia.* Jour. Geol., Vol. X, pp. 182–5, 1902.

The great valleys of northern British Columbia show evidence of glacial action which occurred after the valleys had reached about their present dimensions. There appears to have been regional glaciation followed by a partial or local glaciation. There is also a present active glaciation in coast ranges to the westward. The regional glaciation left its marks on the slopes up to an altitude 5,000 feet above the valleys, and the movement was northward. The local glaciation was restricted to the upper valleys and slopes, but did not cover the high parts of mountains.

The paper closes with a brief description of the Llewellyn glacier near Atlin lake. The upper surface of the ice-field is about 5,000 feet above sea level or 3,000 feet above Atlin lake.

MCCONNELL, R. G. *The Yukon District.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 23–37, 1902.

Results of examinations at several of the smaller placer camps in the Yukon district are presented. Livingston creek valley shows evidence of glacial action in its upper part and heads in a steep amphitheater. In most of the creek valleys the terraces and terrace material are reported to consist of ordinary stream wash, and no mention is made of glacial action.

PARKINSON, J. *Some Lake Basins in Alberta and British Columbia.* Geol. Mag., Decade 4, Vol. VIII, pp. 97–101, 1901.

Lake Agnes in the Canadian Rocky mountains is found to be in a rock basin. Mirror lake, into which it discharges, is not so clearly a rock basin. Lake Louise, farther down the valley, probably receives the discharge from Mirror lake by underground channels. Whether Lake Louise is a rock basin is not certain. Lake Marion in the Selkirk range is another case in which the evidence is not clear as to its being a rock basin. Among the agencies which may have been operative in producing the Lake Agnes rock basin, warping, glacier erosion, and decay of soft rocks in the upper end of the basin should be considered. The soft rocks might have been removed either by stream or glacier action.

VAUX, GEORGE, and WILLIAM, S., Jr. *Observations Made in 1900 on Glaciers in British Columbia.* Proc. Phil. Acad. Nat. Sci., for 1901, pp. 213–15.

Notes on the movements of the glaciers are presented.

ALASKA.

BROOKS, A. H., and COLLIER, A. J. *Glacial Phenomena of the Seward Peninsula.* Abstract, Science, N. S., Vol. XIII, 1901, pp. 188, 189.

No evidence of general glaciation was found, but there were centers of local glaciation. The valleys of the Kiglow-aik range are glaciated to 500 feet above the valley floors, and the moraines were deposited close to tide water. Shrunken remnants of some of the glaciers still persist, and are, so far as known, the most northerly in Alaska, being in latitude 65°. There is evidence of a recent elevation of 600 to 800 feet, but it antedates the maximum extension of the glaciers.

BROOKS, A. H. *Sketch of the Geology of Southeastern Alaska.* Professional Paper No. 1, U. S. Geol. Surv., pp. 31–3, 1902.

Existing glaciers are found chiefly on the Pacific mountain system, and the largest development is on the seaward slope. On the Pacific side of the St. Elias range the perpetual snow limit is about 2,000 feet, and on the inland slope about 6,500 feet. The glaciers on the Pacific slope are much larger than on the inland slope. The Coast Range has less conspicuous glaciers than the St. Elias, and they are mainly on the seaward slope.

The extent of former glaciation was much greater than at present, though its limits were fully determined at but few points. It is not known whether the higher mountains were covered. On Prince of Wales Island glacial action was found up to 2,200 feet, but near Niblack Anchorage it seems to have reached no higher than 2,000 feet. In general the Alexander Archipelago was glaciated up to at least 2,000 feet. Farther north glaciation reached higher altitudes, there being glacial bowlders near Juneau at 3,200 feet, and this town stands on a moraine. Terraces along the valley walls of Chilcat and one of its tributaries are thought to have been built while the valley was still occupied by glacier ice. Rock-cut basins occupied by lakes are not uncommon, especially in the Ketchikan region. On Prince of Wales Island is a lake basin a mile long and a quarter of a mile broad entirely surrounded by a rock rim.

BROOKS, A. H., RICHARDSON, G. B., COLLIER, A. J., and MENDENHALL, W. C. *Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900.* House Doc., No. 547, 56th Cong., 2d Sess., 222 pages, 1901.

The surface geology is briefly discussed on pp. 41–7 under the topics: river and stream gravels, beach deposits, terrace deposits, glacial deposits, extra-morainic drift, ground ice, and soil. No evidence of regional glaciation was found, but four local centers of glacial action are reported. Of these the most important is in the Kiglu-aik mountains. There the valley slopes are glaciated up to an elevation 500 to 600 feet and head in glacial cirques, while at the margin typical moraines were found. Remnants of glaciers still persist in the higher mountain valleys. The extra-morainic drift found in the vicinity of Nome reaches an altitude of 800 feet. It is not necessarily glacial, but may have been brought by ice-floes at a time when the land stood about 800 feet lower than now. A subsidence of that amount would greatly change the contours of the coast and make islands of part of the mainland.

The Norton Bay region has suffered no general glaciation, but may have carried small local glaciers.

COLLIER, A. J. *Reconnaissance of the Northwestern Portion of the Seward Peninsula, Alaska.* Professional Paper No. 2, U. S. Geol. Surv. 68 pages, 1902.

Surface deposits are discussed on pp. 24–9. Aside from the sand and gravel along the coastal plain and the streams, there are a few places where rounded pebbles and washed gravel occur at high altitudes remote from streams. There has been but little glaciation in the mountains of this region.

Evidences of uplift and warping are discussed on pp. 34–43. The plateaus, benches, and plains indicate four extensive cycles of uplift and erosion, all of which are post-Mesozoic.

GANNETT, HENRY. *General Geography of Alaska.* Harriman Alaska Expedition, pp. 257–77, 1901; also Nat. Geog. Mag., Vol. XII, pp. 180–96, 1901.

Attention is called to the fact that nowhere else on the earth is such magnificence of mountain fiord and glacier scenery to be found. It is thought that glaciation has been a very important factor in shaping the fiords and rounding the mountain surfaces. The present glaciers, though far larger than those of Switzerland, are trifling compared to their predecessors. There is a narrow strip of low coast from the Mount. St. Elias region westward, and the Alaskan coast of Bering sea is mainly low and marshy. The Yukon delta covers thousands of square miles. The Yukon river is navigable for small steamers throughout its course in Alaska. The interior of Alaska is but little known, but so far as explored is found to be traversed by a system of rivers navigable for canoes, though in some cases interrupted by rapids and low falls. The Pacific coast climate is very damp and the skies are cloudy. It is much warmer than the coast of Bering sea, because the latter is practically a closed sea to which the warm waters of the Pacific do not have access. The interior is subjeet to a far greater range in temperature than the coast, there being a known range of about 150° Fahrenheit in certain localities along the Yukon.

MUIR, JOHN. *The Pacific Coast Glaciers.* Harriman Alaska Expedition, Vol. I, pp. 119–35, 1901.

The Sierra Nevada of California carry sixty-five small glaciers at altitudes of 11,000 to 12,000 feet. They are mainly between latitude 37° and 38°. On Mount Shasta a glacier extends down to 9,000 feet. The Cascade range of Oregon and Washington has groups of glaciers on the highest mountains. From Mount Ranier they descend to 3,000 to 4,000 feet above the sea.

In British Columbia and southeastern Alaska the broad lofty mountains along the coast are usually laden with ice, and the upper branches of nearly all the canyons occupied by glaciers. The highest and snowiest are between latitude 56° and 61°, and they afford a considerable number that discharge icebergs into the sea. This very snowy field is about 500 miles long and 100 miles broad, and probably includes nine-tenths of the ice on the coast. Glaciers are very few and small north of latitude 65°.

There are about 100 large glaciers that do not reach the sea. The Malaspina is the largest, being about 20 miles by 65 or 70. Many are 2 to 4 miles wide. Of glaciers that flow out into the sea the author has seen twenty-eight, and knows of at least three more, while several fiords in Prince William sound remain unexplored. The southernmost is Leconte glacier in latitude 56° 50′. Three reach the sea in Taku Inlet and nine in Glacier bay. Of the last named the largest is the Muir glacier, which is twenty-five miles wide below the junction of the main tributaries, while the area of its basin is scarcely less than 1,000 square miles.

Glaciated surfaces testify to a grand continuous ice-sheet that not long ago fringed this coast along all the island region as far south as the strait of Juan de Fuca. Traces of former glaciation are also found farther north than the present limits, especially on the fiords below mountain ranges. Muir in 1881 noted evidences of glaciation in Plover bay on the Siberian coast.

SCHRADER, F. C., AND SPENCER, A. C. *Geology and Mineral Resources of a Portion of the Copper River District, Alaska.* House Doc. No. 546, 56th Cong., 2d Sess., 94 pages, 1901.

The Pleistocene deposits, physiography, and glaciation are discussed on pp. 58–82. There are heavy deposits of till and other glacial material in the Copper river basin, and the rounded topography of a glaciated region at higher altitudes. The deposits appear to have been formed by a glacier that had its source in the Wrangell mountains and adjacent Alaska range. Streams have cut to a depth of several hundred feet, and have not yet reached the level of the old rock floor.

In Prince William sound the evidence of glaciation extends to the water's edge along the mainland, for the shore is striated. Several of the islands also contain glacial material brought from the mainland. It is thought probable that the topography of the sound has been greatly affected by glacial erosion.

THE CORDILLERAN REGION OF THE UNITED STATES.

ARNOLD, RALPH. *The Pleistocene Geology of Southern California.* Abstract Science, N. S., Vol. XV, pp. 415, 416.

A summary statement of the marine Pleistocene of southern California with the subdivisions of Pleistocene formations.

ARNOLD, DELOS, and ARNOLD, RALPH. *The Marine Pliocene, and Pleistocene Stratigraphy of the Coast of Southern California.* Jour. Geol., Vol. X, pp. 117–38, 1902.

The faunas indicate a fluctuation of conditions along the California coast from the beginning of Pliocene times. Southern or warm conditions prevailed in the early Pliocene, northern or boreal in the late Pliocene and early Pleistocene, and warm conditions again in the remaining or greater part of the Pleistocene.

DILLER, J. S. *Glaciation of Mount Mazama.* Professional Paper No. 3, U. S. Geol. Survey, pp. 41–4, 1902.

This paper, which discusses the geology of the Crater Lake National Park, contains a brief discussion of the glaciation. Mount Mazama was a volcanic cone which apparently collapsed as a result of the withdrawal of the liquid interior of the cone at a time subsequent to the glaciation. By this ingulfment seventeen cubic miles of material is thought to have disappeared. A correlative effusion at some other point is likely to have occurred, but it has not yet been located.

This mountain, which once occupied the position of Crater lake, had glaciers whose deposits and striæ are to be found on the rim of the crater and the mountain slope outside, but not on the slope toward the lake. On the lower slope of the mountain were tongues of glacier ice occupying the valleys only, but at the level of the rim (about 8,000 feet A. T.) nearly all the surface was glaciated. Ground moraine material is widespread, and a few terminal moraines occur. Mention is made of one which is 200 feet in height. Canyon-cutting by glaciers is also a marked feature.

FAIRBANKS, H. W. *Lake Chelan, Washington.* Abstract Science, N. S., Vol. XV, pp. 412, 413, 1902.

The Lake Chelan valley was occupied in recent times by one of the largest glaciers on the eastern slope of the Cascade range. Previous to that there was another lake in the valley at a somewhat lower level, which must have emptied into the Columbia river. The author holds that the great depth of the lake is due, not to the erosion by the glacier, but to stream erosion, and this erosion must have occurred prior to the formation of the Columbia lava plateau. A morainal dam holds the lake to its present level of 325 feet above the Columbia river. The author knows no reason to suspect that bed-rock will be encountered above the level of the Columbia river.

FAIRBANKS, H. W. *Pyramid Lake, Nevada.* Pop. Sci. Monthly, March, 1901.

A popular discussion of the features of this lake and of the history involved in the greater Lake Lahontan which once covered this site.

FENNEMAN, N. M. *The Arapahoe Glacier in 1902.* Jour. Geol., Vol. X, pp. 839–51, 1902.

A glacier formerly nine miles long is now reduced to a mile in length and occupies a cirque opening eastward to North Boulder creek in Colorado. Deficiency of snow the past three winters and excessive melting in the summers give exceptional opportunity for study and bring out features not known before. The glacier is really much branched, because of inequalities of the rock-bed, and has interesting moraines and crevasses and a prominent *bergschrund* at the line between the névé and the glacier proper. There is evidence of an uplift, but it is thought to have long antedated the glaciation.

GANNETT, HENRY. *Origin of Yosmite Valley.* Nat. Geog. Mag., Vol. XII, pp. 86, 87, 1901.

This paper was called out by the appearance of a paper by H. W. Turner on the origin of the Yosemite valley,[1] in which the potency of a glacier for the work of erosion is denied. Gannett thinks that the gorges in the high Sierra were cut by glaciers and holds the view that the line of demarkation between the channels made by the ice, and the valleys made by the streams, can be determined almost to a foot.

[1] "The Pleistocene Geology of the South-Central Sierra Nevada, with a Special Reference to the Origin of the Yosemite Valley," *Proc. Calif. Acad. Sci.*, Vol. I.

HERSHEY, OSCAR H. *The Quaternary of Southern California.* Bull. Dept. Geol. Univ. Calif., Vol. III, pp. 1-30, 1902.

The paper discusses the orographic disturbances in the early part of the Quaternary which lifted upper Pliocene beds to altitudes several thousand feet above the sea. A provisional scheme of classification is then brought out, which is expressed in the table below. The last column represents mere suspicions as to relative lengths of the different epochs.

TABLE OF QUATERNARY CONDITIONS.

	Recent Period	Modern Epoch		Deposition	Land-Level Below Normal	Length Ratio 5
Quaternary Era	Pleistocene Period	Le Conte's Sierran Period	Glacial Epoch	*Not represented*	*Not known*	5
			Not named	Erosion	Normal	10
			San Pedran Epoch	Deposition	Below normal	5
			Los Angelan Epoch	Erosion	Normal	75
			Red Bluff Epoch	Deposition	Below normal	10
			Santa Claran Epoch	Erosion	Normal	890

HERSHEY, OSCAR H. *The Term Sierran.* Am. Geol., Vol. XXIX, pp. 88-95, 1902.

It is considered doubtful if the contemporaneity of uplift on the Pacific coast with that in the eastern part of the United States has evidence to amount to a demonstration. For this reason it seems premature to attempt to correlate erosion cycles on opposite sides of the continent. The Sierran valleys cannot be directly compared with the Ozarkian valleys of the Mississippi basin. It appears highly probable that the Sierran excavation on the Pacific coast began before the opening of the Glacial epoch of the eastern states and was contemporaneous in part with the Ozarkian. But it is still in progress and was only slightly affected by glaciation in the high Sierra Under LeConte's definition Sierran covers, apparently at least, part of the Ozarkian and nearly all of the Glacial epoch. The so-called Glacial epoch of the California mountains was probably one-twentieth or one-fiftieth of the Glacial epoch of the eastern part of the United States. The author does not attempt to use "Ozarkian" on the Pacific coast, nor "Sierran" in the interior of the United States.

HILGARD, E. W. *The Débris Fans of the Arid Regions in their Relation to Water Supply.* Abstract, Science, N. S., Vol. XV, p. 414, 1902.

The structure of the débris fans is described and the value of these fans in forming natural storage and regulating reservoirs for water is brought out.

HILGARD, E. W. *A Sketch of the Pedalogical Geology of California.* Abstract, Jour. Geol., Vol. IX, pp. 74, 75, 1901; also Bull. Geol. Soc. Amer., Vol. XII, pp. 499-500, 1901.

The paper discusses the soil conditions, including also the difference between rock decomposition in arid and humid climates. In the humid regions loams and clay soils are produced, while in arid regions the soils are sandy and dusty unless derived from pre-existing clay formations which give rise to "adobe." In the arid regions there is a uniform soil mass to a depth of four to ten feet, with practically no subsoil, and these soils almost universally contain high percentages of lime and potash, because not subject to the leaching process which affects the soils of the humid regions.

RITTER, WILLIAM E. *Subsidence of Santa Catalina Island in Recent Geological Times.* Science, N. S., Vol. XIV, pp. 575–7, 1901.

A submerged cobblestone beach three quarters of a mile to a mile out to sea from the present shore is cited in proof of the subsidence.

SALISBURY, R. D. *Glacial Work in the Western Mountains in 1901.* Jour. Geol., Vol. IX, pp. 718–31, 1901.

Reports results of investigations by several parties in northwestern Montana both east and west of the Rocky mountains; in the mountains of New Mexico, and in the Wasatch mountains.

The work east of the Rockies in Montana determined the limits of the northeastern ice-sheet and developed evidence concerning moraines of fourteen glaciers from the Rocky mountains. The work west of the Rockies was largely given to mapping the moraines of glaciers which extended southward in the lowlands and valleys.

In the Wasatch the positions of fifty Pleistocene glaciers exceeding one mile in length were determined, as well as traces of smaller glaciers and more than a dozen névé fields. Several of the glaciers reached the shore of Lake Bonneville, and the moraines of at least three of them are partially buried by the fluviatile deposits near the shore or possibly by the shore deposits. The altitude necessary to give rise to a glacier in that region was 8,000 to 9,000 feet. The glaciers were more numerous and larger, and the glaciation more vigorous, on the western slope than on the eastern, because of larger catchment basins and heavier snowfall. These mountains afford evidence of two widely separated episodes of glaciation.

In the New Mexico Rockies an altitude of 11,700 to 12,000 feet was necessary to produce glaciation. At least no evidence was found on peaks of lower altitude, though the search was not exhaustive. The longest glacier track is seven miles, and extends down to 9,200 feet.

It was also discovered that the Spanish Peaks of Colorado were once glaciated on their northern slopes.

STONE, G. H. *Note on the Extinct Glaciers of New Mexico and Arizona.* Science, N. S., Vol. XIV, p. 798, 1901.

The former occurrence of glaciers on the La Plata and San Juan mountains of southwestern Colorado is referred to, an account of which had previously been published. The Conejos range of the San Juan in New Mexico was glaciated for only thirty to fifty miles south of the Colorado-New Mexico line. The Sangre de Christo range both in Colorado and New Mexico was glaciated, and glaciation extended nearly to Santa Fé. The farthest southwest that evidences of glaciation were found in Arizona is near Prescott. The névé of this glacier scarcely rose above 9,000 feet. The occurrence of glaciation so far south (latitude 34° 30′) was probably due to great snowfall owing to proximity to the ocean. It is suggested that glaciers may have existed on the lofty Mogallon mountains of New Mexico and Arizona which had not been examined.

Turner, H. W. *A Post-Tertiary Elevation of the Sierra Nevada.* Abstract, Science, N. S. Vol. XV, pp. 414, 415, 1902.

A comparison is made of the grades of the Tuolomne river in Neocene times and the present, showing a grade of 142 feet to the mile for the Neocene, in the 33 miles above the mouth of Piute creek and 92 feet to the mile for the present channel. The Neocene stream flowed in a broad channel making deposits, which indicate comparatively gentle grades, though they are scarcely so marked on this river as on streams farther north. It is thought that the grade was at least as low as that of the modern stream, so that the present grade of the Neocene channel is much greater than the grade at the time it was occupied by the stream, and this must have been brought about by a differential uplift on the east.

Princeton Patagonian Reports. Vol. I. Narrative and Geography. By J. B. Hatcher. Published by the University, 1903; pp. 314; pls. L.

No better augury could be desired for the success of the Princeton Patagonian Reports, the publication of which has been eagerly awaited, than is furnished by this, the initial volume of the series. Although entitled "Narrative and Geography," this handsome volume contains much more than the mere record or field-notes of an explorer's itinerary, being as a matter of fact replete with all manner of observations on the natural history, geology and physiography of the region visited. A Nansen, a Stanley, in fact no one short of a trained naturalist could have produced such a work, which is of the order one might expect from a Humboldt or Darwin. Without doubt the present contribution ranks as one of the most noteworthy that has yet appeared concerning the physical and biological features of the lower extremity of the South American continent.

One cannot review this work of Mr. Hatcher without appreciating the justice of Professor Scott's tribute, who remarks in the editorial preface that, "the whole forms a monument of energy and skill which it is difficult to characterize without using terms which savor of exaggeration." Three large monographs dealing with the rich palæontological material brought back from South America are promised by Professor Scott, and he further states in regard to Mr. Hatcher's stratigraphic determinations, that they were "most useful, making possible for the first time a rational account of the geology of large areas in southern Patagonia." It deserves also to be remembered, in judging of the extent of these achievements, that an elaborate volume by Drs. A. Ortmann and T. W. Stanton on the invertebrate material has already made its appearance.

Besides having had the good fortune to secure tons of highly interesting palæontological material, Mr. Hatcher has placed geologists the world over in his debt by having definitely settled the problem as to the age of the Santa Cruz beds, which has long been a serious stumbling-block. Not only this, but he was able to trace the entire stratigraphic succession from the Cretaceous upward, thus furnishing us with a complete section of Patagonian formations. Doubts as to the occurrence of certain strata in particular areas have been satisfactorily cleared, and in a word, light has been shed upon a number of burning issues in geology and palæontology. The author also has much to say in his narrative of interest to the meteorologist and anthropologist. Climatal conditions, the character of the soil and its vegetation, very full accounts of the native Indians, their customs and peculiarities, and a great deal regarding the habits of wild animals, even the psychological experiences of himself and companions whilst buried in the wilderness — all these and many other topics are presented in a simple aud pleasing style; and what with the narrative and camera illustrations, the reader has a sense of being fairly transported into the heart of Patagonia.

With characteristic modesty, the author touches but lightly upon the hardships and privations endured by himself and faithful companions; yet we know that the party had only the most meager facilities and very limited means at its command, and we can only picture to ourselves in imagination how extremely serious the situation was at times, how apparently insurmountable the difficulties. No one can fail to admire the quiet courage, patience and energy of the man who planned and successfully carried out, almost single-handed, an expedition of such magnitude and so rich in scientific results, and at the same time in the face of such discouraging obstacles.

C. R. E.

NOTE TO THE ARTICLE ON "FORAMINIFERAL OOZE IN THE COAL-MEASURES OF IOWA.[1]

SINCE the publication of my article on "Foraminiferal Ooze in the Coal-measures of Iowa," which appeared in the preceding number of the JOURNAL, I have found, while at work on the University of Texas Mineral Survey, another bed of minute foraminifera in the Upper Carboniferous of Texas, on the east foothills of the Chinati mountains. The Upper Carboniferous has a thickness here of probably more than 3,000 feet, and the upper member consists of a series of limestones, several hundreds of feet in thickness, evidently equivalent to "the upper or white limestone" described by Tarr in his "Reconnaissance of the Guadalupe mountains" (*Geol. Surv. of Texas, Bull. No. 3*, p. 29). The small foraminifera are also here associated with *Fusulina cylindrica*, and occur most frequently in the lower 200 feet of this limestone.

J. A. UDDEN.

SHAFTER, TEX.,
May 9, 1903.

[1] JOUR. GEOL., No. 3 (April-May, 1903), p. 283.

THE

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THE RELATION BETWEEN CERTAIN RIVER TERRACES AND THE GLACIAL SERIES IN NORTHWESTERN CALIFORNIA.

INTRODUCTION.

By a reconnaissance trip in February, 1903, the writer traced a definite system of river terraces between the coast at Humboldt Bay and the Summerville basin on the border of a high mountain cluster which was extensively glaciated in the Pleistocene period and still possesses three tiny glaciers. The importance of connecting the terrace system with the glacial series was recognized and the writer devoted some days to a detailed study of the extremely rocky and brushy canyon, seven miles in length, which separates the Summerville basin from undoubted deposits of the last great glacial stage. The work was greatly facilitated by the operations of the early placer miners, who have beautifully exposed most of the remnants of old channels. It is believed that this study was rewarded by exceptional success, of the truth of which the reader may judge by perusal of the following pages:

I have now discriminated in this region six distinct channel levels (including the present river bed) which, to facilitate the discussion, I will classify by letters, beginning with the highest. In my descriptions I distinguish constantly between "terrace" and "channel." Ordinarily each terrace consists of a rock bench with a flattened or channeled, water-worn surface (the channel level) overlaid by 5 to 20 feet of river gravel and this by a variable thickness of sandy clay and angular local rock débris, the surface of which constitutes the terrace level. Therefore, the height which I may give for a channel level is always less than that of the corresponding terrace level. Where mining has been carried on extensively, it is often difficult to determine the original surface level of the deposit, but where there has been no mining, the terrace level is the conspicuous feature. The channel is by far the most constant and safest guide to follow as the terrace level is locally raised by torrent fans from neighboring gulches.

The South Fork of Salmon River, in this region, has a nearly straight course (minor deflections excepted) from east to west, being controlled by the predominant joint system of the hornblende schist into which it has trenched a narrow valley, 3,500 feet in depth. It has migrated southward with the dip of the joints. In consequence, the channel remnants occur predominantly on the north side of the river. On the south of the river, back of the immediately overlooking peaks, there is a group of higher peaks, including Mt. Thompson (altitude 9,345 feet) and Mt. Courtney (altitude about 8,800 feet). Within the shadow of these peaks, there are a number of *cirques*, each of which, in the glacial period, was the gathering ground of an independent glacier.

CHANNEL REMNANTS FROM SUMMERVILLE TO BIG BEND BASIN.

The channel which comes up through the gorge below Summerville at a height of 30 to 50 feet, upon entering the Summerville basin seems to separate into two strands, of which the first becomes lower, relative to the river, partly because of partial filling of the channel by tailings, and spreads out to a bench, on the north side of the stream, several hundred feet wide (Channel E). Back of it, and apparently 15 or 20 feet higher, there is another broad shallow channel (Channel D). As we travel up through the basin, we find this latter occurring at 30 to 40 feet above the river, on both sides. The canyon in it is unusually wide and contains important remnants of the lower terrace. These two lower terraces have dark and light brown débris over the channel gravels proper, but no decided reddish tint. All higher terraces are characterized by a bright red color of the upper dirt layers.

Channel D seems to be the equivalent of the "lower terrace" or "broad valley floor," described elsewhere from the basins on the lower Klamath and lower Trinity rivers, and Channel E is a local development, scarcely occurring anywhere below Cecilville. Channel F is mostly buried under the gravel and bowlders of the present river bed.

At the upper end of the Summerville basin, at the mouth of Rush Creek, there is a very well defined terrace whose surface is at the outer edge about 100 feet above the river. It is well marked along the opposite side of the river as a rather sharp bench. On the north side, facing the river, it has been mined extensively, showing that under its sloping surface there are buried two distinct channels. The outer (Channel C) contained a very bowldery gravel bed from 20 to 30 feet deep, and the inner (Channel B) a similar but thinner and less coarse bed. Most of the bowlders are of the granite of the area on which it rests and from up Rush Creek. A few are of Courtney granite and there are rare small bowlders of serpentine, both from the main valley. The granite bowlders in places are thickly packed. Many are rotten to the center although three feet thick. The red stain in places extends from the surface to a depth of 20 feet. The deposit appears old. It rests on rotten granite. There is a fairly well defined granite platform about 75 feet above the river and a similar platform 30 to 40 feet higher. The sloping surface over these two channels is the main upper terrace of the Summerville basin, but seems to correspond to an intermediate terrace of the system studied nearer the coast.

Channel A is represented by a small river deposit occurring at about 250 feet above the river, just below the Summerville buildings. It is much older than any subsequent channel and the space between its level and that of the main upper terrace is characterized in many places by a peculiar rolling topography developed in rock. This high channel represents the floor of a comparatively broad valley, of which only a very few remnants remain. It dates back at least as far as the Red Bluff epoch. There are no traces of any higher river deposit in this region.

The valley carved below the main upper terrace at the mouth of Rush Creek may be 500 to 800 feet wide. In it are two main terraces, both well defined. The lower is 15 to 20 feet above the river level, and is trenched by the winding canyon of the present river, which is here several times as wide as the low-water stage of the stream because the soft granite erodes easily. The second terrace may be 50 feet above the river. These two lower terraces have fewer and less rotten large granite bowlders than those higher.

At Miller's suspension bridge the terraces, here well defined, are at about 20, 55 and 120 feet respectively. The rock is harder and the lower canyon getting smaller. The river next swings into the north bluff, cutting away the terrace system but leaving it well defined on the south side. The next swing is into the south bluff and cuts it out on that side.

From here to Big Bend Creek, the north side of the valley contained abundant remnants of the main upper terrace, which have nearly everywhere been mined off. The gravel layer was thin and contained few large bowlders. Over it there was, in the first remnants, 10 to 20 feet of indistinctly stratified local débris such as in the torrent fan at Cooper's mine (but less coarse) discussed in another paper [1] and the significance of which will come out later in this. In places it contains much clay and is red in color. The surface of this terrace sloped distinctly toward the river, but its rock bench, in so far as it constitutes Channel C is level. The latter is well defined on four points and stands about 75 feet above the river. One can look across these points and see that there is absolute correspondence in height of the flat rock platforms.

The rocks are here hard hornblende schist and the canyon narrow from the upper terrace level down, but in it there are

[1] "Some Evidence of Two Glacial Stages in the Klamath Mountains in California," *American Geologist*, Vol. XXXI, March, 1903.

several beautiful remnants of the middle terrace (Channel D), half way down to the river. There is no room for the lower terrace. Above Channel C there seem to be several remnants of a level 30 or 40 feet above it (Channel B). Still higher there is a little channel about 30 feet wide, with a distinct outer rim of bed-rock, a few bowlders and a little gravel in the channel and this overlaid by about 20 feet of red, indistinctly stratified, rather subangular local débris. This may occur nearly 175 feet above the river and probably approximately represents Channel A. Far below it is the main upper terrace.

Just below Big Bend Creek, the covering of the regular river gravel in the main upper terrace by brown, not red, distinctly stratified and partly water-worn hornblende schist pebbles and subangular débris, as in Cooper's mine, becomes quite apparent. This is the downstream edge of the torrent fan of Crosby Creek, elsewhere discussed, and it is here 20 to 40 feet thick. It buries two channels. At 65 feet above the river we have the floor of Channel C, which from here upstream becomes the main or best developed upper channel. We know that it is Channel C because this is one of the four points just mentioned, and we can see that it absolutely corresponds to the channel which, farther down stream, stands at 75 feet above the river. The canyon is getting shallower. Channel D occurs on the opposite (south) side of the river at only 20 feet above the stream.

Channel C contains some large bowlders of Courtney granite and the regular river deposit is covered by about 40 feet of the Crosby Creek alluvium. Just back of it we have at 80 feet above the river, Channel B, which contains few large bowlders and is covered by a less thickness of the Crosby Creek alluvium. It is quite evident that the mass of local débris which came with a rush of water down Crosby Gulch and was distributed down the valley and stratified by the river, rests on nothing lower than Channel C of the Summerville basin. It is of the same age as the completion of this channel and it is the equivalent of the local débris which nearly everywhere seems to form the surface deposit of the main upper terrace of the Summerville basin and gives it its sloping surface. Its relation to Channel B is simply that there was such an abundance of material that it succeeded also in submerging the higher channel remnants.

At the mouths of Big Bend and Grizzly creeks, a belt of chlorite schist enabled the excavation of a basin about 1,000 feet square. The river makes a large bend around by the south, and descends rapidly, so that the terraces are higher above the stream on the downstream than the upstream side. In the east central portion of the basin there was a flat whose surface rose about 30 feet above the river on the upstream side, and whose bed-rock floor rises 10 to 15 feet above the same portion of the river. This is Channel D and the gravel was not covered by the local alluvium. On its downstream side there is a broad terrace rising 12 feet above the river. On the other side of the river there is a terrace whose bed-rock floor is 10 to 15 feet above the river and surface 20 to 25 feet above the stream. There is no local alluvium on it. It seems to be the last development upstream of Channel E. Back of it there is a marked remnant of a terrace whose bed-rock floor seems to be about 75 feet above the river. The surface is possibly 100 feet above the river. Within the canyon at the lower end of Big Bend basin, remnants of this channel occur on both sides of the river and lead directly to the last discussed development of Channel C. Similarly, the next lower channel occurs in the gorge as a long narrow bench on the north side, with rock floor 20 feet above the river.

At the mouth of Big Bend Creek there is an alluvial fan apparently made by that stream. It rests on the same bed-rock surface as the "15-foot channel" (Channel D) which is 25 feet above the river at the downstream end of the basin. The gravel is 65 feet thick and remarkable for the many large granite bowlders of Big Bend granite, some of which are so large that it seems incredible that the Big Bend Creek could have carried them. The surface is rough and bowldery, and sloped distinctly toward the river. Some features indicate a glacial origin but the deposit seems waterlaid. The age is the same as that of the gravel of Channel D.

FROM BIG BEND BASIN TO COOPER'S MINE.

Between the Big Bend and Little South Fork creeks, there are several marked remnants of the main channel (Channel C), crossing points on the inner side of curves in a new course of the river. The local alluvium which was deeply piled over the regular river deposit, displaced the river repeatedly and compelled it to take a somewhat serpentine course. Consequently the new canyon is not everywhere directly under the old.

At the upper end of Big Bend basin, Channel C has a height above the river of only 50 feet, but is clearly seen to be the same level as the 75-foot channel at the lower end of the basin. Small remnants of this 50-foot channel occur on each rock point on the south side of the river for some distance upstream. Below them there is a long narrow bench of the 15-foot channel (Channel D). On the first prominent point on the north side, the main channel is 50 feet above the river, but at 70 feet there is another channel (Channel B). Both of them were buried under the stratified local débris, the lower the deeper. On the same point occurs a marked remnant of the 15-foot channel, which was not buried under local débris.

The next point on the south of the river has a marked remnant of the main old channel whose floor is here 55 feet above the river. There is a distinct outer rim. The new canyon is 75 feet (minimum) in depth. Over the old channel gravel there is at least 40 feet of local stratified alluvial débris (including that of the Crosby Creek fan). There is also a remnant of the higher channel.

The next point on the north side of the river has a narrow remnant of the old channel system. It is about 50 feet above the river and is distinctly higher than the main channel remnants on the south points both above and below this point. Hence it represents Channel B. There is not much local débris left over it.

The next point on the south side of the river, which is a short distance below Little South Fork Creek, has an important remnant of Channel C. Its rock floor is 75 feet above the river, it has a distinct outer rim, and the new channel has been cut into solid rock 100 feet deep as a minimum. Over the gravel there was stratified local débris 30 to 40 feet thick.

The slight variation in height above the river, of the different remnants of a given channel is due to the facts that the river always has had a variable grade because of harder and softer rock belts and that the present higher grade and lower grade sections do not quite correspond with those of the past. As a matter of fact, the older channels were better graded than is the present river bed.

In ascending the river from Summerville, Channel C gradually approaches the present river level and the new canyon, at first thought, might appear to be smaller. In reality, I have found, to my surprise, that the river everywhere has accomplished about the same amount of cutting in rock of a given hardness. The new canyon above Big Bend basin is largely excavated to one or the other side of the old course and includes the removal of considerable rock above the level of Channel C.

Along the old Spooner ditch on the north side of the valley, overlooking the old channel remnant just described, there is an area of gravel about 1500 feet in length and 100 to 200 feet in width. Its lower edge seems to be about 300 feet above the river, and it ranges to at least 100 feet higher. Near the western end it seems to rest on a bed-rock slope of 10° to 20°, much less than the slope above or below. The ditch is cut into it for several hundred yards to a depth of about 10 feet and splendidly exposes its interior. It is a heterogeneous agglomeration of bowlders and pebbles and subangular rock fragments embedded in a grayish (partly brown stained) sandy clay. There is no sorting of the material and not a trace of stratification. Its general appearance is that of a glacial deposit, but it is so old and rotten that if any striae existed they have been destroyed by decay.

The larger bowlders are chiefly of hornblende schist from the subjacent terrane, Courtney granite from near the head of the river and massive serpentine. The latter are plentiful enough to be conspicuous. Bowlders 18 inches to 2 feet in diameter are found without much difficulty. The largest bowlder observed is a serpentine 4 × 4 × 5 feet. The remarkable feature of this serpentine constituent is that serpentine does not occur in place anywhere in the basin of the *old* Salmon River between this point and its head. The evident source of these bowlders is a serpentine area on the eastern side of the *old* Coffee Creek valley, within several miles of its head. That portion of the *old* Coffee Creek valley has been captured and is now drained by Salmon River. A study of the gorge at the head of the *old* Salmon River valley indicates that the beheading occurred late in the glacial period, that is, was associated with one of the later glacial stages as will appear later in this paper. Salmon River now has access to the serpentine and is bringing a small percentage of serpentine pebbles and cobbles below the gorge, but they are soon worn out so that at the distance of three miles from the gorge they are extremely rare in the present river deposit. One so rarely finds a specimen of them in the old channels up to this deposit under discussion, that they may be considered practically absent. Why are they so characteristically abundant in this higher and older gravel? I have but one plausible explanation of it. A glacier headed in the *old* Coffee Creek valley, overrode the col at the head of this valley and sent a shallow tongue far beyond any point reached by subsequent glaciations—three miles farther down the valley than the distinct glacial moraines to be described later, and to a locality now but 3,700 feet above the sea.

Whether this is a glacial or a river deposit, I am going to refer its level to Channel A. I am going to show traces of the same deposit for several miles up the valley at nearly a uniform level. They seem to have been deposited on the valley floor where it joined the steeper mountain slope. Therefore, I consider them to represent the level of the valley floor of that time in much the same way as do the old channel deposits.

In this deposit along the Spooner ditch all the granite bowlders are thoroughly rotted to the core. So they are in certain portions of the lower channels. But here other rock species which are not usually much decayed in the river channels, fall to dust. Various porphyries, diorites, gabbros, and schists will not bear handling. The serpentine bowlders are hard, but pitted and honey-combed. Even the hornblende schist, which is one of our most resistant rocks, has an aged and incipiently decayed appearance.

The local material is mostly somewhat angular, but the foreign material is better rounded. Some pebbles undoubtedly show river action, but more convey impressions of the faceting characteristic of glaciation. An otherwise angular hornblende schist fragment a foot in length has been worn smooth and flat on one side and there are the faintest traces of striation.

The unique character of this deposit is generally recognized by the people who refer to it as a "glacier wash." Prospectors say that it contains a little fine gold uniformly distributed through it, and not concentrated into a basal stratum as in an old river channel. The bed-rock surface is somewhat uneven, but is decayed and, besides, not well exposed. Following the deposit toward the east the bed-rock surface on which it rests very quickly gets to 50 feet above the ditch, and the serpentine-bearing débris ranges to over 100 feet higher. This is quite unlike the habit of an old channel remnant.

There is a 12-inch serpentine bowlder and some rounded cobbles, associated with red dirt, along the old Spooner ditch above the mouth of the Little South Fork Creek. About one-fourth of a mile farther up stream there is a 12×18-inch serpentine bowlder in a draw on a very rocky and steep slope just below the old Spooner flume and probably 200 feet above the river. There are no other erratics and this has evidently slidden from higher on the hill-side.

From the mouth of the Little South Fork Creek to a little point just below the Deep Bank mine, the new course of the river approximately coincides with the old, and all the old channel gravels and local alluvium have been swept from the canyon. The canyon is very narrow and extremely rocky, there being at places, particularly on the south side, perpendicular rock bluffs 75 to 100 feet high. Probably the new canyon has been cut down from 50 to 75 feet below the floor of Channel C, but in addition there have been considerable slices of rock taken off from the walls of the old canyon, so that the steep rocky walls of a modern appearance rise to 200 and 300 feet above the river. This canyon is so narrow, crooked, and rough-walled, and there are so many projecting narrow rock points, that it is unreasonable to suppose that it has ever been glaciated. If the serpentine-bearing horizon which occurs above this canyon is truly referable to glacial action, the valley has been cut down into very resistant hornblende schist to a depth of at least 200 feet and probably nearly 300 feet since the glaciation. Channel C is far below and very much newer than these supposed old glacial deposits.

The School-house Flat, opposite the mouth of the Little South Fork Creek, probably 500 or 600 feet above the river, has dimensions about 400 × 500 feet, seems to be composed of broken hornblende schist, shows slight landslide topography, no gravel and is very steep on the side toward the river, so that it resembles an old river terrace remnant. A considerable area for some distance west of this flat shows typical landslide topography. Farther up the valley there is another terrace-like landslide deposit, occurring probably 600 feet above the river and occupied by Lakeview, a small ranch.

At the lower end of the Deep Bank deposit the bottom of Channel C is 45 feet above the river. Just across the river on a small point there is a fragment of the same channel and below it a newer channel (Channel D) with its rock floor 15 feet above the river. The outer edge of the Deep Bank is about 200 feet above the river and the inner edge about 250 feet. Just west of the Deep Bank, resting on a steep slope at about the level of the inner edge of the Deep Bank, there is a large granite bowlder (Channel A). The face of the Deep Bank displays stratified, coarse, subangular dark brown (reddish in layers) Crosby Creek alluvium about 100 feet thick. In the channel deposit there are many granite bowlders, rotten but with a hard core. The rock cutting of the new canyon is from 100 to 150 feet in depth, the latter on the south side.

The first south point above the Deep Bank has a marked rock bench at 15 feet above the river (Channel D, occurring in the new canyon) and back of it a remnant of Channel C. Immediately opposite is the lower end of the most important remnant of this old channel, that opened as Cooper's mine, discussed in the paper before cited. It is preserved for several hundred yards, the river occupying a rock canyon on the south of it. At the lower end the deep narrow channel has its floor about 40 feet above the river. On the borders of the deep channel are flattish, water-worn rock benches which probably represent Channel B. Thin remnants of the ordinary river deposit occur in the bottom of the deep channel. The pebbles are well rounded and the granite bowlders comparatively small. Over this occurs 40 to 50 feet of a stratified deposit partly of subangular local débris, but abounding in granite bowlders, many of large size. This is not the regular river deposit, thins rapidly down stream, becomes very bulky from here up, and I consider it the combined Crosby Creek alluvium and the overwash gravel and bowlders of a glacier which terminated over a mile up the river. Over it is the stratified angular local débris of the Crosby Creek torrent fan, extending to the brow of the hill, nearly 300 feet above the river. Granite bowlders derived from up the river are sparingly scattered through it.

A ditch in the slope of the mountain just above the inner edge of this alluvial fan, exposes a small area (possibly twenty yards in diameter) of rotten granite bowlders and local débris embedded in a sandy clay. It seems to pass down under the edge of the torrent fan and is certainly older. It seems to represent Channel A, having the proper height (350 feet above the river), the aged appearance and the apparent glacial characteristics. On the same line west, but in Crosby Gulch, a large rotten granite boulder is buried under the stratified alluvium of the Crosby Creek fan.

NEAR AND IN THE GLACIAL AREA PROPER.

At the upper end of Cooper's mine a depression crossing a rock point seems to represent the deep channel naturally mined off by the river. Its floor is 45 feet above the stream. Directly opposite the present river but in line with the old channel below, the bowlder bed which is so characteristic in Cooper's mine passes into the bank, has been mined somewhat and the rock floor shown to be a stream channel. But this rock floor is 100 feet above the river. The old channel may have descended very rapidly at this point, although it is more likely that it is one of the higher channel surfaces in Cooper's mine that is represented, and that the deep channel passed up through the gorge.

The channel on the south of the gorge is preserved for about 500 feet, and is covered by a mass of angular local débris whose surface forms a sloping terrace with outer edge several hundred feet above the river. From where this channel issues from the bank, for fully half a mile up the river, the old and new courses are coincident. But the level of the old channel floor is marked by a change from the precipitous canyon wall to a gentler and less rockier slope above, with an occasional granite bowlder at this level.

On the north side of the river, about one-fourth mile from the lower end of Cooper's flume, there is a cutting through a narrow point, on which occurs a remnant of gravel about 30 × 100 feet in extent and 5 to 20 feet deep. It rests on a rock slope of about 45° and ranges from the level of the flume, about 300 feet above the river, to 75 feet higher. The bed-rock surface under the gravel is broken and decayed and somewhat irregular. It does not seem to be in the form of a distinct channel. The material abounds in large granite bowlders which are thoroughly rotten to the core, even one 6 × 8 feet. The remainder of the rock fragments are mainly angular and subangular hornblende schist up to bowlder size. Aside from the granite bowlders, very little of the material is rounded. It is embedded in a sandy clay, inclined to a reddish color. There are no apparent lines of stratification. It looks more like a glacial than a stream deposit. It is very old and rotten and a mere remnant of a once more extensive formation. The lowest portion is over 150 feet above the floor of Cooper's channel, the surface of which, as already described, forms a terrace on the opposite side of the river. This gravel contains an 8-inch and a 2-foot serpentine bowlder, and represents the serpentine-bearing horizon, down the river.

Higher on the same slope, by the "Cape Horn" trail, about

600 feet above the river, there are the huge fragments of a single granite bowlder which had dimensions about 15 × 20 × 30 feet, about 700 tons in weight. There is no gravel with them. They rest on the sloping surface of the hornblende schist and apparently were higher but have slipped down. The configuration of the country is not now, and never has been, such that this bowlder of Courtney granite could have rolled down from its original position on the high mountain to the south. Further, Salmon river never was large enough to have transported this huge bowlder by any process speedy enough to have avoided wearing it out. Bowlders nearly as large are now lying in the bed of the river, but I have recently discovered that they rode into the valley on the backs of glaciers, and the river has not been able to move any of them far down stream. This bowlder apparently reached about its present position by glacial action, and I am compelled to refer it to the supposed glaciation represented by the "Channel A deposits." A flat-lying remnant of them occurs 30 feet above Cooper's flume at "Cape Horn."

At the upper end of the gorge (at the head of Cooper's flume, one and one-eighth miles up stream from Cooper's mine) we have the floor of Cooper's channel (Channel C) well marked as a bench on the south of the canyon, lying 75 to 100 feet above the river. It is encumbered with huge granite bowlders, not much decayed. Turning down stream from the head of the flume, the channel bench occurs on a point overlooking the deep, narrow canyon. Immediately back of it and advancing a point completely across it to the edge of the canyon, there is a pile of rock débris rising in a steep slope to over 100 feet above the old channel and then going back several hundred feet with a gently rising but undulating surface. It abounds in large granite bowlders, some of which occur on its surface. The flattened, plateau-like surface sends a narrow ridge northwestward to the edge of the canyon. On its southwest side there is a gently descending, broad, shallow, rounded depression, clearly not the result of erosion, but such a depression as commonly is found outside of glacial moraines. Back of this depression there is a long, smooth, gentle slope (without granite bowlders) gradually changing into the steep slope of the mountain above. The bowldery ridge is a glacial moraine. Its steep inner slope is largely due to erosion by the river. It obstructed the old channel and caused the erosion of the canyon.

The surface of the bowlder deposit rises toward the southeast at the rate of 10 to 20 feet in 100 feet, and soon attains a height of over 500 feet above the river. It has, at first sight, the appearance of a typical lateral moraine, with steep inward (ice-ward) slope, then a flat surface 30 to 150 feet wide and then the smooth slope of the unglaciated mountain. This moraine leads to the mouth of a deep gulch (Brown's Gulch) which comes down steeply from the mountain on the south and enters the river valley not far above the head of Cooper's flume. A glacier headed in a basin in the granite at the head of the gulch, extended down the steep, narrow gulch and out into the valley of the Salmon River. This may be called the Brown's Gulch glacier.

The moraine surface at the mouth of the mountain gulch is about 200 feet above the creek. The gulch is so sharply V-shaped as to indicate considerable postglacial erosion. From here up the bowlders on the west are simply scattered over the slope of the mountain, bed-rock appearing frequently, and in many places there is little to indicate a glaciated gulch.

The corresponding "lateral" moraine on the east side attains prominence farther up the gulch and quite likely extends without a break to the glacial basin at the head. The appearance is that this supposed lateral moraine really represents the floor of the glacier and that of the stream has cut a V-shaped gulch 150 to 200 feet deep and partly in hard rock, since the disappearance of the ice. This is an amount of erosion that I am not accustomed to for the time since the maximum extent of the Wisconsin glaciers.

Following the east moraine down, I find it finally separating from the general mountain slope as a broad, transversely flat-topped, independent ridge. This gradually diverges from the west moraine, showing that the glacier, upon entering the main valley, spread out like a fan.

The ridge ends abruptly on the edge of the main valley at a height perhaps 300 feet above the river. A small ditch passes around the point not far below the brow of the hill and its bank exposes the glacial débris. Proceeding east along the ditch, one comes to a fresh ravine leading down the steep slope from the ditch. It exposes 100 feet in thickness of horizontally-stratified, fine, subangular, brown gravel and reddish-brown silt, like in the high bank above Conzetti's mine, discussed in the paper before cited ; but here containing a number of granite bowlders, all rotten even when 3 feet in diameter. It is evident that this glacier dammed the valley and formed a pond 300 feet deep, in which the fine gravel and silt accumulated, but right here along the edge of the moraine, granite erratics slid from the glacier into the pond.

Two hundred feet farther east along the ditch we seem to be completely beyond the limit of the glaciation as the bank thence for a long distance shows only residuary débris.

Remnants of the terminal moraine occur on the north side of the valley, opposite the ends of the lateral moraines and connecting these two points, a distance of about 500 feet. Scattered bowlders reach a height of several hundred feet, but hardly high enough to explain the damming of the valley above and formation of the stratified gravel and silt by the moraines alone. Apparently the silt and gravel reached their upper levels by actual ice-damming.

Returning now, to the head of Cooper's flume, we will take up Cooper's channel, here marked by a rock bench 70 feet above the river, and trace it up stream. By reason of the high grade of the present river, the old channel reaches the stream level about 400 feet up stream, and the present rock canyon ends at that point. From here up the valley is comparatively broad, is encumbered by huge bowlders (the residua of the eroded glacial deposits) and no bed-rock shows in the south bank for some distance. From here up the old channel is buried under the present river-bed and passes out of the discussion.

The connection of Channel C with the maximum extension of the Brown's Gulch glacier seems sufficiently definite. This glacier built its moraines directly across the old channel, compelling the river to adopt a more northerly course and erode a new canyon. The overwash gravel and bowlders from the glacier were distributed down Channel C to a point below Cooper's mine. Before this was completed a cloud-burst in the basin of Crosby Creek, formed the torrent fan which is so certainly traceable down the main valley nearly to Summerville. The building of local débris fans over Channel C was an especially characteristic feature everywhere and we are now able to connect it with the glacial stage represented by the maximum extension of the Brown's Gulch glacier. I accept this as evidence of an abnormally moist climate and heavy precipitation in the territory outside of that involved by glaciation.

We will now transfer our attention to the vicinity of the upper falls of the Salmon River, in the gorge which marks the original head of the *old* Salmon valley. Above the gorge, the flat floor of hornblende schist extends out into the broad valley 100 yards as exposed by the river. Since the last or Wisconsin glaciation, the river has carved in this rock platform a canyon 30 to 50 feet deep, and 30 to 50 feet wide at the bottom, with steep, in places, precipitous slopes Through the upward rise of this rock platform and the high grade of the stream, the canyon has become probably 75 feet deep at the upper end of the gorge. A sort of terrace is traceable from the edge of the glaciated platform down through the gorge, particularly on the south side. Next to the river there is a precipitous rock slope capped by granite bowlders. Back of this there is a comparatively gentle slope, encumbered by huge granite bowlders. Above this there is a very steep, rugged slope, apparently unglaciated. The summit of the ridge is rounded, smoothed and covered with erratics. The Salmon River glacier in the last stage clearly overrode this ridge, and seemingly spanned across the gorge to the ridge on the north, whose summit it rounded and covered with glacial débris. The slopes within the gorge are apparently unglaciated (so far as the last stage is concerned) as ragged rock surfaces abound. But the bottom of the gorge at that time was a U-shaped valley descending as rapidly as the present river; certainly it was not such a narrow, rocky canyon as the present bottom of the gorge. Possibly a small glacial tongue extended down this valley at times, but the bowlders on the south terrace are so numerous and are piled up above the soil in a way to indicate that they were carried over the crest of the ridge on the south and rolled down to the bottom of the valley. Since this event, Salmon River has cut a rock gorge under the older valley, 50 to 75 feet deep. *It descends several hundred feet in less than a quarter of a mile.*

This canyon I attribute to late Wisconsin and post-Winconsin stream erosion. It is rather larger than I am accustomed to for the product of that time, but the flat platform above the gorge, in which this canyon is partly excavated, certainly was glaciated during the last or Wisconsin stage. This canyon is proportionally somewhat smaller than that eroded since the abandonment of Channel C down the river, but at first thought there does not seem to be any very great contrast between them. However, on the ground, the impression is very quickly made on the observer's mind that this upper canyon is much newer than that down the river which succeeded Channel C. Conditions for erosion are exceptionally favorable because it is very high grade. The river descends through it in a series of falls, with perpendicular drops at two places of over 20 feet. The rock is not exceptionally resistant. If this same river had flowed through this gorge since the abandonment of Channel C, it could not have failed to have cut back to the center of the broad valley above instead of only cutting a notch in the edge of the broad, inward-sloping valley rock-floor.

Tongues of ice from the main Salmon River glacier undoubtedly overrode the col during the earlier glacier stages, but during the interglacial or minimum stages, Salmon River did not flow through the gorge, as otherwise it would have completely destroyed the very high grade character of this short section of its course. The broad valley above the gorge was drained by Coffee Creek until late in the Wisconsin or last glacial stage as is evidenced by a broad valley eroded in the earlier glacial deposits just outside of the terminal moraine of the Salmon River glacier in its last stage. This terminal moraine is trenched by an insignificant notch, too small for such a stream as Salmon River to have flowed through it for a single week. When the glacier front fell back a mile, it formed another moraine which dammed the broad valley and turned the drainage of the upper valley through the gorge into the *old* Salmon valley. Therefore, I place the inception of cutting of the canyon in the gorge at a time very little later than the maximum extension of the glaciers of the Wisconsin stage and consider this canyon not more than one-third as old as that eroded since the maximum extension of the Brown's Gulch glacier.

Following the bowlder slope on the south side of the gorge down the valley, its edge gradually gets higher above the river. The bowlder strip becomes pretty steep, then rather suddenly changes to a flat terrace, 150 feet above the river, and whose surface has granite erratics about as numerous as on the floors of most glaciated valleys. This apparently represents the floor of a glacier and we have passed beyond the bowlders which have rolled down from the mountain. The steep slope facing the river is due to stream erosion. Half way to the river is a remnant of another flat terrace, also encumbered with bowlders.

Very shortly the glacial terrace gives out and we come to a slightly higher and steeper slope which has no granite bowlders and seems to be composed superficially of local débris. This is bounded on the river-ward side by a steep bluff 200 or more feet high. On this slope occur granite bowlders. The phenomena indicate a glacial deposit upon which has been built up an alluvial cone of local débris. The river flows in a rather broad canyon trenched below this level.

This slope has an angle of about 15°. Its width from the upper to the lower edge is about 400 yards. Following it down the valley we find built on it a bowldery terminal moraine of the Cohnrad Gulch glacier, which came down from a *cirque* on the northern face of Mt. Courtney. Between this moraine and the river the long slope descends to within 100 feet of the stream, acquires granite bowlders, then becomes undulating and very bowldery, and forms a distinct moraine which appears on both sides of the river and has been cut through by a gorge probably

50 feet deep. Thence extending a quarter of a mile down stream, we find a strong moraine development, great piles of huge granite bowlders rising from along the river to the foot of the steep mountains, a quarter mile back from the stream. This was evidently the work of the Cohnrad Gulch glacier, which barely reached the north side of the valley and scarcely dammed the river. It is a strand of this moraine system that rests on the between 100 and 150 feet of stratified fine gravel and silt above the Conzetti mine, as discussed in the paper before cited. From the way the same moraine system comes down near the river one-fourth of a mile farther up, there was apparently much erosion between the deposition of the gravel and the glaciation of its surface. This is a different conclusion than I have heretofore expressed, as I maintained, in the paper referred to above, that there was no dissection of the fine gravel deposit before the formation of the overlying glacial moraine, but it now appears that that statement was too hastily made. It now appears that a deep, comparatively broad canyon was excavated by the river into this gravel deposit, and subsequently when the Cohnrad Gulch glacier reached the edge of this canyon it tumbled much of its moraine material into it. The maximum extension of this glacier certainly occurred later than the maximum extension of the neighboring Brown's Gulch glacier, and there is evidence of such a long interval between them as constrains me to refer the former to the Wisconsin or last great stage of glaciation. This conclusion is supported by Cariboo Creek having excavated in this glacial débris a much smaller trench than Brown's Creek eroded in solid rock since the maximum extension of the Brown's gulch glacier. Why these two neighboring glaciers should have see-sawed in this manner is not clear, but from a neighboring mountain I have seen that they headed in adjoining *cirques* which seem to have been fed jointly by a higher *cirque*, and a careful examination of the locality may furnish a satisfactory explanation.

Under the stratified gravel and silt just mentioned there is a thin layer of fine gravelly blue clay, which rests on a bed of coarse bowlders and ordinary river gravel. The blue gravelly clay is very strongly contrasted with both the underlying and overlying deposits. A little farther west it is exposed along the bank for several hundred feet and has a thickness of 6 to 8 feet, with the bottom not seen. It is partially indurated so as to resist erosion well. It is without any apparent stratification and its general appearance is that typical of the ground moraine of a glacier. The included pebbles are partly subangular and partly well rounded. There are faint traces of striation. No serpentine is present, consequently the deposit must be referred to an early stage of the Cohnrad Gulch glacier, a stage apparently closely preceding the maximum extension of the Brown's Gulch glacier and certainly long preceding the stage which formed the moraine *over* the stratified fine gravel and silt.

We will return our attention again to the vicinity of the gorge at the head of the *old* Salmon valley. At Cooper's saw-mill, which is just below the gorge, there is the first of a series of remnants of a terrace which extends down the valley, with a level at first about 50 feet above the river, but gradually decreasing to 30 feet. It is, at the saw-mill, a rock bench covered with gravel and bowlders. The canyon trenched below it is comparable with that developed in the rock platform above the gorge, and I consider this level to represent the closing stages of glaciation in the broad valley above the gorge. The rock bench rapidly descends below the river level and thence the terrace remnants appear to be built entirely, displaying nothing but gravel and bowlders in the bank. This deposit partially filled a rather wide trench excavated by the river into the earlier glacial deposits and the lake deposit of fine gravel and sand. In the vicinity of Conzetti's mine there are several flat-topped remnants of this terrace which lie 30 feet above the river and which formed part of the valley floor at a time long succeeding the Brown's Gulch maximum glaciation; Conzetti is probably in part working this deposit in his hydraulic mine. Unfortunately, between here and the lower old channel remnants farther down the river, there are no more remnants of this late Wisconsin terrace; but it is safe to say that it is not older than Channel D and not newer than Channel E.

On the northern side of the valley, above the saw-mill just mentioned and hence just below the gorge, glacial débris is scattered thinly over the slope to the summit of the ridge, fully 700 feet above the river and 250 feet above the Big Flat on the opposite side of the ridge. There are some large granite bowlders, but among the material of lesser size, serpentine is conspicuously abundant. This I suppose to represent the last or Wisconsin glacial stage, the material seemingly having fallen from the ice spanning across the gorge. Serpentine occurs in equal abundance in the Wisconsin drift in the broad valley above the gorge. The serpentine is only proportionally abundant among the finer material. Small bowlders and cobbles well-smoothed represent the subglacial and the lower stratum of the englacial drift. Among the large angular and subangular bowlders which were superglacially carried, serpentine is rare in the Wisconsin drift near the gorge, a fact which must be taken into account in comparing this with the serpentine-bearing apparent drift farther down Salmon River.

Leading down the river for about a mile and a half from the saw-mill, the north side of the valley has a more or less continuous strip of glacial moraine material which shows a tendency to form an imperfect terrace at a level between 100 and 200 feet above the river, with a few scattered erratics higher on the mountain slope. This terrace corresponds to that which we have traced on the opposite side of the river. The depression between seems to be a valley of erosion, several hundred feet wide and containing the lower terrace which I have referred to the last glacial stage. If this interpretation be correct, a longer time of erosion separated the two glacial maxima stages than has succeeded the close of the last.

The glacial material forming the indistinct upper terrace on the north of the valley, contains an occasional serpentine bowlder, proving that it was formed by a glacier coming from beyond the gorge, but so far I have failed to find within it serpentine in nearly the abundance in which it occurs on the higher slope just west of the gorge and in the supposed old glacial deposit along the Spooner ditch. I am constrained to consider it as representing neither the earliest nor the latest glacial stage yet recognized here, but an intermediate stage, probably equivalent to the maximum extension of the Brown's Gulch glacier.

GENERAL CONCLUSIONS.

The preceding detailed descriptions seem to have pretty definitely developed the following:

1. That there was apparently a very old glaciation which connects chronologically with the highest series of river terraces developed in the Pleistocene valleys between Summerville and the coast.

2. That there was an intermediate stage of glaciation which connects definitely with one of the intermediate terraces down the river.

3. That there was a last great glacial stage which connects indefinitely with the lowest series of river terraces, including the "flat valley floor" of the basins between Summerville and the coast.

The relation between the glacial deposits and the river terraces is of extreme importance because a knowledge of it enables us to roughly determine the relative ages of the different glacial stages by erosion studies in a region without the glaciated area and where conditions were more uniform. In this manner I derive the following ideas:

1. That the intermediate glacial stage (always referring to the maximum extension of the ice in each glacial stage) was about three times as long ago as the last glacial stage.

2. That the earliest apparent glacial stage occurred at least ten times and perhaps twenty-five times as long ago as the last stage.

Now, in personally inspecting the various drift sheets in the Mississippi basin and in comparing my observations with those of others, I have acquired the idea that the Iowan drift is from three to five times as old as the Wisconsin, the Illinoian ten or fifteen times as old as the Wisconsin, and the Kansan at least fifty times as old as the Wisconsin. Hence, there naturally follow, as final conclusions:

1. That the deposits of the last great glacial stage in the Klamath mountains fully represent the Wisconsin glaciation.

2. That the intermediate glacial stage probably corresponds to the Iowan.

3. That the deposits supposed to represent the earliest glacial stage yet recognized are *at least* as old as the Illinoian and perhaps as old as the Kansan glaciation.

CLIMATIC CONDITIONS DURING THE SEVERAL GLACIAL STAGES.

The comparative abundance of serpentine in the earliest supposed drift of the Salmon River valley and its rarity as superglacial material in later drifts raises a question as to the cause of this difference. A given glacier in each stage occupied the same valley and would be expected to yield drift of like constitution.

Linked with this phenomenon there is another. I know that the earlier glaciers ran farther than the later, and I have acquired the idea that they were of a radically different character, particularly that they were much thinner at a given distance from the end than were the glaciers of the last stage. This may be wholly imaginary, but I usually do not acquire such ideas without there being some basis for them; in the field I have now studied the earlier drift in three distinct areas (the Union Creek, Coffee Creek, and Salmon River valleys) and each independently has made a similar impression on me. This is after eliminating all differences due to the profound erosion of the earlier drift.

The only satisfactory explanation of the phenomena that has come to light is that as between the earlier and later glacial stages there was a radical difference in the *character* of the climate. *The earlier drift was formed under low altitude conditions and the later drift under high altitude conditions.*

On a recent trip from the coast at Eureka to this region, made shortly after a severe snow-storm, I had the opportunity of observing some meteorological phenomena having a direct bearing on the question at issue. On Redwood Mountain near the coast I found at an altitude of 3,600 feet, a depth of six feet of snow. As I advanced inland, the line of, say, two feet depth of snow gradually rose, and when I reached the region under discussion, I found that there had been not more than two and a half feet of snow at an altitude of 4,300 feet. A yet greater difference was observed in the melting of the snow. Near the coast the atmosphere was uniformly cold and dense, the sun's direct rays had comparatively little power, and there was no very great difference in the rate of melting of the snow on opposite sides of the valleys. Farther inland and at a higher altitude, the atmosphere was clearer and lighter; weakly absorbent of the sun's rays and radiation rapid. The result was a great contrast in the rate of melting of the snow on opposite sides of east-west valleys. It is well known that it is the great characteristic of an alpine climate that the general temperature of the air is low, but that the sun's rays by direct impact on the earth are very powerful. There is, therefore, a great contrast between the heat in light and shadow, a contrast which is much less at lower altitudes. At this camp, the southern side of the valley will be covered with snow down to the river level, while the sunny slope will be completely bare to an altitude 2,500 feet higher. A northerly facing gulch will be impassable from snow a month after flowers have been in full bloom in a southerly facing gulch at the same altitude.

In my first paper on the ancient glaciers of this region I called attention to the fact that in the last stage (the only one there discussed) they were apparently very sensitive to light and shadow, in their retreat creeping up close to precipitous peaks. It has long been evident to me that the Salmon River glacier in its last great stage was much higher on the west than on the east side, because its chief gathering ground was in the shadow of a high spur of Mt. Courtney, where there is even now a small glacier. Blocks of granite fell from the saw-like crest of the mountain and traveled across the surface of the glacier so as to be distributed along the east slope of the valley. Under these conditions serpentine from the east side of the valley could not very well superglacially reach the gorge on the west side and be carried down the *old* Salmon River valley.

Under low altitude conditions, this glacier would not have been so sensitive to sunlight and one side would not have greatly predominated over the other. Indeed, it is probable that in that case the longest feeders would have come from the heart of the serpentine area on the east and the conditions for the distribution of the serpentine would have been at least equally as favorable as for the granite. The serpentine-bearing drift appears to me to be more nearly normal than the other. It is fair to acknowledge that the earliest glaciation undoubtedly incorporated in its drift preglacial river deposits in which serpentine occurred in proportion to its outcrop area but this does not fully explain the contrast. It was the peculiar or abnormal character of the later glaciers which caused granite erratics to be present in the drift in a proportion entirely in excess of the outcrop area that caused the difference.

Further, the more uniform temperature of a low altitude climate would enable the early glaciers to run farther down the valleys even though thinner at a given distance from the end than the later glaciers and perhaps containing no more ice. Earlier glaciation was less vigorous than later glaciation. Probably the climate was colder at a given altitude than during the last glacial stage and the ice was sluggish. There seems to have been less tendency for the formation of large moraines than later.

At about the time of the last glacial stage, the country was uplifted and brought under high altitude conditions. The glaciers formed rapidly in the shadow of the peaks, but when they ran out into the open, into strong sunlight, they were soon pinched off by melting.

The character of the climate during the last glacial stage was similar to the present, except for a general lower temperature. Therefore, the altitude may have been at least as high as the present. The character of the climate during an early glacial stage seems to have been similar to that which now belongs to a lower altitude than the present, except for a general lower temperature. These mountains might have been, in an early glacial stage, 3,000 feet lower than at present, but not more, as a depression to that amount would nearly submerge the Summerville basin. Glaciation occurring at such an altitude would, judging from observations made near the coast, yield products similar to the earlier drift discussed in this paper.

In studying the river terraces between the coast and the Summerville basin, I independently arrived at the conclusion that the region of glaciation rose at least 2,000 feet and perhaps nearly 3,000 feet relative to the coast line, at approximately the time of the last great glacial stage and that this region is now as high as it has been at any time during the Quaternary era. Thus two distinct lines of argument are mutually corroborative and virtually establish, to my satisfaction, the fact of such an uplift. It is practically certain that the early glaciation of this region occurred under a lower altitude than the present. Therefore, the theory of elevation as directly and solely the cause of glaciation is inadequate.

I will suggest that there is between the earlier and later drifts in the Mississippi basin a contrast of practically the same character as I have imagined to exist here and perhaps the same explanation may apply. It is well known that there are in connection with the Wisconsin drift sheet evidences of greater elevation during that epoch than during preceding glaciations. During the Kansan, Illinoian and Iowan stages, the altitude may have been low, the climate very cold and comparatively uniform over broad areas, the ice-fields sluggish and the moraines formed, weak. The cause of the glaciation, as many now think, may have been something quite independent of elevation. During the Wisconsin stage, differential elevation may have temporarily resuscitated the ice-fields, but it also brought them under the influence of higher altitude climatic conditions, they were vigorous, but melted rapidly along the borders, ended abruptly and formed massive moraines.

As to the prime cause of the past glaciations, I am as yet far from convinced. At present I am most strongly inclined toward the atmosphere-composition-variation theory as defined by Chamberlin, but some of the ideas advanced in this paper hardly support it. My attention has been called to the fact that what I have described as the great characteristic of the glaciers of this region in their last stage, namely, their sensitiveness to sunlight, may have been produced at a lower altitude than the present, by a decrease in the carbon dioxide in the atmosphere, which is true. At the same time, the theory seems to imply that to bring about glaciation it was necessary to produce in the atmosphere at the altitude at which glaciation occurred, a depletion in carbon dioxide to considerably less than the present. This would intensify and bring down to a lower altitude than at present what I conceive as the characteristic of a high altitude climate. The earlier glaciation in this region, it would seem to imply, was produced under climatic conditions similar to those which obtained in the region of the later glaciation, although in the former case the altitude was apparently 3,000 feet less. This is contrary to the testimony of the field evidence, if I have read it aright. Perhaps my meaning will be clearer if I state that I conceive that the earlier glaciations occurred in an atmosphere having a larger percentage of carbon dioxide and watery vapor than is now present in the air of this locality.

I expect the reader to accept my argument as to the essential difference of the climate during the earlier and later stages of glaciation of these mountains as suggestions rather than as settled convictions even in my own mind. The study is yet too new and the observations too limited to make the conclusion absolute. My object is to stimulate research along this line in other sections of our western mountains. I see in it a powerful check on speculations as to the cause of the past glaciations.

OSCAR H. HERSHEY.

LAS PERLAS MINE,
May 14, 1903.

VARIATION AND EQUIVALENCE OF THE CHARLESTON SANDSTONE.[1]

The first detailed geologic work of importance in southern West Virginia was undertaken by Dr. I. C. White[2] in the Kanawha valley in 1884, shortly after the completion of the Second Geological Survey of Pennsylvania.

In transferring his field of activity to southern West Virginia it was natural for Dr. White to look for the same key rocks that he had so successfully used in Pennsylvania, and although the coal-bearing formations increase greatly in thickness toward the south, he identified the sandstone beds showing in the river bluffs at Charleston as the southern representatives of the Mahoning sandstone. Apparently this correlation was based on the lithologic similarity of the two formations, on the division into the same number of members by shale intervals carrying well-marked beds of coal, and on the general succession of rocks upward to the great Pittsburg coal and downward to the heavy beds of the Pottsville sandstone. These correlations of Dr. White were generally accepted, even in detail, by the people of the Kanawha valley, and all of the coal beds were definitely referred to the well-known horizons of the Pennsylvania field.

In beginning areal geologic work in southern West Virginia in 1895, the writer doubtless would have accepted the determinations of Dr. White but for the fact that he was associated with Mr. David White, who was carefully studying the fossil floras of the coal-bearing rocks contemporaneously with the progress of stratigraphic work.

As fossil material accumulated, it became more and more apparent to Mr. White that the correlations then generally accepted were not in agreement with the fossil evidence, and that in the end there would be difficulty in making direct comparisons with the type Pennsylvanian section.

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] *The Virginias*, Vol. VI, p. 716, 1885; also *Bulletin No. 65, U. S. Geological Survey.*

At that time Mr. White's knowledge of the floras of the northern end of the Appalachian bituminous coal basin was based entirely upon published descriptions and a personal familiarity with the Lacoe collection. He had had no opportunity to study the Pennsylvanian floras and their geologic relations in the field and establish for himself a standard section for comparison. But notwithstanding this lack of field experience, the evidence against the identifications previously made was so strong that the writer did not feel justified in accepting the name Mahoning for the sandstone of the Kanawha valley, and proposed in lieu thereof the non-committal term Charleston sandstone.[1]

In proposing the new name the writer was aware that in case the identity of the Charleston and Mahoning sandstones were established the new name would have to give way before the old and well-known term "Mahoning," but on account of the uncertainty he preferred to use the new term and trust to future work to settle the question.

Six years have now elapsed since the name "Charleston" was introduced, and by many the question is still regarded as unsettled, but in that time Mr. White has accumulated such a mass of Paleobotanic evidence against the correlation of these two sandstone formations that there is no longer any doubt except in the minds of those who would discredit entirely the evidence of fossil plants. Although in the opinion of the writer the question is virtually settled, he takes this occasion to present some stratigraphic facts which seem to explain the apparent disagreement between the paleobotanic and stratigraphic evidence.

In order to show the bearing of the facts described in this paper it is necessary to go back and review the evidence that has been presented on the different phases of the question.

In 1900 Mr. David White's study of the fossil floras of the coal-bearing rocks of the Kanawha valley had progressed to such a stage that he published a paper on "Relative Ages of the Kanawha and Allegheny Series as indicated by Fossil Plants,"[2]

[1] CAMPBELL AND MENDENHALL, "Geologic Section along New and Kanawha Rivers, W. Va." *Seventeenth Annual Report*, Part II, pp. 473–511; also *Geologic Atlas of the United States*, folios Nos. 69, 72, and 77.

[2] *Bull. Geol. Soc. Am.*, Vol. XI, pp. 145–78.

in which he stated that the Stockton coal (so-called Upper Freeport bed of the Kanawha valley) carries a flora resembling the Clarion; that the coal bed occurring in the Charleston sandstone in the vicinity of Clendenin on Elk River contains plants belonging to the Kittanning group; that fossils from a higher horizon, but still within the sandstone beds at Clay, are found in the Freeport group of the Allegheny valley, and that the Charleston sandstone is not equivalent to the Mahoning sandstone of Pennsylvania.

These conclusions were not generally accepted. Dr. I. C. White maintained that land plants varied irregularly, and that when they conflict with stratigraphic evidence the latter should be given the preference and the former disregarded. He maintained that the Mahoning sandstone is continuous in outcrop from Pennsylvania to the Kanawha valley, and that consequently his original determinations are correct. In order to be certain of his position Dr. White again took the field and traced the outcrops of the formations in question across the state of West Virginia, and the result was the complete verification, in his own mind, of his former conclusions.[1]

In discussing Mr. David White's paper the present writer called attention to the fact that the Charleston sandstone is a complex formation composed of overlapping lenses of coarse sandstone, and that in tracing it in any direction from the type locality it is doubtful if the original limits can be identified and maintained. He also showed that this variation from point to point might easily explain the apparent continuity of the sandstone outcrop from Pennsylvania to the Kanawha valley, and at the same time allow the diagonal extension of the Allegheny floras across the sandy belt. The conditions which permit such phenomena are shown diagrammatically in the following sketch (Fig. 1) representing an ideal section of the Charleston-Mahoning sandstone from Pennsylvania to the Kanawha valley. The sandstone formation is conceived as being made up of a number of overlapping plates which gradually descend lower and lower in

[1] "Geological Horizon of the Kanawha Black Flint," *Bull. Geol. Soc. Am.*, Vol. XIII, pp. 119–26.

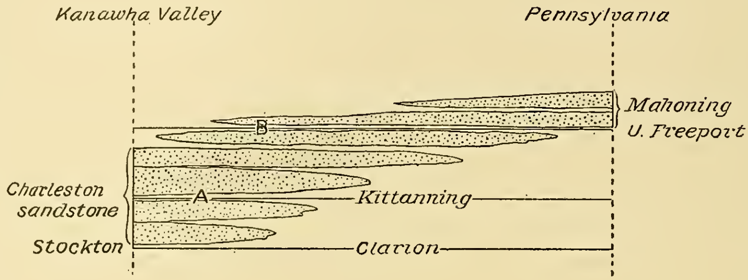

Figure 1.
Diagramatic Section of the
Charleston-Mahoning Sandstone.

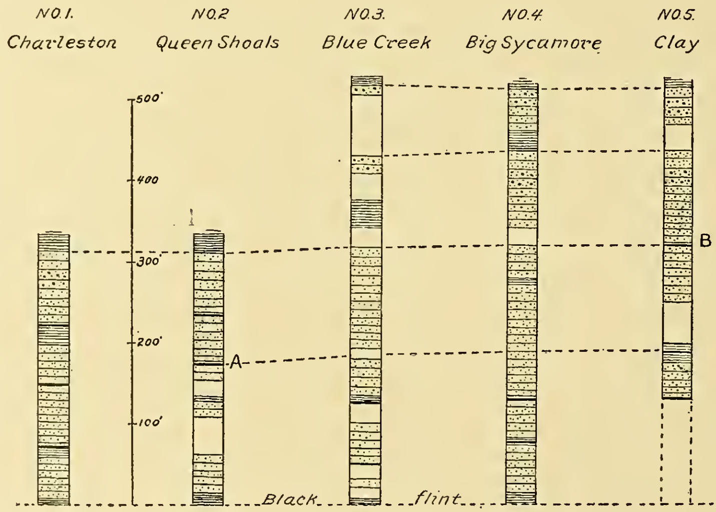

Figure 2.
Sections of the Charleston Sandstone.

the series toward the south, until it probably includes the Kittanning horizon, as shown by the fossil flora found in the coal bed (A) at Clendenin twenty miles northeast of Charleston. In support of this proposition the writer called attention to the disappearance of the uppermost bed of sandstone of this group at Sutton, W. Va., and the lowering of the upper limit south of the river by 200 feet, but this being an isolated example, was not given much weight in the discussion of the subject. Recently, however, an excellent example of the variation of these rocks has been brought to the writer's notice and incontestible evidence furnished regarding a marked change in its upper limit between Charleston and Clay. The five sections given in Fig. 2 show something of the nature of this variation, but many intermediate sections might be interpolated so as to make the transition complete.

Throughout the region the base of the formation generally is marked by the presence of a bed of black flint which occurs only a short distance above the Stockton or Lewiston coal bed that has been regarded as the equivalent of the Upper Freeport coal. This is the only bed of flinty character known in the region, and it is easily identified by its débris, which decays so slowly that it is almost always in evidence along the outcrop of the bed. The flint is a local feature covering an ellipsoidal shaped territory, whose longer axis lies east and west, and extends from Charleston to near Summersville, in Nicholas county. In a north-south direction it is more limited, reaching only a few miles south of Kanawha River in the vicinity of Brownstown and Montgomery, and showing on Elk River in the vicinity of Queen Shoal. Toward the north and west the horizon of the flint passes below water level, but in many places it loses its flinty character before disappearing and becomes a silicious shale which cannot be distinguished from adjacent beds. Throughout the region here discussed, which lies between Charleston and Clay the flint is generally present, and it affords an ideal datum from which to measure.

At Charleston the sandstone overlying the flint has a total thickness of about 320 feet, and its general characteristics are shown in Fig. 2. It is composed of a number of distinct beds separated by coal and shale intervals, but the sandstone greatly predominates, and the series is essentially sandy from top to bottom. It is well exposed on the south side of the river, and the section was measured on the road which ascends the bluff from the south end of the bridge. The upper limit is marked by a bed of red shale, which is well shown in this region. Above this horizon the material is generally shaly, and the few sandstone beds which appear are generally green, micaceous sands which do not resemble the buff, coarse, sandy beds of the Charleston formation.

The rocks dip gently to the northwest, and the Charleston sandstone is well exposed along Elk River, which follows the strike of the beds to the northeast as far as Sutton in Braxton county. Owing to the crooked course of the river and to the slight undulations which affect the rocks, different parts of the formation are exposed in the river bluffs at different points, but there are only a few places where the base of the series is reached and a complete section exposed. From Clendenin to Queen Shoal the rocks rise steadily eastward up the river, so that a coal bed which is near water level at the former place is by barometer about 170 feet above the river at the latter point. It is from this coal bed that most of the fossils were obtained which Mr. David White[1] has referred provisionally to the Kittanning horizon. Although only a partial section of the Charleston sandstone was obtained at this point, it is introduced to show the position of the coal bed relative to the great mass of sandstone above and below, and to the black flint which is exposed at water level at Queen Shoal. The coal agrees, as stated by Dr. I. C. White,[2] with the North Coalburg horizon of the Kanawha valley.

The base of the Charleston sandstone shows in most of the stream valleys on the south side of Elk River, and the flint is particularly well developed on Blue Creek, which is one of the largest tributaries from this region. The third section, shown in Fig. 2, was measured on this creek six or seven miles above Elk River. Above the black flint occurs a mass of sandy beds

[1] *Op. cit.*, pp. 170–73. [2] *Op. cit.*

having a thickness of over 300 feet. These are broken in a few places by shaly intervals, one of which, about 200 feet from the base, carries a coal of workable thickness. The sandstones are more massive in this locality than in the vicinity of Charleston, and the upper part of the formation is a particularly prominent feature in the topography of the region. In comparing this with the Charleston section, which is regarded as the type, it is clearly seen that the section so far described is almost an exact counterpart, but in the Blue Creek region coarse sandstones are known above the limits just given, which appear to have no equivalents in the Charleston section. The first bed shows a thickness of about 25 feet and it occurs about 100 feet above the top of the regular sandstone section; the other appears to have a thickness of from 10 to 20 feet, and it lies approximately 200 feet above the top of the regular section. The beds of conglomerate are separated by soft shale, in which reds and greens are of common occurrence. In this section it is manifest that the upper conglomerates should not be classed with the Charleston sandstone, since they are separated from it by a distinctly shaly interval.

Along Elk River, from Clendenin to Clay, the Charleston sandstone is well developed, and gives a rough and rugged topography. The fourth section, shown in Fig. 2, was obtained by Mr. Charles Butts near the mouth of Big Sycamore Creek, where the horizon of the flint appears to be near water level. It is true that the flint does not show, and it is possible that its horizon is not exposed, but all the evidence seems to point to the fact that the horizon of the flint is either at or below the grade of the railroad. Although broken by a number of thin, shaly partings, the section consists of a sandy series from near railroad grade to a height of 510 feet. The lower part resembles that found on Blue Creek and also the typical section at Charleston. At a height of 320 feet the rocks are concealed, and it is possible that there is 15 or 20 feet of shale at this point. If such is the fact, it would seem to mark the upper limit of the Charleston sandstone as known at the type locality, but lithologically the section cannot be broken at this point, for the material above is essentially the same as that below. At a height of 450 feet there is a small shaly interval, which is overlain by 60 or 70 feet of heavy conglomerate.

In comparing sections 3 and 4, it is apparent that the great increase in thickness of the sandy series at the mouth of Big Sycamore Creek is not accomplished by the swelling-out of the Charleston sandstone proper, but by the addition to its upper part of about 200 feet of coarse sandstones and conglomerates, which are feebly represented in the Blue Creek section by thin and independent beds of conglomerate, and are not represented at all in the Charleston section by coarse material. If the three sections given above stood alone, the identity of the beds might be open to question, but in the areal work a score or more of intermediate sections were obtained which make the transition complete and incontestible.

From Big Sycamore Creek to Clay exposures are good along the line of the railroad, and continuous tracing proves that the coal bed which is at railroad level opposite Clay is the same as the coal shown in section No. 4, 125 feet above railroad grade, and occurs only a short distance below the coal bed which is mined between Clendenin and Queen Shoal.

Section No. 5 was obtained on the road which climbs to the upland back of Clay. Although broken by a few small shale intervals the section consists generally of coarse sandstones for a height of about 380 feet above railroad grade. If the section is placed according to the coal horizon, there is a very close agreement with the Big Sycamore section both in total thickness and in the detail of the beds.

Dr. White in discussing the coal outcrops along Elk River[1] correlates the Clendenin coal with a small coal bed 375 feet above Clay, or in other words about the top of section No. 5. It seems probable that this error in correlation is due to the assumption that the observed rise of the beds between Clendenin and Queen Shoal is continued eastward to Clay. In that case it is probable that the Clendenin coal would appear near the top of the sandstone series, but the eastward rise is an assumption which is not in accord with the facts. A broad anticline in

[1] *Op. cit.*, p. 125.

the great northward bend of the river carries the coal high in the hill slopes at Queen Shoal and then allows it to descend to near water level at the mouth of Little Sycamore Creek. The writer is very willing to testify to the general accuracy of Dr. White's work, but he is not willing to have the evidence of fossil plants impeached in the eyes of the public by stratigraphic evidence of this charactcr.

According to fossil plants the Clendenin coal probably belongs to the Kittanning group and the plants collected near Clay[1] from a horizon about 300 feet above the flint are related to the Freeport flora. Although Dr. White calls these two beds the same, a glance at the accompanying sections shows that the stratigraphic evidence is against such a correlation, and that the plant-bearing bed of Clay is distinctly above the Clendenin coal; therefore the latter may be the representative of the Freeport group, if the Clendenin coal belongs to the Kittanning horizon.

A comparison of the sections given in Fig. 2 shows clearly that the observed increase in thickness of the sandy series in the direction of Clay is not due to the great expansion of the formation, but to the addition of coarse conglomeratic members to the top of the original section. These extra members appear first as thin beds of conglomerate in shaly material above the Charleston sandstone proper; they thicken gradually to the east, and finally merge not only with each other, but also with the underlying sandstone formation.

This gives a distinctly sandy series at Clay, which can be traced continuously in outcrop to Charleston, but which manifestly does not represent the same time interval as the Charleston sandstone at the type locality. The uppermost bed at Clay is very much younger than the uppermost bed at Charleston, and if similar changes occur north of Clay, it is possible for the sandstone to be as young as Mahoning on the Pennsylvania line.

The variation in the sandstone between Charleston and Clay appear to be limited to its upper part, but beyond the latter place the writer feels assured that a similar change occurs at

[1] DAVID WHITE, *op. cit.*, pp. 170–73.

the base of the series, except in reverse order as shown in Fig. 1.

If the writer has observed correctly (and the facts seem to be beyond question), it is possible for Dr. White to trace sandstone in outcrop from the well-known Mahoning of Pennsylvania to the Charleston of the Kanawha valley, but that does not necessarily mean that they are of the same age. Dr. White contends that he has traced the coals in a similar manner, but from the great difficulty in tracing coal beds and in identifying their outcrops from place to place, the writer declines to accept this sort of evidence when in conflict with that afforded by the sandstone beds and the fossil plants which accompany them.

Marius R. Campbell.

THE PHYLOGENIC STAGE OF THE CAMBRIAN GASTROPODA.

(WITH PLATES I AND II.)

WHETHER it is due to imperfection of the geologic record of the Cambrian age, or whether it is because the class Gastropoda was at that time small and at an initial stage of its differentiation, the species of that age, as known to us, are few, simple-structured, and little diverse, as compared with those of later geologic ages. From the looks of the fossils it might, indeed, be granted that the fauna is both imperfectly represented and primitive. But, as well known, the very simplest and most primitive-looking ones are referable to families the living members of which are believed by zoölogists to be quite remote from the initial or primitive type of the class. If their theory is correct, then the Cambrian Gastropoda must be considered as not near the initial stage of its differentiation, but far advanced, and the Cambrian geologic record as very incomplete. On the other hand, it has not been found explicable why the Cambrian record is so peculiarly and greatly incomplete, and, in short, the primitive looks of the Cambrian Gastropoda are not geologically explained, and the question returns to the interpretation which zoölogists have made of the Recent animal and its shell, whether this is not somewhat at fault for the dilemma. The following paragraphs are intended to offer a concordant interpretation of the geologic and biologic evidence on the Cambrian Gastropoda.

According to the generally accepted view, the gastropod shell, which is the modification of a hollow cone in structure, arose from a symmetrical conical tegulum, and thence the conical, curved conical, spirally coiled, and plane coiled types of shell were successively evolved. The development of the spiral shell has been accompanied by, or has been the cause[1] of, a twisting of the mantle complex of the animal, and since the

[1] See ARNOLD LANG, *Lehrbuch der vergleichenden Anatomie* (Zweite Auflage, 1900), pp. 81–7.

consequent asymmetrical visceral structure is seen in all Recent Gastropoda, including those which now have simple conical shells and the families to which the simplest Cambrian shells are referable, these appear, because of their visceral asymmetry, to have descended in turn from ancestors which had spirals or coils. Some Recent cones are indeed traceable by fossils to coiled ancestors. The larva, too, of many Recent species has a curved or coiled protoconch or larval shell, and this has been taken as evidence or as proof that the gastropods with conical shells had ancestors with spiral shells.[1] Conical shells may therefore be either the ancestral cones or again the last derived stage in their evolution. One is led finally by the evidence of continual series, apparently, of conical shells from Cambrian to Recent time, to the conclusion that, though they seem primitive, the Cambrian shells are not more so than Recent ones — a conclusion, indeed, which it is difficult to accept in view of the very primitive aspect of the whole Cambrian gastropod fauna; and first of all therefore I desire to emend the theory of the relation of the spiral shell to the visceral asymmetry.

ORIGIN OF THE SPIRAL SHELL.

Known Cambrian fossil Gastropoda are referable to Order I, Prosobranchia, excepting provisionally the Hyolithoidea. Regarding the range of the Prosobranchia, Suborder 1, Diotocardia (Aspidobranchia) includes the group Docoglossa, to which belong Scenella and Patella with conical shells, and these together range from Cambrian to Recent time, without known coiled or spiral ancestor. The group Rhipidoglossa includes some Recent conical shells, Fissurella and Fissuridea, which together range from Carboniferous to Recent, and whose only earlier representatives are coiled, such as Bellerophon and Salpingostoma of Upper Cambrian and Ordovician to Triassic. Suborder 2, Monotocardia (Pectinibranchina), has also simple conical-shaped species, the Capulus of Recent time, and Stenotheca and Platyceras which range from the Cambrian upwards. Of these the earlier ones especially have a short coiled apex.

[1] See recently, A. W. Grabau, *American Naturalist*, Vol. XXXVI (1902), p. 918.

The conical shells of other Gastropoda, *i. e.*, those among Pulmonata and Ophistobranchia, are presumably vestigial from spiral ones, and, moreover, are historically distinct from the Cambrian fauna. The Docoglossa are, therefore, seemingly the only ones without known coiled or spiral-shelled ancestor, and any such ancestor must have existed, if at all, before Cambrian time.

The question is, then, whether the Docoglossa had evolved their shells prior to others through all the stages from the primitive conical through the spiral to the derived conical form, or whether they have had no other than the conical shell as yet. It is not necessary to assume that the Docoglossa had a spiral-shelled ancestor. The aspect of the Cambrian fauna, indeed, suggests that such a theory is not the clue to their evolution. And if it could be proved that the Docoglossa had not a coiled or spiral-sheiled ancestor, the dilemma could be removed from the interpretation of Cambrian Gastropoda. It seems at least desirable to avoid the set conclusion that the Docoglossa had spiral-shelled ancestors; and this is practicable only by using a conservative view as to the theory of the visceral twisting and by changing the above-cited theory of the spiral-shelled ancestor.

In support of a new theory, it may further be noted here that the Fissurella type of Rhipidoglossa does not appear early enough in geologic time nor in such association as to indicate the probability of truth in the view of the apical slit of its shell[1] having any homology with the similar structure in Dentalium of the class Scaphopoda. The known early Paleozoic gastropods have not even the marginal slit.

Judging from comparison of the living gastropods, it is obviously not to be assumed that the phylogenic groups or lines in which the spiral shell has longest persisted have the visceral asymmetry most strongly developed; but rather the contrary would seem to be the case. It may even be taken that an asymmetrical long cone, while developing phylogenically, was the sufficient cause for the asymmetrical twist of the viscera as seen now in Gastropoda, and that the short conical shell, on the one

[1] *Op. cit.*, p. 83.

hand, and spiral shell, on the other, mark restored equilibrium. A spiral or complete coil may never have existed in the case of the Docaglossa.

THE TIME SEQUENCE AND FORM SERIES.

If we go back in theory to an ancestral mollusc with solid-layered tegulum, the stages from that to the marginal growth, and consequent hollow enlarged conical shell, seen in the simplest Cambrian mollusc fossils, may be as many as from the latter to the most modified Recent form of it; and the first conical Cambrian shell must well be called gastropod, and considered as far removed from the mollusc common ancestor. How much farther advanced it was may be discussed. Considering that the known Cambrian gastropod shells, in a morphologic sense, may be, some of them, more ancestral or primitive than others, some species or genera should be found among them, as in the later faunas, which were surviving ancient types. Just as the genus Pleurotomaria ranges from Upper Cambrian to Recent time, so also Cambrian genera may have ranged from pre-Cambrian, and the first known fauna may represent an evolutionary series. As said, the long, curved cone is the one which I prefer to consider as the most ancestral type of Cambrian gastropod shell, and the series, on the one hand, to the simple spirals and, on the other, to the short, low conical form, is one-half as long an evolutionary change as from the low conical to the long conical, and to the spiral coil would be. To add, then, from the spiral coil, to the coiled apex, to the secondarily low conical shell, again doubles the length of evolutionary change. In short, the evolutionary series, as represented by the Cambrian fossils, is about one-fourth as long, considering the long curved cone as ancestor of the short cones, as it is if the spiral is taken to precede the derived short cones among Docoglossa.

The time sequence and form series of the Cambrian fossils should indicate the course of development. But that the known Cambrian fauna should not be taken as geologically complete is indicated by the sudden appearance of the first genera. And since the genera known in the Lower pass into the Upper Cambrian, where others suddenly appear, it is necessary, in the interest of fairness, to admit that the other Upper Cambrian genera may have existed in earlier time. This admission breaks the force of argument which otherwise would accompany the comparison of Lower and Upper Cambrian faunas, as a developmental sequence. Yet comparison of the Cambrian fauna with the Ordovician Gastropoda, which are numerous as fossils, is competent to decide whether the Upper Cambrian known types are a fair representation of the marine fauna of that time—which, indeed, they appear to be—and this fauna indicates that the Lower Cambrian known fossils are such as should be expected, provided the group is near its initial, from a long curved conical shell, but that also there may have been many other simple-structured species.

IMMIGRATION THEORY.

The Baraboo, Wis., fauna is one which contains several gastropod genera whose geologic and biologic relations are, I think, very characteristically Cambrian, and which are of prime importance. This fauna has been described by R. P. Whitfield,[1] and was referred by him to the Lower Magnesian limestone, an equivalent of the New York Calciferous sandrock. It is from an older formation, as indeed suspected from the first, and is in the Potsdam equivalent. C. P. Berkey has found the fauna at Taylor's Falls, Minn., in the Dresbach formation,[2] in the zone of *Lingulepis pinniformis* Owen, with *Lingula ampla* Owen, *Obolella polita* Hall and *Hyolithes primordialis* Hall. These gastropod species, which were first discovered around the Cambrian Islands of the Baraboo region, as well known, recur at the Cambrian shore region about Taylor's Falls, Minn., in the basal conglomerate, and less frequently in the adjacent brachiopod shales. Any considerable geographic distribution of them in the then seaward direction seems to be disproved because, although the Dresbach formation is soon concealed, it emerges at a greater distance around Trempealeau and La Crosse, Wis., and Dresbach, Minn.;

[1] *Geology of Wisconsin*, Vol. IV., pp. 194–203.

[2] *American Geologist*, Vol. XXI (1898), pp. 270–94.

and there the species of gastropods do not reappear, excepting the *Hyolithes primordialis* Hall. There is, therefore, a good reason for considering the Baraboo gastropod fauna as one occurring only near the Cambrian land, excepting the Hyolithes, which occur also in the normal marine sediments.

This is, I think, the aspect of the known earlier Cambrian molluscan faunas, that Hyolithes and other supposed pteropodous similar genera are common and widely distributed in the marine sediments, and gastropods, Scenella, *et al.*, are rare, local, and probably lived adjacent to land. Their occurrence may, therefore, require an interpretation similar to that which T. C. Chamberlin[1] makes for the fish of the Paleozoic, which he shows to have probably originated in the rivers and later become marine inhabitants, for geologic reasons becoming then abundant fossils. The Gastropoda may be immigrants to the marine habitat in Cambrian time. Assuming that there was a fresh-water molluscan fauna in Cambrian and Ordovician times, and that it is unknown to us, except as it is reflected in the early immigrants and in the preserved land and fresh-water faunas of later ages (Devonian to Recent), then we are able to explain some peculiarities of the Cambrian Gastropoda. From an ancestral gastropod stock in fresh water several immigrations to the sea may have taken place in Cambrian to Ordovician time, and that is what causes the emergence of new genera which we see in the marine fossils.

To illustrate from the region of the upper Mississippi valley, where the encroachment of the Cambrian Sea, as shown by Walcott, was in later Cambrian time, the oldest exposed strata are in the Dicellocephalus zone and of the Potsdam equivalent, and above this follows the Magnesian series, which is the Calciferous sand rock equivalent. Both have a known gastropod fauna; though it is necessary to offer a correction here, since inadvertently lists of fossils, such as that in *North American Geology and Palæontology* by S. A. Miller, refer species of the upper division only to the lower or Potsdam, and those of the "Potsdam" all to the upper division, which is the Calciferous or "Lower Magnesian," excepting *Hyolithes primordialis* Hall, which is rightly

[1] Jour. Geol., Vol. VIII, pp. 400–412.

placed. Correctly referred, the faunas appear as follows: Associated with the brachiopod Lingulepis and the trilobites Agraulus and Dicellocephalus in the Dresbach formation occurs the *Hyolithes primordialis* Hall, widely distributed seaward, while at the seashore, as described, with it are the gastropods Tryblidium (Metoptoma), Hypseloconus, and Scævogyra. The succeeding Franconia sandstone, at Taylor's Falls, Minn., has the same genera of gastropods. This may be taken as the equivalent to the top of the Potsdam of New York.

The next succeeding formation, the St. Lawrence, contains in a trilobite zone at Osceola, Wis., near Taylor's Falls and only a mile or two from the then seashore, *Tryblidium* sp.?, *Pleurotomaria sweeti* Whitf., *Murchisonia putilla* Sar., and *Bellerophon antiquatus* Whitif. At another point on the Blue Earth River, Minnesota, which is near another shore of that time, *Murchisonia putilla* Sar., was found either in the base of the Jordan sandstone, or as I suspect, now really the top of the St. Lawrence formation. Also *Raphistoma minnesotense* Owen and *Ophileta alturensis* Sar., occur in the same matrix. *R. minnesotense* Owen also comes from Red Wing, Minn., which is distant from the shore. Next, the coarse Jordan sandstone is practically the unfossiliferous basal sand of the Oneota dolomite, and this one is the supposed Lower Calciferous sand rock equivalent. Fossils generally have been obliterated in the Oneota, but a few Lingulas, and two fragments of trilobites, have been found, with a number of gastropods, which are the same species as those enumerated from the St. Lawrence formation, with also others of the genera Straparollus, Holopea, and Ophileta. Cephalopods also occur, of the genera Ascoceras, Piloceras, Orthoceras, *et. al.* The superjacent Shakopee dolomite (Upper Calciferous) contains only gastropods and cephalopods, as far as known, and, excepting the genus Subulites, they are species very similar to, though not identical with, those of the Oneota,[1]

In all these localities and horizons where the gastropods occur there are evidences of shallow water to be found, con-

[1] F. W. SARDESON, "The Fauna of the Magnesian Series," *Bulletin of the Minnesota Academy of Natural Science*, Vol. IV (1896), pp. 92–105.

glomerate, breccia, oölite, or mud balls. Rounded pebbles one or two inches in diameter occur even in the St. Lawrence formation of Red Wing, Minn. The species of fossils are quite all different from those of eastern America. Also the St. Peter sandstone (Chazy) has its peculiar molluscan species, but following this formation the Galena (Trenton) has numerous species which are largely identical with those from other regions, and surely of normal marine habitat.

Thus in this region one appears to see the Gastropoda crawling off the rocks of the Cambrian seashore, migrating seaward, and becoming in Ordovician time the companions everywhere of the Brachiopoda and Trilobita, and this has suggested to me the probability of non-marine origin of Mollusca.

Such a theory does not change in any way the estimated imperfection of the geologic record as to the Gastropoda, except that the meaning of the same is differently taken when the ancestral stock is assumed to be the fresh-water fauna and not the salt-water one. The fresh-water and land faunas are totally unknown, and our Cambrian gastropods are immigrants, and thence the marine ancestors of Prosobranchia. The later emerging groups of Pulmonata and Ophistobranchia, for example, are not necessarily descended from the known Eo-Paleozoic, but would be descended from that unknown common stock. Cephalopoda may be derived from the first immigrated, widely found marine pteropodous genera Hyolithes, Hyolithella, etc. The class Pelecypoda, all but unknown in the Cambrian, might be taken as the third immigration seaward, and Scaphopoda the fourth. In this connection, I recall a former occasion for surprise when, in discovering Ordovician fossils in the St. Peter sandstone, I found that the Pelecypoda were both present and predominated, and Gastropoda and Cephalopoda were also in it. That formation is as unfavorable for fossils as any of the Cambrian fossil-bearing zones well could be, and therefore the Pelecypoda seem to have just arrived.

THE EARLIER CAMBRIAN FAUNAS.

A review of the Cambrian representatives in the light of these theories may elucidate somewhat the phylogenic stage, whether primitive or whether advanced in Cambrian time. Walcott[1] describes about twelve species of gastropods in the Olenellus zone, or Lower Cambrian, and as many of the Hyolithoidea, or supposed pteropods. The Gastropoda include four species of Scenella (Plate I, Fig. 1) which are conical shells, about as high as wide; aperture elliptical or oval, tending to narrow posteriorly when the apex also inclines backward. The species are rather variable as described (*loc. cit.*), and in that respect not unlike the species of the Ordovician.[2] The genus apparently merges into the Patella of Silurian to Recent time, and is therefore of the Cyclobranchia as now known. Stenotheca (Plate II, Fig. 13) includes three species, distinguished from Scenella by concentric wrinkling of shell. A tendency in such shells toward curvature of the apex is worthy of note (*S. curvirostra* S. and F.). Platyceras, two species, includes *P. primaevum* Bill (Plate II, Fig. 14), which has a short, dextrally coiled apex or spire. The apex coils obliquely to the assumed dorsal direction. The aperture has the narrower side next the suture. *Straparollina remota* Bill (Plate II, Fig. 20) is a short dextral coil, with spire depressed and rounded in outline; whorls nearly uniformly rounded, more narrowly so on the upper side near the suture and also on the basal side. *Raphistoma attleboroughense* S. and F. (Plate II, Fig. 25) is a small dextral shell of three spiral whorls. These are rapidly expanding, closely coiled, and rather narrowly rounded on the outer side, which is a little thickened.

Helenia bella Walc. (Plate II, Fig. 17) is long, curved dorsally, and has an elliptical aperture, beveled toward the posterior. The apical end of it is imperfectly known. Similar to this one are the genera supposed to be pteropods. Hyolithes, including eight species, are long, conical, transversely broadened, anteriorly flattened, dorsally more or less angular, and the aperture is extended at the anterior side. There are sometimes apical loculi, and there is an operculum. In some there is a tendency to curve dorsally. Hyolithellus includes one species—a very

[1] U. S. Geological Survey, *Tenth Annual Report*, pp. 616–25.

[2] The variability of Ordovician species of Scenella, Archinacella, etc., has been greatly underestimated by some authors.

long cone, or tubular. Coleoloides, one species, and Salterella, three species, of short tubular shells, complete the list as given by Walcott.

The above species are very small shells, as compared to later ones like those of the Ordovician, and they were the kind to be the less easily and often fossilized because small and thin. There is little doubt that their small size and simple structure are truly representative of the earlier Cambrian marine Gastropoda of the Canadian and New England region.

The Baraboo fauna includes several species in three genera. Tryblidium (*Metoptoma* Whitf.) (Plate I, Figs. 2, 3) includes shells similar to Scenella, but the apex is more excentric and directed toward the narrower end of the oval or acuminate aperture, and the muscle scar is broken into distinct paired spots arranged in a circle or in horseshoe-shape, open anteriorly. In Hypseloconus (Plate I, Fig. 6) the apex rises posteriorly to the center, but by the curvature of the shell is directed forward. The muscle scars are apparently like those in Tryblidium. Scævogyra species (Plate I, Figs. 8, 9) are short, sinistral spiral coils. *Hyolithes primordialis* Hall is the accompanying pteropod. The western Upper Cambrian has therefore a primitive gastropod fauna similar to that of the eastern Lower and Upper Cambrian.

In interpreting these very simple types of gastropod shells there is noticeable difficulty at the start in choosing the right point of view. I have taken the generally oval aperture to be posteriorly acuminate and the apex as directed backward. In Scenella it ranges to anterior in position, but points rather backward because of a concave slope on that side of the shell. In Hypseloconus it rises posteriorly, but points forward. In other cases the curvature or coil may be assumed as backward directly or obliquely. There may have been a reason why the aperture was posteriorly narrowed. The animal is presumed to have been longer than wide, whence an oval shell could be well fitted to it, and, in case the shell rested back of the middle, the anterior of the shell might well be broader than the posterior, to accommodate the body at retraction. The curvature may be backward from some like simple cause. But in larger coils the

JOUR. GEOL., Vol. XI, No. 5 Plate I

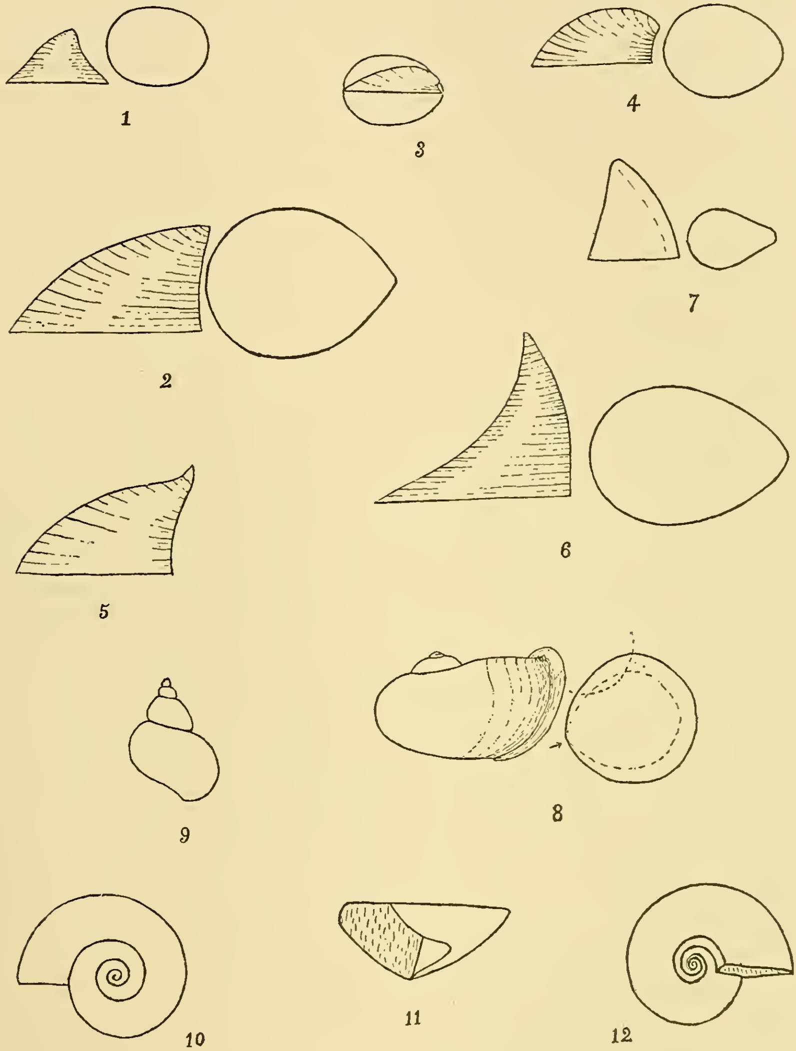

FIG. 1, *Scenella reticulata* Bill., after Walcott; 2, *Tryblidium barabuense*, Whitf., ×½; 3, *Tryblidium simile* Whitf., ×½; 4, *Tryblidium nycteis* Bill., ×½; 5, *Tryblidium retrorsum* Whitf., ×½; 6, *Hypseloconus recurvum* Whitf., ×½; 7, *Metoptoma orithyia* Bill., ×½; 8, *Scævogyra sweezeyi* Whitf., ×½; 9, *Scævogyra elevata* Whitf., ×½; 10, 11, and 12, *Maclurea acuminata* Bill., after Whitfield, ×½.

same cause could not operate well because of change of poise or relation of shell to the body, and the acuminate aperture may not remain evident where the curvature has changed. The curvature may be taken as backward or lateral, and backward not forward, by rule, since the exception in Hypseloconus is seen to be a reversal (*vide H. recurva* Whitf., Plate I, Fig. 5). It is also notable that the Hyolithes curve backward when at all, and a reason for considering the angular side of Hyolithes as the posterior one may be deduced also from the triangular cephalopods. The initial of Endoceras is hyolithoid-shaped and angular dorsally; and, indeed, the frequent angular feature in early Cephalopoda, such as Gonioceras, and Triptoceras suggests that the oval acuminate aperture may have been ancestral. The cephalopod shell may have derived the marine hyolithoid species by formation of lateral loculi, in the manner described by Holm, in place of terminal ones, and the descent may have been in Cambrian time from Gastropoda to Hyolithoidea and to Cephalopoda, whence an ancestral trait of the oval aperture. Further, Cephalopoda and Hyolithoidea have not a coiled embryonic shell. Gastropods in the Cambrian should not, then, have, and are not known to have.

The curvature or coiling in the apex of the early Cambrian Gastropoda appears either equal to or greater than that in the maturer shell (*Platyceras primaevum*, Fig. 14), and correspondingly we may outline the morphologic series from that of the long conical to the apically curved, the apically coiled with curved base, and the entirely coiled, in accordance with the theory advanced, *i. e.*, that the shells of Cambrian time were coiling and not uncoiling. That these belong to an uncoiling stage would be tenable only on the evidence of an unknown fauna of spiral shells as old as, or older than, this one. Of that there is no proof. We do not know that there was a Cambrian larval spiral protoconch. In Recent shells such may have resulted altogether as it has in part since then. And, as said, the twisted mantle complex may have required no further cause than the shifting of a long cone. Taking the theory that the long conical shell, in Cambrian time, was ancestral to both the

JOUR. GEOL., Vol. XI, No. 5 Plate II

FIG. 13, *Stenotheca rugosa* Hall, after Walcott; 14, *Platyceras primaevum* Bill., restored, after Walcott, ×2; 15, *Platyceras primordiale* Hall, ×½; 16, *Subulites exactus* Sar., ×½; 17, *Helenia bella* Walcott; 18, *Ecculyomphalus triangulus* Whitf., ×½; 19, *Helicotoma similis* Whitf.; 20, *Straparollina remota* Bill.; 21, *Holopea obesa* Whitf., ×½; 22, *Trochonema exile*, Whitf.; 23, *Pleurotomaria sweeti* Whitf.; 24, *Murchisonia putilla* Sar.; 25, *Raphistoma attleboroughense* S. and F., ×4; 26, *Raphistoma minnesotense* Owen, ×½; 27, *Raphistoma leiosomellum* Sar., ×½; 28, *Owenella antiquata* Whitf.; 29, *Bellerophon vel Protwarthia*, ×½.

shorter cones and the spiral coils, the manner in which the spirals arose may be interpreted from the phenomenon seen in the Cambrian Gastropoda, where ontogenically the apex of the shell coiled most; and the conclusion is drawn that phylogenically the apex coiled first and the "body whorl" last. This is contrary to the view which has heretofore been held.

Possibly the example of uncoiling spiral shells in later geologic ages and the embryonic evidence of the Recent larval coiled shell have been applied too hastily to the interpretation of Cambrian Gastropoda. In the Cephalopoda the coiling is better known and affords fine examples for comparison. The correspondence of stages in phylogeny and ontogeny among the Ammonoidea, where the straight, curved, coiled, and uncoiled structure follow in order, is well known. In the Nautiloidea there very early occur both the coiling and the supposed uncoiling; and, indeed, there are such types as Ophidioceras, which is convolute in the middle and uncoiled at both ends. In this case the interpretation of the apical end as progressive and the apertural end as retrogressive might be taken as not sufficiently proved to serve as evidence. The Belemnoidean Recent genus Spirula is seen to have derived from a straight phragmocone, but is apically coiled, *i. e.*, it is in a genetic sense coiling, but appears uncoiling. After all, the Cephalopoda afford indecisive results, even if it was safe to apply a cephalopod measure to the grastropods. If anything fitting this case is indicated by them, it is that even within the group Gastropoda such uncoiling shells as Vermetus do not prove the rule.

The "Studies of Gastropoda"[1] by Grabau has come to hand after the above paragraphs were outlined and it may serve to indicate how firmly the view opposite to that here presented is held generally. Grabau unhesitatingly interprets *Platyceras primaevum* Bill., as a phylogerontic unrolled type.[2] He further cites Ordovician species as phylogerontic, following Ulrich's figures and descriptions in these, where, in the first instance, my collections lead me to conclusions widely different from those of Ulrich. We have to do with highly variable shells of fewer

[1] *American Naturalist*, Vol. XXXVI, pp. 917–45. [2] *Op. cit.*, p. 938.

species than he describes. The "various degrees of uncoiling" are rather within a species in each case. That they are gerontic is, secondly, not assured.

Returning to the early Cambrian shells, the feature, in long cones, of the apical region coiling more than the maturer portion of the shell does is not necessarily to be interpreted as "uncoiling" in a genetic sense, but is as well or better to be considered as due to the curvature having set in at the apical region, and thence affecting the entire shell. Similarly, the reverse curvature is seen to affect the apex of *Tryblidium retrorsum* Whitf. (Fig. 5.), and the entire shell of *Hypseloconus recurva* Whitf. (Fig. 6), the former being then the transition from the normally curved long cones to the recurved short cones of the latter.

In all cases the change from straight to curved and coiled shell is accompanied by a change from directly transverse to obliquely cut back aperture in a very natural manner, as if the curvature of the shell preceded the elongation of the anterior, *i. e.*, the convexed side of the cone.

The next noteworthy feature is that, while the conical shells, which are very variable species, appear in each fauna, the coiled spiral shells are dextral in the eastern Olenellus fauna and sinistral in the Baraboo fauna. In this case the sinistral shells are evidently not sinistral derivatives of dextral ancestors by the depressing of the apex, as once suggested by Billings, below the median plane, since such transitions are unknown. A coiled intermediate type between the Raphistoma and the Scaevogyra does not appear, and coiling in bilateral symmetry was seemingly not yet developed or not yet immigrated. The link from the sinistral to the dextral shells may be interpreted as the known long conical type, and the two kinds of spiral shells as arising by parallelism. The sinistral might also be simply a mysteriously reversed form of the dextral, though they do not appear to be the sinistral individuals, or the near reverse of any dextral form, but relate rather to the retrorse long conical, Hypseloconus.

THE CALCIFEROUS FAUNA.

The next succeeding fauna is in the Calciferous. This group may be considered as descended in main from the earlier types which are known to us, though a few are probably from unknown ancestors. In this Calciferous fauna there are, first, a number of short obtuse cones, of which *Tryblidium niobe* Bill. and *T. nycteis* Bill. (Fig 4) have the same general aspect as species of of the Baraboo fauna; *i. e.*, the shell smooth, curved with the apex overhanging the narrower end of the ovate aperture. The apex is, therefore, directed posteriorly, as I take it, though authors generally have designated the same as the anterior, because the line of paired scars of the type species were supposed to be open at this end, in a similar way as the continuous scar opens anteriorly in Patella. Ulrich and Scofield find otherwise for Tryblidium, and it may be better compared to Archinacella and Scenella, which have a continuous muscle scar which is not open anteriorly. These two genera occur also in the Calciferous zones. The one is low, smooth, conical, the other somewhat higher and ornamented, the apex being either central, or toward the broader, or toward the narrower end of the oval aperture. They, with Metoptoma (Fig. 7), may readily be taken to be the descendants of earlier species of Tryblidium, Hypseloconus, and Scenella, together comprising all such as have changed to shortened or lower cones, and they may be taken as tending toward the Patella, *et al.*, of more recent ages. Further, an interpretation of them might indicate that the apex is centrally or posteriorly directed, except in the Hypseloconus line, which would be the reverse of that, *e.g.*, *Metoptoma orithyia* Bill. (Fig. 7), and again that the broader end of the aperture is probably anterior.

Next to be mentioned is the genus Platyceras (Plate II, Fig. 15), which continues through and beyond the Calciferous zones, and is still intermediate between Stenotheca and the dextrally spiral shell type. Closest related to it is probably Holopea, but this is not clearly derived from it. Strangely enough, the division line between Diotocardia and Monotocardia, which so narrowly separates Scenella and Stenotheca, would also seem to divide the genus Holopea; or probably the Holopea-like species, when better known, may be found to be distributed between Holopea proper and Straparollus or a similar genus.

The Calciferous species of Holopea (Plate II, Fig. 21), Trochonema (Fig. 22), Straparollus, if the presence of this genus is conceded, and Raphistoma (Fig. 26), including *Raphistomina*, U. & S., are advanced little, except in respect to size, over earlier Cambrian dextral shells. They have the aperture simply formed, *i. e.*, cut obliquely from the sutural side (posterior) to the opposite (anterior) side. Holopea has rounded whorls, slightly impressed, forming a moderate spire with open umbilicus. Trochonema is similar, with angulations of the right or upper side of the aperture, producing keels on the whorls. Straparollus is a longer tube, coiled with wider umbilicus and more nearly discoid than Holopea. Raphistoma is low-coiled, with angulated anterior or periphery.

Other and associated types in the main may be viewed as modifications of these, by change of aperture and spire. In the case of these — to make a theory to fit the phenomena — there is a tendency in many species toward an extension of the apertural margin at the under outer side of the whorl, which produces a sinus, as in *Pleurotomaria* (*Seeleya*) *sweeti* Whitf.[1] (Fig. 23), which otherwise is like Holopea (Fig. 21.) Whether this apertural change is considered to be the building forward of certain parts or the cutting back of another, as writers generally have held of such shells, the species are in later time followed by others in which the change is more developed, the Calciferous species appearing to be midway in an evolutionary change which, in general terms, is a tendency to produce the aperture nearly in the plane of the shell's axis of coiling, *i. e.*, transverse to the volution. At the same time a notch is formed. The sinus in this case arises apparently not in front, but to the right side.

Closely related, though a link nearer to it may be shown, is the *Bellerophon* (*Owenella*) *antiquatus* Whitf. (Fig. 28), which is bilaterally symmetrical, since the spire is drawn in or sunken to the median plane of the volutions, and at the same time the aperture is built out below symmetrically, to form a broad sinus, which probably in this case was shifted to anterior, median of

[1] *Holopea sweeti* Whitf. There can be no doubt that the specimens in hand are Whitfield's species.

the animal. The genus or subgenus Protwarthia (Bellerophon) is also reported from the Calciferous. *P. cassinensis* Whitf. has the shell more rapidly expanding, (*i. e.*, shorter), the aperture larger, and the sinus narrower by reason of its sides projecting or building forward, as in the later *Bellerophon bilobatus* (Fig. 29). On the other hand, Oxydiscus, *e. g.*, *Bellerophon macer* Bill., while likewise bilaterally symmetrical, is convolute with abrupt umbilicus, and the aperture cuts obliquely backward, forming a wide sinus, the middle of which coincides with an angulation which is a keel peripheral to the volution.

A composite of these four genera and a transitional form from *P. sweeti* to the other three would be such as the species which I formerly described, as *Raphistoma leisomellum Sar.*[1] (Fig. 27), which consists of "about four rapidly increasing volutions, which embrace in such a manner as to form a lenticular coil," nearly equally convex above and below. The body whorl overlaps notably the periphery of the spire, though it is not a plain coil, the spire rising a little on the upper side, and an abrupt umbilicus, about one-fourth the width of the shell, being on the lower side. The periphery is narrowly rounded and slightly inflated, and the aperture is like those in Bellerophon and Pleurotomaria of the Calciferous.

Contemporaneous with and related to *P. sweeti* are a number of shells with high spires, in contrast to Bellerophon. They are comprised in the name Murchisonia *auct.*, or again under several generic terms — Lophospira, Clathrospira, Plethospira, Hormotoma, Cœlocaulus, and Tunitoma. These have a sinus, the abrupt middle of which produces a band upon the volutions, often coinciding with a keel (Fig. 24) or one of the keels. None of the species seem to have the sinus narrowed to a slit, as in the case of some of the later genera.

It may be true of these Murchisonia-like shells that the transition from a sinus to a slit has not yet been observed,[2] and this observation is not supplied here. The slit appears geologically later in species which logically seem to be the descendants of

[1] *Bulletin of the Minnesota Academy of Natural Science*, Vol IV (1896), p. 99.

[2] *Quarterly Journal of Geological Society*, Vol. LVIII, p. 317.

those which have the sinus. The view of Ulrich and Schofield, and Koken, that the sinus precedes the slit genetically is rather unavoidable, since apparently in Bellerophon, Pleurotomaria, *et. al.*, in later geologic time a slit appears where in shells of Calciferous age a sinus only occurs. There is, however, formed in species of Calciferous age a more or less distinct band by the more or less distinctly truncated bottom of the sinus. The building out of the apertural margin so as to narrow the sinus is in process of formation, though a "slit" would not be formed until the sinus is narrowed to the width of the band. The slit differs from the sinus in that growth-lines coincide upon its sides, as they were tending to do in the sinus, and a slit appears to have arisen from the sinus in several distinct genera, by parallelism of development. Further, the theory may be extended to the effect that the sinus, as seen in Protwarthia, Seeleya, Lophospira, *et al.*, is best explicable as the result of a genetically parallel development, their common ancestor having then had only its incipient stage developed. In the genera next to be mentioned here the presence of a sinus is not taken as evidence that the ancestor common to them and the preceding genera had other than a simple oblique shell aperture.

The low coiled shells, Helicotoma and Ophileta, have, therefore, been well united[1] with Straparollus in the family Enomphalidæ. The Straparollus has, of course, the obliquely cut aperture which I consider primitive. The other genera have the outer lip produced, making a sinus which as a rule coincides with a keel on the outer upper side of the whorls; and a band, when present, runs upon the keel. A slit has not been perfected in any of them. Helicotoma (Fig. 19) has the apex of the spire rather above the level of the elevated keel on the upper side. Ophileta has it rather lower, and the shell is less rapidly expanding than in Helicotoma. Another genus similar to these, Ecculyomphalus (Fig. 18), is coiled in one or more free volutions in nearly one plane. Authors generally have considered it an uncoiled shell, though it is better to regard it as coiling, showing a comparatively less rapidly developing retarda-

[1] ULRICH AND SCHOFIELD, *Geological Survey of Minnesota*, Vol. III, p. 1023.

tion rather than retrogression. The existence of a well-developed sinus in view of parallelism of development does not argue that the shells are uncoiling. For the probable Lower Cambrian ancestral type of Ecculyomphalus, one may as well or better choose Helena (Fig. 17), a long curved cone, rather than the coiled Straparollina, since it is nearer the former in stage of coiling and equally far from both as to the aperture.

The genera which are referable to Montocardia in the Calciferous are Platyceras (Fig. 15) again and probably Holopea (Fig. 21) proper, the latter a symmetrical, short, spiral coil with primitive oblique aperture, reminding one of Straparollina, but much larger. With these, some species of high spiral shells, referred to the genus Subulites (Fig. 16) or somewhat uncertainly to Fusispira, emerge in the Calciferous. Like Holopea, they have no ornamentation, but a high, closely coiled spire, shallow sutures, and an elongated aperture. Between the straightness of the outer side and the impress of the preceding volution the sutural or posterior end of the aperture is narrowly acuminate. The apertural margin diverges from the simple obliquely backward course, or primitive aperture, by arching forward of this direction from the suture across the periphery, and then backward near the anterior end, and forward equally to the columella, making a neat sinus or canal at the anterior end.

It is unnecessary to more than mention the probable ancestral position of these Subulites shells in relation to the geologically later siphonate forms of the Monotocardia. The form of aperture in Subulites follows the tendency, herein suggested, to build forward from the obliquely and backward to the axially parallel direction, the difference from Pleurotomaria shells being in the position of the remaining notch, sinus, or canal, which is near the columellar instead of the peripheral margin.

In that way one can compare the Calciferous coiled shells with supposed primitive dextrally coiled Lower Cambrian ones with simple aperture, excepting in case of Maclurea (Plate I, Figs. 10, 11, 12), which is more difficult. If it is viewed as a dextral coil (Fig. 12), the spire, as Billings suggested, has sunk far below the median plane, in short, the umbilicus is then plane, the spire is reversed, and the aperture is then equally changed from the primitive obliquely backward position to somewhat obliquely forward. On the other hand, if it is viewed as a sinistral shell (Fig. 10) related to Scævogyra, the aperture runs then somewhat obliquely backward, and the narrower or posterior side of the aperture is at the umbilical margin (Fig. 11), as in that genus, to which the coil also corresponds, being more or less completely convolute (*vide M. speciosa* Bill.), though the spire's height is rather uniform. From what is known to me of Scævogyra, its species are considered to be rather greatly variable ones, and those of Maclurea, including Maclurina, are also not entirely constant. Even the great number of taxonomic species given by Ulrich (*op. cit.*) from the Galena is reduced to one species when a large number of specimens are examined. Comparison of immature specimens of Maclurea with Scævogyra will, I think, argue a close relationship between the two genera.

It is probable that Maclurea descended from Scævogyra, and that these are nearest to Hypseloconus and Tryblidium. Scævogyra does not occur after the Cambrian time, and, regarding later descendants of Maclurea, none are known, unless they become dextral shells. The mooted transitional forms or linking species between Ophileta and Maclurea in the Calciferous, if ever demonstrable, may be turned to argue the conversion of a primitive sinistral type to dextral Enomphaladæ, instead of inversely. The Enomphalidæ are, indeed, an ambiguous group, but whether, by reason of diverse origin of species, included in the family or not, does not yet appear.

Whether the Baraboo gastropods and Maclurea became extinct by dying out, or whether they have converged in part into other taxonomic groups, does not appear. They may be related to Recent Gastropoda in the manner of an offshoot from the ancestral fresh-water ancestors, and may be wholly extinct.

THE ORDOVICIAN GASTROPODA.

The Ordovician gastropods next succeeding the Calciferous present an increased diversity, which is obviously an advance or continuation of the supposed development through Cambrian time It is unnecessary here to interpret it all in detail. Suffice it to note that in genera like Salpingostoma there is a maturity stage which was a new feature then in gastropod shells.

It will be useful to determine for the Ordovician species how much less constant they are in their characters than later gastropod faunas. There is danger of exaggeration, no doubt, if experience gained from a study of later Gastropoda is applied *a priori* to these earlier ones, since these may have the shell in a highly plastic stage, and seemingly great differences may not have a high taxonomic value. Such seems to me to be the case in studying large, carefully made collections, and accordingly I am inclined to desire a simplification of the taxonomic plan. In case of Pleurotomaria, both it and Bellerophon may have arisen from Raphistoma species, which argues close linking between these three. Again, Pleurotomaria may be from Raphistoma in part and from Holopea-like species in part; but this argues not only that the dividing up of Pleurotomaria, somewhat as Ulrich and Scofield have done, is logical, if practicable, but also that Raphistoma and Holopea-like species and their consequents are not genetically far apart. In case of Ordovician gastropod species, very excellent specimens are to be had in large numbers, at least in the upper Mississippi valley region, and these, when carefully studied, appear to show a high degree of variability. Ulrich and Scofield (*op. cit.*) have repeatedly based many taxonomic species on a few rather highly variable ones. The Ordovician fauna confirms the Cambrian shells to be rightly considered as little diverse, but variable to a high degree as compared with Mesozoic and recent probable descendants from them.

CONCLUSION.

The early Cambrian Gastropoda are taken to be in an initial stage of differentiation, the amount of their evolutionary development at that time being represented by the change from a long curved conical to a short conical, on the one hand, and to short spiral coils on the other. The asymmetrical long conical shell is taken as the most primitive form among Cambrian Gastropoda, and the one from which the short conical shells, on the one hand, and the spiral and coiled shells on the other, have descended. Conical shells have arisen also from coiled and spiral ones in later geologic ages. The visceral twist probably correlates with the development of the long asymmetrical cone, or most primitive form, and not with the spiral shell.

The ancestor of the Mollusca was probably living in fresh water, and there the ancestral gastropods began. The Cambrian Gastropoda which are known to us appear to be immigrants to the sea, the fresh water and land stock remaining unknown to us geologically, though they may be reflected in the known marine immigrants. The Hyolithoidea may represent the first migration seaward. They comprise long conical, more or less curved, often triangular shells, and are the normal marine species, very probably representing the class Pteropoda; and from the same the Cephalopoda may have derived.

The second migration comprised the other Lower Cambrian Gastropoda. They are taken to be the ancestral group of Prosobranchia, and to be in process of change from long curved conical to short conical, on the one hand, and, on the other, to spirally coiled. The coiling is at the shell apex first and strongest; *i.e.*, the coiled form of mature shell arises by retardation. The aperture is simple and is oblique to the radius of the curve, or, in other words, the shell is not longest on the convex anterior side, for which reason the aperture runs obliquely backward from the inner (posterior) to the outer (anterior) side of the volution.

The gastropods in the Calciferous formations are readily interpreted as derived from the Lower Cambrian species, with certain exceptions. These are short conical shells, the Docoglossa. The Rhipidoglossa comprise species of long coils, with more or less changed aperture, which arises essentially by the building forward of the anterior or convex side of the shell, leaving near it a sinus in the margin, *e.g.*, Bellerophon, Pleurotomaria, and Murchisonia. These forms undoubtedly belong to Suborder 1, Diotocardia. To Suborder 2, Monotocardia, belong similarly Platyceras and Subulites, in the latter of which the aperture forms a shallow anterior canal.

The third immigration is that represented by the Baraboo fauna, with curved conical shells, retrorse shells, and sinistrally spiral ones. In the Calciferous there are the shorter cones, Tryblidium, and the sinistral spiral Maclurea. This group is somewhat problematical, being doubtfully Prosobranch and possibly Ophistobranch, recognizable species of Order II, Ophistobranchia, appearing first in the Devonian and Carboniferous, in the genus Actæonina. Order III, Pulmonata, at the same time appears in the genus Archæozonites and Dendropupa. Those three genera are primitive-looking, but of no recognized exact relation to any contemporaneous or preceding ones of the Prosobranchia among fossils; and it may be considered that their ancestors of Cambrian time were in the fresh-water fauna, from which also the Prosobranchia separated by migrating seaward in Cambrian time. The practically sudden emergence of marine Pelecypoda in the Ordovician time finally permits a theory of their freshwater origin, at that time, in accord with the view that Mollusca as a whole began in fresh water habitat.

FREDERICK W. SARDESON.

MINNEAPOLIS, MINN.
May 30, 1903.

NODULAR-BEARING SCHISTS NEAR PEARL, COLORADO.[1]

THE central area of the Pearl district consists of schistose rocks which are cut by numerous dikes of coarse pegmatite, varying from two to forty feet in width, and having a general northwesterly and southeasterly strike. Numerous copper prospects are being developed upon these, and in several instances bodies of copper ore have been discovered. Associated also are veins of quartz, which are of great interest because of the fine crystals of spinel, of the variety ceylonite, which they contain. Octahedra of from 5 to 25^{mm} in diameter are found in large quantity. That which makes them especially interesting is the fact that all the crystals contain quartz inclusions in the greatest abundance, often to such an extent as considerably to lower their specific gravity. The spinel occurs in portions of the dikes which are almost wholly quartz. The included quartz appears to be identical with that surrounding the spinel. It would seem, therefore, that part of the quartz had crystallized out before the formation of the spinel, and the remainder followed the crystallization of the spinel. In other words, we have two generations of quartz crystals, the first generation being partly included in the spinel.

To the southwest of this lies another area of schistose rocks which are cut by dark basic dikes. These dikes are mineralized, and upon them prospects are also being opened up. They are an example of what the average miner firmly believes to be always the case — increase of value in depth. At the surface they show little sign of mineralization, but upon sinking chalcopyrite appears in considerable quantity, and seems to have been original with the dike matter, as the dike is perfectly fresh and shows no sign of mineralizing action. If the chalcopyrite was

[1] The recently opened mining town of Pearl is situated in Larimer county, Colo., about two miles south of the state line between Colorado and Wyoming, and at an elevation of about 8,400 feet (barometric).

original with the dike matter, why it appears in depth and not at the surface is a question that I am not prepared to answer.

Between these areas is a band of biotite schist which presents an unusually fine example of the stringing out and plication of quartz lenses. At times a single lens will have been squeezed to a band scarcely an inch thick and folded on itself from a dozen to twenty times, the folds being several inches to several

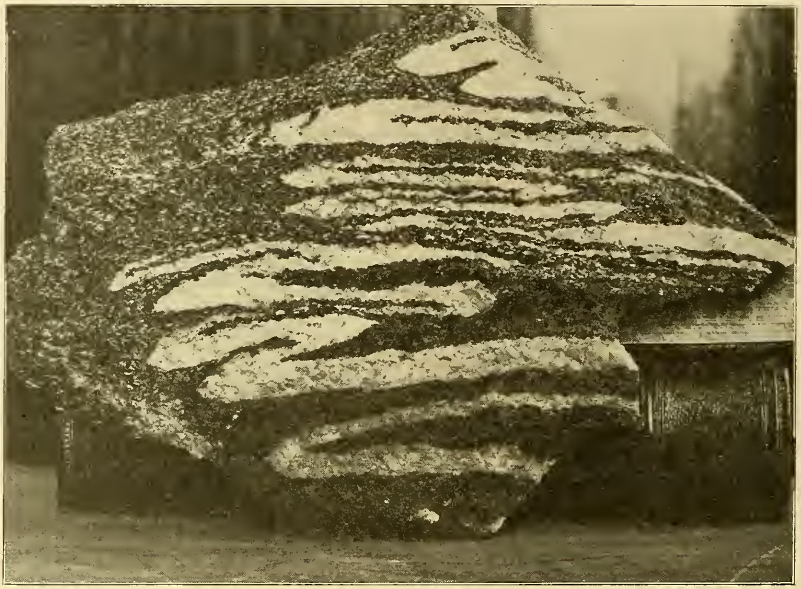

FIG. 1.—Plication of quartz vein in schist.

feet long and sometimes only a fraction of an inch across. The white quartz against the dark background of the schist presents a most striking appearance. This is shown by the accompanying photograph (Fig. 1). The size of the specimen can be judged from the volume of the *Neues Jahrbuch* which is used to prop it up. In a width of about six inches we have twelve folds, so that the same band appears twenty-four times. It seems most probable that in this case the quartz must have existed as a vein in the rock before its metamorphism, and the oscillations which took place during the metamorphic processes have produced this interesting effect. It is to be noticed that, in general, the thicker portions are on the same phase of the fold.

The occurrence of the greatest interest lies in the second area mentioned above. This is a belt of schist about one hundred feet wide, full of ellipsoidal nodules which vary in length from one to four inches along the greatest axis. As they are harder than the schist, they weather out in relief, and immediately suggest to the beholder the "prune granite" of Quincy, Mass., excepting that the "prunes" are in this case lighter in color than

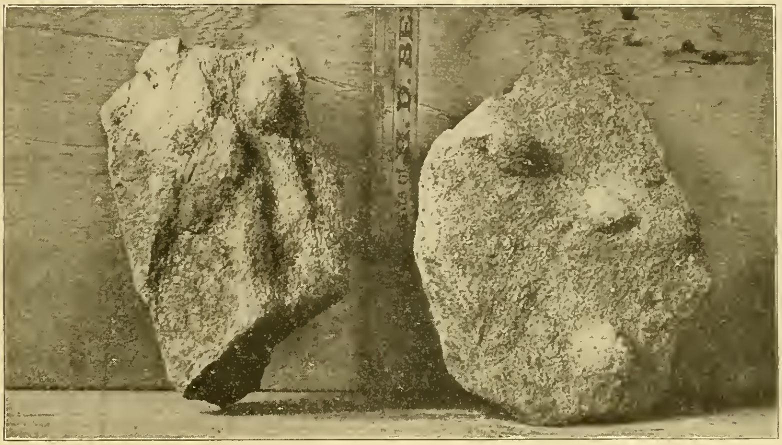

FIG. 2.—Iolite schist, showing projecting nodules.

the rock mass. The accompanying photograph of specimens of the rock will afford an idea of their appearance (Fig. 2).

Upon microscopic examination these nodules prove of unusual interest, because they largely consist of, or have been derived from, a mineral which has had very little notice in North American petrography, namely, iolite. Except as an accessory in certain basic rocks in Minnesota and as a mineralogical occurrence in various localities in the East, it has scarcely been mentioned. Abroad, however, it has frequently been described.[1]

Only surface material was available for study, and in this the iolite, as is usually the case, is much altered, the common altera-

[1] *Vide Zeit. für Kryst.*, Vol. XXIX, p. 305; also Vol. XXXI, p. 248; *Neues Jahrbuch*, Vol. XI (1899), p. 84; *Bull. de la Soc. de Sc. Boucarest, Roumanie*, Vol. III.

tion products of pinite and other secondary minerals having replaced it to a considerable extent. In most cases, however, what Dana describes as the first stage in the alteration of iolite has taken place—namely, the division of the iolite prisms into plates parallel to the base, and the development of a pearly luster on the plates. This pearly luster is especially prominent, and at first glance would deceive one into believing that the mineral is muscovite. The hardness and brittleness of the plates quickly dispel that illusion, however. It is interesting to note that, usually, a nodule displays this luster equally all over its surface at the same angle of illumination, showing that the crystallographic axes coincide throughout the mass, as though it were originally a single crystal.

In the hand specimen the nodule appears practically homogeneous, but in thin section, in addition to the iolite and alteration products, grains of quartz appear. How much quartz is present cannot be readily determined, for where the interference figures cannot be obtained quartz and iolite are indistinguishable, except by microchemical tests. I do not think the amount is large, however. The iolite shows its characteristic pleochroic halos, and often contains inclusions whose nature could not be determined.

The ground-mass of the schist is ordinary muscovite-biotite schist, the two micas being about equal in amount. It seems extremely probable that the muscovite has resulted from the alteration of grains of iolite scattered throughout the rock mass, as it is slightly more brittle than the ordinary muscovite.

The origin of the iolite, and, more especially, the origin of the nodules, is a question that could not be answered without further study of the region and also of the rock.

Three miles northeast of Pearl, in Wyoming, and apparently diametrically across the pegmatite area from the iolite schist, is another interesting belt containing veins of argentiferous lead and zinc ores. It is a schist resembling in a general way that in which the iolite occurs, and it, too, is full of nodules. These are irregularly prismatic in shape, differing from the iolite nodules in that respect. Further, they consist entirely of quartz which is full of rutile needles to an unusual extent. The needles seem to be arranged in approximately parallel positions, and are so numerous that they create false lines of cleavage in the quartz, it cleaving readily in one direction and with more difficulty at approximately right angles to this. The sagenitic structure common to rutile needles when they occur in quartz in large amount does not appear to be anywhere present.

The occurrence of the two schists in such proximity, and both containing nodular segregations, would lead one to suspect that there must be some connection between them. Speculation upon it with present data is useless, however. After further study features of great geologic interest may be discovered.

In concluding I wish to thank Dr. W. C. Knight for the notes and specimens put by him at the disposal of the writer.

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Reviews

SUMMARY OF THE LITERATURE OF NORTH AMERICAN PLEISTOCENE GEOLOGY 1901 AND 1902. II.

FRANK LEVERETT.

CENTRAL AND EASTERN CANADA.

BELL, ROBERT. *Report of an Exploration on the Northern Side of Hudson Strait.* Geol. Survey Canada, Ann. Report, Vol. XI, Part M, 38 pp., 1901.

Baffin Land, which forms the northern side of Hudson Strait, was until 1875 supposed to consist of a group of islands, but now it appears to be one great island with an area of about 300,000 square miles. There are, however, numerous small islands along the south coast. Three prominent mountain ranges trend north-northwest to south-southeast parallel with the eastern coast, the highest of which borders that coast. The high interior north of Cumberland Sound is reported by Boas to be ice-capped like Greenland. Around the margins of the ice-cap the general elevation is about 5,000 feet, and it reaches about 8,000 feet in the central part. Another area of smaller extent, but apparently equally high, lies a short distance farther northwest. The mountainous region between Cumberland Sound and Frobisher Bay stands apparently between 2,000 and 3,000 feet. The tract between Hudson Strait and Frobisher Bay is largely covered by the Grinnell glacier, which is 70 to 100 miles in length and about 20 miles in breadth. It was reported (but not verified) that one narrow tongue of ice extends down to the water of the strait. The mountains are apparently interspersed with lakes, two of which are of great size, Lake Netelling being 60 by 140 miles, and Lake Amadjuak at least 40 by 120 miles. Their greatest diameter runs parallel with the mountain ranges north-northwest to south-southeast.

Hudson Strait, as pointed out in 1895[1] was probably occupied by a river that drained the Hudson Bay basin at a time of high altitude when the basin was dry land. Soundings show the strait to have a channel 200 to 300 fathoms in depth. The ice-sheets of the glacial period moved down from the high land on both sides, and then down the valley itself, as shown by the striation and the materials of the drift.

On the part of Baffin Land examined, bowlders are a conspicuous feature, and a sandy or gravelly till is abundant. Osars were noted southwest of Amadjuak Lake. The general glaciation seems likely to have been rather remote, for the surface of the drift is much oxidized, and the limestone surfaces show considerable decay. Striæ are conspicuous only at low levels along the coast. A table containing observations of twenty-two striæ is given. Giant potholes 8 to 20 feet in diameter were noted on the border of the entrance to Canon Inlet.

The sea has stood at various levels, above the present, long enough to form well-defined beaches. Beaches were noted at several points at elevations of 360 to 400 feet, as well as at various lower altitudes. On a mountain side west of Akuling Inlet

[1] In a paper by DR. BELL in the *Scottish Geographical Magazine.*

beaches and terraces were found at 378 and 528 feet. Drinkwater reports observing a beach about 600 feet above the sea on the hills above O'Brien Harbor at Cape Chidley. Shells of *Saxicava rugosa* and *Mya truncata* were found imbedded in till on one of the Islands of God's Mercie at 200 feet, and the Saxicava shells in drift at lakes Gertrude and Greely at 110 feet.

CHALMERS, ROBERT. *Notes upon the Pleistocene Marine Shore Lines and Land Slips of the North Side of the St. Lawrence Valley.* Geol. Survey Canada, Vol. XI, Part J, Appendix I, pp. 63–70, 1901.

The marine plain or bottom land of the St. Lawrence valley extends from 8 to 30 miles north of the river in the district between Quebec and Montreal. The river bank is usually but 15 to 25 feet, but in passing back toward the northern limits, along the base of the Laurentian hills, there is a rise to 400 or 500 feet. The slope is terraced, apparently by marine shore action. The shore lines are found to increase in height from east to west, the rate of rise of the highest one between Quebec and Lachute being about two feet per mile.

The landslips here reported have occurred at various dates from 1840 to 1898, and lie below the level of the highest shore line. The most recent one, May 7, 1898, filled the Rivière Blanche valley 25 feet for a distance of nearly two miles. The cause of the landslips is stated by the author to be due to (1) the silty and arenaceous character of the Leda clay, rendering it capable of absorbing and retaining a large amount of water, and (2) the increased precipitation during the season these landslips occurred, which saturated the deposit and gave them greater weight than usual.

CHALMERS, ROBERT. *Surface Geology of Part of Ontario.* Geol. Survey Canada, Summary Rept. for 1901, pp. 158–68.

In company with R. W. Ells, the western limit of marine beds was traced northward from Brockville to Smiths Falls. Clay thought to be of fresh-water deposition was noted at Lyn, Gananoque, Kingston, and westward.

Oil wells at Petrolia, Oil Springs, and Sarnia penetrate 100 to 125 feet of surface deposits before striking rock. Rock is reached near Bothwell at 210 feet and at Dutton at 255 feet, while at Tilsonburg it is reached at 74 to 81 feet.

In parts of the Thames valley gas is obtained from sand and gravel below hardpan at a depth of about 90 feet.

The following series of drift beds is reported to occur in western Ontario:

1. Surface clay, sand, or gravel, more or less oxidized.

2. Bowlder clay of irregular thickness, sometimes wanting.

3. Sandy and silty beds, in places forming the upper part of the Saugeen clay (interglacial).

4. Saugeen clay, interglacial, partially oxidized and somewhat sandy in upper part, fresh-water shells in lower part.

5. Erie clay, interglacial, color bluish-gray, sometimes darker, stratification more or less distinct; contains fresh-water and land shells (Campeloma, Succinea, Polygyra, etc.), in upper part; localities noted are Pelee Island and shore of Lake Erie.

6. Bowlder clay, usually a thin sheet resting either on the decomposed or the solid surface of the "fundamental rocks."

The so-called interglacial beds Nos. 3 to 5 often have a combined thickness of 100 to 150 feet.

A former level of the Great Lakes lower than the present is shown by the following lines of evidence: (1) by stumps along the Lake Erie shore west of Port Rowan with their roots in soil below lake level; (2) by tree trunks in a layer of clay and marl in the mouth of Maitland River at Goderich 10 to 15 feet below the level of Lake Huron; (3) streams discharging into Lakes Huron, St. Clair, Erie, and Ontario have their lower courses flooded from the lakes. In the case of the Thames and the Sydenham the depth of flooding is 10 to 25 or 30 feet, and extends for several miles up the stream.

Spits and dunes on the north shore of Lake Erie are being built mainly by winds that blow from the southwest, those on the north shore of Lake Ontario by winds blowing from the east.

Coleman, A. P. *Marine and Freshwater Beaches of Ontario.* Bull. Geol. Soc. Amer., Vol. XII, pp. 129–46, 1901.

Marine deposits and shell-bearing gravel and sand extend up the St. Lawrence valley to Brockville, both on the Ontario and New York side, but have not been found farther west, though the same body of water is known to have extended into the Ontario basin. Plant remains found in clay nodules in Ottawa are those of a cool-temperate climate like the present climate of that region. The remains of marine animals are of species found now in the Gulf of St. Lawrence.

Higher shore lines are found, and other evidences of static water at high levels, but the author doubts if any of these higher shore lines are postglacial and marine. On the contrary, they appear to have been produced by glacial lakes. In some cases the beaches contain fresh-water fossils.

Attention is called to evidences of northward differential uplift in the Great Lakes region, and it is considered probable that the highest beaches were formed at a comparatively slight altitude above the sea. The objection raised against ice-dams, that no glacial mass could withstand the pressure of a head of water hundreds of feet in depth, may find no application here if the land was relatively low, and is thought to be of doubtful pertinence even under conditions of high altitude.

Coleman, A. P. *Sea Beaches of Eastern Ontario.* Rept. of Ontario Bureau of Mines for 1901, pp. 215–27.

Describes the character and distribution of the sea beaches and the faunas which they contain. Also gives a few observations on the Leda clay and the Saxicava sand.

Coleman, A. P. *Iron Ranges of the Lower Huronian* [Ontario]. Rept. of Ontario Bureau of Mines for 1901, pp. 181–211.

Although dealing chiefly with the iron-ore bodies, a brief discussion of the Pleistocene geology is presented.

Coleman, A. P. *Glacial and Interglacial Beds near Toronto.* Jour. Geol., Vol. IX, pp. 285–310, 1901.

Presents a connected history of events in the Ontario basin from the retreat of the Iowan ice-sheet, which is summed up as follows:

1. Retreat of the Iowan ice-sheet.
2. Interval of erosion, with water probably lower than at present.
3. Don stage, warm-climate trees, and Mississippi unios, water dammed by differential elevation toward the northeast to 60 feet above the present lake.

4. Scarboro peaty clays, cold-temperate climate with trees and mosses, and 70 species of extinct beetles, formed as a delta by Laurentian River in interglacial Scarboro Bay.

5. Scarboro stratified sand with some trees and freshwater shells of cold-temperate climate, delta completed; lake stood 152 feet above the present.

6. Water drawn off by lowering of outlet, subaërial erosion of previous beds, and cutting of river valleys more than 150 feet deep.

7. Advance of Wisconsin ice-front raising the water to about 160 feet, as shown by stratified interglacial clay, retreat for 50 miles and readvance, followed by two later retreats and advances, the water finally rising 360 feet above the present lake.

8. Final retreat of ice-sheet followed by water levels of lakes Warren and Iroquois, and a brief entry of the Gulf of St. Lawrence into the Ontario basin, which, however, remained fresh.

The reviewer questions whether the Iowan drift is well represented or even present at this locality, since the interval shown by the interglacial beds appears to be much greater than observations in the region where Iowan and Wisconsin drift sheets are well displayed would lead one to expect. This does not invalidate in any way the conclusions announced in this paper; it simply suggests that the lower till sheet may be Illinoian.

COLEMAN, A. P. *Duration of the Toronto Interglacial Periods.* Am. Geol., Vol. XXIX, pp. 71–79, 1902.

In reply to a paper by Upham which had appeared in the *American Geologist*, Coleman estimates the time required for the processes which took place between the two advances of the ice. Of this time 1,300 years is considered a low estimate for laying down the interglacial beds and 2,500 years for trenching them; it is considered probable that the time should be more than doubled. The warm-climate flora is shown to be inconsistent with the view that the ice-sheet was near by. The author holds it probable that the ice had disappeared as completely from Canada in that interglacial period as at the present time, which perhaps is embraced in another interglacial period.

COLEMAN, A. P. *Relation of Changes of Levels to Interglacial Periods.* Geol. Mag., Dec. 4, Vol. IX, pp. 59–62, 1901.

It is thought there was an uplift to the northeast, followed by a depression. The uplift would render Labrador cooler and help start an ice accumulation, and this in turn would tend to depress the region. The melting of the last ice-sheet would allow the land to rise again. It is a problem whether this elevation to the northeast would be sufficient of itself to cause glaciation.

CURRIE, P. W. *On the Ancient Drainage at Niagara Falls.* Trans. Can. Inst., Vol. VII, pp. 7–14, 6 pls., 1901.

(Not examined.)

DOWLING, D. B. *Physical Geography of Red River Valley.* Ottawa Nat., Vol. XV, pp. 115–20, 1901.

The geological history is sketched, and with it the development of the main physical features. The effect of glaciation and of the occupancy by the Glacial Lake Agassiz form the closing part of the discussion.

Dowling, D. B. *West Shore and Islands of Lake Winnipeg.* Geol. Survey Canada, Ann. Rept., Vol. XI, Part F, 100 pp., 1901. Published as a separate in 1899.

Superficial deposits are discussed on pp. 93–100, and include till, drumlins, reassorted bowlder clay, stratified sands and gravels, and lake beaches. The bearings of striæ are also given, and a map of part of Lake Winnepeg shows striæ and drumlins.

Dowling, D. B. *East Shore of Lake Winnipeg and Adjacent Parts of Manitoba and Keewatin.* Geol. Survey Canada, Ann. Rept., Vol. XI, Part G, 98 pp. 1901. Published as a separate in 1899.

This report is edited from notes by J. B. Tyrrell. While dealing mainly with the hard-rock geology, there are brief references at various points to glacial deposits, lacustrine deposits, striæ, potholes, etc. The eastern limit of lacustrine deposits is noted (p. 43).

Dowling, D. B. *The West Side of James Bay.* Geol. Survey Canada, Summary Rept. for 1901, pp. 107–15, 1902.

A traverse was made on the west shore of James Bay, and a survey of Equan River. The deltas of Moose and Albany rivers are briefly described. Clays with marine fossils occur up to nearly 400 feet above tide in the vicinity of Sutton Mill Lake.

Dowling, D. B., and J. B. Tyrrell. (See Tyrrell.)

Ells, R. W. *Three Rivers Map Sheet of Quebec.* Geol. Survey Canada, Ann. Rept., Vol. XI, Part J, pp. 63, 1901. (Published as a separate in 1900.)

The occurrence of marine shells in sand or gravel above clay is apparently restricted to the vicinity of the St. Lawrence River, none having been noted on the high areas to the north. Striæ are rather rare because of the limited outcrop of Paleozoic rocks and because weathered quickly from the gneiss. The general bearing is north-south.

Ells, R. W. *Ancient Channels of the Ottawa River.* Ottawa Nat., Vol. XV, pp. 17–30, with map, 1901.

The paper opens with a reference to the Ottawa as one of the great historic waterways, Champlain having ascended it in 1615, and crossed the portage at Lake Nipissing, "presumably the first white man to gaze upon the vast expanse of our inland seas," while afterward the river became the chosen route of the voyageurs inland to the great unexplored country, and the principal channel for the business of the Hudson Bay Company. The geologic history of the river is made to begin far back of the Glacial epoch, though it is recognized that marked changes were produced by glaciation. Borings show that part of the lower course has a rock floor below the sea level, and the depth of Lake Temiscaming (470 feet) brings its bottom to within 121 feet of sea level. The valley is thought to have experienced several cycles of uplift and depression. The author inclines to the view that a postglacial marine submergence covered lands between the Ottawa and Hudson Bay now standing over 1,000 feet above sea level.

The paper deals mainly with the departures of the present stream from a deep preglacial channel, the course of which was determined by borings, and is represented on a map for a distance of about 200 miles, from Roche Capataine, in longitude 78° nearly to Montreal.

ELLS, R. W. *The District around Kingston, Ontario.* Geol. Survey Canada, Summary Rept. for 1901, pp. 170–83.

Notes briefly marine deposits at Brockville, the probable Iroquois shore line near Tamworth, and the occurrence of shell marl in many lakes in the area north of Kingston.

ELLS, R. W. *Marl Deposits of Eastern Canada.* Ottawa Nat., Vol. XVI, pp. 59–69, 1902.

Discusses deposits in Ontario, Quebec, New Brunswick, and Nova Scotia, and refers the deposition of marl to the action of air upon spring water containing bicarbonate of lime.

FLETCHER, HUGH. *Kings and Hauts Counties, Nova Scotia.* Geol. Survey Canada, Summary Rept. for 1901, pp. 208–14.

Refers briefly (p. 211) to drift material, striæ, old beaches, and shell marl.

JOHNSTON, J. F. E. *Eastern Part of the Abitibi Region.* Geol. Survey, Canada, Summary Rept. for 1901, pp. 128–41.

Describes briefly the streams, lakes, peat, timber, soils, fish and game, as well as the hard-rock geology.

LAFLAMME, J. C. K. *Geological Exploration of Anticosti.* Geol. Survey Canada, Summary Rept. for 1901, pp. 188–94.

The stream valleys are largely excavated in gravel and calcareous detritus of modern origin, and postglacial clays are also present. A few striæ bearing northeast-southwest were found at Rivière Du Cap. The highest parts of the island carry glacial bowlders. The island was apparently covered by the Champlain sea. The uplift following the submergence is distinctly marked, and the two phases of it are shown by systems of terraces. The present shore seems to be undergoing uplift, for parts of its beach are not reached by high tide. Marl lakes are common on the island. Soils are variable.

LOW, A. P. *Exploration of the South Shore of Hudson Strait.* Geol. Surv. Canada, Ann. Rept. Vol. XI, Part L, 47 pp., 1901. (Published as a separate in 1899.)

The glacial geology is discussed on pp. 34–47. Although the highest hills are glaciated, there is little drift material except bowlders above 400 feet A. T. The ice movement was radial toward the coast. The highest marine terrace noted is 405 feet. Reference is made to a marine limit of 700 feet at Richmond Gulf in Hudson Bay, of 300 feet at the south part of Ungava Bay, and of 325 feet at the mouth of Payne River.

LOW, A. P. *Report on the Exploration on the East Coast of Hudson Bay.* Geol. Surv. Canada, Ann. Rept., Vol. XIII, Part D, 86 pp, with 2 maps, 1902.

Describes the physical features of the coast and presents a few notes concerning the northern interior. The northern limit of forests, the climate, and the fisheries are briefly treated. Near Cape Wolstenholme patches of perpetual snow were discovered. Three sets of striæ were noted in the Labrador peninsula, which are interpreted to indicate a transference of the center of glaciation northward, it being at an early time between the 50th and 51st parallels near the center of the peninsula, at a later time north of the 54th parallel, and still later between the 55th and 56th parallels and only about 100 miles inland from the east coast of Hudson Bay.

South of Hudson Bay two sets of striæ were noted, the older set running from northwest to southeast, thought to be the product of the Keewatin ice-field, and a later set from north-northeast to south-southwest, referable to the Labrador ice-field. A long list of striæ observed east and south of Hudson Bay is presented.

Subsidence of land accompanied, and perhaps continued subsequent to, the ice accumulation, and this was followed by an uplift which has carried the old marine shores to a maximum height of nearly 700 feet above the present sea-level. The limits, however, appear to be much lower in the northern part of the peninsula. (See preceding paper.)

McEvoy, James. *Report on the Geology and Natural Resources of the Country Traversed by the Yellow Head Pass Route from Edmonton to Tête Jaune Cache.* Geol. Surv. Canada, Ann. Rept., Vol. XI., Part D, 44, pp., 1901. (Published as a separate in 1900.)

The route described leads from the plains east of the Rocky Mountains westward over the front range of mountains. The physiography and the general character and extent of the several formations including the Pleistocene are briefly discussed. Glaciers were noted in the Selwyn Range on mountains 8,000 to 9,000 feet in height, and west from there on mountains that reach 11,000 feet. The drift deposits are heavy near Lake St. Anne, with bowlders of Laurentian granite and fossiliferous Devonian limestone brought from the north and northeast. The limits of eastern drift are placed about a mile west of Wolf Creek. Farther west the bowlders are from the Rocky Mountains. A glacier apparently flowed northward down the Athabaska valley. The highest mountains show no striæ, and their sharp angular appearance is thought to indicate that they have not been glaciated. However, a mountain 8,000 feet high, situated eight miles east-southeast from Tête Jaune Cache, was glaciated; the striæ bear south 25° west.

McInnis, William. *Region Southeast of Lac Seul.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 87–93, 1902.

Contains brief notes on the fall of streams, the river terraces, the outline and depth of lakes, and the features of the drift.

Parks, W. A. *The Country East of Nipigon Lake and River.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 103–7, 1902.

Several lakes were mapped, and the location of the headwaters of several rivers flowing to Lake Superior were determined. The explorations were carried through considerable territory hitherto unexplored.

Tyrrell, J. B. and D. B. Dowling. *Reports on the Northeastern Portion of the District of Saskatchewan and Adjacent Parts of the Districts of Athabasca and Keewatin.* Geol. Surv. Canada, Ann. Rept., Vol. XIII, Parts F and FF, 48 and 44 pp., 1902.

The report by Tyrrell covers explorations in Saskatchewan and Keewatin, while that by Dowling extends also into Athabasca. Tyrrell's report is based upon an exploration in 1896 involving a trip of about 700 miles. Notes were made on topography and agriculture as well as the several geological formations. The recent and Pleistocene deposits are briefly treated under the topics: peat beds, shore lines, Pleistocene clay, eskers, till, kettleholes. The striæ of the Keewatin and the Labrador ice-fields are discriminated. Those in the western part were made entirely by the Keewatin, while those in the eastern part, with one or two exceptions, have been made by the Labrador ice-field. How far east the Keewatin ice field extended was not clearly worked out.

Dowling's report covers an exploration in 1899 and later visits. The encroachment of the Labrador ice-field on territory previously glaciated by the Keewatin is mentioned (p. 12.) The relation of the two ice-fields to Lake Agassiz is also briefly touched upon. The beaches in the northern part of the district belong to the later ones of Lake Agassiz, and it is inferred that the ice-sheet still occupied that ground while the earlier ones were forming. In the detailed discussion glacial and lacustral deposits along Saskatchawan River are first discussed, then the features about Moose and Cormorant Lakes and along Cowan River, and after this in turn the Menago, Burntwood River, Athapapuscow Lake, Kississing River and Lake, and Churchill River. The report is of especial interest because it extends into the territory near the limits of Lake Agassiz, though it does not work out fully the relationship of the lake beaches to moraines and other glacial features.

UPHAM, WARREN, *Toronto and Scarboro Drift Series.* Am. Geol., Vol. XXVIII, pp. 306–16, 1901.

The interglacial beds are interpreted to be part of a delta with a fan-like lakeward slope, which after being built up nearly 200 feet was deeply channeled by the same streams which built them, the change from building to channeling being brought about by the relief of the streams from much of their burden of silt. It is thought that the ice was close at hand all the time, and that the whole interglacial and subsequent glacial history is comprised in a few hundred or possibly a thousand years. (For a reply to this paper see Coleman, above.)

WILSON, A. W. G. *Physical Geology of Central Ontario.* Trans. Can. Inst., Vol. VII, pp. 139–86, 1901.

About half of this paper pertains to the older rock formations, but the latter half discusses the present topographic features and Pleistocene geology of that part of the province of Ontario lying north of Lake Ontario. The conclusion is reached that the main topographic features are preglacial, and that the work of the ice-sheet is restricted to the rounding off of pinnacles, small spurs, and outlying features. The Ontario lowland is thought to owe its origin to normal weathering, and erosion rather than glacial excavation. The main drainage, it is thought, may have led westward through the Dundas valley toward the Mississippi in a direction opposite to that advocated by Spencer (J. W.). Many of the tributary valleys are traceable, though greatly obstructed and concealed by the glacial deposits. (Summary taken from review by F. D. Adams in *Geologisches Centralblatt.*)

WILSON, A. W. G. *The Country West of Nipigon Lake and River.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 94–103, 1902.

Seventeen small lakes and connecting streams were mapped and the rocks of the country examined. Chief attention is given to the hard-rock geology, but glacial deposits are briefly discussed. The river valleys are more or less filled with sand and gravel occurring occasionally as eskers or kame-like mounds. There are also extensive bowlder-strewn plains. The country explored is regarded as a partly dissected tableland with a trap-capped cuesta.

WILSON, W. J. *Western Part of the Abitibi Region.* Geol. Surv. Canada, Summary Rept. for 1091, pp. 115–28, 1902.

Describes briefly streams, lakes, soils, topographic features, surface deposits, climate, and game, as well as the hard-rock geology.

UNITED STATES.

MAINE.

MANNING, P. C. *Glacial Potholes in Maine.* Proc. Portland Soc. Nat. Hist., Vol. II, pp. 185–200, 1901.

Describes the occurrence and character of the potholes along the coast of Maine and discusses the evidences indicating their origin. (Review by F. B. Weeks. Paper not examined.)

NEW HAMPSHIRE.

HITCHCOCK, C. H. *Interglacial Deposits in the Connecticut Valley.* Bull. Geol. Soc. Am., Vol. XII, pp. 9, 10, 1901.

Interglacial is not used in the customary sense, but has reference to deposits made in the midst of an episode of glaciation. Deposits underneath the eskers are called interglacial because they were formed earlier than the eskers. There are deposits of tough clay which have been contorted apparently by pressure induced by the overlying glacier. It is thought that the features support the view that a local Connecticut valley glacier succeeded an ice-sheet which had a general southeasterly movement.

VERMONT.

FINLAY, GEORGE. *Granite Area of Barre, Vermont.* Ann. Rept. State Geologist for 1902, pp. 46–8.

Describes sand plains and eskers in the vicinity of Barre, as well as the crystalline rocks. The features are thought to support the view that one esker at least is of subglacial rather than superglacial origin.

MASSACHUSETTS.

CLAPP, F. G. *Geological History of Charles River.* Tech. Quart., Vol. XIV, Nos. 3 and 4, 1901; also Am. Geol., Vol. XXIX, pp. 218–33, 1902.

An interpretation of the causes for the very devious course of the river is presented and the several stages of development discussed. A map sets forth the probable course of pre-glacial streams in the Charles River basin and vicinity. The retreat of the ice is supposed to have been such that a glacial lake was held in this drainage basin whose extent and whose outlets varied with the position of the ice-front The several distinct levels are discussed and named. These lake outlets control to some extent the course of the present river.

Crosby, W. O. *Origin of Eskers*. Proc. Boston Soc. Nat. Hist., Vol. XXX, pp. 375–411, 1902; also Am. Geol., Vol. XXX, pp. 1–39, 1902.

Attention is first called to the evidence obtained from existing ice-sheets. The Malaspina glacier has often been referred to as affording examples of eskers in process of formation, but as only one esker has been found in the tracts recently abandoned by that glacier, it is thought that the deposits now being made in tunnels under the glacier will, when uncovered by the recession of the ice, be cut down by streams issuing from the ice or buried by detrital material. It is concluded, therefore, that the Malaspina glacier does not afford a good illustration of the way in which eskers were formed. The Greenland ice-sheet also is found to afford no good example of eskers in process of formation.

Eskers are generally admitted to be the product of a waning stage of glaciation in which the marginal zone of ice is practically stagnant. It is suggested that this stagnant portion may be partially overridden by newly formed ice, and thus material might be carried from lower to higher levels by a shearing motion. The superglacial hypothesis of the origin of eskers is favored by the author for the following reasons: (1) Their courses are to a marked degree independent of topography, and they will maintain their normal courses even if it leads them to forsake or to cross large valleys and rise to levels far above the other types of modified drift. (2) They seldom, if ever, occupy channels in either the bed-rock or till which are referable to the streams which formed the eskers. (3) The major and minor deviations or meanders of the eskers, as well as their general trend, seem hard to account for on the subglacial hypothesis, but are natural enough for superglacial streams. (4) The great length of eskers is thought to be consistent with subglacial stream action, but not with superglacial, for superglacial streams are limited in their length only by the breadth of the zone of ablation. It is difficult to believe in a tunnel of the great length of some eskers 100 to 150 miles, and such an explanation should be accepted only as a last resort. It is thought doubtful if crevassing would extend far back in continental ice-sheet to aid the subglacial work. (5) Double and reticulated eskers seem natural to superglacial streams, but not to subglacial, though Stone thinks these reticulations occurred where the subglacial stream became locally superglacial. (6) The eskers are largely made up of distantly derived material, and differ from the underlying till, which is largely of local material.

The reviewer would call attention to the necessity either for qualifying or throwing out two of the above-mentioned reasons for favoring the superglacial origin of eskers. His observations in Ohio, Indiana, Illinois, and Michigan show that the channels, which under the second reason are said not to occur, are really present in the above-mentioned states, and are cut in the surface of the Wisconsin till. A description and map of one of these appears in Monograph XXXVIII, *U. S. Geol. Survey*, pp. 284–86, Pl. 14, 1899. The second point which the reviewer would make is that in the states just mentioned the eskers are very largely composed of local material, and have a constitution strikingly similar to the till which borders them. For notes concerning the proportion of local rocks both in eskers and till see Monograph XXXVIII, *U. S. G. S.*, pp. 78 and 286. Possibly the eskers of the states which the reviewer has examined, have had a different origin from those of New England, where the author's observations were made. The conditions in a very hilly or uneven country like New England may be different from those in the smooth districts in the states examined by the reviewer. Possibly in New England itself some eskers are of superglacial and others of subglacial origin. (See paper by Finlay reviewed above, p. 606.)

Crosby, W. O. *Hard-Packed Sand and Gravel.* Tech. Quart., Vol. XV, pp. 260–64, 1902.

At certain points in the Nashua valley near Clinton, Mass., deposits of sand and gravel are found which are very difficult to penetrate with the drill. An examination of samples shows that scaly fragments of schist, mica, etc., form a notable constituent in some cases, but in others the material consists very largely of angular or subangular quartz fragments. Upon experimenting with the latter under various conditions of water admixture it has been found that where there is insufficient water to fill the pores the surface tension of the water causes it to act as a cement binding the grains together, and it is thought that this affords a solution of the cause for the "hard-packed" material noted in the Nashua valley.

Davis, W. M. *River Terraces in New England.* Bull. Mus. Comp. Zoöl., Harvard College Geological Series, Vol. V, No. 7, pp. 278–346, 1902. Abstract published in Bull. Geol. Soc. Am., Vol. XII, pp. 483–85, 1901.

The control exerted by rock ledges or other resistant material on certain river terraces of New England is discussed in some detail, and attention is called to the bearing on the interpretation of terraces that heretofore had been referred to gradation with respect to temporary base levels. It is also shown that the arrangement of terraces in flights of steps does not depend on the stream volume, however true it may be that the stream volume has diminished during the process of terracing.

Davis, W. M. *Terraces of the Westfield River, Massachusetts.* Am. Jour. Sci., 4th series, Vol. XIV, pp. 77–94, 1902.

The Westfield River is taken as a good illustration of the effect of resistant obstacles in developing terraces. (See previous paper.)

Fuller, M. L. *Probable Representatives of pre-Wisconsin Till in Southeastern Massachusetts.* Jour. Geol., Vol. IX, pp. 311–29, 1901.

The supposed pre-Wisconsin till is of a very different type from the ordinary till of that part of New England. It contains about four times as much clay, and only about one-fourth the per cent. of coarse rock fragments and pebbles found in the ordinary till. In its composition a more striking dependence on the underlying rock formations is shown, and its material is also more highly oxidized than the overlying till, and often differs from it strikingly in color. Aside from the exposures noted, which are near Brockton and Stoughton, there are numerous exposures in which pre-Wisconsin age is suspected from the advanced stage of weathering of the rock fragments in the till.

Hollick, Arthur. *Reconnaissance of the Elizabeth Islands.* Ann. N. Y. Acad. Sci., Vol. XIII, pp. 387–418, Pls. VIII–XV, 1901.

The islands are composed largely of a bowldery moraine, which has points reaching altitudes of 125–150 feet above the sea, though the greater part is much lower. The moraine is thought to be a portion of the later or northern branch of the terminal moraine on Long Island, and is more recent than the moraine on Marthas Vineyard, Block Island, and Montauk Point. Considerable attention is given to the vegetation, and especially the forestry conditions.

JEFFERSON, MARK S. W. *Limiting Width of Meander Belts.* Nat. Geog. Mag., Vol. XIII, pp. 373–84, 1902.

The small Matfield River of Massachusetts was made a subject of special study, and the results are compared with published results on the moderate-sized Oder and the great Mississippi River, for each stream has meanders on its flood plain. The data concerning a few rivers having incised meanders are then examined and found to be insufficient to establish definite relations, though it is thought that the discordances might be removed by more detailed studies. The mean meander ratio is found to be 17. 6 : 1; that is a meander belt is that many times the width of the stream.

JULIEN, ALEXIS A. *Geology of Central Cape Cod.* Am. Geol., Vol. XXVII, pp. 44, 1901.

Discusses the glacial formations with special reference to the district from Chatham to Yarmouth. Attention is called to the intercalation of clays in the stratified deposits south of the morainal backbone of the Cape which have suffered some disturbance and flexure. Kettle-shaped hollows and pond basins are discussed in their relation to preglacial drainage valleys. Attention is also given to changes of level.

JULIEN, ALEXIS A. *Erosion by Flying Sand of the Beaches of Cape Cod.* Abstract Ann. N. Y. Acad. Sci., Vol. XIV, pp. 152, 1901.

Not examined.

WILSON, A. W. G. *The Medford Dike Area.* Proc. Boston Soc. Nat. Hist., Vol. XXX, pp. 353–74, 1901.

The discussion relates mainly to the crystalline rocks, but the glacial phenomena of the region are briefly described.

CONNECTICUT.

HOBBS, W. H. *An Instance of the Action of the Ice Sheet upon Slender Projecting Rock Masses.* Am. Jour. Sci., 4th series, Vol. XIV, pp. 399–404, 1902.

Discusses the abrading effect of the ice-sheet on slender masses of projecting rock along the bluffs of the Pomperaug valley of Connecticut, and trains of bowlders resulting therefrom.

NEW YORK.

FAIRCHILD, H. L. *Pleistocene Geology of Western New York.* Twentieth Rept. of State Geologist for 1900, pp. 103-39 Pls. 9–41, 1902.

The results of a special study of the Iroquois shore line between Richland and Watertown, N. Y., are first presented. The chief attention is given to the rate of differential elevation of the beach, though its constructional features are mapped in some detail. This study seems to support the conclusion that the warping of the eastern end of the Ontario basin has mostly, if not entirely, taken place since the extinction of Lake Iroquois, for the entire eastern shore seems equally tilted. The large amount of tilting considered in connection with the usual estimates of post-glacial time (10,000 to 50,000 years) would indicate that the rate of deformation has been much greater than the present rate of 0.42 foot in 100 miles in 100 years, estimated by Gilbert.

A study of the territory between Syracuse and Oneida with special reference to the higher and earlier channels cut by the overflow of the glacial waters is illustrated by a large number of photographs showing the features of these channels and of cataract basins and ancient deltas along them. The retreat of the ice being westward in this region, the eastern channels are older than the western, and they were apparently formed in regular succession westward.

A reconnaissance in the Cattaraugus-Chautauqua district along the divide between the Ohio and Lake Erie drainage throws light upon the character of the glacial drainage. Few channels cross the divide, the only important one being at Persia Siding, where waters passed from the Cattaraugus to the Conewango drainage basin. Most of the channels which drain southward head in uncut morainic drift. The explanation is found in the fact that there was southwestward escape along the ice-front for the glacial waters of this region as soon as the ice had receded a little from the divide. Several channels representing successively lower levels taken by waters draining a lake in the Cattaraugus basin westward along the ice-front into the Erie basin are described in the eastern portion of their course in the vicinity of Gowanda, but were not traced westward their entire length. The report closes with a brief description of drumlinoidal aggregations of drift near the head of Lake Chautaugua.

GRABAU, A. W. *Guide to the Geology and Paleontology of Niagara Falls and Vicinity* (*with a Chapter on Post-Pliocene Fossils*, by ELIZABETH LETSON). Bull. 45, New York State Museum, 284 p., 1901.

The introduction deals with the best routes for viewing the Falls region. Chap. 1 discusses the physical geography of the region and chap. 2 the life-history of the Falls, while chaps. 3 and 4 discuss the stratigraphy and fossils of the hard-rock formations, and chap. 5 (by E. J. Letson) the post-Pliocene fossils. The bibliography of ten pages forms an appendix, and this is followed by a glossary of fourteen pages. This guide-book affords a comprehensive interpretation of the region, presenting the results of the various workers in that field as well as the author's contributions and interpretations.

Certain parts of the interpretation of the drainage development are extremely hypothetical, and in the reviewer's opinion somewhat doubtful. For example, the eastern end of the Ontario basin is represented to have drained southward in Tertiary time through the Genesee (reversed). The view that the drainage of the Ontario, Erie, and Huron basins was southwestward toward the Mississippi seems to be in harmony with the latest results obtained in Michigan, though it can hardly be considered well established. The drainage of the Ontario and Erie basins toward the Mississippi in Tertiary times seems, however, to be a good working hypothesis.

GILBERT, G. K. *Summary History of Niagara Falls.* Published with topographic map of Niagara, U. S. Geol. Survey, 1901; reprinted in Am. Geol., Vol. XXVII, pp. 375–77, 1901.

As the title implies, the several events in the history of this region are briefly outlined. The St. David's channel is referred to without question as an interglacial gorge, and it is also stated that there were two times when the upper Great Lakes discharged by other lines than the Niagara River for periods of considerable length. These diversions make it necessary to lengthen the estimates of time required to excavate the gorge beyond that necessary for a continuous stream of the present capacity.

It is considered a matter of doubt whether the time is expressible in tens of thousands or in hundreds of thousands of years.

HITCHCOCK, C. H. *The Story of Niagara.* Am. Antiquarian, Jan., 1901.

The geological history is reviewed and the leading views concerning the falls themselves are briefly presented. It is estimated that the time since water began falling over the Niagara escarpment is 18,918 years, distributed as follows: Erosion of lower gorge below the cove, 6,844 years; erosion of the cove section, 937 years; erosion of the gorge of the whirlpool rapids, 7,800 years; erosion from the railroad bridges to the existing cataract, 2,962 years. In addition to this 475 years is estimated for the wearing out of the whirlpool basin.

MARTIN, J. O. *The Ontario Coast between Fairhaven and Sodus Bays, New York.* Am. Geol., Vol. XXVII, pp. 331–334, with map, 1901.

Describes the encroachment of the shore of Lake Ontario upon the drumlins and the building of beaches between the drumlins with materials cut from them. The shore has advanced at least one-fourth to one-half mile since the lake has had its present level, and the rate of cutting varies from a few inches to ten feet a year.

OGILVIE, I. H. *Glacial Phenomena in the Adirondacks and the Champlain Valley.* Jour. Geol., Vol. X, pp. 397–412, with map, 1902.

Striæ indicate that the Champlain–Hudson valley ice-lobe spread southwestward into the Adirondacks, and there appears to be no change in direction resulting from differences in altitude. There was very little scouring by the ice in the valleys of the interior of the Adirondacks. Variations in the glaciation are separable into three zones: (1) a zone of abundant striation, though variable bearing, along the Cham plain valley; (2) a zone along the gneissic hills in which striæ are not numerous, but are uniform in bearing (northeast–southwest); (3) a zone among the high anorthosite peaks where striæ are lacking, but the mountain tops are smooth.

The glacial deposits are largely of stratified material. A glacial lake which occupied the Champlain valley has its shores marked by large delta accumulations at each of several lake levels. This glacial lake was followed by an incursion of the sea, which brought in a marine fauna.

There appears to have been a glacial gathering ground in the interior of the Adirondacks late in the Glacial epoch, and its local glaciers built up small moraines across a few valleys.

The drainage lines were begun far back in geologic time. The lakes are generally partially filled preglacial valleys, broadened perhaps by ice action.

SALISBURY, R. D. *New York City Folio, Pleistocene Formations.* Geol. Atlas of the United States, U. S. Geol. Survey, Folio No. 83, pp. 11–17, 1902.

The four fifteen-minute quadrangles in the New York City Folio are covered by glacial deposits and glacial outwash except a small driftless tract of scarcely one square mile near New Dorp on Staten Island. On this driftless tract is a gravel deposit of late Pliocene or early Pleistocene age which is referred to the Beacon Hill or Bridgeton formation. Gravel of the Pensauken formation is exposed under glacial deposits in clay pits around Kreisherville, Staten Island, and by the waves in the cliff at Princess Bay Light. The Pensauken is thought to be no older than some of the glacial deposits, though not of glacial origin.

The growth of the ice-sheet, the recurrent glaciations, and the characteristics of glacial drift are briefly discussed before taking up the features and deposits found within the New York area. The topography, topographic relations, and composition of the moraine on Staten and Long Island, the stratified drift south of the moraine, and the ground moraine to the north, are discussed in some detail, after which striæ, mixed drift, and stratified drift north of the moraine are considered, and attention is called to a surface loam, which, it is thought, may have originated in several different ways. Gravel near Rockaway on Long Island, though nonglacial, is thought to be of late Glacial age or even younger, and is correlated with the Cape May formation. The oscillation of the land, stream erosion, shore erosion, and weathering in postglacial time are then considered. The evidence concerning land oscillation is found to be indecisive. The slight amount of weathering of the drift surface, of stream erosion, and shore erosion testify to the briefness of the postglacial epoch.

STEVENSON, A. E. *Glacial Action in Schoharie Valley.* Ann. N. Y. Acad. Sci., Vol. X, 1901.

Not examined.

UPHAM, WARREN. *Preglacial Erosion in the Course of the Niagara Gorge and its Relation to Estimates of Postglacial Time.* Am. Geol., Vol. XXVIII, pp. 235–44, 1901.

The St. David's channel is thought to be preglacial rather than interglacial, because of its wide mouth. Fish Creek, a small eastern tributary of the Niagara, entering just south of the Niagara Escarpment, is thought to be occupying a preglacial valley which continued in the course of the Niagara River (reversed) to connect with the St. David's channel at the whirlpool. This would render but a small amount of rock excavation necessary in opening a part of the gorge below the whirlpool, and would materially affect estimates of the length of postglacial time. On the assumption that much of the northward differential uplift followed very closely upon the ice retreat (an assumption which Fairchild's observations at the east end of Lake Ontario show to be unfounded for that region) Upham concludes that the three upper lakes could not have discharged through either the Trent or the Mattawa valley, and considers the erosion of the Niagara gorge the work of a stream whose volume never was much less than the present and for the early part of the erosion was much greater. From this it is reasoned that postglacial time has been very brief, 7,000 years being considered ample for that part of it involved in cutting the Niagara gorge.

WOODWORTH, J. B. *Pleistocene Geology of Portions of Nassau and Queens Counties, New York.* Bul. 48, N. Y. State Museum, pp. 53, 1901.

This bulletin is the first of a series which is planned for the discussion of the Pleistocene geology of the eastern part of New York. It embraces a discussion of topographic features, glacial deposits, Pleistocene history, and postglacial changes and processes now in action, but deals mainly with the Pleistocene deposits.

The topographic features embrace a morainic system with two ridges separated by a sand plain, and south of this morainic system an extensive outwash plain sloping from a morainic border to the sea. North of the morainic system is a tract of uneven drift, coated generally by till, but having thick deposits of sand and gravel underneath the till.

The glacial deposits exhibit three marked phases of Pleistocene history: (1) a group of old gravels and sands with an intercalated till bed, the group considered to be the equivalent of the Columbia formation of the Atlantic coastal plain; (2) a deglaciation interval with marked erosion; (3) the moraines and their attendant stratified gravels and sands of Wisconsin age forming the topographic details of the surface.

No decisive local evidence was found concerning the relation of land to sea-level during the deposition of the old gravels and sands, but subsequent to deposition they appear to have been channeled by open-air streams. In the subsequent ice advance the land appears to have been as high as now, if not higher. During the retreat of the ice temporary lakes existed back of the moraine, one of which stood at 80 feet above sea-level, and its successor at a lower level. Possibly the lower body was at sea-level. Glacial action ceased with the retreat of the ice across East River. The streams on the outwash plain south of the moraine flow in courses which appear to have been carved by the more vigorous glacial streams, while those on the north slopes are, in some cases, apparently in partially filled interglacial channels. Modern marine action has encroached on the south edge of the outwash plain and thrown bars of sand and gravel across the old glacial stream channels. There are two lines of evidence pointing to a sinking of the coast in recent time, one being the occurrence of peat beds below present sea-level, the other the absence of wave cutting at present sea-level on points which stand back of the recently formed barrier beaches.

WRIGHT, G. F. *The Rate of Lateral Erosion at Niagara.* Am. Geol., Vol. XXIX, pp. 140–43, Pls. 6–8, 1902.

Measurements of the amount of crumbling and recession of the shale portion of an unprotected part of the wall of the Niagara gorge from 1854–1898 indicate a marked change, the average of fifteen measurements in the Clinton Shale showing extreme erosion of 3 inches per year, and the average of eleven measurements in the Niagara Shale 3¼ inches per year. Taking the entire exposed face into consideration, the average rate for the Clinton and Niagara shales is estimated to be 1½ inches per year. As these are unprotected by talus or vegetation, the allowance of such protection was estimated, and is thought to possibly reduce the rate of recession of the walls of the gorge to one-seventh that of an unprotected slope, but not more. This would give one-fourth inch per year, which is all that would be necessary to accomplish the actual enlargement of the mouth of the Niagara gorge in 10,000 years, and that is what the author set out to demonstrate by these measurements.

NEW JERSEY.

SALISBURY, R. D. *The Glacial Geology of New Jersey.* Final Report of State Geologist, Vol. V, xxiii, 802 pp., 66 Pls., and 102 figs. in the text, Trenton, 1902.

The volume consists of two parts, a general discussion and a discussion of the local details. In the general discussion the glacial formations and questions pertaining to glaciation are taken up. It differs from the author's papers already published in the JOURNAL OF GEOLOGY in containing numerous references to the glacial deposits of New Jersey. It is such a presentation of glacial geology as will be of much use in class work in universities and colleges, and at the same time is of interest and easy comprehension to the general reader. The reviewer hesitates to refer to certain misleading statements (which appear on pp. 183–86) in a work which otherwise is so accurate and comprehensive. The Iowan drift is but little more weathered and eroded than the Wisconsin, and cannot be separated from it by the long interval mentioned in this report. The Illinoian drift-sheet which in this report is doubtfully admitted to rank with the Kansan, Iowan, and Wisconsin, really marks the culmination of the Labrador ice-field, and is no more due to a local advance than is the Kansan drift-sheet which marks the culmination of the Keewatin icefield.

The discussion of local details opens with a description of the terminal moraine of the Wisconsin drift-sheet throughout its course across New Jersey, after which are considered in turn the drift of the Appalachian province, of the Highlands, and of the Triassic plain, in each of the several phases which are exhibited. Recessional moraines were traced for short distances in the Appalachian province and in the Triassic plain, but the tracing was not carried far enough to bring out, as has been done in states west of the Appalachians, the successive positions of the ice-border in its retreat. It appears from the scant notice given these later moraines that they constitute very inconspicuous features. After discussing the drift north of the terminal moraine, the stratified drift of late glacial or Wisconsin age lying south of the moraine is considered. It includes not only valley gravel and overwash gravel plains, but also lacustrine clays and silts, subaqueous overwash, kames, and certain deposits attributed to icebergs.

An old sheet of extra morainic drift, which has been described somewhat fully in the *Reports of Progress* for 1892 and 1893, is briefly considered in this final report. It is found to be discontinuous or patchy, and in this respect is strikingly in contrast with the drift-sheet north of the moraine. It is estimated that about four-fifths of the surface north of the moraine is deeply covered with drift, while about the same proportion south of the moraine is nearly destitute of drift. In lithological make-up the extramorainic drift is not greatly different from the drift in and north of the moraine. But much of it is more highly oxidized and weathered than the moraine and drift-sheet to the north. It is thought that the most highly weathered drift is at least as old as the Kansan drift of the western states.

MARYLAND.

SHATTUCK, GEORGE B. *The Pleistocene Problem of the North Atlantic Coastal Plain.* Johns Hopkins Circulars No. 152, May, 1901; also Am. Geol., Vol. XXVIII, pp. 87–107, 1901.

Results of studies by McGee, Darton, and Salisbury are reviewed and attention called to lack of harmony in the interpretations, and to changing views that have been advanced. The author fails to find evidence of such complexity as his predecessors have discovered, and considers the simple interpretation of marine action at different levels sufficient to account for all the phenomena. Certain features which one of his predecessors had interpreted to be unconformities pointing to a period of elevation and subaerial erosion the author thinks to be due to slight changes in current or freshet conditions differing in no way from the ordinary cross-bedded structure. An excursion into New Jersey confirmed the author in his view that the simple interpretation of marine action furnishes as complete a solution there as in Maryland, and he expects this interpretation ultimately to find application over much of the Atlantic coastal plain.

WEST VIRGINIA.

CAMPBELL, M. R. *The Huntington Folio.* Geol. Atlas of the United States, U. S. Geol. Survey, Folio 69, 1901.

Drainage and Pleistocene deposits are the topics pertinent to this review. The Huntington Quadrangle includes several streams with an unsymmetrical arrangement in their respective basins, which is explained by tilting. This quadrangle includes also a part of the well-known Teazes or Teays valley, the former course of Big Kanawha River. The diversion of the river into its present course is referred to an ice-gorge near Milton, and so is the heavy accumulation of silt in the abandoned valley, which is here given the name Teay formation. The gorging is thought to have been accomplished by river ice concurrent with the culmination of glaciation in the adjacent part of the glaciated region. The same ice gorge is thought to have caused Hurricane Creek to continue northward past Teays valley in a course parallel with that of the diverted Kanawha. An ice-gorge on Guyandotte River near the Lincoln-Wayne county line is thought to have diverted the stream to a course a short distance east of the old one. This river sustained another diversion near its mouth in passing across Teays valley, which, however, is not mentioned. In support of the view that these diversions were caused by ice-gorges, the smaller amount of silt below the site of the supposed gorging in Teays valley is brought forward. The reviewer, however, doubts whether there was a smaller deposition in this valley below the site of the supposed gorge than above. There is still a heavy deposit in part of this lower course near where the Guyandotte River has been diverted, and Mud River has apparently removed much of the silt between there and Milton. The value and applicability of this new hypothesis remains to be determined. In Monograph XLI, *U. S. Geological Survey* (pp. 105, 106), the reviewer called attention to the fact that the silting was sufficient to build the valley up to a level as high as low cols in the district north of it, thus making it possible for a stream to take a new course without having to open a channel.

The Teay formation or silt deposit which graded up the old course of the Big Kanawha is a fine deposit overlying coarse material such as commonly characterizes river beds. It has a depth of about sixty feet where best preserved from erosion, as is the case near Hurricane village.

New Ichthyosauria from the Upper Triassic of California. By J. C. MERRIAM. University of California Publications, Bulletin of the Department of Geology, Vol. III (1903), pp. 249–63, Plates XXI–XXIV.

THE interesting discoveries made by Dr. Merriam, during the past few years, of many new and strange forms of Ichthyosauria from the Californian Triassic have added much to our previous knowledge of this remarkable order of reptiles. To the six species of *Shastosaurus* previously described by the author two new genera, *Leptocheirus* and *Torotecnemus*, are added in the present paper. The limbs in these forms are of strangely primitive structure, in some respects. The propodial and epipodial bones are elongated, and there are but three digits, with a rudimentary or vestigial fourth. The hind limbs are also larger than the fore limbs, in some at least; and the ribs of the dorsal region in some of the species are single-headed. The author promises us the description and illustration of still other and divergent forms soon, and, from the thoroughness with which he is studying his abundant material, we may confidently expect much new light upon the history of this strange, and in many respects puzzling, order of reptiles.

S. W. W.

On the Skull of a True Lizard (Paliguana Whitei) from the Triassic of South Africa. By R. Broom. Records of the Albany Museum, Vol. I, p. 1.

Hitherto the mesozoic history of the Squamata, aside from the Dolichosauria and Mosasauria, has been very scanty indeed. The discovery by Broom of what is undoubtedly a real lacertilian from the Triassic is, therefore, of more than passing geological interest. The author believes that its relationships are close with the American Iguanas. The teeth are apparently pleurodont, the quadrate is free, and the upper temporal arch has the disassociated elements of the lacertilia. With this addition to the Triassic fauna, all the known orders of reptiles are now represented in this formation, as also the mammals.

S. W. W.

Recent Publications.

—Adams, George I. Stratigraphic Relations of the Red Beds to the Carboniferous and Permian in Northern Texas. [Bull. Geol. Soc. of Am., Vol. XIV, pp. 191–200; Rochester, May, 1903.]

—Bell, Alexander Graham. The Tetrahedral Principle in Kite Structure. [Reprinted from the National Geogr. Mag., June, 1903.]

—Biddle, H. C. The Determination of Molecular Weights. [Reprinted from Amer. Chem. Jour., Vol. XXIX, No. 4, April, 1903.]

—Coste, Eugene. The Volcanic Origin of Natural Gas and Petroleum. [Paper read at annual meeting of Canadian Mining Institute, Montreal, March 4 and 5, 1903; Ottawa, 1903.]

—Davis, W. M. An Excursion to the Plateau Province of Utah and Arizona. [Bull. of the Mus. of Comp. Zoöl., Harvard College, Vol. XLII; Cambridge, June, 1903.]

—Diller, J. C. Klamath Mountain Section of California. [Am. Jour. of Sci., Vol. XV, May, 1903.]

—Fuller, M. L., and Clapp, F. G. Marl-Loess of the Lower Wabash Valley. [Bull. G. S. A., Vol. XIV, pp. 153–76; Rochester, April, 1903.]

—Grant, Ulysses S. Preliminary Report of the Lead and Zinc Deposits of Southeastern Wisconsin. [Wis. Geol. and Nat. Hist. Surv., Bull. IX, Economic Ser. No. 5; Madison, 1903.]

—Hobbs, William Herbert. Meteorite from Algoma, Wisconsin. [Bull. Geol. Soc. of Am., Vol. XIV, pp. 97–116; Rochester, April, 1903.]

—Kindle, Edward M. The Niagara Domes of Northern Indiana. [Am. Jour. of Sci., Vol. XV, June, 1903.]

—Kotô, B., and Kanazawa, S. A Catalogue of the Romanized Geographical Names of Korea. [Imperial Univ. of Tōkyō, Japan, 1903.]

—Lee, Willis T. The Canyons of Northeastern New Mexico. [Reprinted from Jour. of Geogr., Vol. II, No. 2, February, 1903.]

—Ordóñez, Ezequiel. El Sahcab de Yucatan. [Imprinta de le Gobierno Federal en el ex-Arzobispado; Mexico, 1903.]

——— Le Xinautecatl ou Volcon Nevado de Toluca. [Imprimerie du Gouvernement Fédéral, Mexico, 1903.]

—PENHALLOW, D. P. Notes on Cretaceous and Tertiary Plants of Canada. [From Trans. of Roy. Soc. of Canada, Sec. Ser., Vol. VIII, Sect. IV, 1902–3; Ottawa: J. Hope & Sons.]

——— Osmundites Skidegatensis. [From Trans. of Roy. Soc. of Canada, Sec. Ser., Vol. VIII, Sect. IV, 1902–3; Ottawa: J. Hope & Sons.]

—RUSSELL, ISRAEL C. The Topographic Survey of Michigan. An address before the Michigan Academy of Science at ninth annual meeting. [Reprinted, Ann Arbor, March 30, 1903.]

—SCHUCHERT, CHARLES. On the Manlius Formation of New York. [From American Geologist, March, 1903.]

——— Morse on Living Brachiopods. [American Geologist, February, 1903.]

——— The I. H. Harris Collection of Invertebrate Fossils in the United States National Museum. [American Geologist, March, 1903.]

—SPENCER, ARTHUR C. Pacific Mountain System in British Columbia and Alaska. [Bull. Geol. Soc. of Am., Vol. XIV, pp. 117–32; Rochester, 1903.]

—WEED, WALTER HARVEY. Copper Deposits of New Jersey. [Reprinted Ann. Rept. of State Geologist for 1902; Trenton, N. J.: John L. Murray Publishing Co.

——— Ore-deposition and Vein-enrichment by Ascending Hot Waters. A paper read before the Am. Inst. of Min. Eng. at New Haven, October, 1902. [Author's edition, 1903.]

—WILLIAMS, HENRY SHALER. Shifting of Faunas as a Problem of Stratigraphic Geology. [Bull. Geol. Soc. of Am., Vol. XIV, pp. 177–90; Rochester, April, 1903.]

—WILLIS, BAILEY. Ames Knob, North Haven, Maine. [Bull. Geol. Soc. of Am., pp. 201–6; Rochester, May, 1903.]

—WINCHELL, N. H. Was Man in America in the Glacial Period? [Bull. Geol. Soc. of Am., Vol. XIV, pp. 133–52; Rochester, April, 1903.]

THE

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THE NOMENCLATURE OF THE OHIO GEOLOGICAL FORMATIONS.[1]

INTRODUCTION.

THE great advance in stratigraphical geology during the last fifteen years, together with the more precise and accurate description of geological formations, will lead, in most states, to a revision of the geological scale. The effect of this advance in the science was shown in New York, the classic state in American geology, when four years ago Dr. J. M. Clarke and Mr. Charles Schuchert published a revised classification of the geological formations of that state.[2] Most of the changes proposed by these distinguished authors have been accepted by working geologists and are now becoming a part of American geology.

At about the same time the writer began an investigation of the Ohio formations, but the work has not yet reached the desired completeness and accuracy; and, as will be seen by reference to the geological scale, in the case of certain formations a definite classification cannot be proposed until the information is more complete.

The advance in our knowledge of the stratigraphical geology of the state, together with the introduction of a considerable number of new names for different formations and the approach-

[1] This article has been read by Professor Edward Orton, Jr., state geologist of Ohio, and it is published with his permission.

[2] *Science*, N. S., Vol. X (December 15, 1899), pp. 874–78. The article was reprinted in the *American Geologist*, Vol. XXV (February, 1900), pp. 114–20.

ing publication of reports by the Ohio Geological Survey, led the state geologist, Professor Edward Orton, Jr., to request a revision of the geological scale of the state for these reports. In compliance with the above request, the following scale has been prepared, which in its preliminary form is now submitted for discussion. The writer will be pleased if geologists familiar with the Ohio formations will communicate to him their opinions in regard to this classification or any part of it. Such communications will be retained, duly considered, and credited in an extended discussion of this subject which the writer has in preparation.

GEOLOGICAL SCALE OF OHIO.

System.	No.	Formation.	Thickness.
Quaternary.	26	Alluvium. Glacial lake beds.[1] Wisconsin drift - - - Chamberlin '95 Peorian soil - - - - - - Leverett '98 Silt or Iowan drift (?) - - Chamberlin '95 Sangamon soil - - - - - Leverett '98 Illinoian drift - - - - - - Leverett '97	0–550′ [2]
Permian[3] (?)	25	Dunkard formation[4] - - - I. C. White '91 (Upper Barren Coal-measures).	525′ ±
Carboniferous.	24	Waynesburg Coal, No. 11.[5] Monongahela formation - - H. D. Rogers '40 (Upper Productive Coal-measures). Pittsburg coal, No. 8.	200–250′
	23	Conemaugh formation[6] - - - F. Platt '75 (Lower Barren Coal-measures).	400–500′
	22	Upper Freeport coal, No. 7. Allegheny formation - - H. D. Rogers '40 (Lower Productive Coal-measures).[7]	165–300′
	21	Pottsville formation,[8] Lesley '77 { ———————[9] Sharon conglomerate,[10] I. C. White '79 (?)	250′ ±
	20	Maxville limestone - - - Andrews '70	25′ ±
	19	Logan formation - - - - Andrews '70	100–150′
	18	Black Hand formation - - - - Hicks '78	50–500′
	17	Cuyahoga formation[11] - - - Newberry '70	150–300′
	16	Sunbury shale - - - - - Hicks '78	5–30′
	15	Berea grit - - - - - Newberry '70	10–135′
..(13)..	14	Bedford shale[12] - - - - Newberry '70	50–150′

GEOLOGICAL SCALE OF OHIO.—*Continued.*

SYSTEM.	NO.	FORMATION.	THICKNESS.
DEVONIAN.	13	*Southern and Central Ohio.* Ohio shale,[14] Andrews '70 *Northern Ohio.* Cleveland shale, Newberry '70 Chagrin formation,[15] Prosser Huron shale,[16] Newberry '70	300–2600′
	12	Olentangy shale - - - N. H. Winchell '74	20–35′
	11	Sandusky limestone[17] - - - Newberry '73	30′
	10	Columbus limestone[18] - - Newberry '73	110′
UPPER SILURIAN.	9	Monroe formation,[19] Lane '93 *Northwestern Ohio.* The formation is composed of the three following members in this part of the state : Lucus limestone,[20] Prosser Sylvania sandstone, Orton, '88 Tymochtee member (?) N. H. Winchell '73	50–600′
	8	*Northern Ohio.* "Niagara group,"[21] Vanuxem '42 *Southern Ohio.* Hillsboro sandstone,[22] Orton '71 Cedarville limestone, Orton '71 Springfield limestone, Orton '71 West Union limestone, Orton '71 Osgood beds,[23] Foerste, '97 Dayton limestone.	150–350′
	7	Clinton limestone - - - - Vanuxem '42	10–50′
	6	*Northern Ohio.* Medina shales (?),[24] Vanuxem '42 *Southern Ohio.* Belfast bed,[25] Foerste '96	Wells give 50–150′ Belfast 5′
...(26)..			
LOWER SILURIAN.[27]	5	Saluda bed[28] - - - - - Foerste '02	20′ ±
	4	Richmond formation,[29] - - - N. H. Winchell and E. O. Ulrich '97	300′ ±
	3	Lorraine formation - - - Emmons '42	300′
	2	Utica shale - - - - - Emmons '42	250′
	1	Trenton limestone[30] - - - Vanuxem '40	130′

NOTES ON THE GEOLOGICAL SCALE OF OHIO.

1. The glacial formations of Ohio have recently been very fully described by Mr. Frank Leverett, to which account the readers interested in these deposits are referred.[1]

2. The thickness assigned to the various formations is frequently that given in the last volumes of the Geological Survey of Ohio or other late reports of Dr. Orton. Changes have been made in stating the thickness of certain formations based upon data secured by the writer or upon trustworthy statements of other authors. The thickness, however, of most of the formations differs so greatly in different sections that it is almost impossible to make general statements which will apply throughout the state. This variation is often indicated by giving the thickness as ranging *from* and *to* a certain number; as, for example, the glacial drift is given as from 0 to 550 feet in thickness.

3. In 1880 Professors William M. Fontaine and I. C. White described the flora of the Upper Barren Coal-measures of West Virginia and southwestern Pennsylvania, and stated:

> To sum up finally the evidence derived from all sources, we find ourselves irresistibly impelled to the conclusion, that the . . . . Upper Barrens of the Appalachian Coal Fields are of Permian age.[2]

The fauna of these rocks is very small and does not afford any conclusive evidence as to their age, but the flora has recently been re-examined by Dr. David White, who corroborates the earlier conclusions of Fontaine and I. C. White. Dr. David White writes:

> Recent collecting materially increases the Permian evidence, and seems to leave little room for doubt that the beds in and above the Washington limestone are referable to the Lower Rothliegende of western Europe. The data so far obtained from the lower beds of the Dunkard are, in the judgment of the writer, not yet conclusive as to Permian age.[3]

The Rothliegende is the older division of the Permian of western Europe, which is found typically in Germany. The lower Washington limestone occurs in the lower part of the Dunkard formation and at the typical locality at Washington in

[1] U. S. Geol. Surv., *Monograph XLI*, *1902*.

[2] *Second Geol. Surv. Pa.*, PP., p. 119.

[3] *Science*, N. S., Vol. XVII (February 20, 1903), p. 298.

southwestern Pennsylvania, 117 feet above the top of the Waynesburg coal or base of the Dunkard formation. A number of the European geologists have accepted Permian as the age of the Dunkard formation, and Dr. Frech states that the Dunkard Creek beds and Cassville plant shale, the latter of which is the shale at the base of the Dunkard formation immediately overlying the Waynesburg coal, are the equivalent of the Kusel stage, which is the oldest formation of the Lower Rothliegende of Germany. And in another sentence is the statement that the petrographical and paleontological similarity of the Dunkard with the Rothliegende of western Europe is therefore beyond doubt.[1]

4. The formation was named the "Dunkard Creek series" on account of the fine exposures found for thirty miles along the banks and bluffs of this stream, which flows along the West Virginia-Pennsylvania line;[2] later, with Dr. White's sanction, the name was shortened to the "Dunkard formation," thus bringing it in harmony with the terms now usually selected for the names of formations.[3] On the scale below the accepted name for this formation is given in parenthesis "Upper Barren Coal-measures," the name which has generally been used for this formation in the Ohio reports. The corresponding name which has been used in the Ohio reports for the three succeeding formations is given in the same manner.

5. The top of the Waynesburg coal, or its horizon, and the base of the Pittsburg coal mark the top and bottom of the Monongahela formation.

6. Franklin Platt applied this name to the "Middle Barren Measures" and "Mahoning sandstone" in his "Column of Palæozoic formations," but failed to define it more precisely.[4] Later the name was defined and used for this formation in Maryland.[5]

[1] *Lethaea geognostica*, Th. I; *Lethaea palaeozoica*, Bd. II, Lief. 3 (1901), p. 546.

[2] *Bull. U. S. Geol. Surv.*, No. 65, pp. 19, 20.

[3] O'Harra, *Maryland Geol. Surv., Allegany County*, 1900, pp. 86, 128; and Prosser, Jour. Geol., Vol. IX (1901), p. 428.

[4] *Second Geol. Surv. of Pa.*, H, p. 8.

[5] O'Harra, *Maryland Geol. Surv., Allegany County*, 1900, pp. 86, 118; and Prosser, Jour. Geol., Vol. IX (1901), p. 426.

The "Conemaugh formation" includes all the rocks between the base of the Pittsburg coal and the top of the Upper Freeport coal. On the Huntington folio of the *Geologic Atlas of the United States*, Mr. Campbell has referred between 200 and 300 feet of conglomeratic rocks succeeding the Kanawha black flint to the "Charlestone sandstone,"[1] which was named by Campbell and Mendenhall in 1896 from exposures near Charleston, W. Va.[2] and probably represents about the lower third of the Conemaugh formation. The succeeding 800 feet of shales and sandstones of the Huntington quadrangle are correlated with the "Braxton formation" by Mr. Campbell and represented as covering all that portion of southern Lawrence county, O., to the east of Ironton, which is represented on this quadrangle. This formation, as described in this folio, probably includes about the upper two-thirds of the Conemaugh and the lower part of the Monongahela formation. It was named in 1896 by Taff and Brooks from exposures in Braxton county in central West Virginia.[3]

7. Drs. Orton and I. C. White practically agreed in tracing the Lower Coal-measures or Allegheny formation from the Ohio-Pennsylvania state line across the state to the Ohio River.[4] On the Huntington folio, West Virginia-Ohio, of the *Geologic Atlas of the United States*, Mr. Campbell used the name "Kanawha formation" for the rocks considered of this general age which occur on the southern part of the sheet.[5] The formation was described by Campbell and Mendenhall in 1896;[6] but it is probably somewhat greater than the Allegheny formation, since it includes the rocks from the top of the Pottsville to the horizon of the Kanawha black flint, which is given by Campbell as 30 or 40 feet above the horizon which Dr. I. C. White considered as the top of the Allegheny formation.[7]

[1] No. 69, p. 4, and sheets.

[2] U. S. Geol. Surv., *Seventeenth Ann. Rept.*, Part II, p. 508.

[3] *Geologic Atlas of the United States*, Buckhannon folio, No. 34, p. 2, and sheets.

[4] Orton, *Rept. Geol. Surv. Ohio*, Vol. V, pp. 1–128, and Vol. VII, pp. 276–82; I. C. White, Bull. U. S. Geol. Surv., No. 65, pp. 130–36.

[5] Folio 69, 1900, p. 4 and sheets.

[6] U. S. Geol. Surv., *Seventeenth Ann. Rept.*, Part II, p. 499.

[7] *Ibid.*, p. 4.

The name was apparently preoccupied, however, when used by Campbell and Mendenhall, for in 1877 Franklin Platt, in his classification of the rocks that would be penetrated by a well ten miles in depth near Waynesburg in southwestern Pennsylvania, proposed the name "Kenawha (as he spelled it) river system," from the river of that name in West Virginia, division *b* of which he called the "Kenawha Coal-measures."[1] The Pottsville conglomerate formed the upper part of the Kenawha river system and the Mountain limestone its base, so that the rocks were all older and below the Kanawha formation of Campbell and Mendenhall. In case it is held that Platt did not define this division with accuracy, and that the Kanawha formation of Campbell and Mendenhall ought to be accepted by prescription, then it is to be remembered that the name "Kanawha black flint" was definitely applied by Dr. I. C. White to a subdivision of the Barren Measures, or Elk River series, in 1891.[2]

In reference to the correlation of the Kanawha and Allegheny formations, it may be said that Dr. David White has studied the flora of the Kanawha formation in its typical region, and claims that the lower portion is older than the Allegheny formation;[3] while the flora of its upper part is "probably not higher than the Clarion group in the Allegheny series."[4] The horizon of the Upper Freeport coal, the top of the Allegheny formation, is indicated as between 200 and 300 feet above the Kanawha black flint.[5]

This paper has been very positively answered by Dr. I. C. White, who says:

During the present year (1901) I have attacked the problem in question by direct tracing of the Upper Freeport coal and its associated strata from the Pennsylvania line along their eastern outcrops across to the Kanawha valley. In this I was entirely successful, and the result is a complete confirmation of my original conclusion with reference to the horizon of the Upper Freeport coal on the Great Kanawha, namely, that it is the first one below the black-flint stratum, and hence this latter member belongs near the *base of the*

[1] *Second Geol. Surv. of Pa.*, H[2], pp. xxiv–xxvii.

[2] *Bull. U. S. Geol. Surv.*, No. 65, p. 98.

[3] *Bull. Geol. Soc. Amer.*, Vol. XI (1900), pp. 165–67.

[4] *Ibid.*, p. 170. [5] *Ibid.*, pp. 173, 178.

Conemaugh formation, or just above the *top* of the Allegheny, where my studies in 1884 first placed it, instead of near the *base of the Allegheny*, to which position Dr. David White has assigned it on the basis of fossil plants[1]

Dr. I. C. White also states in this paper that in the red-shale belt of the Conemaugh formation

occurs an important fossiliferous limestone horizon, the "green Crinoidal limestone" of the Pennsylvania series, which has been traced from central West Virginia northward to the Pennsylvania line and through southwestern Pennsylvania into Ohio [where it is known as the Ames limestone] and across that state without a break to where it re-enters West Virginia again at Huntington.[2]

And finally he states that "the Pittsburg coal is found in the summits of the hills only two miles north from Charleston," W. Va.[3]

Recently Dr. David White is reported to have said that:

The further study of the floras indicates not merely that the middle of the formation [Kanawha] may be of Mercer age, but that beds up to within 125 feet of the "Black Flint" are clearly referable to the latter group, while the basal Allegheny time boundary is probably very much nearer the level of the Black Flint."[4]

For a further discussion of this subject, by Dr. I. C. White, especially regarding the horizon of the Kanawha black flint, see the W. Va. Geol. Surv., Vol. II, July, 1903, p. 501 and other pages.

For an explanation of the adoption of "Dunkard," "Monongahela," "Conemaugh," and "Allegheny" as formation names in Ohio, see a former paper by the present writer.[5]

Dr. I. C. White prefers to consider these terranes as series, and writes me as follows:

I think the term "series" better describes the different divisions of the Carboniferous system, like Dunkard, Monongahela, Conemaugh, Allegheny, Pottsville, etc., and have so used it in my coal volume.[6]

8. So far as the writer is aware, the name "Pottsville conglomerate" did not first appear over the name of Professor

[1] *Ibid.*, Vol. XIII (1902), p. 122. [2] *Ibid.*, p. 123. [3] *Ibid.*, p. 124.

[4] MENDENHALL's Report of the 144th Meeting of the Geological Society of Washington, *Science*, N. S., Vol. XVII (June 12, 1903), p. 942.

[5] *Am. Jour. Sci.*, 4th ser., Vol. XI (1901), pp. 191–200 and in particular p. 199.

[6] Letter of April 2, 1903.

Lesley, but on its first publication in 1877 it is distinctly stated by both Ashburner[1] and Franklin Platt[2] that it is "proposed by the present State Geologist of Pennsylvania," and the following year Professor Stevenson mentioned Professor Lesley's name in crediting the authorship of the formation.[3] In the Ohio reports this formation has generally been termed the "Conglomerate group," although Dr. I. C. White as early as 1881 applied the name "Pottsville conglomerate" to the continuation of these rocks across the state line in Crawford county, Pennsylvania. Certain geologists, however, have thought that these rocks of Ohio and western Pennsylvania represented a longer time interval than the typical Pottsville conglomerate of eastern Pennsylvania, and hence it has appeared doubtful whether the name "Pottsville" should be applied to the Ohio formation. At the base of the formation in northern Ohio is a conglomerate or coarse grained sandstone which has generally been called the "Sharon conglomerate," and is perhaps equivalent to the Olean conglomerate of southwestern New York. Regarding the stratigraphic position of this latter conglomerate Dr. J. M. Clarke has written me as follows:

> It may interest you to know with regard to the Carboniferous horizons that . . . . Messrs. David White and Campbell have been over the field in Cattaraugus county, and they have convinced themselves that there is no longer any question of the Pottsville age of the Olean. This determination seems to be based largely on the evidence of fossil plants.[4]

This conclusion agrees with the statement of Mr. M. R. Campbell, apparently based upon the investigations of Dr. David White, regarding the age of the Sharon conglomerate of western Pennsylvania. Mr. Campbell says:

> From the evidence afforded by fossil plants, Mr. White proves conclusively that about the beginning of the Pottsville epoch an uplift occurred, which affected much of the Mississippi Valley. A large land area was formed that extended as far east as the Broad Top Basin and the Northern Anthracite field. This land area persisted until at least 600 feet of Pottsville sediments were deposited in the southern Anthracite basin. A subsidence then occurred

[1] *Proc. Amer. Phil. Soc.*, Vol. XVI, p. 533.

[2] *Second Geol. Surv. Pa.*, H^2, p. xxvi.

[3] *Ibid.*, K^3, 1878, p. 12.

[4] Letter of April 30, 1903.

in the western part of the state, which allowed the Sharon conglomerate and its associated coal group to be deposited.[1]

Pottsville sandstone is used by Mr. Campbell as the name of the formation in the Masontown-Uniontown folio in southwestern Pennsylvania, and it now appears that there is sufficient evidence to warrant the application of the term Pottsville to the Ohio formation, as has been done by the United States Geological Survey.[2]

9. In the later reports of the Ohio Survey the following main divisions of the "Conglomerate group" were given as succeeding the Sharon conglomerate in the following order: Sharon coal, Lower and Upper Massillon sandstones, Lower and Upper Mercer groups, and Homewood sandstone, the last one named forming its upper part;[3] while in Pennsylvania, in Crawford county, along the Ohio line, Dr. I. C. White gave the Pottsville as composed in ascending order of the following divisions: Sharon, Conoquenessing, Mercer group, and Homewood sandstone. The Sharon Division consisted in ascending order of a conglomerate, Lower shales, Coal and Upper iron shales, and the Conoquenessing division of the Lower and Upper sandstones separated by the Quakertown beds.[4] Finally, in the Charleston, W. Va. folio, which is the next quadrangle east of the Huntington, Mr. Campbell has used the name "Sewell formation" for the rocks of Pottsville age shown in that area;[5] but it is not known how much of the "Conglomerate group" of Ohio is included in this formation. It was named in 1896 by Campbell and Mendenhall from the outcrops near Sewell on the New River in southern West Virginia.[6]

In northern and central Ohio it appears probable that the Pottsville formation will be divided into at least two members. The lower one is the conglomerate or coarse sandstone, generally

[1] *Geologic Atlas U. S.*, Masontown-Uniontown folio, No. 82, 1902, p. 7.

[2] *Twenty-second Ann. Rept.*, Part III (1902), Pl. XII.

[3] *Rept. Geol. Surv. Ohio*, Vol. VII (1895), p. 36.

[4] *Second Geol. Surv. Pa.*, Q^4, 1881, pp. 55 ff.

[5] *Geologic Atlas of the United States*, Folio 72, 1901, p. 4, and sheets.

[6] U. S. Geol. Surv., *Seventeenth Ann. Rept.*, Part II, p. 494.

termed the "Sharon conglomerate," which is a conspicuous lithologic division. At present we are not prepared to propose a classification for the remaining part of the formation.

10. In the later reports of the Ohio Survey this division is usually called the "Sharon conglomerate." Professor Lesley used the name "*Sharon conglomerate* (Ohio conglomerate)" in the list of geological divisions for Lawrence county, Pa.,[1] and on p. xxxiv he states that the Sharon conglomerate "is undoubtedly part (or the whole) of the *Ohio conglomerate*." Also on p. 296 is a brief description by Dr. I. C. White of the Sharon conglomerate as exposed near the town of that name. Of the two names used by Professor Lesley, "Ohio" was preoccupied, since Andrews used it in 1870 for the Ohio shale; and it is a question whether Sharon was available, since Professor H. D. Rogers in 1858 proposed the name "Sharon group" for the Sharon coal and associated rocks overlying this conglomerate, but apparently *not* including it,[2] and in 1877 Professor Stevenson followed Rogers in describing the Sharon coal group of western Pennsylvania.[3]

The "Olean conglomerate" was formally named and described by Ashburner in 1880 in his description of the geology of McKean county.[4] The above statement is corroborated by Professor Lesley, for he has stated that "The Olean conglomerate received its name during the survey of McKean county from the magnificent fragment of it at the rock city north of the state line, west of the town of Olean [N. Y.]."[5] The above, however, was not the first usage of the name "Olean" for this conglomerate, for Professor Lesley himself in 1875 used the term "Olean conglomerate (Garland)" in referring to this formation in northwestern Pennsylvania.[6] Later in the same report Mr. Carll used the name "Garland conglomerate" for the rocks

[1] *Second Geol. Surv. Pa.*, Q^2, 1879 (?), Preface, p. xxix.

[2] *Geol. of Pa.*, Vol. II, p. 489. [3] *Second Geol. Surv. Pa.*, K^2, p. 103.

[4] *Ibid.*, p. 56; and see "General Vertical Section of the Rocks of McKean County," on p. 43.

[5] *Ibid.*, "A Summary Description of the Geology of Pennsylvania," Vol. III, Part I, 1895, p. 1873.

[6] *Ibid.*, I, p. 38, footnote.

capping the hills in the vicinity of Garland, Warren county, Pa. (p. 45). I cannot say positively that the names "Olean" and "Garland conglomerate" made their initial appearance in geological literature in the above-quoted instances. In 1875, however, under the direction of Mr. Carll, a spirit-level line was run across northwestern Pennsylvania "for the purpose of connectedly tracing the several *outcrops of Garland conglomerate*, that they might thus be identified with cotemporaneous rocks in the state of New York on the one side and in the state of Ohio on the other."[1] As a result of this work, Mr. Carll stated that the Garland conglomerate "is apparently identical with the *Olean* conglomerate in McKean county; with the *Sharon conglomerate* in Mercer county; [and] with the *Ohio conglomerate* in Ohio,"[2] and the chapter is headed "The Garland (Olean or Sharon) Conglomerate."[3] In Carll's succeeding report he abandoned the use of "Garland conglomerate" in favor of "Olean conglomerate," and in explanation said:

In Report I, I[2], I[3], I have used the term *Garland conglomerate*. It is now demonstrated that my *Garland conglomerate* is the *Olean conglomerate* of Mr. Ashburner's report on McKean county, and I shall therefore use the latter term in this report.[4]

Professor H. S. Williams apparently considered the "Sharon conglomerate" in the Cuyahoga and Painesville sections as equivalent to the "Olean conglomerate," for in those sections it is lettered H, and in the paper is the statement that "H is the conglomerate (Olean and equivalent)."[5]

Finally, on the *Geologic Map of New York*, by Frederick J. H. Merrill, published in 1901 [1902], the "Olean conglomerate" appears as the name of this Carboniferous formation in southwestern New York. Regarding the identity of these two conglomerates, Dr. J. M. Clarke has written me as follows:

I have recently come into possession of an elaborate compilation of all the well sections in the region of McDonald, Pennsylvania, prepared by Mr. F.

[1] *Ibid.*, I[3], 1880, p. 11.

[2] *Ibid.*, p. 13.

[3] *Ibid.*, p. 11.

[4] *Ibid.*, I[4], 1883, p. 185, footnote.

[5] *Proc. A. A. A. S.*, Vol. XXXIV (1886), p. 225; and see "Meridional Sections of the Upper Devonian Deposits of New York, Pennsylvania, and Ohio."

H. Oliphant, wherein the Sharon conglomerate is made identical with the Olean.[1]

Dr. I. C. White would retain the name "Sharon" for this conglomerate, and has written me to this effect. He says:

> I do not think the use of "Sharon" for the *conglomerate* of that name is forbidden because it had previously been given to a *coal* bed, since the things are so unlike, ... I think "Sharon" conglomerate which applies only to a particular bed of the "Pottsville" series, should stand, and not be replaced by "Olean," since the term "Sharon" is older as applied to the stratum in question.[2]

Regarding the age of the Olean and the question of its correlation with the Sharon conglomerate Dr. David White has written as follows:

> The Olean is shown to be Pottsville. It contains sufficient Upper Carboniferous plants to prove it to be Pennsylvanian; but not enough to strictly define its age beyond Upper Pottsville. . . . . The correlation of Sharon and Olean is a working assumption based in part on circumstantial evidence, both formations being found in the same relation, beneath the thin sections of Pottsville, on the eroded Lower Carboniferous. I have no conclusive proof that they are equal and represent the same formation. And, since over part of the way between Sharon and Olean the Conoquenessing seems to rest directly on the Pocono, I personally favor the use of Sharon, in conformity with Dr. I. C. White's usage, until satisfactory proof of the identity of Olean and Sharon may be established.[3]

Therefore, since there is yet some doubt regarding the identity of the Olean and Sharon conglomerates, the latter name is retained for the present for this member of the Pottsville formation in Ohio.

11. Possibly later studies may decide that for eastern Ohio it will be better to drop the name "Cuyahoga formation" and use the classification of western Pennsylvania for the rocks between the top of the Berea grit and the base of the Sharon conglomerate, which in ascending order are Orangeville shale, Sharpsville sandstone, Meadville shales, and Shenango sandstone, all named and described by Dr. I. C. White in 1880, with the exception of the Meadville shales, which was published in 1881. Professor H. P. Cushing, however, writes me as follows regarding this matter:

[1] Letter of March 23, 1903. [2] Letter of April 2, 1903. [3] Letter of June 10, 1903.

I do not believe that the Pennsylvania subdivisions can be made out west of Ashtabula and Trumbull, or even that they are well marked on the highland west of the Grand River, in those counties. Here in Cuyahoga the shales between the Berea and the conglomerate show only a twofold lithological division, to the best of my knowledge, and the boundary occurs about half way up. The lower half consists of soft, blue-black, clay shales with a few local flags, especially toward the base. On top of these comes a flaggy horizon, at what I take to be the Sharpsville level, followed by alternating shales and concretionary layers, with some flags. . . . . The basal shales are sparingly fossiliferous, a big *Orbiculoidea* most abundant, and impressing a layman as being a Sunbury fauna in depauperate condition. The flags and following shales hold a numerous fauna, pyritized and badly preserved in the flags, excellently preserved in the concretions, which form definite bands.[1]

Again in southern Ohio, in the Ohio River section, below and above Portsmouth, succeeding the top of the Sunbury shale, which is a very conspicuously marked horizon, it is a matter of some difficulty to divide the remaining Waverly rocks into the formations which are so clearly marked lithologically in central Ohio.

12. The formations from Nos. 14 to 19, inclusive, form the Waverly series. For a revision of the classification of this series see a paper by Prosser in JOURNAL OF GEOLOGY, Vol. IX (1901), pp. 205–32; and for an extended discussion of the Sunbury shale, *ibid.*, Vol. X (1902), pp. 262–313.

13. The line of division between the Carboniferous and Devonian systems is in doubt, as indicated by the dotted line on the chart. In recent years it has generally been drawn at the base of the Bedford shale, but Professor C. L. Herrick has indicated the line as high as the lower part of the Black Hand formation, or perhaps even higher.[2] Dr. I. C. White writes me as follows concerning this point:

The *red Bedford shale* is undoubtedly of Catskill age, as is also the Berea sandstone and its overlying shale (I think), since it becomes *red* in passing eastward. If you mean to class the Catskill as *Carboniferous*, then your division is correctly drawn, but if you think the Catskill is Devonian, then the Carboniferous line should be drawn at the base of the Cuyahoga. I am non-committal on the general question as to whether we should include

[1] Letter of April 2, 1903.

[2] *Bull. Den. Univ.*, Vol. IV (1888), pp. 100, 106.

the Catskill in the Carboniferous or not, but the *red Bedford* and the overlying Berea with its shale above (red at the east) are certainly of Catskill age.[1]

14. David Dale Owen in giving a summary of the geology of Indiana, after stating that the soft freestone knobs of that state were equivalent to the Waverly rock of Ohio, said: "The black slate in the base of these knobs is the equivalent of the Scioto slates and shales."[2] In the above reference Dr. Owen undoubtedly referred to the shales which were later named the Ohio by Andrews; but it is thought that this casual use of the term "Scioto slates and shales" ought not to replace the definite one of Andrews, which is now a well-known name in geological literature.

In 1877 Professor Shaler, evidently unaware that Professor Andrews had named the Black shale of southern Ohio the "Ohio black slate," proposed as a new name for this formation "Ohio shale."[3]

In northern Ohio, equivalent to the "Ohio shale" of southern and central Ohio, are three formations, the lower and upper ones composed mainly of black shale and called the "Huron and Cleveland shales," separated by a mass of grayish shales, and thin sandstones now called the Chagrin formation.

15. This formation was named the "Erie shale" by Newberry in 1870, but it was preoccupied. Vanuxem in 1842 named one of the divisions of the New York system, the "Erie," which was composed of the formations ranging from the Marcellus shale to the Chemung inclusive; while Logan in 1863 named one of the Quaternary formations of Ontario the "Erie clay."[4] Finally, the name "Girard" shale, applied by Dr. I. C. White in 1881 to a mass of Devonian shales in Erie county in northwestern Pennsylvania,[5] is only equivalent to a portion of Newberry's Erie shale.

The name *Chagrin formation* is, therefore, proposed for this

[1] Letter of April 2, 1903.

[2] *Cont. Geol. Rec. of the State of Indiana*, 1838, Part II, 1859, p. 59.

[3] Geol. Surv. Ky., *Rept. Prog.*, Vol. III, N. S., p. 169.

[4] Geol. Surv. Canada, *Rept. Prog. from Com. to 1863*, pp. 896, 897.

[5] *Second Geol. Surv. Pa.*, Q^4, pp. 117, 118.

mass of argillaceous and arenaceous shales and calcareous layers on account of the excellent exposures on the banks of this river extending from Willoughby to the south of Pleasant valley. With perhaps the exception of the cliffs on the shore of Lake Erie, there are probably no finer outcrops of the formation to be found than those forming the steep banks of the Chagrin River. One and one-half miles south of Willoughby is a cliff nearly a hundred feet high, and a magnificent one more than a hundred feet high occurs a mile below Pleasant valley, about four miles up the river southeast of Willoughby.

16. The term "Huron shale" was proposed by Dr. Newberry in 1870 for "the great mass of black, bituminous shale, designated by the former Geological Board as the 'Black Slate.'"[1] Its outcrop was described as forming "a belt from ten to twenty miles in width, reaching from the Lake shore [Erie] at the mouth of the Huron River, almost directly south to the mouth of the Scioto." Its outcrop on the shore of Lake Erie was given as extending from east of Sandusky to Avon Point. The higher black shale outcropping near Cleveland was named the "Cleveland shale," which was separated from the lower black shale or Huron by the Erie shale. It is generally supposed that Newberry's "Huron shale" in northern Ohio, although represented on the *Preliminary Geological Map of Ohio*, accompanying this report, as extending across the state from Lake Erie to the Ohio River and in the southern part apparently comprising all of the black shale which Andrews, later in the same report, named the "Ohio black slate," represented only the lower mass of black shale which occurs in the northern part of the state. It was not until much later that it was known that the top of the Ohio shale in southern Ohio corresponds with the top of the Cleveland shale and that Andrews's "Ohio Shale" is equivalent to the Huron, Erie, and Cleveland shales of Dr. Newberry in northern Ohio.

In 1861 Professor Alexander Winchell gave the name "Huron group" to a division of the Michigan rocks, which included all the deposits between the top of his Hamilton group

[1] Geol. Surv. Ohio, *Rept. Progress in 1869*, Part I, p. 18.

and the base of a conglomerate overlying the Pt. aux Barques gritstones.[1] This comprised a much greater stratigraphic range than the Huron shales of Newberry, since on the Ohio scale it represents approximately all the rocks from the base of the Huron shales nearly to the top of the Cuyahoga, and perhaps into the Black Hand formation.[2]

Newberry, however, in his first description of the Huron shales, did not refer to the Huron group of Winchell, although together they had examined the rocks about Cleveland[3]; but in a later report he stated that in Michigan they form "the lower part of Professor Winchell's *Huron group*." And he furthermore said that the two members of Winchell's Huron group "having nothing in common either in lithological characters or fossils, we have in Ohio separated them; giving the name *Erie* shale to the upper portion, retaining the name of *Huron* for the lower."[4] This plan, however, does not appear to have been a happy solution of the question, and it was, therefore, submitted to the Committee on Geologic names of the U. S. Geological Survey, and the chairman, Mr. Bailey Willis, has sent me the following communication:

> *Huron group* or *Huron shale* was brought before the committee through a letter from Professor Prosser of May 28, 1903, the question being whether a formation . . . . the *Huron shale* . . . . may bear the same name as a group to which it belongs; it was the sense of the committee that such use of terms in duplication was contrary to the regulations of the Geological Survey, and that, as the group had been named in 1861 and the shale not until 1869 [1870], the term *Huron* should be applied to the *group*.[5]

In 1893 A. C. Lane named the shales forming the lower part of Winchell's Huron group the "St. Clair," which were included between the Traverse group and the Richmondville or Berea sandstone of the Michigan formations.[6] Dr. Lane has written me that: "I do not now think that [the Richmondville] is

[1] Geol. Surv. Mich., *First Bien. Rept. Prog.*, 1861, pp. 71, 139.

[2] See LANE, *Geol. Surv. Mich.*, Vol. VII, Part II (1900), Pl. I.

[3] Geol. Surv. Mich., *First Bien. Rept. Prog.*, 1861, p. 78.

[4] *Rept. Geol. Surv. Ohio*, Vol. I, Part I (1873), p. 70.

[5] Letter of June 13, 1903.

[6] Mich. Geol. Surv., *Rept. State Board for 1891 and 1892*, p. 66.

the Berea but a stray sandstone, somewhat higher up."[1] In the Ohio formations the "St. Clair shale" represents approximately the rocks from the top of the Olentangy shale to the base of the Berea grit, and therefore is neither synonymous with Newberry's Huron shale nor with Andrew's Ohio shale, since the equivalent of the Bedford is included in the St. Clair shale. The name "St. Clair," however, was preoccupied when used by Lane, because Dr. Penrose, Jr., in 1891 gave it to a Silurian limestone in northern Arkansas,[2] and therefore Lane has renamed the St. Clair the "Antrim shales."[3] In 1874 Mr. William W. Borden named the black shale in southern Indiana the "New Albany black slate;"[4] but it is considered that this represents more nearly the thinned westward extension of the Ohio shale, after crossing Kentucky, than Newberry's Huron shale. Outcrops of the New Albany shale have been described by Dr. Kindle in the Wabash River region of northern Indiana to the westward of Logansport.[5]

It does not appear to the writer that the term "Huron shale" of Newberry can stand as the name of this formation, for, as Dr. Orton has said in discussing the name, "it would have served the interest of geological classification much better to have replaced the term altogether than to have restricted it to a small fraction of what it was originally made to cover."[6] Neither does it appear that either of the other names is applicable for this shale. On a recent trip to the Huron River, however, the writer found that the shale banks above and below Monroeville were composed mainly of an upper black shale, apparently the Cleveland, below which are blue and olive shales alternating with black ones; this lower division probably representing part of the Chagrin formation. Apparently only the upper part, if any, of

[1] Letter of April 20, 1903.

[2] Geol. Surv. Ark., *Ann. Rept.*, 1890, Vol. I (July, 1891), p. 124.

[3] *Michigan Miner*, September 1, 1901, p. 9; *Rept. State Board Geol. Surv. Mich. for 1901, 1902*, pp. 66, 209, footnote 48; and RUSSELL in U. S. Geol. Surv., *Twenty-second Ann. Rept.*, Part III, 1902, Pl. XLIV, p. 668.

[4] Geol. Surv. Ind., *Fifth Ann. Rept.*, p. 158.

[5] Ind. Dept. Geol. and Nat. Res., *Twenty-fifth Ann. Rept.*, 1901, pp. 562–65.

[6] *Rept. Geol. Surv. Ohio*, Vol. VI (1888), p. 24.

the Huron shale is shown in the gorge of this river, which was supposed to afford excellent exposures of this shale, while to the west of the Huron River the streams have not cut deep gorges and the older rocks are poorly shown. It is evident that further field work in northern Ohio is necessary before a satisfactory name and classification can be proposed for these shales; therefore, for the present, the name "Huron shale" is retained.

The present year Professor T. C. Hopkins has applied the name "Huron limestone" to a formation in Indiana.[1]

17. The local names of "Sandusky" and "Columbus limestones" are used for the Devonian limestones instead of Onondaga (Corniferous) of the New York classification, because it is probable that the Sandusky limestone ought to be correlated with rocks of later age than the Onondaga limestone, viz., the lower part of the Erian series of New York. Confirmation of this idea is found in a paper by the late Edward Claypole which has just been published.[2]

"Sandusky" is used instead of "Delaware limestone" because both names evidently refer to the same formation, and "Sandusky" antedated "Delaware limestone" by five years. Dr. Newberry published the name "Sandusky limestone" in 1873, and stated that it "is the rock quarried at Sandusky and Delaware,"[3] and the "Delaware limestone" was apparently named by Dr. Orton in 1878 on account of "its occurrence at Delaware, and the extensive use made of it at that point."[4]

18. Mather in 1859 in a "Concise Geological Section of the Rocks Perforated by the State House Artesian Well, at Columbus," used the name "Columbus limestone" for No. 3 of the section which was given as 138½ feet in thickness, the top of which was 138 feet below the surface and covered by 15 feet of "slate" above which was 123 feet of drift.[5] The slate and Columbus limestone are again mentioned on p. 11, where he stated that they "approach in character, and may be equivalents

[1] *Bull. Geol. Soc. Amer.*, Vol. XIII (February, 1903), p. 519.

[2] *Am. Geol.*, Vol. XXXII (July, 1903) p. 35.

[3] *Rept. Geol. Surv. Ohio*, Vol. I, Part I, p. 143. [4] *Ibid.*, Vol. III, p. 606.

[5] *Report on the State House Artesian Well at Columbus, Ohio*, p. 6.

to the Marcellus shales, and Corniferous limestones of the New York Geological Reports." It is evident that No. 3 of Mather's section included both the Sandusky and Columbus limestones of Dr. Newberry's later classification, as Newberry stated in his section of the "State House Well," where he called No. 3 the "Corniferous limestone,[1] and which later he divided into the Sandusky and Columbus limestones.[2]

Mather's article was simply a report to the state house commissioners, and the terrane is very imperfectly defined. Since it has never been recognized in geological literature, while the Columbus limestone of Newberry is a well-known formation, it is not considered necessary to recognize Mather's name, and therefore Newberry's name of "Columbus limestone" is retained for this formation.

19. In the Ohio reports this mass of limestone, with some included beds of gypsum and sandstone, has frequently been termed "the Lower Helderberg or Waterlime formation."[3] The Lower Helderberg, however, represents now the Helderbergian series of the New York classification, while the Waterlime belongs in the next older series, the Cayugan. There are in New York, however, according to Mr. Schuchert, two divisions of the Waterlime — the lower, named the Bertie, and the upper, the Rondout, which are separated by the Cobleskill (Coralline) limestone.[4]

The correlation of the Ohio formation with those of New York is indefinite, and it appears advisable to adopt the name applied by Dr. Lane to these rocks in southeastern Michigan. The name "Monroe beds" first appeared in a "Geological Column" prepared by Dr. Lane and incorporated in a report of Dr. Wadsworth published in 1893.[5] In this publication the formation was not defined; but in 1895 it was fully described by Dr. Lane and shown to include all the rocks between the Niagara

[1] *Rept. Geol. Surv. Ohio*, Vol. I, Part I (1873), p. 114.

[2] *Ibid.*, p. 143. [3] See Vol. VII, pp. 4, 14.

[4] *Am. Geol.*, Vol. XXXI (March, 1903), pp. 160, footnote, and 169–78.

[5] *Rept. State Board Geol. Surv. for 1891 and 1892*, p. 66. Dr. Wadsworth states in a letter to Dr. Lane that "the late winter or early spring of 1893 was the date of publication."

and Dundee limestones of Michigan.[1] In 1894, however, Mr. Darton named and described the Monroe shales, a Devonian formation of southeastern New York,[2] and on this account there was some uncertainty whether the Michigan name would be retained or not. The question was submitted to Mr. Bailey Willis, chairman of the Committee on Geologic Names of the U. S. Geological Survey, who has sent me the following answer:

The Committee on Geologic Names on May 12 took action on the validity of the term *Monroe* in several publications of 1891, 1892 [1893], and 1895, as the name of a group of rocks distinguished in southern Michigan, as against the standing of the name published in 1894 for a shale formation in southeastern New York.

The committee recommended that the *Monroe group* of southern Michigan should retain the name, and this action has been approved for official publications of the Geological Survey.

The conclusion was reached on the ground that priority and prescription, or established usage, are combined in the Michigan application of the term in such a way as to make its continued use more desirable than that of Monroe shale in New York; but the case was not considered one in which priority was so definitely obvious as to justify the conclusion on the ground of the publication of 1891–2 [1893] only, since in that publication the definition was inadequate.[3]

In 1898 Professor Grabau proposed the name "Greenfield limestone" for the Ohio Waterlime, from the town of that name in the northeastern corner of Highland county, in southern Ohio, where the limestone is well shown and extensively quarried.[4] This is certainly an appropriate name for the formation in central and southern Ohio, which will be available in case further study shows that "Monroe" is not a suitable name for the Waterlime in this section of the state.

It is to be remembered, however, that Dr. Orton published the name "Greenfield Stone" in 1871 in a chart of the "Geological Series of Highland County;"[5] but did not use it as a formation name, since he described it under the name of "Helderberg limestone."[6]

[1] *Geol. Surv. Mich.*, Vol. V, Part II, pp. 26–8.

[2] *Bull. Geol. Soc. Amer.*, Vol. V (March, 1894), p. 374.

[3] Letter of May 18, 1903.

[4] *Science*, N. S., Vol. VIII, p. 800.

[5] Geol. Surv. Ohio, *Rept. Prog. in 1870*.

[6] *Ibid.*, pp. 287–94.

20. The Monroe formation, however, in northwestern Ohio contains a light-colored, very quartzose rock, which in 1888 was named the "Sylvania sandstone" by Dr. Orton,[1] from the exposure in a quarry about four miles west of Sylvania village, in Sylvania township, Lucas county. The stratum was first described by Mr. G. K. Gilbert in 1873, who referred it to the "Corniferous group" with a thickness of 20 feet,[2] although on the accompanying geological map of Lucus county it is apparently the division termed the Oriskany sandstone, and represented as crossing the county from the Michigan state line to the Maumee River on the south. The same terrane was represented in Wood county, south of the Maumee River,[3] and perhaps in some of the other counties of northwestern Ohio. The sandstone thickens as followed to the northeastward in Michigan, and Mr. Sherzer gives it as 50 feet in thickness in Exeter township, Monroe county, the one immediately north of Lucas county, Ohio; while still farther north it is given as ranging from 95 to 130 feet in thickness.[4] On Mr. Sherzer's geological map of Monroe county the "Monroe beds" are represented in five divisions, and the only one to which a geographic designation is given is the Sylvania sandstone. The dolomitic limestones below the Sylvania sandstone are separated by an oölitic bed, which is given as about 100 feet below the sandstone and from 20 inches to 2 feet in thickness.[5]

It appears to the writer that the Monroe formation of northwestern Ohio may probably be divided into at least three members. For the upper one the name *Lucas limestone* is proposed, from Lucas county, which it crosses from north to south. It may be studied at the typical locality in Sylvania township, described by Mr. Gilbert in 1873, where are the extensive quarries of the Toledo Stone and Glass Sand Company and the place now named Silica, or in the banks of the Maumee River bordering Providence township. It includes all the rocks between the top of the Sylvania sandstone and the

[1] *Rept. Geol. Surv. Ohio,* Vol. VI, p. 18.

[2] *Ibid.*, Vol. I, Part I, p. 576.

[3] *Ibid.*, Vol. II, Part I (1874), op. p. 368.

[4] *Geol. Surv. Mich.*, Vol. VII, Part I (1900), p. 54.

[5] *Ibid.*, p. 61.

base of the Columbus limestone, or the base of the formation which Dr. Lane in Michigan has named the "Dundee limestone.[1] The middle member is the Sylvania sandstone of Dr. Orton which was called the "Oriskany sandstone" on the geological maps of Lucas and Wood counties. The rocks below the sandstone are shown at various localities on both banks of the Maumee River from the vicinity of the Providence-Waterville township line, Lucas county, to Maumee. Provisionally this member is termed the "Tymochtee," a name given in 1873 by Professor N. H. Winchell to the thin-bedded Waterlime exposed on the banks of this creek in Crawford township, Wyandot county.[2] The limits of the "Tymochtee slate" were not definitely fixed by Winchell, and further investigation may render it inadvisable to retain this name. Professor Winchell, however, used it for the thin-bedded Waterlime in several of the northwestern counties, and compared the beds of this character in Wood county with it.[3]

21. In the New York classification this division has been abandoned, and the two older ones of "Rochester shale" and "Lockport limestone" accepted as formations; the former representing the lower, and the latter the upper part of the old "Niagara group." At present we are unable to correlate precisely the Ohio rocks with these two eastern formations; therefore the more general term of "Niagara," which has been used for this mass of rocks in Ohio, is retained for the time being.

22. The following subdivisions of the "Niagara group" have been recognized and defined in southwestern Ohio; but whether these shall be considered as formations or subformations, or part of them be grouped together to form new formations, we are not prepared to state at present. It does not appear probable that all of these divisions can be recognized in northern Ohio.

23. Dr. Aug. F. Foerste has stated that the Niagara shale of the Ohio reports "evidently corresponds stratigraphically to the

[1] Mich. Geol. Surv., *Rept. State Board for 1891 and 1892* (1893), p. 66; *Geol. Surv. Mich.*, Vol. V, Part II (1895), p. 25; and SHERZER, *ibid.*, Vol. VII, Part I (1900), p. 35.

[2] *Rept. Geol. Surv. Ohio*, Vol. I, Part I, p. 633. [3] *Ibid.*, Vol. II, Part I, p. 375.

Osgood beds of Indiana;" and apparently refers the Dayton limestone, Orton 1870, which occurs at the base of the shale, to the same division.[1] He also stated that "the West Union cliff may correspond to the limestone courses in the upper part of the Osgood beds in Indiana and western Kentucky, but it has so far not been sufficiently investigated to admit of correlation."([2])

24. The Canadian Survey has shown that the Medina formation may be traced by surface outcrops from Niagara River across Ontario and along the western shore of Georgian Bay.[3] Later the red rocks penetrated in deep wells in southern Ontario,[4] the Lower Peninsula of Michigan,[5] and Ohio[6] have been referred to the Medina formation. Dr. Lane, however, stated that in Michigan the Medina shale, "both lithologically and in the driller's records, is quite as likely to go with those below it. It is really a transition bed."[7] There is evidently uncertainty regarding the age of the red shales penetrated in the oil and gas wells of northwestern Ohio; but, in the absence of positive knowledge, they are left provisionally in the Upper Silurian and called Medina with a query.

25. There is a question whether the Belfast bed is of sufficient importance to be given the rank of a formation.

26. At present whether the line of separation between the Upper and Lower Silurian should be drawn at the top or bottom of the Belfast bed is a matter of uncertainty. Dr. Foerste states: "I am not certain as to the age of the Belfast bed myself;" and he also says that "it is the only bed which may be Lower Silurian and which may be of Medina age."[8] And in an earlier paper Dr. Foerste stated that

[1] *Ind. Dept. Geol. and Nat. Res., Twenty-fourth Ann. Rept.* (1900), pp. 44, 80.

[2] *Ibid.*, p. 80.

[3] Geol. Surv. Canada, *Rept. Prog. from Commencement to 1863*, 1863, pp. 312–21; and also see Atlas, *Geol. Map of Canada*, 1864.

[4] Brumell, *ibid., Ann. Rept.*, N. S., Vol. V, Part II (1892), pp. 52 ff.

[5] Lane, *Geol. Surv. Mich.*, Vol. V, Part II (1895), p. 30 and plates.

[6] Orton, *Rept. Geol. Surv. Ohio*, Vol. VI (1888), pp. 11 ff., as well as in later reports of the Ohio Survey.

[7] *Geol. Surv. Mich.*, Vol. V, Part II, p. 30.

[8] Ind. Dept. Geol. and Nat. Res., *Twenty-fourth Ann. Rept.* (1900), p. 68.

The Clinton formation of Ohio is the lowest formation in that state, belonging without question to the Upper Silurian. Between the Clinton of Ohio and the upper fossiliferous beds of the Cincinnati formation occur in many parts of the state a series of unfossiliferous beds which it is difficult to assign definitely either to the Upper or to the Lower Silurian. [1]

The fossils of the Belfast bed, as reported by Dr. Foerste, are *Halysites catenulatus* — a Clinton and Niagara coral not known in the Cincinnatian series of Ohio, Indiana, or Kentucky; annelid teeth, which are identical specifically with forms found in undoubted Lower Silurian limestones; and an *Orthis* allied to *O. calligramma* of the Clinton. [2]

27. By some geologists this system is called the "Ordovician," a name introduced by Lapworth in 1879 for the Lower Silurian of Murchison, which Sedgwick called "Upper Cambrian." This usage, however, is strenuously opposed by the distinguished British geologist, and former director-general of the Geological Survey of Great Britain and Ireland, Sir Archibald Geikie, who has written as follows:

I consider that this proposal, which was honestly intended to obviate confusion and to promote the progress of the science, is fair to neither of these fathers of English geology, and is especially unjust to Murchison. The division of "Lower Silurian" has the claim, not only of priority, but of having been established and of having had its component members defined by the author of the Silurian system in the early years of his investigation.[3]

When "Ordovician" is used in place of "Lower Silurian," then the term "Silurian" is usually applied to the division which Murchison named the "Upper Silurian." A very cogent reason has been presented against this arrangement by Dr. William B. Clark, who states:

I prefer the use of Lower Silurian to Ordovician, as I do not think the term Silurian of Murchison can with propriety be restricted to the Upper Silurian. If the Upper and Lower Silurian are to be raised to period position, and Ordovician used, I think some other name should be substituted for Silurian.[4]

28. The mottled clays and thin arenaceous limestones which outcrop in southwestern Ohio, and in the Ohio reports have gen-

[1] *Jour. Cin. Soc. Nat. Hist.*, Vol. XVIII (1896), p. 163.

[2] *Ibid.*, pp. 163, 165.

[3] *Text-Book of Geology*, 3d ed., 1893, p. 738.

[4] JOUR. GEOL., Vol. VI (1898), p. 342.

erally been termed the "Medina shales"—the lowest formation of the Upper Silurian in western New York—apparently belong in the upper part of the Lower Silurian. Dr. Foreste has studied these beds quite carefully and reports in them several species of fossils, which are of Lower Silurian age. He states:

> It should be remembered that the identification of the Medina in Ohio has not only been solely lithological, but has been practically made upon the sole basis of color. Had the clays near the top of the Lower Silurian not had a single touch of red, or purple color, it is probable that the name Medina would never have been applied to them.[1]

While later in the same article it is stated "the red, purple, and otherwise colored clays below the Belfast bed and its equivalent are, however, Lower Silurian, as is shown by the presence in them of Lower Silurian fossils."[2] The fauna, as reported by Dr. Foerste, is not very extensive, and includes two brachiopods, *Orthis* (*Hebertella*) *occidentalis*, which is not known above the Richmond formation, and "Lower Silurian forms of *Orthis* (*Platystrophia*) *biforata*"[3] (although it must be remembered that this species occurs in the Clinton limestone), "bryozoans of Lower Silurian age," "annelid teeth such as are found in the Lower Silurian," corals as *Tetradium*, and stromatoporoid sponges.[4]

These rocks were named the "Madison beds" by Dr. Foerste in 1897,[5] on account of the typical exposures at Madison, Ind.; but the name was preoccupied as a geological term, for in 1875 Professor Irving named and described the Madison sandstone of Wisconsin. If this formation be a synonym for the "Jordan sandstone," which was named and described by Professor N. H. Winchell in 1874, then the name "Madison" is still preoccupied, for it was applied by Dr. Peale in 1893 to a Carboniferous formation of Montana. Dr. Foerste in some of his reports has used the name "Cumberland sandstone," which was applied by Shaler in 1877 to the upper part

[1] Ind. Dept. Geol. and Nat. Res., *Twenty-fourth Ann. Rept.* (1900), pp. 67, 68.

[2] *Ibid.*, p. 68. [3] *Jour. Cin. Soc. Nat. Hist.*, Vol. XVIII (1896), p. 165.

[4] Ind. Dept. Geol. and Nat. Res., *Twenty-fourth Ann. Rept.* (1900), pp. 65, 66.

[5] *Ibid.*, *Twenty-first Ann. Rept.* (1896), pp. 218, 220.

of the Lower Silurian rocks exposed along the Cumberland River in southern Kentucky, as apparently equivalent to the Madison beds; but in a late paper he states that the term Cumberland sandstone includes a much larger series of rocks than the name Madison bed.[1] Finally he gives his opinion "that the major part of the rock designated as the Cumberland sandstone by Professor N. S. Shaler must have been of Lorraine age, and if any part of the Richmond is to be included under this name, this is due rather to accident than to the original intention of the author."[2] In this paper Dr. Foerste recognized that the name Madison was preoccupied and stated:

It is therefore considered desirable to change the name of the beds at the top of the Richmond, hitherto called the Madison beds; the name Saluda bed is therefore introduced, taken from Saluda creek, six miles south of Hanover [Jefferson county], Indiana.[3]

The writer is not certain that this bed in Ohio merits a separation from the Richmond formation, as is indicated by the dotted line on the chart. In fact, Dr. Foerste states that "there is no doubt that in southern Indiana and northern Kentucky the Madison beds are merely the upper unfossiliferous part of the Richmond group,"[4] and in proposing the "Saluda bed" he speaks of the hitherto called "Madison beds" as "at the top of the Richmond."[5]

29. The rocks of southwestern Ohio described in the later volumes of the Ohio reports under the name "Hudson River group or series" are here given as the Richmond and Lorraine formations and Utica shale. Clarke and Schuchert did not use "Hudson River" in their revised classification of the New York series and formations in 1899, stating that

It is becoming increasingly evident that the great mass of shale in the Mohawk and Hudson River valleys which was designated at an early date by this term [Hudson River beds] is resolvable into horizons extending from the middle Trenton to and including the Lorraine beds. At present it seems unlikely that, when this determination of horizons has been carried through

[1] *Bull. Geol. Soc. Amer.*, Vol. XII, 1901, p. 436.

[2] *Am. Geol.*, Vol. XXX (December, 1902), p. 368. [3] *Ibid.*, p. 369.

[4] *Bull. Geol. Soc. Amer.*, Vol. XII (1901), p. 436.

[5] *Am. Geol.*, Vol. XXX (1902), p. 369.

the series, any part will remain to which the original term can be applied by virtue of its distinctive fauna, though it may still serve to designate a facies of the formations mentioned.[1]

Finally, Dr. Ruedeman, after an exhaustive study of the Hudson River beds near Albany, N. Y., has reached the conclusion that

> On account of the fact that the mass of beds hitherto called Hudson River shales and correlated with the Lorraine beds of central New York, is composed of terranes ranging from the Lorraine to the lower Trenton, and on account of the lack of a fully representative fauna and of a complete section of the Lorraine portion of these terranes, it is proposed to drop the term Hudson river shales, for the uppermost part of the Lower Siluric, and the term Hudson river group, for the Utica and Lorraine beds.[2]

Clarke and Schuchert have adopted "Cincinnatian" as the name for the series and period composed of the Utica, Lorraine, and Richmond formations.[3]

This formation was named the "Lebanon beds" by Dr. Orton in 1873;[4] but the name was preoccupied, for Professor Safford in 1851 had applied it to a still older limestone of central Tennessee, using it for the two upper divisions of his Stones River group.[5] For the above reason, Professor N. H. Winchell and Mr. E. O. Ulrich in 1897 renamed it the "Richmond group," on account of the excellent exposures at Richmond, Ind.[6]

30. The Trenton limestone is exposed on the northern bank of the Ohio River in Clermont county, particularly in the vicinity of Point Pleasant and on the southern bank of the river opposite Cincinnati.[7] The paper just cited by Professor John M. Nickles gives an excellent account of the last four formations of the Ohio scale, as admirably exhibited in the vicinity of Cincinnati and at other localities in southwestern Ohio.

CHARLES S. PROSSER.

COLUMBUS, O., July 3, 1903.

[1] *Science*, N. S., Vol. X, p. 877.

[2] *Bull. N. Y. State Mus.*, No. 42, Vol. VIII (1901), p. 568.

[3] *Science*, N. S., Vol. X (1899), p. 876.

[4] *Rept. Geol. Surv. Ohio*, Vol. I, Part I, p. 371.

[5] *Am. Jour. Sci.*, 2d ser., Vol. XII, pp. 353–55.

[6] *Geol. Minn.*, Vol. III, Part II, pp. lxxxix, ciii.

[7] *Jour. Cin. Soc. Nat. Hist.*, Vol. XX (1902), p. 60.

A TOPOGRAPHIC FEATURE OF THE HANGING VALLEYS OF THE YOSEMITE.

THE larger hanging valleys around the Yosemite valley have topographic features in common that are interesting in themselves, and they likewise afford some evidence in regard to the comparative cutting powers of ice and water.

When formerly I used to look up from the valley below at the Upper Yosemite fall, I always wondered what kind of topography there could be up on top to cause Yosemite Creek to come over the rim of the valley at an elevation much higher than the gorge just east of it—the gorge through which the trail to Eagle Peak passes. A glance at Fig. 4 will show what is meant. That topography was explained during a recent visit to the Yosemite, when I had an opportunity to see the valleys above some of the falls.

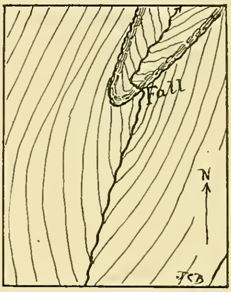

FIG. 1.—Sketch showing how Illilouette Fall enters the gorge at the side.

The Illilouette fall is not quite at the head of the canyon; the canyon passes by or overlaps the creek so that the creek enters the canyon on its east side, as shown in the accompanying sketch. (Fig. 1.)

At the Nevada fall this overlapping of the canyon below by the stream above the fall is still more marked, although, owing to the choking up of the head of the gorge, it does not attract one's attention so promptly. The trail leading to the top of the Nevada fall passes up through this side gorge.

At the Vernal fall again the gorge below extends up past the fall, though the overlap is only short in this case.

The explanation seems to be the same for each of these forms. Take first the Illilouette fall: the South Canyon Creek, or Illilouette Creek, which forms the Illilouette fall drains a large area, especially on the south and west side of the stream. Toward the close of the glacial epoch, when the main Yosemite valley was free from ice, or at least free enough to allow the water flowing in from the side valleys to fall over precipices, the waters from the melting snows and ice over the drainage basin of Illilouette Creek flowed down along the west side of the glacier that still filled the Illilouette valley above the fall. When this water reached the canyon, it found the bottom of the upper valley full of ice, and it was thus obliged to fall into the canyon —not from the bottom of the valley trough, but at the west side of the glacier. (See Fig. 2.) This stream cut the head of the gorge back past the lower end of the axis of the upper valley. When the ice disappeared, the water returned to the real bottom of the valley, and was then obliged to fall over the side of the gorge instead of at its upper end.

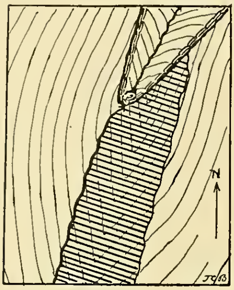

FIG. 2.—Sketch to show how the glacier above Illilouette Fall (shaded area) crowded the stream to the west and caused it to cut a gorge that overlaps the axis of the upper valley.

The topography of the Nevada fall is even more striking than that of the Illilouette fall. The gorge that overlaps the stream and site of the present fall is so long and large that the trail leading to the upper valley and to Clouds Rest passes through it. It is much choked up with loose débris, while there are large quantities of waterworn material exposed at the upper lip of the gorge.

Ice marks are abundant at the head of the Nevada fall, though most of them have been obliterated from exposed surfaces.

The explanation of this overlapping gorge is the same as that for the Illilouette fall: towards the close of the glacial epoch, but while the Little Yosemite—the valley just above the fall—was still filled with ice, the water flowing down the north side of the glacier there plunged into the lower gorge and gradually cut its way back by the side of the glacier. When in time the ice disappeared from the edge of the bluff, the stream abandoned its old place beside the glacier and flowed over the cliff at the site of the present Nevada fall. (Fig. 3.)

The overlapping gorge of the Vernal fall is not so long as that of the Nevada fall, and for some reason it is on the south side of the stream.

These explanations also show why the Upper Yosemite fall is not in the deep gorge that cuts back into the north wall of the valley on the west side of the stream. The stream follows the axis of the original valley; the gorge just west of it was cut toward the close of the glacial epoch by a stream that was crowded to one side by the great glacier that filled the main

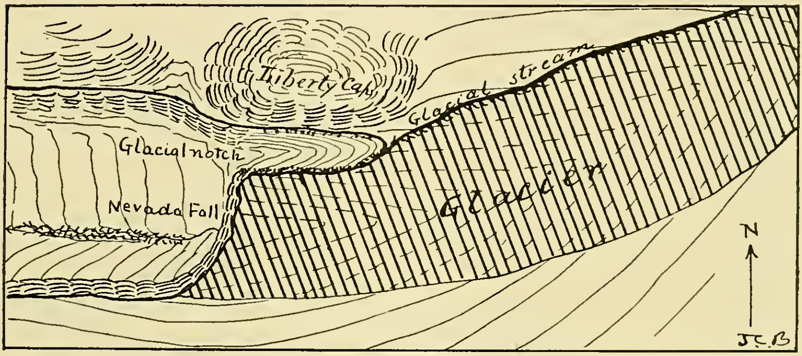

FIG. 3.—Sketch to show how the stream above Nevada Fall was crowded northward by the ice (shaded area), and how it cut a gorge past the present position of Nevada Fall.

valley. For the glacier that came down Yosemite Creek was fully ten miles long above the site of the present Yosemite fall.

It is quite probable that other notches in the canyon walls near these high falls from the hanging valleys have had a similar origin.

In each of these cases it is evident that the cutting done by the stream was much more rapid than that done by the ice, for in every instance the stream gained upon the glacier until the two channels overlapped each other.

If the explanation here offered for these peculiar forms be correct, it may well be asked why there is no such feature at the Bridal Veil fall, for this last apparently has no such overlapping canyon, while its position and history is otherwise similar to those of the other falls around the Yosemite valley. On the west side

FIG. 4.—The Yosemite falls seen from the valley below. When the ice along the west side of the glacier filled the upper valley the water came down and cut the deep notch seen on the left of the upper fall.

of the Bridal Veil fall is a notch that may have been formed in the fashion here indicated; but if it was made in this manner, it does not at present overlap the end of the valley trough where the fall is. Seen from the Coulterville road across the valley to the north, it looks as though a stream on the east side of the Bridal Veil glacier may have fallen through the deep notch that opens on the side of the valley toward Cathedral Rock. I cannot say positively that this happened, however, for I did not go above the fall to look for the evidence.

It is worthy of note that in both instances where the falls occur in pairs, namely at the Yosemite (upper and lower falls) and at the Nevada and Vernal falls, narrow subglacial channels are cut between. This was to have been expected. When the ice broke at the upper fall, the water flowing from above entered the crevasses below and flowed as subglacial streams at least as far as the lower falls.

Since the glacial epoch the rocks have exfoliated and disintegrated so rapidly that ice marks are still visible at less than a dozen places on the exposed surfaces of the Yosemite valley walls. At the top of Vernal falls a dark inclusion in the flat granite surface preserves the ice marks perfectly, but the surrounding rock has disintegrated to a depth of fully two inches since the melting ice uncovered the spot. Similar instances may be seen above the Nevada fall and about Inspiration Point on the road from the valley to Wawona. Everywhere the exposed surfaces are rapidly going to pieces. The same agencies must have hastened the formation of the valley before the glacial epoch.

The evidence of the falls at the mouths of the hanging valleys shows that the wearing done by the ice was trivial as compared with the wearing done by the glacial streams. The subglacial streams also cut channels beneath the ice a great deal faster than the ice alone cuts the broader floors over which it moved. Considered alone, these canyons overlapping the streams that enter them from above afford evidence that the period since the glacial epoch has been very short as compared with the length of the glacial epoch itself.

I venture to add that I quite agree with Mr. Turner's views of

FIG. 5.— Nevada Fall, and the glacial notch just north of it, through which the trail passes.

the origin of the Yosemite valley itself (by stream erosion before the glacial epoch) and of the influence of the nature of the rock and of rock joints upon the topography.[1]

Unfortunately the large and constantly increasing number of visitors to the valley are misled by so excellent a guide as Baedeker's *U. S. Handbook*, edition of 1899, p. 509, which still gives as the accepted explanation of the origin of the Yosemite valley the fault theory advanced by Whitney many years ago. It is very desirable that the U. S. Geological Survey should bring out as soon as possible Mr. Turner's Yosemite folio and set the question at rest in the popular mind.

J. C. BRANNER.

[1] H. W. TURNER, "The Pleistocene Geology of the South Central Sierra Nevada, with Especial Reference to the Origin of Yosemite Valley," *Proc. Calif. Acad. Sci.*, 3d ser., Vol. I, pp. 262-321.

SILURIAN AND DEVONIAN LIMESTONES OF WESTERN TENNESSEE.

CONTENTS.

H. The Age of the Cincinnati Geanticline.

15. As determined by observations in Tennessee.

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J. Lists of Fossils.

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A. SILURIAN STRATA ALONG THE WESTERN FLANK OF THE CINCINNATI GEANTICLINE.

1. *In southern Indiana, Kentucky, and northern Tennessee.*—In southern Indiana[1] the Silurian strata are divided into the following beds, named in descending order:

Louisville limestone.
Waldron shaly clay.
Laurel limestone.
Osgood shaly clay.
Clinton limestone.

Southward, along the western flank of the Cincinnati geanticline, the equivalents of these beds may be traced with varying success even as far as northern Alabama.

The ease with which any beds may be traced for long distances depends greatly, of course, upon the constancy of their lithologic features. In this respect the subdivisions of the Silurian along the western flank of the Cincinnati geanticline are remarkable. Very little change is shown in the lithological characteristics of any of these subdivisions between southern Indiana and northern Tennessee. North and south of this area, however, the Osgood bed rapidly becomes more calcareous and is changed from a shaly clay to a soft limestone, weathering more readily than the Clinton limestone below or the Laurel limestone above. The Waldron bed also becomes calcareous northward, and is replaced by limestone in central Indiana. Southward it may be traced as far as northern Alabama, but in central and southern Tennessee it is only 3 to 4 feet thick, and along the middle part

[1] *Twenty-first* and *Twenty-second Annual Reports of the Indiana Survey*, for the years 1896, 1897.

of the bed the clay is replaced by a layer of limestone, 6 to 10 inches thick. Both northward in Indiana and southward in Tennessee the Waldron bed maintains its characteristics as a shaly clay farther than the Osgood bed.

The thickest sections of the Osgood bed are found in central Kentucky. Here the Osgood bed consists almost entirely of soft shaly clay, often 38 feet thick. In southeastern Indiana this clay is represented by the Lower Osgood clay. Along the Ohio River the Lower Osgood clay horizon usually consists of soft shaly clay, locally replaced by a more or less indurated clay rock. Northward the amount of induration increases, especially in the upper half of this horizon. Farther northward, beyond a line connecting Versailles and Vernon, lenses and nodular layers of limestone begin to appear in the upper half of the Lower Osgood clay horizon. Still farther northward, the calcareous element increases at all levels, so that at New Point the equivalent of the Lower Osgood clay consists of an inferior quality of limestone. Both the Osgood bed and the lower part of the Laurel bed are quarried here. The Waldron bed may be traced 15 miles farther northward, to Milroy, but at Sandusky and at various other localities a considerable quantity of thin limestone is interbedded with the clay.

At Bledsoe, in northern Tennessee,[1] the Osgood bed consists chiefly of soft clay. At South Tunnel most of this clay is more or less indurated. At Baker station the upper half of the bed contains sufficient crinoidal material to form an inferior quality of limestone. Along the Harpeth River the greater part of the Osgood horizon is occupied by more or less calcareous, indurated clay rock, grading into clayey limestone at the top and bottom. Locally, the larger part of the Osgood section may consist of soft clayey limestone. In central and southern Tennessee the Osgood bed consists of rather thin-bedded limestones, weathering back more readily than the Laurel bed above and the Clinton bed beneath. Here its identity can often be established only with difficulty. The Waldron bed maintains its character

[1] "Silurian and Devonian Limestones of Tennessee and Kentucky," *Bull. Geol. Soc. Am.*, 1901.

as a shaly clay horizon much farther southward than the Osgood bed. It is typically developed along the Harpeth River near Newsom. At this locality it contains a large part of the fauna characteristic of this horizon at Waldron, Ind. In central and southern Tennessee a thin bed of limestone, 6 to 10 inches thick, replaces the clay along the middle of the bed.

2. *Centreville, Riverside, and Iron City, Tenn.*—At Centreville the Devonian is represented, in descending order, by the phosphatic nodule layer, 4 inches thick; the Chattanooga black shale 4½ feet thick; and the Hardin sandstone, 8 inches thick. It rests unconformably upon soft shaly clay, the equivalent of the Waldron bed. The original thickness of the Waldron bed at this locality is unknown; at present the thickest section preserved beneath the Hardin sandstone is 2½ feet thick. Twenty-five feet are assigned to the Laurel bed. It is underlaid by limestone, 4 feet thick, which weathers badly and forms a transition between the more solid limestone above and the softer, more clayey limestone, 6 feet thick, beneath, which, stratigraphically, appears to belong to the Osgood horizon. The upper beds of the Clinton limestone are more solid and more or less cherty. They contain *Triplesia Ortoni*. Along the railroad only the upper part of the Clinton, 12½ feet thick, is exposed. Ordovician limestone, probably the Leipers Creek bed, occurs about 25 feet lower down. Since a part of the unexposed interval is probably occupied by the Mannie clay,[1] the total thickness of the Clinton at this locality cannot be determined. Across

[1] In western Tennessee, west of the Central Basin, the following Ordovician beds named in descending order, have been recognized:

Cincinnati Group	Richmond	Mannie shale. Leipers Creek limestone.
	Lorraine	Warren limestone. Swan Creek limestone.
	Utica	Absent in western Tennessee.
Trenton Group	Trenton	Saltillo limestone, belonging to lower part of Trenton.
	Black River	Absent in the Tennessee River valley.
	Stones River	Wells limestone, belonging to the upper part of the Stones River; exposed in central part of Wells Creek basin; identified by Safford as the Knox dolomite.

The Cincinnati Group in Western Tennessee, between the Tennessee River and the Central Basin. JOUR. GEOL., January-February, 1903.

the bridge northeast of town there is an exposure of Clinton limestone, 20 feet thick.

At Montgomery's Mill the limestone referred to the Laurel bed is 28 feet thick: the Waldron bed, 4 feet; the Louisville bed, 25 feet thick, is unconformably overlaid by the Black shale series; the original thickness of the Louisville bed at this locality is therefore unknown.

South of Centreville no exposures extending from the Ordovician to the Waldron horizon are known until Riverside, 25 miles distant, is reached. The upper part of the Mannie clay, 5 feet 9 inches thick, is exposed northwest of Riverside, on the western side of the Buffalo River, immediately north of the railroad bridge. It is overlaid by a massive bed of limestone, 5 feet 9 inches thick, strongly cross-bedded, very ferruginous in places, referred to the Clinton horizon. Several hundred yards north of the bridge, at the base of a large bluff, the top of this cross-bedded limestone contains Silurian fossils. Here the Clinton is overlaid by soft, rather thin-bedded limestone, 4 feet thick, weathering back. A slight unconformity exists between this soft limestone and the layers immediately above. The soft limestone beneath this line of unconformity probably occupies the Osgood horizon, although the base of the Laurel bed at this locality is also soft, and weathers back, so that it cannot be distinguished lithologically from the Osgood bed. Immediately north of the railroad bridge the Osgood bed appears to be absent; this is probably due to the unconformity already mentioned.

Immediately above the cross-bedded Clinton, north of the railroad bridge, the base of the Laurel bed contains numerous specimens of *Pisocrinus gemmiformis*, one specimen of *Holocystites* 4 inches long, and several specimens of large species of *Orthoceras*. At the cliff, farther northward, the thickness of the limestone referred to the Laurel bed is 36 feet 3 inches. The upper half of this limestone is more massive, and some of the courses are slightly reddish in color; the lower part is softer and weathers back. The Waldron bed is 3½ feet thick, and consists, in ascending order, of clay, 14 inches thick; soft white crumbling limestone, 6 inches thick, containing *Bilobites biloba;* and clay, 22 inches thick. Only the lower part of the Louisville bed, 5 feet 8 inches thick, is exposed. It consists of massive limestone overlaid unconformably by a layer of chert, 8 inches thick. At the large quarries between Riverside and Mannie this layer of chert is overlaid by phosphatic nodules, some of them 4 inches long, followed by brown sandstone, 8 inches thick, containing traces of fish remains.

The coarse, cross-bedded, ferruginous limestone identified as Clinton contains recognizable Silurian fossils only at the top. The possibility therefore exists that further research may prove the greater part of this rock to be of Ordovician age, although for the present it is regarded as equivalent to the Clinton.

The section at Iron City, just north of the state line of Alabama, closely resembles that at Riverside. The best exposures occur directly north of the town, at Cedar Point, along the western side of the railroad branch to Pinckney. The top of the Mannie clay is exposed at various points at the level of the railroad. The total thickness is unknown, but probably exceeds 16 feet, this being the distance of the exposures above the creek. The coarse-bedded ferruginous limestone, 2½ feet thick, was formerly extensively mined. It is overlaid by cherty rock, varying from 2 to 12 inches in thickness, and containing species of Silurian fossils identical with those in the upper part of the Clinton bed at Riverside. The coarse-bedded rock at Cedar Point contains very few recognizable fossils, and the few found belong apparently to new species. For the present it is referred to the Clinton, the cherty bed at the top being regarded as its summit. The Clinton is overlaid by soft, red, clayey limestone, 3 feet thick, weathering back, and referred to the Osgood horizon. Above this is more solid limestone, 23 feet thick, referred to the Laurel horizon. In general it is white, but within 3 or 4 feet of the base it is usually more or less strongly tinged with red. The Waldron bed is 3 feet thick, and as at Riverside consists, in ascending order, of clay, 1 foot thick; white crumbling limestone, 5 inches thick; and clay, 18 inches thick. Only the lower part of the Louisville bed, 19 feet thick, is present. It consists of hard, white limestone, and was formerly quarried at Cedar Point. It is unconformably overlaid by brown rock, 2 feet thick. At the Taylor quarry, one and a half miles northeast of Iron City, along the railroad line to Columbia, the Louisville bed is extensively quarried. It is unconformably overlaid by the Black shale series, consisting, in ascending order, of deep brown shaly rock, 6 inches thick; greenish, fine-grained Hardin sandstone, 15 inches thick; fissile Chattanooga black shale, 6 inches thick; greenish shale similar to the greenish shales above the black shale southwest of Mount Pleasant, 10 inches thick; and a layer of phosphatic nodules. In the railroad cut through Iron city, now abandoned, some of the heavier beds in the lower part of the Waverly contain plant remains.

The coarse, cross-bedded limestone at Riverside and Iron City, referred to the Clinton, suggests that these localities were not far distant from the shoreline at the beginning of the Silurian period. This suggestion is apparently corroborated by an outcrop about half a mile east of Cedar Point. Here the road leading eastward from Cedar Point crosses the railroad to Columbia. In a dry run along the southern side of the road, about a hundred feet east of the railroad, a coarse conglomerate bed, about 1 foot thick, is exposed. Some of the pebbles are 3 inches long. This conglomerate is referred to the Clinton. It rests upon a bluish, thin-bedded limestone, interbedded with more shaly material, referred to the Ordovician.

Careful search in the valleys of Brush and Bluff Creeks, northeast of Waterloo, in Alabama, failed to reveal any Devonian, Silurian, or Ordovician rocks in the areas credited with rocks beneath the Subcarboniferous horizon, on the geological map of Alabama, published in 1894.

B. SILURIAN STRATA IN THE TENNESSEE RIVER VALLEY.

I. CLINTON, OSGOOD, LAUREL, AND WALDRON BEDS.

3. *New Era, Glenkirk, Clifton, Swallow Bluff, Maddox mill, Waynesboro.*—The most northern exposures of Ordovician rocks along the Tennessee River occur between the mouth of Cedar Creek and New Era.

On the road leading from Kelley Landing to New Era, north of the branch north of Bee Creek, the Saltillo limestone is overlaid by Richmond limestone, 17½ feet thick, followed by crinoidal fine-grained limestone forming the base of the Silurian.

Along the Dry Branch, directly north of New Era, the Saltillo limestone is overlaid by Richmond limestone, 12½ feet thick. The Richmond limestone is of a bluish color. At the top it is very coarse-grained, consisting chiefly of fragments of brachiopod shells. The base of the Silurian is formed by a hard, white, massive limestone, 20 feet thick. The lower and middle part of this bed is more crinoidal. The upper third is more dense, and where weathered has a greenish-brown tint, similar to that shown by the cherty Clinton at Clifton. No characteristic fossils were discovered in the bed at New Era. Stratigraphically, however, the bed occupies the same position as the beds referred to the Clinton at Clifton, Riverside, and Iron City. Overlying the hard white Clinton limestone along the road leading east from New Era is a soft reddish limestone, 6½ feet thick, referred to the Osgood, followed by reddish limestone interbedded with whitish layers, a section 3 feet thick, also referred to the Osgood and evidently forming a transition to the Laurel limestone. The Laurel limestone, 27 feet thick, is a rather hard, well-bedded, reddish limestone. The Waldron bed is about 3½ to 4 feet thick. As in the case of the exposures at Riverside and Iron City, the shales along the middle of the Waldron bed are replaced by a layer of very white limestone, 9 inches thick.

At the foot of the bluff northwest of Glenkirk, three miles north of Clifton, the Richmond limestone is overlaid by a considerable thickness of Mannie clay, also of Richmond age. The massive white limestone at the base of the Silurian section, referred to the Clinton, is only 3 feet 9 inches thick. It contains *Illaenus Daytonensis*. The Clinton is followed by soft, reddish limestone, 12 feet thick, weathering back, referred to the Osgood. Overlying this is a more solid reddish limestone, 3 feet thick, forming a transition to the solid Laurel limestone immediately above. The Laurel Limestone is reddish as at New Era and northward. It is 21½ feet thick. The Waldron bed is

3 feet thick. As at all other localities in southern Tennessee, it consists of three layers, in ascending order: soft clay containing a calcareous rubble, 18 inches thick; hard limestone, 6 inches thick; and soft red clay, 1 foot thick.

At Clifton the Saltillo limestone is overlaid by the Warren bed, a cherty limestone, 3 feet 4 inches thick. This bed has so far not been identified elsewhere in the Tennessee River Valley. The Warren bed is overlaid by the Richmond limestone, 19 feet thick, followed by the Mannie clay, 15½ feet thick. North of the landing the Clinton limestone is exposed. It is 1 foot thick, and consists chiefly of greenish-brown chert, although part of the bed is often less siliceous and is more of the nature of ordinary limestone. The color of this limestone varies usually between white and light brown, but a small part of it is tinged with salmon-brown. Both the limestone and chert is fossiliferous. The fauna has a general resemblance to that found in the Clinton of Indiana and Ohio. The presence of *Lichas breviceps clintonensis*, *Calymmene vogdesi*, *Cyrtoceras* (*Glyptoceras*) *subcompressum*, *Orthoceras ignotum*, and *Cypricardinia undulostriata* may be mentioned. The occurrence of *Cyrtoceras subcompressum* is of special interest, since it indicates that this species has a much wider geographical range than hitherto suspected. Immediately above the Clinton at Clifton there is a series of comparatively thin beds of clayey, reddish limestone, 14 feet thick, referred to the Osgood horizon. *Pisocrinus gemmiformis* and *Stephanocrinus osgoodensis* occur within 2 feet of the base of the Osgood bed, and their range extends from this point through the Osgood into the Laurel. They are especially abundant in the harder limestone, 2½ feet thick, which forms the base of the Laurel bed. Near the middle of the Osgood bed there are several layers full of very large, coarse, crinoid stems. They contain also various undescribed species of *Illaenus*, *Lituites*, *Orthoceras*, *Hyolithes*, *Cyclonema*, and *Platyceras*. *Atrypa reticularis* is also present. *Caryocrinus ornatus*, the typical form, occurs at this level and also within 2 feet of the top of the Osgood bed. Large specimens of *Orthoceras* occur at all levels, as usual at this horizon in central and southern Tennessee. The Laurel bed consists chiefly of hard, reddish-purple limestone. Its thickness has not been determined at this locality. No attempt has been made as yet to identify the Waldron bed within the town limits at Clifton. However, the Waldron bed is well exposed along the river bank, a quarter of a mile above the old cement mill. It is here about 3 feet thick, and consists, in ascending order, of whitish clay, about 8 inches thick; white, very dense limestone, about 8 inches thick; and indurated clay, white below, red above, containing most of the fossils collected. Attached to the top of the white limestone bed were found eight specimens of *Eucalyptocrinus magnus*, and six specimens of *Eucalyptocrinus elrodi*, fossils characteristic of the Waldron bed, and found in great abundance at this horizon at Newsom. Only 16 feet of limestone belonging to the top of Laurel bed are exposed beneath the Waldron at this locality. It is very hard and has a reddish-purple color. The total thickness of the Laurel bed at this locality is unknown.

At Swallow Bluff, about half-way between the mouths of Hardin and Indian Creeks, on the north side of the Tennessee River, the Saltillo limestone is directly overlaid by the Silurian. At the base of the Silurian section there is hard, whitish limestone, 18 inches thick, with scattered specks of black chert, followed by a layer of black chert, 2 to 8 inches thick; both are fossiliferous, and are referred to the Clinton bed. The layer of chert is overlaid by hard, massive white limestone, 8½ feet thick, followed by thin-bedded white limestone, 9½ feet thick, and a softer, more clayey rock, partly tinged with red, 5¼ feet thick. The softer, clayey limestone, partly tinged with red, occupies in a general way the horizon of the Osgood bed. It is overlaid by hard limestone, 28 feet thick, referred to the Laurel bed. The lower part, 6 feet thick, is white and crackled. The middle and upper part is more reddish-purple. The most massive layers are near the top. Above the Laurel bed is the Waldron, 3½ feet thick, well exposed along the upper part of the bluff below the landing, immediately above the broad shelf formed by the top of the Laurel bed. The Waldron bed consists, in ascending order, of soft whitish clay, 14 inches thick, containing small fragments of rubble limestone; very fossiliferous, hard, white, dense limestone, 6 inches thick, the fossils not readily recognizable; and reddish clay, 20 inches thick, containing most of the fossils collected.

Along Horse Creek no exposures of Richmond limestone or Mannie clay have been found, although a single specimen of *Rhynchotrema capax manniensis* was collected in the very thin layer of residual clay intervening between the Saltillo limestone and the Silurian at Maddox mill. The Saltillo limestone is exposed for more than a mile along Willoughby Creek, at the old Lick Ford, near its mouth, and at the Maddox mill. At the mill the lower part of the Silurian, 2 to 7 feet thick, is hard and cherty, and is referred to the Clinton. Above it is massive limestone, 23 feet thick, bluish near the base, white throughout the rest of the section. This massive limestone corresponds stratigraphically to the white limestone section, 18 feet thick, which overlies the layer of chertat Swallow Bluff. The Osgood, Laurel, and Waldron beds have, so far, not been identified along Horse Creek. No exposures have been found at the proper horizons.

At the home of W. D. Helton, about 3½ miles northwest of Waynesboro, on Beech Creek, the Saltillo limestone is well exposed. The Richmond limestone, 7 feet thick, is seen several hundred yards up stream, on the south side of the creek. The Mannie clay is probably 20 to 25 feet thick. The base of the Silurian section forms a cliff on the north side of the creek, about 100 yards farther up stream. The Mannie clay beneath the cliff is weathered back, and immediately above there is almost a foot of ferruginous material, very much weathered, which may represent the ferruginous chert at the base of the Silurian in other sections. Immediately above is massive limestone, 6½ feet thick; followed by massive, bedded limestone, 8½ feet thick; and well-bedded limestone, 12½ feet thick; a total of 27½ feet corresponding stratigraphically to the Silurian limestone exposed at the Maddox mill. Immediatelely above, for a distance of 10 feet, there is no exposure. The total thickness of the Silurian section at the W. D. Helton locality is 104 feet. A careful search along the bluffs lining the creek will, no doubt, reveal the position of the Waldron bed. Until this has been accomplished the stratigraphy of the Silurian at this locality must remain more or less in doubt.

Along the western flank of the Cincinnati anticline, the Osgood bed is reduced to a thickness of 3 or 4 feet. This is shown by the exposures at Riverside and Iron City. With the exception of the exposures in the immediate vicinity of Clifton, the thickness of the Osgood bed is small also along the Tennessee River in southern Tennessee. At the base of the Silurian section at Swallow Bluff, Maddox mill, and W. D. Helton, also at New Era and Kelley Landing, there is a considerable section of limestone, usually whitish in color, massive at the base, and more distinctly bedded near the top. This limestone occurs below the beds referred to the Osgood horizon. It thins out at Glenkirk and Clifton. It apparently thins out also from the W. D. Helton locality toward Riverside and Iron City. The base of the section, at least, is equivalent to the Clinton. The top may belong to the Osgood horizon. The position of the intermediate part is doubtful. It is evident that the plane of division between the Clinton and the Osgood beds is rising southward and that the lithological divisions here do not correspond strictly to those farther north and northeast. For the present the name Maddox limestone may prove convenient for the massive limestone in question.

II. LEGO AND DIXON BEDS.

4. *Nomenclature.*—Along the western flank of the Cincinnati geanticline, in southern Indiana, Kentucky, and Tennessee, the name Louisville bed has been given to the Silurian rocks overlying the Waldron bed. In the Tennessee River valley, in western Tennessee, the Silurian section overlying the Waldron bed is so thick that it has been found necessary to subdivide it.

At the base is a series of limestones, varying from 30 to 45 feet in thickness, to which the name *Lego limestone* is here given. Stratigraphically, this bed occupies the same position as the Louisville bed. Its paleontological equivalence, however, has not yet been determined, owing to the small number of fossils so far obtained in the Lego limestone. Overlying the Lego limestone is a series of red clays, 30 to 45 feet thick, to which the name *Dixon clay* is given. This clay has so far proved comparatively unfossiliferous, *Fistulipora* (*Thecostegites*) *hemispherica* being the only fossil so far found in abundance. Above the Dixon red clay is a section of white limestones and clays, exceeding 100 feet in thickness. This section is often richly fossiliferous and contains the fauna studied by Roemer during his three weeks visit to Decatur county, Tennessee. To this section overlying the Dixon red clay, the name *Brownsport bed* is here given.

Lithologically, the limestones forming the middle and lower part of the Lego bed often resemble those forming the Laurel bed so much that, in the failure to identify the Waldron horizon, it is impossible to distinguish the same. In that case, the name *Glenkirk limestone* may be used to designate the combined Laurel-Lego section.

5. *New Era*, *Glenkirk*, *Clifton*, *Cerro Gordo*, *Paulks*, *Sulphur Spring*, *Martin's mill*, *Rise mill*, *Pegram.*—At New Era, along the road leading eastward from the landing, the Waldron bed is overlaid by whitish limestone, 22 feet thick, followed by alternating layers of whitish and reddish limestones, 10 feet thick; a total of 32 feet, referred to the Lego bed. The Dixon red clay bed is 37 feet thick, and consists of partly indurated, dark brick-red clay. The base of the Brownsport bed is formed by a layer of white clay, 2 feet thick. The nearest post-office is at Lego, about a mile and a half up the river.

At Glenkirk, the Waldron bed is overlaid by a layer of massive limestone, 3½ feet thick; bedded limestone, 12½ feet thick; a reddish clayey layer, ½ foot thick; rubble and solid limestone, 21½ feet; a total of 36 feet, referred to the Lego bed. The Dixon red clay is 22½ feet thick, and is overlaid by the white clay layer forming the base of the Brownsport bed.

Along the slope of the hill back of Clifton, north of the road to Waynesboro, the Dixon red clay bed was estimated to have a thickness of 44 feet.

About a third of a mile above the old cement mill at Clifton, along the river bank, the Waldron bed is overlaid by crackled limestone, 31½ feet thick, followed by similar limestone including layers of reddish clayey rock, 14½ feet thick, a total of 46 feet, referred to the Lego bed. The Dixon bed is 42½ feet thick. It consists chiefly of red, clayey rock, but contains also layers of whiter rock. It is overlaid by the layer of white clay, 1½ feet thick, forming the base of the Brownsport bed.

About a quarter of a mile southeast of Cerro Gordo, at the Cave Spring on the road to Savannah, the upper part of the Lego limestone, 28 feet thick, is exposed above the spring. Along the road leading up hill there is red clayey rock, 35 feet thick, referred to the Dixon bed. At the Landing at Cerro Gordo the white clay layer at the base of the Brownsport bed is underlaid by a layer of massive, indurated clay, 2 feet thick, and this, in turn, by a section 26 feet thick, red and clayey at the top, less red and clayey below, consisting near the base of fairly solid limestone. Beneath this is whitish limestone, 42 feet thick. It is difficult to determine where to draw the line between the Dixon and the Lego bed.

On Horse Creek, about a quarter of a mile below the Paulk or Watson mill, at a cave locally well known, there is a section of red clay and limestone, 34 feet thick, which may belong to the Dixon bed. The top of this section is exposed at water's edge at the mill. As in the case of the section at the Cerro Gordo landing, there is only a general resemblance to the Dixon bed.

A lithologically more typical exposure of the Dixon red clay rock is seen at the Sulphur Spring on the Ike Ross and Arnold place, about a mile above Dodd's mill. Here the Dixon bed is 35 feet thick. It is overlaid by the white clay layer forming the base of the Brownsport bed, and underlaid by white limestone, 5 feet thick, forming the top of the Lego bed.

The Dixon bed is exposed about half a mile north of Martin's mill, on the northern bank of Indian Creek, directly opposite the site of the old Craven mill. It here consists of about 44 feet of reddish clay and clayey limestone, overlaid by the white clay layer forming the base of the Brownsport bed. The top of the Lego limestone is well exposed about a mile down stream.

At the Webb or Rise mill, 1½ miles south of Linden, reddish rock about 11 feet thick, forms the base of the section. It may belong to the top of the Dixon bed.

The red phase of the Dixon bed has not been seen anywhere east of a line connecting Martin's mill and Rise mill. The upper part of the Silurian section at W. D. Helton, 3½ miles west of Waynesboro, probably belongs to this horizon, but it does not have a red color, nor is it a conspicuously clayey section. The horizon of the Dixon bed must be represented by some of the rocks exposed along the headwaters of Buffalo River, west of Riverside; but, if so, they do not possess the strong, brick-red coloring shown by the Dixon bed farther westward.

The exposure at Montgomery's mill is too low to include the Dixon horizon.

At the bridge, 1½ miles west of Pegram, the base of the Brownsport bed is represented by a layer of clay, 8 feet thick, including thin fragments of limestone. This clay contains the typical Brownsport fauna. Beneath it is a section of clayey limestone, white or bluish in color, which evidently must weather readily into a sort of clay, since it is exposed only along the railroad cut. The thickness of this clayey limestone cannot be determined definitely, owing to the irregular dip, but it is known to exceed 22 feet and may equal 40 feet. It is considered the equivalent of the Dixon bed. Northeast of the railroad cut, up Furbee and Greer Hollow, well-bedded limestone flags represent the top of the Lego bed. The Lego bed is at least 28 feet thick, a mile and a half east of Pegram, in the bluffs southeast of the home of Sam Walker. Its total thickness is unknown.

It is evident that the red color is characteristic of the Dixon bed only in the Tennessee River sections. Even in the Tennessee River basin the red color is due chiefly to weathering, the less weathered sections exposed by the more rapid cutting of streams consisting more frequently of beds of red rock alternating with layers of whitish limestone. It some sections the whitish limestone equals, or even slightly exceeds, the red clayey rock in quantity. Where weathered, the whitish limestone is tinged more or less strongly with red.

There is usually no sharp line of demarkation between the Lego limestone and the Dixon red clay. A series of transition beds almost always connects the more typical parts of the section. The change from the solid limestone to the reddish clayey rock takes place in different sections at different levels, so that it is evident that parts included in the Dixon bed in one section may be represented by hard limestone in another section, and may there be included in the Lego bed. The Lego and Dixon beds may therefore be regarded as one horizon, bounded by the Waldron bed below, and the Brownsport bed above, changing from a series of limestones beneath to a series of clayey rocks, usually red in the Tennessee River basin, above.

6. *West of the Tennessee River.*—Both the Lego bed and the Dixon bed are exposed at many points between Swallow Bluff and Perryville. At Swallow Bluff the lower part of the Lego bed, 28 feet thick, is exposed along the river, below the landing. At Bath Spring the top of the Dixon bed is 67 feet above the level of the spring. West of New Era the Dixon bed is well exposed along the road from Vice's store to Brownsport Furnace. At the furnace, south of the store, *Orthoceras amycus* occurs 15 feet below the top of the Dixon bed. The Dixon bed is well exposed at the base of the mound glade, a quarter of a mile north of the home of Noah Butler, 2½ miles north of Vice. Exposures of both the Dixon clay and the Lego limestone are common within 2 miles of Dixon Spring. The Dixon bed usually forms the lower part of the glades so frequent in this part of Tennessee. No attempt has been made to determine the thickness of these beds on the western side of the Tennessee River.

According to Professor Safford, the reddish limestone below the Dixon bed is quarried on Birdsong Creek in Benton county, and in the southern part of Henry county, on the Big Sandy River, where a local but a wide dome brings this bed to the surface.

III. BROWNSPORT BED.

7. *Eastern line of outcrop.*—The most eastern exposure of the Brownsport bed is at the bridge, 1½ miles west of Pegram, and about 21 miles east of Dickson. Here the base of the Brownsport bed, consisting of clay, 8 feet thick, is directly overlaid by the Mesodevonic limestone, most nearly related to the Onondaga or Corniferous. At Montgomery mill, the top of the Silurian

exposure is formed by the Lego bed, 25 feet thick, directly overlaid by the Hardin sandstone. The Brownsport bed is probably exposed several miles farther down the river. At Riverside only the base of the Lego bed, 6 feet thick, is exposed. The westward dip of the strata at this point, however, is so great that 3 miles farther westward, at an exposure about a quarter of a mile south of the home of Ed. Walker on the east side of Tucker branch, the Brownsport fauna is found in a calcareous clay about 14 feet below the Hardin sandstone. It includes such characteristic species as *Favosites Forbesi discoidea* and *Pisocrinus milligani; Fistulipora hemispherica* is also present. Northwest of Flatwoods, at the mouth of Little Opossum Creek, the Silurian exposure is 48 feet thick, and is directly overlaid by the Hardin sandstone. *Thecia major* occurs at the top; *Calceola tennesseensis* was found 9 feet below the top; *Astraeospongia meniscus*, 12 feet below the top; all are Brownsport fossils. The Dixon bed is not exposed; it is therefore impossible to determine whether it retains its red color as far eastward as Flatwoods.

The Brownsport bed was not detected at the W. D. Helton locality, 3½ miles northwest of Waynesboro, on Beech Creek; the total Silurian section is here 104 feet, and the top cannot be far beneath the base of the Brownsport bed. The Silurian here is directly overlaid by the Hardin sandstone. The Silurian bed is exposed about 6 miles west of Waynesboro, on the south side of Hardin Creek, where the road from Waynesboro to Dr. Yeiser and Martin's mill crosses Brewer Branch. It consists chiefly of white clay with some limestone, about 20 feet thick, and contains *Fistulipora hemispherica*. It is directly overlaid by the Hardin sandstone, 11 feet thick. South of this locality, west of the home of Dr. E. R. Yeiser, 6 miles east of Martin's mill, the clay and crumbling limestone immediately beneath the Hardin sandstone contains *Astraeospongia meniscus* and *Uncinulus stricklandi*. The presence of the sponge indicates the Brownsport horizon. Brownsport fossils occur in the white clay, 3 feet thick, which overlies the Dixon bed at the Sulphur Spring on the Ike Ross and Arnold place on Horse Creek. It is not exposed farther eastward along the southern boundary of Tennessee, but probably extends under cover as far as Whittens Stand.

On the geological map of Alabama published in 1894, Chattanooga black shale and Ordovician limestone are recorded as occurring in the valleys of Brush (Four Mile), and Bluff Creeks, southwest of Whittens Stand, within 6 miles of the Tennessee state line. A careful examination of these valleys revealed nothing lower than the Subcarboniferous. At the Taylor quarry northeast of Iron City, the lower part of the Lego bed, 19 feet thick, is directly overlaid by the Black shale series, and, at another locality, by the Waverly.

West of the line of eastern outcrops here enumerated the Brownsport bed is exposed at the proper horizon at all points where not removed by Cretaceous and Tertiary erosion. The thickest sections are found farthest westward in that part of the area in which the Brownsport bed is directly overlaid by the Chattanooga black shale series. This is evidently the area east of the line of outcrop of the Linden or Helderbergian limestones and shales. A study of the outcrops within this area indicates that the Brownsport bed is unconformably overlaid by the Chattanooga black shale series. If the thinning out of the Brownsport bed eastward is due to erosion in times preceding the Mesodevonic, the Brownsport bed may formerly have extended much farther eastward, up the western flank of the Cincinnati geanticline.

8. *Perryville*, *Linden*, *Lego*, *New Era*, *Clifton*, *Cerro Gordo*, *Brownsport.*—At Perryville the upper part of the Brownsport bed is quarried. *Astraeospongia meniscus* occurs at the top, immediately beneath the Linden limestone. The upper part of the Brownsport bed is formed by hard limestone also a mile north of Linden, north of the home of William Patton, and thence eastward, forming a bluff 52 feet high along a branch entering the Buffalo River. Here *Astraeospongia meniscus* occurs again at the top, immediately beneath the Linden limestone, associated with *Caryomanon stellatim-sulcatum*. On Coon Creek, within a mile of the Buffalo River, east of the home of William Goodwin, the Brownsport section is 88 feet thick. It is overlaid by the Hardin sandstone, and 78 feet below the top contains *Conchidium lindenensis*. At the Webb or Rise mill the Black shale series is

underlaid by a Silurian section, 85 feet thick, belonging to the Brownsport horizon, and 11 feet of reddish rock only doubtfully referred to the Dixon bed. Although the Linden bed is not present, the top of the Brownsport bed at this locality is stratigraphically equivalent to the top of the Brownsport bed north of Linden. The most striking characteristic of the exposures near Linden is the fact that the Brownsport bed, as far as exposed, consists chiefly of limestone, and shows comparatively little tendency to weather into clays. It does not form glades, and at no point displays the great wealth of brachiopods and sponges characteristic of the lower part of the Brownsport bed farther southward. At the entrance of Jacks Branch into Short Creek, east of the home of E. Duncan, numerous corals are found 18 feet below the Hardin sandstone.

Northeast of Lego, on Short Creek, 300 yards southeast of the homes of W. E. Ashley and P. Denman, the Hardin sandstone, 6 feet thick, is underlaid by 60 feet of limestone belonging to the Brownsport bed. The top contains *Uncinulus stricklandi* and *Gypidula roemeri;* 43 feet below the top *Conchidium legoensis* occurs. Along the road leading east from New Era the lower part of the Brownsport bed, for a thickness of at least 30 feet, forms a glade containing numerous specimens of *Astraeospongia meniscus*, and also specimens of *Astylomanon cratera* and *Caryomanon stellatim-sulcatum.*

In the area included between Perryville, Linden and Lego, the glade forming part of the Brownsport bed appears to belong chiefly to the base of the section, while the upper part is represented chiefly by comparatively unfossiliferous limestones.

At Glenkirk and back of Clifton only the base of the Brownsport bed, with a rather abundant fauna, is preserved. Along the river, three quarters of a mile above Clifton, the Dixon clay is overlaid by an exposure of the Brownsport bed 100 feet thick. The lower part, 25 feet thick, is cherty and full of fossil sponges. The middle part, 50 feet thick, consists chiefly of soft limestones, weathering to clay; it is evidently composed of material which on long exposure would be glade forming. The upper part, 25 feet thick, consists of harder limestone. At the top of the Brownsport bed a form of *Caryocrinus ornatus* occurs.

The rock exposures along the river at Savannah belong to the Glenkirk horizon. The Brownsport bed, overlying red rock, is exposed at Cravens, and also a mile farther down the river, at Cerro Gordo. At the latter locality the Brownsport exposure is 25 feet thick and richly fossiliferous. Above Saltillo the Glenkirk bed is seen again. The Saltillo limestone occurs along a creek southwest of town a little over a mile. At the landing, a well 50 feet deep struck plenty of undoubted Chattanooga black shale. The richly fossiliferous glade region of the Tennessee River valley region between Swallow Bluff and Perryville offers numerous exposures of the Brownsport bed. Swallow Bluff is situated on the north side of the Tennessee River, about halfway between the mouths of Indian and Hardin Creeks.

At Brownsport Furnace, about two miles west of Vice's store, the Brownsport beds, 120 feet thick, forms two glades, south of the old furnace. The southern glade exposes the lower part of the Brownsport bed resting on the Dixon red clay. The northern glade exposes the middle and upper part of the Brownsport bed. At the base of the northern glade occur several beds of limestone containing *Strophonella roemeri* and *Platyceras brownsportensis*. Immediately above, the clay is richly fossiliferous. The horizon occurs about 50 feet above the Dixon bed. Owing to the dip of the rocks, the actual vertical interval is about 35 feet. Fossils occur also at other elevations. The most interesting horizon is formed by the upper 20 feet of the section. At the top corals are numerous. Immediately beneath the coral horizon occur *Atrypa arctostriatus*, *Rhipidomella lenticularis*, and *Rhynchonella lindenensis*. Various silicified sponges belonging to species common in the Brownsport bed occur, loose, at the very top of the exposure. The Chattanooga black shale was exposed by excavations for ore along the hillside northwest of the old furnace. There is no evidence of the presence of the Linden bed at this locality.

9. *Dixon Spring; localities visited by Roemer.*—The Dixon Spring, located on the old Colonel Wallis Dixon farm, 3 miles south of Perryville, is in the midst of classic ground, since the collections of Silurian fossils made by Roemer during his five

weeks' visit to Decatur county were made within a radius of 5 miles from this locality. The Brownsport mentioned in his report is Brownsport Landing, on the Tennessee River, about 5 miles southeast of Dixon Spring, and 3 miles north of Vice Landing. The furnace at this landing was erected in 1839–40. The furnace west of Vice Landing, at present known as Brownsport Furnace, was not put up until 1849, two years after Roemer's visit. The mound glade mentioned in his report as occurring about 1 mile west of Brownsport Landing can no longer be identified. Several mound glades are known within a mile and a half of the old Brownsport Landing. A mound glade is any conical hill capped by the whitish clays and soft limestones of the Brownsport bed. These whitish calcareous clays, for some reason, form soils which are very unfavorable to the growth of most plants. A scanty growth of grass, a considerable number of cedars, and a few stunted oaks, too low to be called trees, usually occupy a comparatively small part of the exposures, leaving most of the hillside open. These open spaces on the hill sides are known as *glades*. Owing to the white clays, these glades are visible for long distances and are often conspicuous landmarks. At the base they are often edged with red, owing to the presence of the Dixon bed. One of these mound glades occurs about a quarter of a mile north of the home of Noah Butler, on the road from Vice to Perryville, 2½ miles north of Vice. Another, not exposing the Dixon bed, occurs about half a mile farther west. Here the Brownsport bed has a thickness of at least 93 feet. Fortunately the identification of the mound glade of Roemer is a matter of little importance, since the species cited from this locality occur at numerous localities elsewhere. Several glades occur on the road leading eastward from Dixon Spring to the river, and numerous glades occur south and southwest of the spring, within the radius of a mile. Glades are also found between Dixon Spring and Perryville, but most of the exposures near the road belong to the Glenkirk and Dixon beds. All of the species described by Roemer were obtained in the glades and therefore belong to the Brownsport horizon.

10. *Bath Springs; Colonel Smith, 4 miles east of Economy; Gant*

place.—Three localities belonging to the Brownsport horizon were referred by Professor Safford with some hesitation to the Helderbergian or Linden limestone.[1] These are Bath Springs, the Colonel Smith locality, and the A. B. Gant locality.

The Bath Springs are located about a mile and a half east of Martin's store, and about the same distance northwest of Martin's Landing; the springs are situated in the valley south of the home of W. N. Davis, and the Silurian exposures occur north of the house. The top of the Dixon bed occurs 67 feet above the level of the springs; it is the top of the *Variegated bed* of Safford. It is overlaid by shaly limestone, 17 feet thick, containing *Astraeospongia meniscus* (Layer A); hard limestone, 4 feet thick; white clay and soft limestone, 22 feet thick (Layer C), containing the fauna investigated by Safford; hard limestone, 7½ feet thick; softer layers of rubble limestone, 19 feet exposed, containing *Caryomanon*, *stellatim-sulcatum*, *Fistulipora hemispherica*, *Enterolasma waynense*, and *Rhipidomella saffordi*. The Silurian is immediately overlaid by the iron-ore gravels of Safford. The absence of the Helderbergian at the Rise mill and at Lego makes it possible that it may have been absent in times preceding Tertiary erosion also at Bath Springs.

The Colonel Jim Smith locality is situated about 9 miles east of Savannah on the road to Waynesboro. The property now belongs to John Godwin. The exposure consists of clay and soft limestone covering the slope between the house and the road, and extends for a short distance both east and west along the road. Numerous brachiopods characteristic of the Brownsport horizon occur. The absence of the sponges so characteristic of the Brownsport bed at many localities probably caused the difficulty in the identification of this bed. About a mile west of the Colonel Smith locality, east of the home of Jim Irwin, numerous corals associated with *Astylomanon verrucosum* are found along the road. Half a mile farther west, east of the home of George Wilson, the brachiopod fauna seen at the Colonel Smith locality is associated with *Astylomanon verrucosum*, in a bed of whitish clay and soft limestone. Half a mile westward, in front of the

[1] Geology of Tennessee, par. 849.

home of J. H. Johnson, *Pisocrinus milligani* and other characteristic Brownsport fossils occur in hard limestone layers. The clayey fossiliferous bed is exposed also about a quarter of a mile south of the Colonel Smith locality, on the south side of Boone Creek, along a road leading up hill. It is here overlaid by more solid limestone.

The old A. B. Gant homestead is located about a mile northeast of Martin's mill. The fossils studied by Safford were obtained a quarter of a mile east of the house, on the hill slope 200 yards northeast of the plantation stables. A considerable interval, stratigraphically, separates the Hardin sandstone,[1] which here is the sole representative of the Black shale series, from the layer of massive, coarse, gray, sandy limestone, 10 feet thick (Layer 3), which furnished the fossils. Owing to weathering, great slabs of the Hardin sandstone have slipped down the hillside until almost in contact with the coarse sandy limestone. However, at a gully farther eastward, and also near the schoolhouse on Indian Creek, still farther eastward, the intervening section is clearly exposed. The existence of a considerable interval between the Hardin sandstone and the coarse sandy limestone was recognized by Professor Safford at Craven's mill (par. 845), where the exposures are better. At this locality the massive, sandy limestone and the overlying Silurian section (2) was referred by Professor Safford provisionally to the Helderberg limestone, but in the statement preceding the list of Helderberg fossils (par. 849) he states that it may be found desirable upon further investigation to refer these beds to the Niagara horizon. For purposes of discussion it will be found convenient to apply the name *Gant limestone* to the coarse sandy limestone under discussion, and the term *Gant bed* to the top of Silurian section including the Gant limestone at its base.

The former site of Craven's mill was located about half-way between the A. B. Gant homestead and Martin's mill, a short distance east of the point where the road following Indian Creek turns southward toward Martin's mill. Almost directly opposite this bend of the road, the Gant limestone is 10 feet thick. An

[1] *Ibid.*, par. 844, Layer 4.

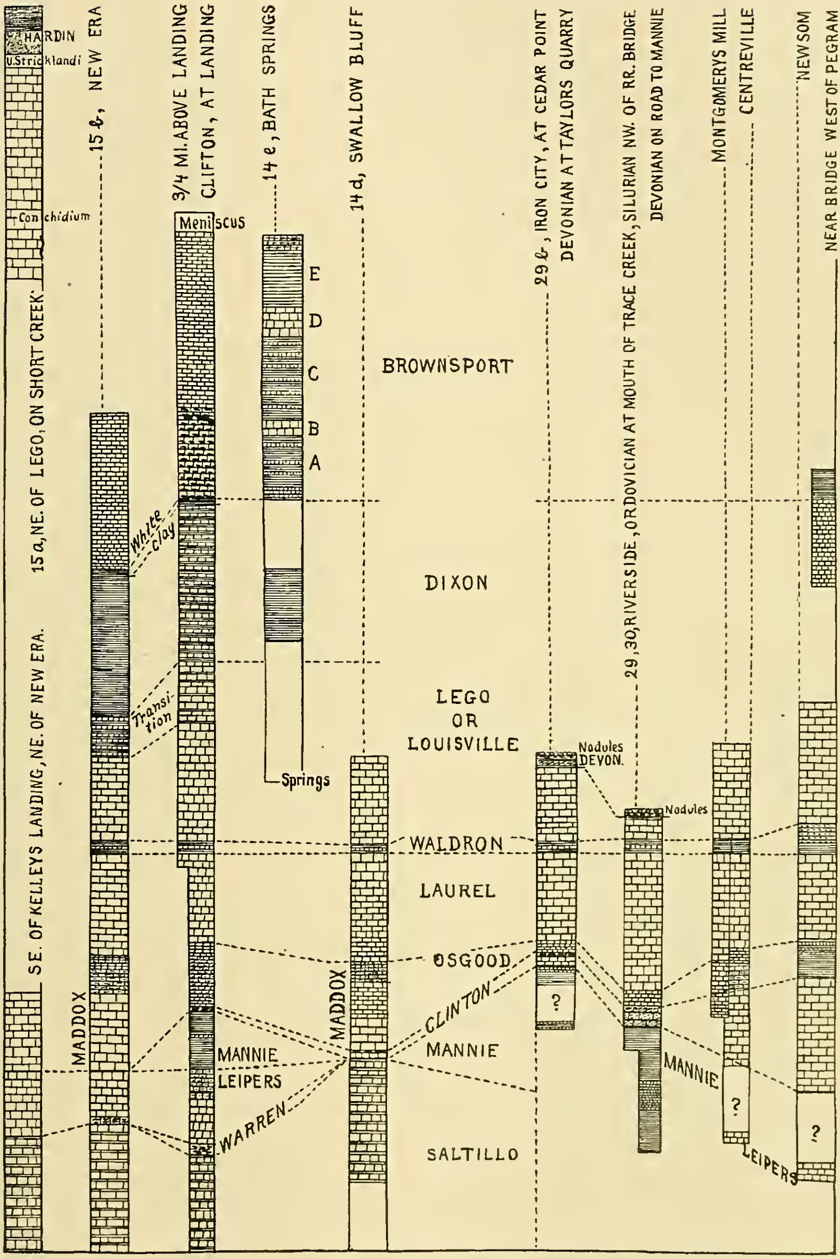

FIG. 1.— Sections between Newsom and Iron City, and between Swallow Point and New Era.

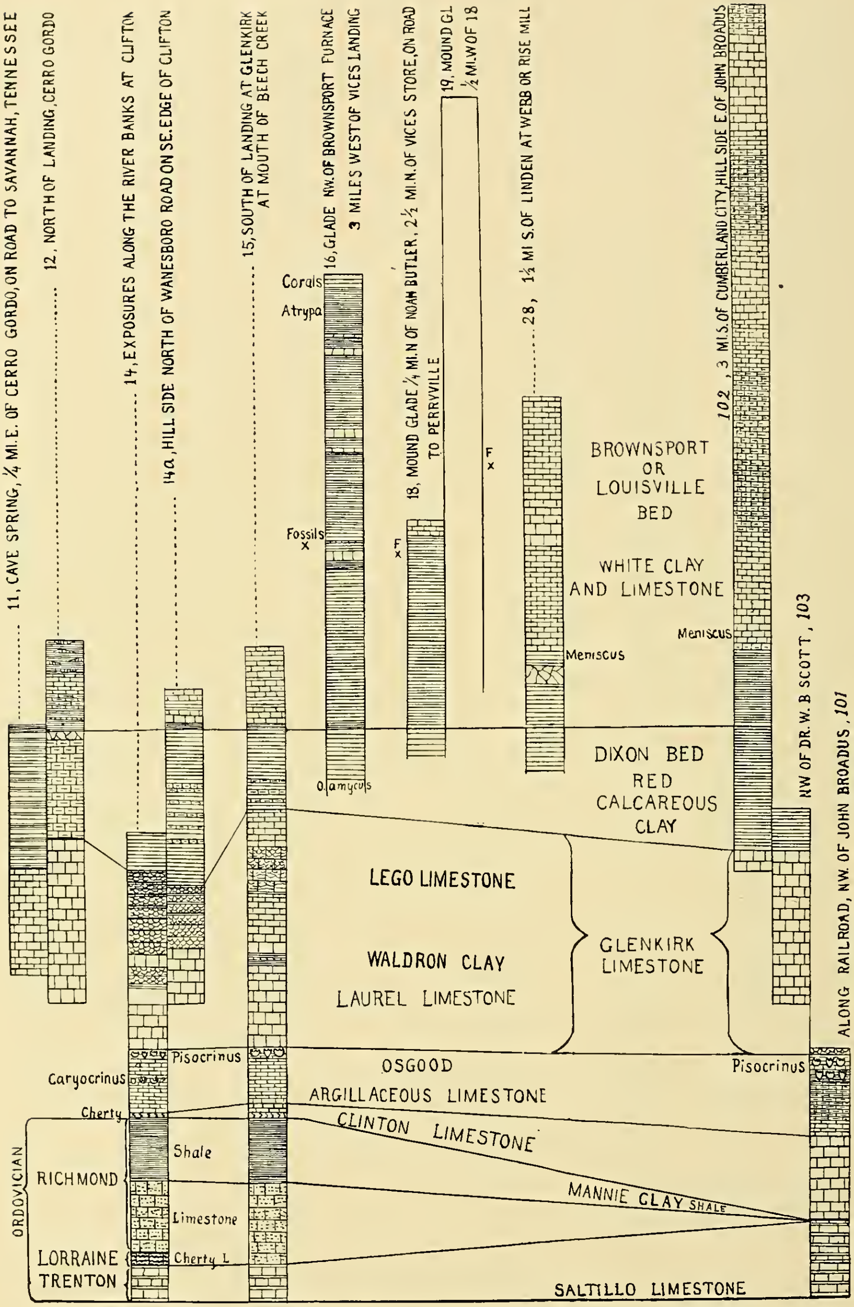

FIG. 2.—Sections along the Tennessee River, and in the Wells Creek Basin.

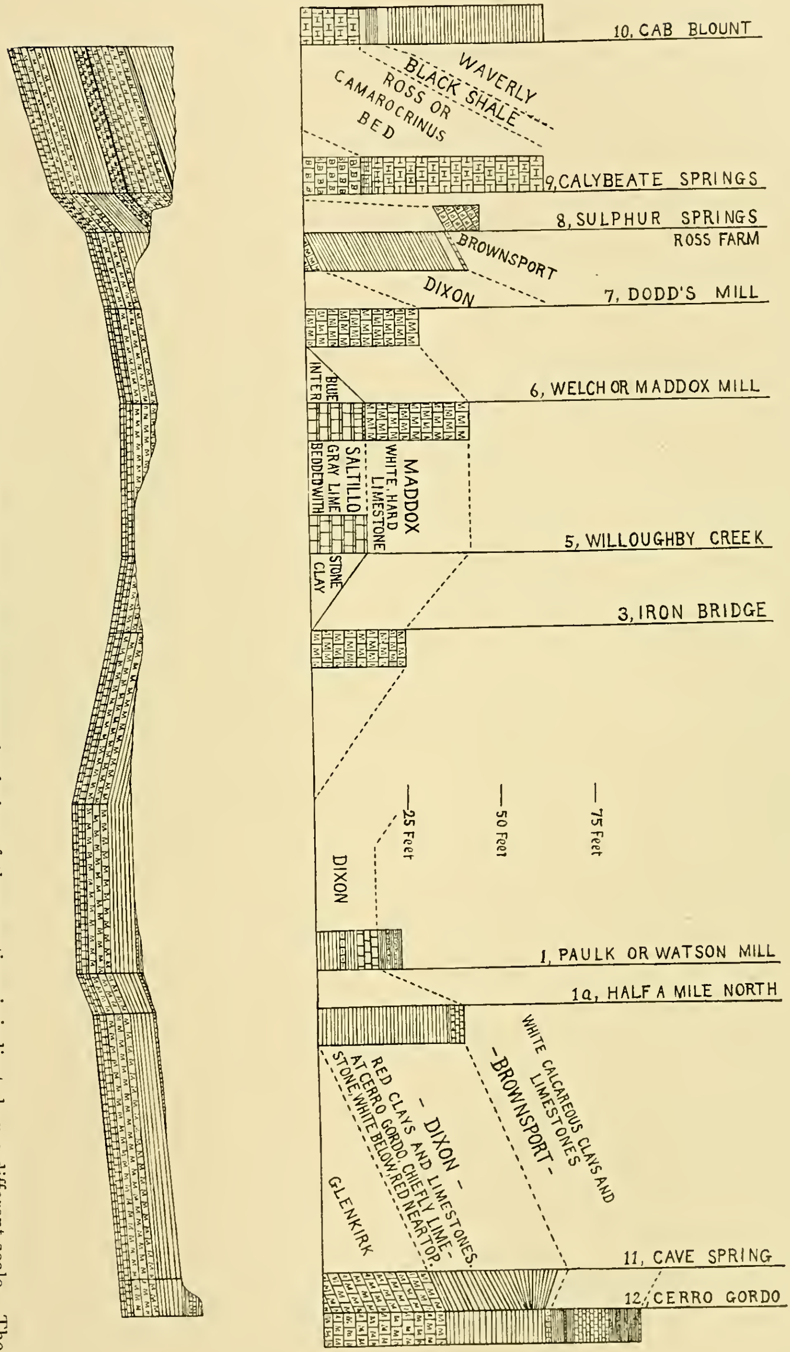

FIG. 3.—Sections along Horse Creek. In the lower figure the general relation of these sections is indicated on a different scale. The Glenkirk limestone overlies the Maddox limestone, and their combined thickness is greater than here represented.

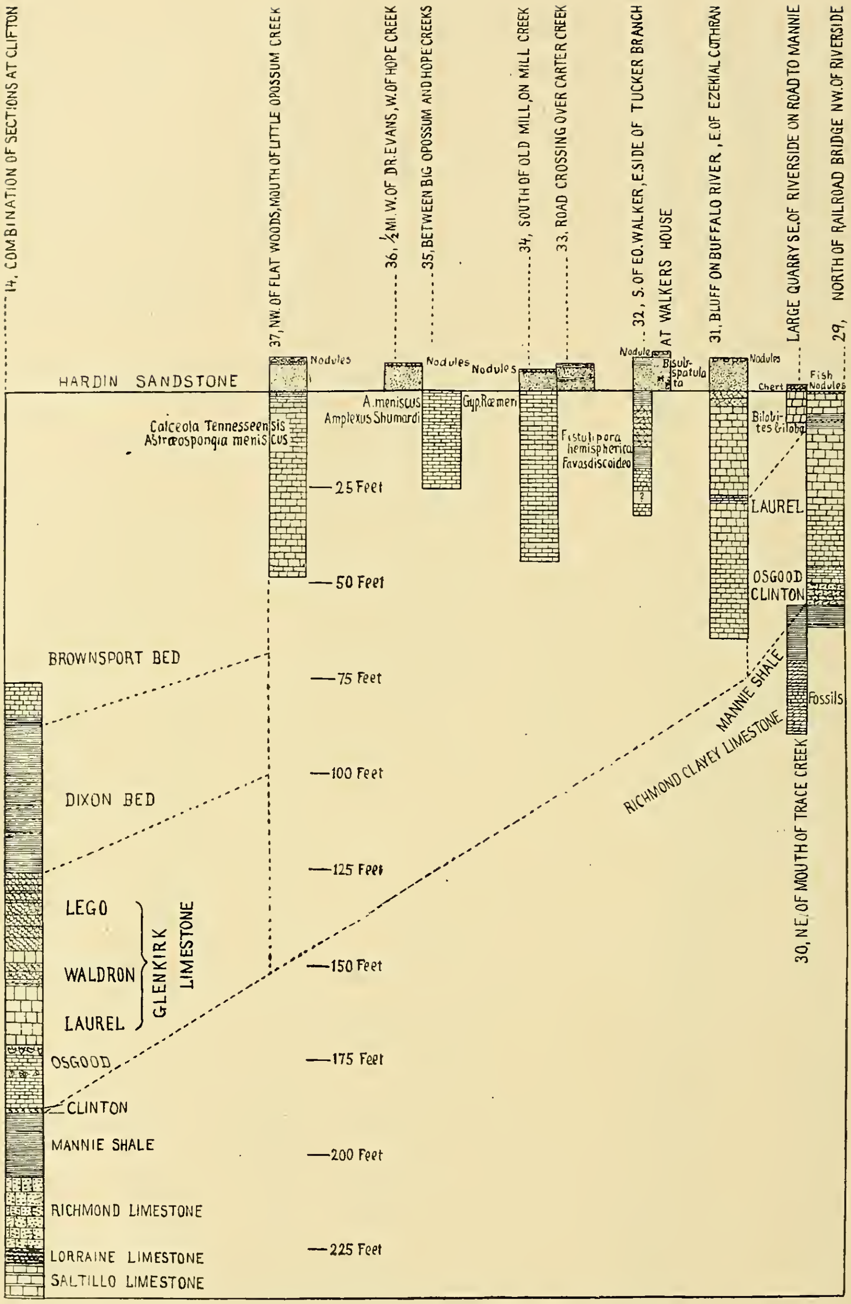

FIG. 4.—Sections between Riverside and Flatwoods.

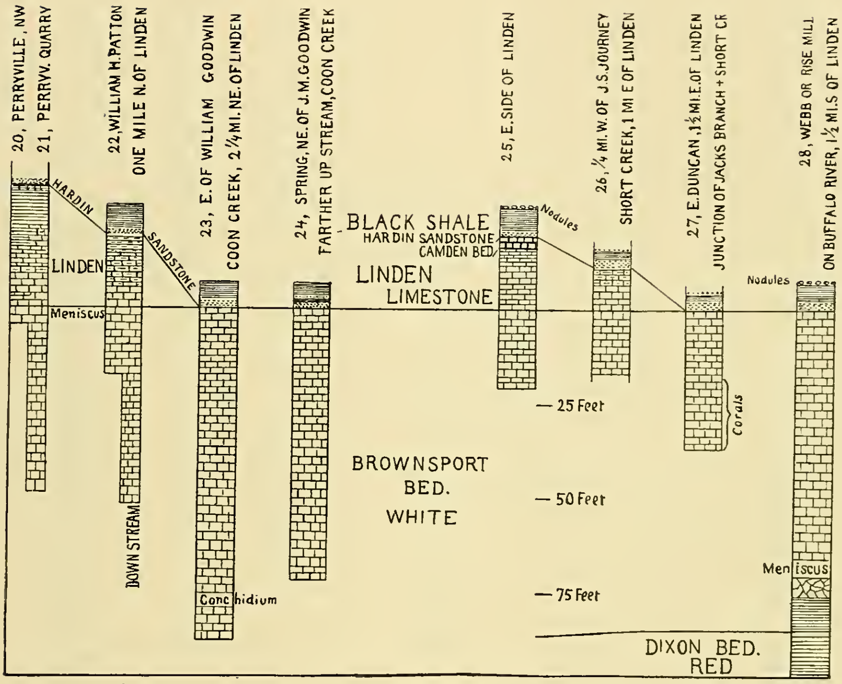

FIG. 5.— Sections at Perryville and Linden.

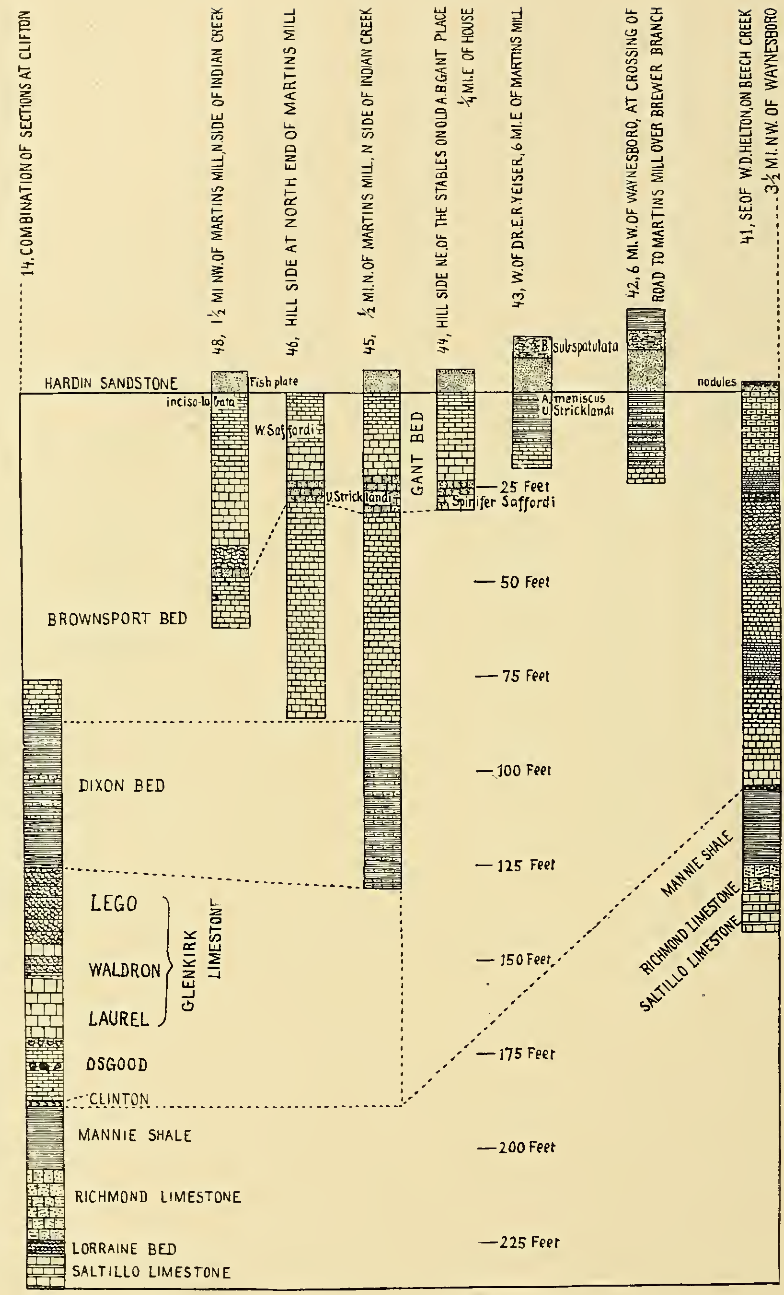

FIG. 6.—Sections between Waynesboro and Martins Mill.

interval of 22 feet separates the limestone from the Hardin sandstone.

A very instructive exposure occurs on the hillside rising above the northeastern part of the cluster of houses known as Martin's mill. Here the sandy Gant limestone (Layer A) is found 57 feet above the road, and about the same distance above the Dixon bed. It is 5 feet thick and forms a projecting ledge. Overlying it is found a bluish, better bedded limestone, partly fine-grained and partly crinoidal, 9 feet thick (Layer B). Following this is more limestone, much weathered and poorly exposed, 14 feet thick (Layer C).

The whitish clays and soft limestones beneath the Gant limestone contain the sponges, brachiopods, and crinoids characteristic of the glade exposures of the Brownsport bed. At the A. B. Gant locality, the Gant limestone contains *Spirifer saffordi*, *Dictyonella gibbosa*, *Nucleospira concentrica*, *Wilsonia saffordi*, *Uncinulus stricklandi*, *and Orthothetes subplanus*. Some of these fossils occur also in the Gant limestone at the northeastern edge of Martin's mill, and at various exposures along the northern bank of Indian Creek, down stream.

In the overlying, more distinctly bedded limestone, Layer B, at Martin's mill, are found *Wilsonia saffordi*, *Uncinulus stricklandi*, *Orthothetes subplanus*, *Gypidula roemeri*, *Camarotoechia neglecta*, *Nucleospira concentrica*, and *Meristina maria roemeri*.

In the poorly exposed limestone at the top of the section, Layer C, occur *Astylospongia praemorsa*, *Caryomanon stellatim-sulcatum*, *Meristina maria roemeri*, and *Wilsonia saffordi*. About a mile below Martin's mill, northwestward, on the northern side of Indian Creek, *Caryomanon incisolobatum* was found within a foot of the Hardin sandstone.

A. F. Foerste.

[*To be continued.*]

THE OVERTURNS IN THE DENVER BASINS.

Geological field work in the foothill region of the Denver Basin has possibly been hampered to some extent by the assumption that the overturn of certain formations—and the locally increased dip of the higher strata in other cases—were caused by the tangential, or nearly horizontal, pressure which is commonly supposed to have produced the mountain range. It is very possible that the direct effect of gravitation has not received sufficient consideration. Without in the slightest degree discrediting the lateral-compression theory of mountain uplift, of which there is

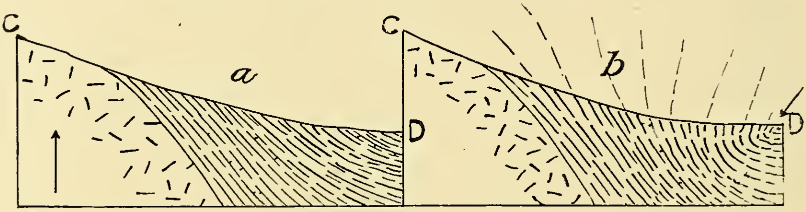

Fig. 1 (after figure in Monograph XXVII, U. S. Geol. Survey, p. 47).—*A* shows effect of vertical upward pressure, with dip of strata nearest the point of uplift greater than at a more distant point. *B* shows effect of tangential pressure.

other evidence along the foothills, it is worthy of notice that the overturning of strata flanking the foothills, may, at least in many places, and in every instance with which the writer is familiar, be, with good reason, ascribed to a very different cause.

In Monograph XXVII, United States Geological Survey, *Geology of the Denver Basin*, the fact is pointed out that the strata at some distance from the Archæan are generally tilted to a much higher angle than those lying nearer the granitic axis of the range, and this is deemed an indication of tangential compression. Two diagrams are given to show the different effects of vertical upward and oblique downward pressure, which are here reproduced, Fig. 1.

Acceptance of that idea without further investigation led the writer and others at first to overlook certain phenomena, until the discovery of what appear to be Benton shales on the south side of Boulder Creek, disappearing under the apparently overturned Jura-Trias at the base of Flagstaff Mountain (the axis of the Boulder Arch, described in the monograph before mentioned), compelled a re-examination of the subject. In this vicinity the most pronounced overturn is in the Niobrara basal limestone, which is very hard and sufficiently resistant to form a ridge-making element. It is normally overlaid by several thousand feet of easily eroded Upper Niobrara and Pierre shales, and underlaid by Benton shales. When these formations are erected to a position approaching the vertical, the rapid cutting away of Upper Niobrara and Pierre shales must inevitably leave the Niobrara limestone partly unsupported on the east side, to bear the burden of the lateral pressure of the mountain column upon its base. Flagstaff Mountain rises abruptly about 1,000 feet above the upturned edge of the limestone. Other foothills are still higher, others still are lower and less abrupt, while beyond the foothills the main Rocky Mountain range towers to a height of from 10,000 to over 14,000 feet above the level of the sea.

There are reasons for supposing that at Flagstaff, as the unsupported limestone gave way and overturned, a break in the underlying Dakota (here very thin) and in Jura-Trias permitted the latter to swing outward at the base and inward and downward at the apex, thus executing a partial revolution on an axis. In the meantime, the yielding Benton shales crowded down into the opening thus made, and the broken edges of the Triassic, swinging outward, passed out over the Dakota, Benton, and Lower Niobrara in such a position as now to rest upon the overturned Niobrara shales, giving the impression at first glance that the Dakota, Benton, and Lower Niobrara had never been deposited, and that the Triassic had participated with the Upper Niobrara in the overturn. The following diagram, drawn by Mr. H. F. Watts, of Boulder, Colo., who was associated with the writer in this work, will be an effectual aid to an understanding of what seems to have taken place.

After solving the problem at this point, it was easy to recognize the same phenomenon (which in local field parlance has been designated a "slump") at various points north and south for some distance. It frequently results in the production of a bench similar to the one on Flagstaff, locally known as Huggin's Park, but does not usually result in covering intervening formations on so extensive a scale. Whether like conditions exist at

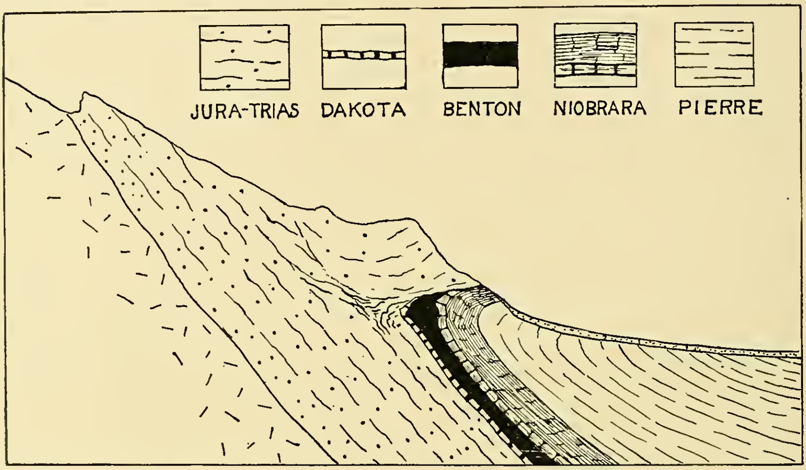

FIG. 2.—Cross-section of east slope of Flagstaff Mountain.

all places in the Denver Basin where overturns occur, the writer is unable to say, not being familiar with the foothill region south of the Boulder county line; but the matter is worthy of further investigation before assuming that such overturns have any bearing upon the theories of mountain structure. The same process that caused the overturns in these cases, has presumably caused the greater dip of the later formations in cases where they have not been overturned.

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Reviews

SUMMARY OF THE LITERATURE OF NORTH AMERICAN PLEISTOCENE GEOLOGY 1901 AND 1902. III.

FRANK LEVERETT.

UNITED STATES.

PENNSYLVANIA.

CAMPBELL, M. R. *The Masontown-Uniontown Folio.* Geol. Atlas of the United States, U. S. Geol. Survey, Folio 82, 1902.

The matters pertinent to this review are the drainage features and the Pleistocene deposits. The valleys of the main streams in this folio, as in much of western Pennsylvania, carry gradation plains into which deep and comparatively narrow trenches have been cut since the beginning of glaciation. The trenches have not yet extended to the headwaters of the tributaries. The Monongahela has made singular departures from its old course, which the author thinks are attributable to blockades of the old courses by river ice concurrent with the glaciation in districts to the north, a view which he had previously expressed in the Huntington, W. Va., Folio. (See Review.) Prior to the cutting of the trench, and coincident perhaps with the diversion of the river into its new course, the valley became filled greatly with alluvial material, but much of this filling has been removed by interglacial and postglacial stream erosion. The rock floor stands about 900 feet above tide, or not far from 150 feet above the river, but the filling reaches 250 feet or more above the stream.

GRIFFITH, WILLIAM. *An Investigation of the Buried Valley of Wyoming* [Pennsylvania]. Proc. Wyoming Hist. and Geol. Soc., Vol. VI, pp. 27–36, with map, 1901.

The valley is filled with gravel and sand and coarser drift to the depth of 200 or 300 feet. Were this filling removed, there would be a lake eighteen miles long and a mile in width, through which the Susquehanna River would flow. This river now flows along the surface of the gravel bed, but slightly impinging upon the rock rim. It is evident that this gravel is permeated by water, for sometimes in mining operations both gravel and water rush into the mines that pass into the limits of the gorge, and this has been the cause of much difficulty and some fatalities in the mining of the coal at Wilkesbarre. (From review by N. H. Winchell in *American Geologist*, Vol. XXVIII, p. 324.)

WILLIAMS, E. H. *The Alleged Parker Channel.* Bull. Geol. Soc. Am., Vol. XII, p. 463, 1901.

The view is presented that the oxbow, which had hitherto been referred to the preglacial Clarion River, is instead made up of two short side valleys that headed on opposite sides of a low col and debouched into the Allegheny within a mile of each other. In glacial time these two valleys were greatly filled by gravel brought down the Allegheny, and also by wash from adjacent hills.

The reviewer has given indorsement to this view in Monograph XLI, *U. S. Geological Survey* (p. 242), but subsequently, upon visiting the region in company with M. R. Campbell and M. L. Fuller, it was found that the contours of the valley are such as strongly to support the earlier interpretation, and the oxbow channel appears to have been abandoned through a sapping which enabled the stream to pass directly across the neck.

WILLIAMS, E. H. *Kansas Glaciation and its Effects on the River System of Northern Pennsylvania.* Proc. Wyoming [Pennsylvania] Hist. and Geol. Soc., Vol. VII, 8 pp., 11 Pls. and Figs., 1902.

The early glaciation in the anthracite region removed portions of the roof or capping of the coal, so that it is mined by stripping the drift. The old drift at West Bethlehem has a known thickness of 165 feet. Changes of drainage in the Lehigh River worked out by Joseph Barrell are noted; also evidence that the ice so blocked the Susquehanna near Williamsport that a glacial lake, called Lake Lesley, was formed, which had its discharge into the Juniata valley at Tyrone. Connected with this were several ephemeral slack waters still further up the west branch of the Susquehanna and the Sinnemahoning.

In northwestern Pennsylvania the advancing ice blocked the northward flowing drainage system, as shown by Carll, and the slack water found discharge down the Allegheny past the col at Thompson and down the Tionesta from Barnesville. There was a deep filling of sand and rock meal before the coarse glacial material was spread over this region.

OHIO.

CLARK, W. BLAIR. *Drainage Modifications in Knox, Licking, and Coshocton Counties.* Denison Univ., Sci. Lab., Bull. Vol. XII, Art. 1, pp. 1–16, Pls. I–III, 1902.

Not examined.

LEVERETT, FRANK. *Glacial Formations and Drainage Features of the Erie and Ohio Basins.* Monograph XLI, U. S. Geol. Survey, 802 pp. 26 Pls., and 8 text Figs., 1902.

The area treated in this monograph extends from the Genesee valley in New York westward across northwestern Pennsylvania and Ohio to central and southern Indiana, and southward from Lakes Ontario and Erie to the vicinity of the Allegheny and Ohio rivers. It embraces a district ranging in altitude from about 250 feet up to nearly 2,500 feet above sea-level, the highest points being in southwestern New York, and the lowest on the border of Lake Ontario. There are plains south of Lake Ontario separated by escarpments, and south of these is a greatly eroded tableland. Farther west are the Grand River and Scioto basins bordered by eroded tablelands, and still farther west is the low plain of the central Mississippi basin whose eastern border is found in western Ohio. Attention is directed to important changes of drainage which have occurred, and the causes of these changes are treated briefly.

The drift border or glacial boundary is not a unit, but is formed in part by the border of the Wisconsin drift, in part by the Illinoian drift, and in part by a sheet of drift that appears to be still older than the Illinoian which may be either Kansan or pre-Kansan. This oldest drift is exposed outside the Wisconsin drift in northwestern Pennsylvania, and is shown to have suffered a greater amount of erosion and weathering than the Illinoian drift. The Illinoian drift is exposed outside the Wisconsin drift from central Ohio westward to the Mississippi River, but is discussed only as far west as the re-entrant angle in the glacial boundary in southern Indiana, the portion farther west having been discussed in Monograph XXXVIII. The main topics considered are structure, topographic expression, and the character of the glacial drainage.

The weathered zone and accompaning soils and peat beds which occur between the Illinoian drift and the overlying loess are described in their exposures outside the Wisconsin drift, and to some extent within the limits of that drift.

The Iowan drift does not appear to be exposed in this region outside the Wisconsin drift, but a deposit of silt with loess-like characteristics occupies the horizon of this drift-sheet, and covers the weathered surface of the Illinoian drift. There appears to have been but a brief interval between the deposition of this silt and the Wisconsin glaciation, if we may judge by relative amounts of weathering. An interval of some importance may be inferred from the change in the attitude of the land by which better drainage conditions became prevalent in the Wisconsin stage of glaciation than attended the loess deposition. The marked difference in the outline of the Iowan and Wisconsin borders also indicates an interval of some consequence.

The early Wisconsin drift is less extensively exposed in this region than in that covered by the Illinois glacial lobe discussed in Monograph XXXVIII, there being in southwestern Ohio but one moraine and narrow till plain which seem referable to this drift, while in central and eastern Ohio and northwestern Pennsylvania it is not known to be exposed. The evidence of an interval between the early and late Wisconsin glaciations is more clearly shown in the region covered by the Illinois glacial lobe than in this region, for there the border of the outer moraine of the late Wisconsin group is strikingly discordant with that of the neighboring moraine or moraines of the early Wisconsin group, while in this region there is not a marked discordance.

The moraines of the late Wisconsin stage consist of an outer or main morainic system, which was brought to notice by Chamberlin in the *Third Annual Report of the U. S. Geological Survey*, and several minor moraines which appear in a somewhat regular succession between the main morainic system and the Lake Erie basin. Eskers are found in Ohio, Pennsylvania, and New York on the till plains between the moraines, but drumlins are restricted to the western New York portion of this region.

The great glacial lakes, Maumee, Whittlesey, and Warren, which were formed in front of the retreating ice-sheet as it withdrew into the Huron and Erie basin, are each shown on double-page maps, while their beaches and outlets are discussed in some detail. A marked warping of the beaches in Pennsylvania, western New York, and the province of Ontario testifies to differential uplift which has occurred since the ice retreated from this region, and which apparently is still in progress. The portion of the beaches in Ohio shows very little warping or differential uplift.

The monograph closes with a discussion of the soils, which are classified according to their origin, the following classes being recognized: residuary soils, bowlder-clay soils, gravelly soils, sandy soils, loamy soils grading into fine silts, peaty or organic soils.

MOSELEY, E. L. *Submerged Valleys in Sandusky Bay.* Nat. Geog. Mag., Vol. XIII, pp. 398–403, 1902.

Borings made in Sandusky Bay, have brought to light an old channel of the river and channels of some of its tributaries leading across the bed of the bay. They are nearly filled with a much softer deposit than the till of which the banks and the bordering submerged plain is composed. This evidence is in harmony with several lines noted by the author in other publications in support of the view that the water area is being extended at the west end of the Lake Erie basin, the principal lines being submerged stalactites in caves, submerged areas formerly covered by forests, the testimony of the flora of the islands to a former connection with the mainland, the observations of old residents as to encroachments made in the past eighty years, and gauge readings at Erie and elsewhere that show the water to have been lower at times in the first half of the nineteenth century than it has been since. In explanation of this extension of the lake the author cites the results of Gilbert's studies which indicate that a northward differential uplift is now in progress.

PIERCE, S. J. *The Cleveland Water Supply Tunnel.* Am. Geol., Vol. XXVIII, pp. 380–85, 1901.

A tunnel extended 26,000 feet under Lake Erie with a depth of 100 feet below lake level at the shore and 110 feet at the lakeward end is entirely through a stratified blue clay with thin partings of fine sand. The sand partings are from one-sixty-fourth to one-eighth of an inch thick, and separate the clay bed into layers three-fourths to one and a half inches thick. The bedding is generally horizontal, but shows some wave action, cross-bedding, and folding. Chemical analyses of the sand and the clay show them to be strikingly similar in composition where samples were taken close together, but some variation is found in different parts of the tunnel. Fragments of rock up to eighteen inches in diameter are imbedded in this deposit, and they vary greatly in the amount of water wear and glacial scratching. Many are syenites and, with the exception of a moderate number of local shales and sandstones, the rocks are of distant derivation.

The paper concludes with an account of test borings made near the mouth of the Cuyahoga that suggest to the author a continuation of the river channel under Lake Erie, but this is 85 feet below the surface of the lake and may admit of a very different interpretation, the data being, in the reviewer's opinion, insufficient to warrant definite conclusions. The preglacial valley of the Cuyahoga has been found, by borings made by the author, to have a bed about 450 feet lower than the surface of Lake Erie, or not far from 125 feet above tide.

INDIANA.

BLATCHLEY, W. S.. and ASHLEY, G. H. *The Lakes of Northern Indiana and Their Associated Marl Deposits.* Twenty-fifth Rept. Geol. Survey Indiana, pp. 31–233, 248–321, Pls. I and VI–XII, Figs. 1–70, 1901.

Lakes are classified as kettleholes, channel, and irregular depressions. The agencies of extinction mentioned are: material brought in by streams and springs, decrease of water supply from seepage, artificial drainage, and, most important of all, replacement by muck formed through the decay of aquatic vegetation.

Marl deposits occur chiefly in the three northern tiers of counties. They range in area from a fraction of an acre up to about 1,700 acres, but the majority fall below 100 acres. The thickness is known to reach 45 feet, and a large majority of the lakes appear to have a deposit 20 feet or more in depth. The marl is thought to be deposited from spring water through the loss of carbon dioxide caused in three ways: (1) by the increase in temperature : (2) by decrease in pressure; (3) by abstraction of the carbon dioxide to supply plant food.

Maps of many of the lakes are presented with a legend by which the marl conditions may be easily read. The descriptions in the text are full, and the value and accessibility of marl in each lake is clearly indicated.

BREEZE, FRED, J. *The Valley of the Lower Tippecanoe River.* Proc. Indiana Acad. Sci., for 1901, pp. 215, 216, 1902.

A map and description set forth the width of the valley and meanders of the stream.

CAMPBELL, JOHN T. *Evidence of Local Subsidence in the Interior.* JOUR. GEOL., Vol. IX, pp. 437,438, 1901.

Recent levelings of a locality in western Indiana, where bench-marks were established in 1883, show a slight decline southward. The Charlestown earthquake is suggested as a cause for the subsidence.

DRYER, C. R. *Eskers and Esker Lakes of Northeastern Indiana.* JOUR. GEOL., Vol. IX, pp. 123–29, 1901.

The name "esker lakes" is suggested for bodies of water occupying depressions closely connected with esker ridges.

FULLER, M. L. *General and Pleistocene Geology of the Ditney, Indiana, Folio.* Geol. Atlas of the United States, U. S. Geol. Survey Folio, No. 84, pp. 1–7, 1902.

The drainage and Pleistocene deposits are the chief topics pertinent to this review. The main drainage lines of southwestern Indiana became re-established after glaciation, but many of the smaller streams have suffered deflections or diversions as a result of an obstruction by the ice-sheet, drift, or glacial outwash. Little Pigeon and Cypress creeks, however, have been but slightly affected.

The Illinoian drift-sheet constitutes the main member of the glacial series within this quadrangle. There are deeply oxidized sand and gravel deposits found in patches outside the limits of the well-defined drift-sheet and also scattered pebbles, which may prove to belong to an older sheet of drift than the Illinoian. There are also a loess and a black soil beneath the Illinoian drift which are of undetermined age. The main deposit of loess is found above the Illinoian drift and is apparently of Iowan age. The loess along the Wabash valley up to a certain level is stratified, occurs in definite terraces, and appears to be of aqueous deposition, while at higher levels it is thought to be wind-deposited. Certain sand deposits along White River valley are considered of Wisconsin age, but most of the alluvium is post-Wisconsin.

HEINEY, W. N. *River Bends and Bluffs.* Proc. Indiana Acad. Sci. for 1900, pp. 197–200, 1901.

The paper discusses a very crooked section of Salamonie River in southern Huntington county, Ind., and is illustrated by sketch maps and a profile showing how the bend has been extended by the stream.

MCBETH, W. A. *The Development of the Wabash Drainage System and the Recessions of the Ice Sheet in Indiana.* Proc. Indiana Acad. Sci., for 1900, pp. 184–92, 1901.

This paper dissents from interpretations made by Chamberlin and Leverett that in the Wisconsin stage of glaciation the ice from the Huron-Erie basin covered Tippecanoe, White, eastern Benton, southern Newton, and southern Jasper counties, and receded eastward from these counties. The author maintains instead that the ice from the Lake Michigan basin overspread nearly the whole area of these counties, and that its recession was northwestward. The sketch maps which accompany the paper represent several supposed outlines of the ice margin in the course of its retreat. The author's interpretation and mapping are not supported, however; by the distribution of moraines, border drainage channels, and other features which are commonly used by glacialists in determining the outline which an ice-sheet presented at a given time. Instead other features are taken to indicate the position of the ice margin. In one case a change from a level to an inclined plain, in another the irregularities of the Wabash bluff produced by postglacial drainage, appear to have been interpreted as marginal features.

McBeth, W. A. *A Theory to Explain the Western Indiana Bowlder Belts.* Proc. Indiana Acad. Sci. for 1900, pp. 192–94, 1901.

The bowlder belts are interpreted to be a sort of beach formation, produced by the stranding of icebergs and floe ice in shallow lakes.

McBeth, W. A. *Wabash River Terraces in Tippecanoe County, Indiana.* Proc. Indiana Acad. Sci. for 1901, pp. 237–43, 1902.

The terraces are classified as high and low, the former being 80 to 130 feet above the river, and the latter but little above the modern flood plain. Reference is made to the occupancy of a preglacial valley by the Wabash throughout much of its course in Tippecanoe county, whose rock floor is about 150 feet below the present stream. A map repeats the views of earlier papers (reviewed above) as to moraines and lake beds.

McBeth, W. A. *History of the Wea Creek in Tippecanoe County, Indiana,* Proc. Indiana Acad. Sci. for 1901, pp. 244–47, 1902.

The creek is found to have its course governed by the slopes of the region, but the author thinks that its drainage basin was submerged for a time after the ice had disappeared, and it was not until the supposed lake had drained away that the creek began to open a course in conformity to the slopes.

Marsters, V. F. *Topography and Geography of Bean Blossom Valley, Monroe County, Indiana.* Proc. Indiana Acad. Sci. for 1901, pp. 222–37, 1902.

The valley of this creek is found to have been formed by a meandering preglacial stream. There has been a large amount of filling with earthy material, which also is found to antedate the deposition of the glacial material. The ice-sheet covered the head waters and also the lower end of the valley, but the middle portion is unglaciated. An arrest of drainage which resulted from this ice invasion is shown by the presence of benches along the valley borders where material was brought into the flooded valley by tributaries at levels considerably above the valley bottoms. These benches stand about 70 feet above the bottoms in northeastern Monroe county, but are only 25 to 30 feet above them in the northwestern part of the county. The difference is interpreted to be due to a greater accession of material in the higher benches than was received in the lower, rather than to different lake levels.

PRICE, J. A. and SHAAF, ALBERT. *Spy Run and Poinsett Lake Bottoms, and the Abandoned Meanders of Spy Run Creek.* Proc. Indiana Acad. Sci. for 1900, pp. 179–84, 1901.

The features here discussed appear in a small valley one and one-half miles northwest of Fort Wayne, and north of the Fort Wayne outlet of Lake Maumee. It is thought that lakes were present in this valley which have become converted into swamps by the influx of material washed from the bluff. The meandering of the creek over the bottom of Spy Run Lake basin forms the concluding topic.

SCOVELL, J. T. *Lake Maxinkuckee.* Twenty-fifth Rept. Geol. Survey Indiana, pp. 233–47, 261–65, 1901.

The features surrounding the lake and also the features of the lake bottom are set forth by description and map. The flora of the lake is presented in a list of about 150 plants, not including 50 which are found along the beach. The lake contains a large workable deposit of marl, which is thought to have had its origin through the separation of calcic carbonate from the water by mollusks and different species of *Chara.* An attempt made to form a rude estimate of the quantity of the carbonate of lime deposited each year gave 0.01 inch as a conservative amount. Assuming the average thickness of the deposit to be ten feet, about 12,000 years would be necessary to provide for the accumulation of the marl. It is, however, thought probable that the rate of deposition was more rapid in the past, so that the age of the lake may be considerably less than 12,000 years.

SIEBENTHAL, C. E. *Topography, Pleistocene Deposits and Drainage of the Hydraulic Limestone Area in Southern Indiana.* Twenty-fifth Rept. Geol. Survey Indiana, pp. 359–64, 1901.

Borings are thought to indicate that the Ohio River formerly passed the Louisville rapids in a course slightly north of the present.

ILLINOIS.

ALDEN, WILLIAM C. *The Chicago Folio.* Geol. Atlas of the United States, U. S. Geological Survey, Folio 81, 1902.

This folio is very largely devoted to a discussion of Pleistocene features and deposits, for the rock outcrops in the Chicago area are few, and it is the drift that gives the topographic variations. The Valparaiso morainic system covers the western edge; the remainder is largely embraced in the plain occupied by Lake Chicago. The Chicago outlet, with its double-headed channel, forms a conspicuous feature in its passage through the moraine. The discussion of glacial deposits pertains mainly to the Wisconsiu drift, though reference is made to exposures of earlier drift, and to the penetration of old drift in deep wells. The lake history is treated in considerable detail, and the several stages of Lake Chicago are shown by maps. In explanation of the lowering of the lake level from the upper to the second beach a suggestion of Chamberlin's is presented that the outlet may have cut back through the Valparaiso moraine by a stoping process until the barrier presented by the moraine was removed, and then lowering would rapidly take place. The changes in the present shore near the mouth of Chicago River which have occurred since 1821 are represented on a small map. The influence of the beaches of Lake Chicago on the course of Calumet River is also shown on a special map.

MICHIGAN.

GORDON, C. H. *The Port Huron Oil Field.* Report of State Geologist for 1901, pp. 269–82, 1902.

The thickness and character of the glacial deposits are given in connection with the well records, and attention is called to water supply from the gravel beds.

GORDON, C. H. *Wave Cutting on the West Shore of Lake Huron in Sanilac County, Mich.* Report of State Geologist for 1901, pp. 583–290, Figs. 6–8, Pls. XI–XV, 1902.

The amount of encroachment on the land from 1823 (when the government land survey was made) to 1901 was accurately surveyed on part of the shore, and found to average 6.81 chains, or 449.46 feet, an average of 5.7 feet per annum. Were the rate of cutting and transfer of material to the lake bed uniform for the entire 500 miles of coast, it would require 4,000 years to fill the lake one foot, and 800,000 years to fill the 200 feet of average depth. The rate of cutting here is thought, however, to be above the average, and the time required to fill the lake by this process is likely to be much longer than 800,000 years. The paper is well illustrated by maps and photographs of the shore.

GREGORY, W. M. *Preliminary Report on Arenac County, and Parts of Ogemaw, Iosco, and Alcona Counties.* Rept. of State Geologist for 1901, pp. 9–29, 1902.

The report aims to bring to notice economic resources: limestone, gypsum, coal, clay and shales, water supply (especially flowing wells), and agricultural values. The glacial deposits and shores of glacial lakes receive very brief treatment.

The flowing wells are partly from gravel below till on the lakeward slopes of moraines, but many are extended into the rock.

LANE, A. C. *The Preglacial Surface of Lower Michigan.* Science, Vol. XIV, pp. 798, 799, 1901.

Rock outcrops in Saginaw Bay seem to oppose the interpretation made by Spencer that the central part of the southern peninsula drained through the bay. The borings favor the view that drainage was westward or northwestward. The available data are thought to indicate that the drainage from the Grand Traverse region was southward past Manistee, rather than northward toward the Straits of Mackinac.

LANE, A. C. *Deep Wells, etc.* Rept. of State Geologist for 1901, pp. 211–38, 1902.

The records of deep wells in southeastern Michigan, in the Port Huron district, in the northern part of the state, and on the Lake Michigan shore which are here presented, throw light upon the thickness and structure of the glacial deposits.

LEVERETT, FRANK. *Surface Geology of Alcona County, Michigan.* Rept. of State Geologist for 1901, pp. 35–64, 1902.

The physiography, glacial deposits, lake history, soils, wells, marl and clay deposits, and water power form the chief topics of discussion. Rocks included in the drift of this county bear witness to several ice movements, some having been brought from the northwest, others from the northeast, and still others from the southeast. The ice-sheet apparently persisted in the low tracts in the eastern part of the county until Lake Warren had been drained away, for no well-defined beach was found above the Algonquin.

McLouth, C. D. *Some General Remarks on the Topography, Soils, Water Sources, Flora, etc., of Muskegon County.* Rept. of State Geologist for 1901, pp. 104–107, 1902.

The county is largely a sand plain, except the townships of Whitehall, Montague, Casnovia, and Ravenna, in which the predominating soil is clay. The features indicate much oscillation in lake level. The sand plain was covered by Lake Chicago up to a height of perhaps 75 feet above Lake Michigan, but deep-mouthed rivers apparently indicate a lake stage lower than the present surface of Lake Michigan. Flowing wells from the drift are common near the lake shore and range in depth from 35 feet at Montague to 250 feet at the south line of the county.

Sherzer, W. H. *Ice Work in Southeastern Michigan.* Jour. Geol., Vol. X, pp. 194–216, 1902.

The paper deals mainly with striation, and this is thought to be referable to four stages or episodes in the history of the Labrador ice-field; the Illinoian, Iowan, early Wisconsin, and late Wisconsin. The oldest movement is southwestward; the next, west-southwestward; the third, south-southwestward; and the fourth, mainly southwestward, but on the west side of the Huron-Erie lobe, northwestward toward its moraines. The lowering of the rock surface is thought to have been accomplished mainly in the first ice invasion. The amount of lowering in the three later ice invasions seems likely to be expressed in inches rather than in feet. The suggestion is made that this interpretation of greatest modification of rock topography at the earliest ice advance may also be applicable over the Great Lakes basins.

Taylor, F. B. *Surface Geology of Lapeer County.* Rept. of State Geologist for 1901, pp. 111–17, 1902.

This county, which is situated on the "Thumb" of Michigan, shows a range in altitude of about 500 feet, from 780 up to nearly 1,300 feet above tide. Five moraines traverse the county in a curving course convex to the north. These include a few clusters of sharp hills, but generally present a swell and sag topography. The Imlay outlet to Lake Maumee, brought to notice by the author's earlier studies, follows a sag between the third and fourth moraines, while earlier lines of glacial drainage which had their head in the ice-sheet in the eastern part of the county made use of sags between the first and second and the second and third moraines. The relative strength of moraines and the courses of glacial drainage are well brought out in a shaded map.

WISCONSIN.

Buckley, E. R. *Ice Ramparts.* (With a discussion by C. R. Van Hise.) Trans. Wis. Acad. Sci., Vol. XIII, Part I, pp. 141–62, Pls. I–XVIII, 1901.

The changes of temperature during the winter months cause sufficient expansion and contraction of the ice covering the inland lakes of Wisconsin to shove up the shore material into ridges, known as ice ramparts. The discussion pertains chiefly to ramparts on Lakes Mendota and Monona at Madison, Wis., formed in the winter of 1898–99, light precipitation and temperature conditions of that winter being exceptionally favorable for their development. The ice reached a maximum thickness of 30 to 40 inches, and shallow portions of the lake were frozen to the bottom.

Three forms of ramparts were observed: (1) along a sand or gravel beach of gradual slope, where the frozen lake bottom was shoved up the incline and left as a thin mantle upon the melting of the ice; (2) along an abrupt shore, were ice ridges were heaped up and bowlders from the lake bottom carried to heights of several feet above lake level, and in places the banks of the lake greatly disturbed; (3) at the head of bays occupied by mud, marl, and weeds, where the rampart has the shape of a more or less symmetrical fold. The folds are on the lakeward side of the shore where banks are abrupt, and on the landward side where they are very gradual, and on both sides where lakeward and landward conditions were balanced. In some cases a series of folds resembling the Appalachian Mountain structure was developed, features of which are noted below (in reviewing Van Hise's discussion).

The changes involved in the production of the ramparts are summarized as follows: (1) Beginning of freezing process. (2) Ice over the lake and temperature falling, ice thickens below and raises upper surface, setting up tensile stresses and producing surface cracks. The cracks receive water from below which freezes. Cracks open repeatedly until lowest temperature is reached, when the ice is approximately adjusted to the size of the lake basin at minimum temperature. (3) The temperature rises, compressive stresses are set up, and relief comes either through forming ridges in the ice or ramparts along the shore. Cracks also form from the under surface. (4) Freezing temperature, the water wells up into the cracks and freezes, and again the ice-sheet becomes a solid mass adjusted to the size of the basin, and the cycle of changes is completed.

In the discussion of this paper (pp. 158–62 of volume cited) Van Hise calls attention to analogies which the ice phenomena present to the crustal deformation of the earth, among which are noted: (1) the manner in which normal folds pass into overturned folds; (2) the successive development of folds; (3) the elevation of anticlines more than the depression of synclines; (4) the formation of folds at right angles to each other; (5) the combination of folds and faults; (6) the forcing of water up through cracks by the pressure exerted by synclines. The force acting upon the earth's crust is gravitative stress which comes from various causes, including changes in temperature, which is the controlling cause of ice ramparts.

COLLIE, GEORGE L. *Wisconsin Shore of Lake Superior.* Bull. Geol. Soc. Am., Vol. XII, pp. 197–216, 1901.

The paper deals with the shore phenomena of Chequamegon Bay and the Apostle Islands. These islands, it is thought, have resulted from the drowning of preglacial valleys. The strong topographic features of the mainland were produced in preglacial time, but glacial deposits have produced a marked influence on the topography.

Changes in lake level are found to involve a rise, now going on, as well as the lowering from high levels of glacial lakes that once occupied this lake basin. The recent rise is shown by two lines of evidence: (1) The lower courses of the streams tributary to the lake are drowned through the incursion of the lake water; (2) certain shore features, such as bars and spits, are in process of rapid destruction. The lake bars, island spits, tombolos, beaches (platform, barrier, cliff, and storm), shoals, lagoon and marsh, deposits, are considered, and also features produced by wave erosion, such as caverns, coves, cliffs, benches, and stacks. The last mentioned are small portions of rock cut off from the parent cliff through the action of waves in opening and enlarging the joint planes.

COLLIE, GEORGE L. *Physiography of Wisconsin.* Bull. Am. Bureau Geog., Vol. II, 20 pp., Winona, Minnesota, 1901.

Not examined.

FENNEMAN, N. M. *Development of the Profile of Equilibrium of the Subaqueous Shore Terrace.* JOURNAL OF GEOLOGY, Vol. X, pp. 1–32, 1902.

The profile of a shore at any given time is a compromise between the form it possessed when the water assumed its present level, and a form which the water is striving to give to it. While there are ever changing conditions with which no fixed form can be in equilibrium, there are certain adjustments of current, slope, and load which, when once attained, are held with some constancy, and the form thus involved is called the profile of equilibrium. The entire form may shift its position toward or from the land, but its slope will change little or not at all.

Waves are first considered in their free form in deep water where no external work is done, after which the various ways in which the bottom or shore may offer resistance and be subject to work by waves and currents is discussed in detail.

FENNEMAN, N. M. *On the Lakes of Southern Wisconsin.* Wis. Geol. and Nat. Hist. Survey, Bull., No. 8, 178 pp., 36 Pls., 38 Figs. in the text, 1902.

This bulletin is one of an educational series designed to assist students of physiography, and especially the teachers of the southeastern part of the state, in using the natural features of the region as an aid to instruction in physical geography and geology. The origin and history of the lakes and the features of their shores is discussed in some detail. The bulletin should be used in connection with a series of hydrographic maps which had been previously issued by the same survey.

Lake basins are classified under the headings: pits, erosion valleys blocked by drift, valleys between terminal moraine ridges, troughs of small glacial lobes, inequalities in the ground moraine. Under the heading, extinction of lakes, it is estimated that a great part of the material which contributes toward the filling of the lakes is obtained by the action of the waves upon the shores. Another important factor of extinction is the down-cutting of the outlet. The marl and vegetal accumulations are also factors of great influence. A chapter is devoted to the work of lakes upon their shores, in which the following topics are considered: waves and currents, shore forms due chiefly to cutting, shore forms due to transformation and deposition, shore forms due to ice, and cycles of shore lines.

The lakes discussed in this bulletin are: The lakes at Madison (chiefly Mendota and Monona), Lake Geneva, Delavan Lake, Lauderdale and Beulah lakes, Pewaukee, and Nagawicka lakes, Nashotah-Nemahbin chain of lakes, the Genesee lakes, Beaver, Pine, North, Mouse, Okauchee, and Oconomowoc lakes, Lac Labelle, Fowler and Silver lakes, Big and Little Cedar lakes, Elkhart Lake, and the Waupaca chain of lakes.

UPHAM, WARREN. *Pleistocene Ice and River Erosion in the St. Croix Valley of Minnesota and Wisconsin.* Bull. Geol. Soc. Am., Vol. XII, pp. 13–24, 1901.

The paper attempts to give a broad outline of the history of the St. Croix River, and especially of its upper and lower Dalles. The preglacial rivers which have contributed toward the production of the St. Croix valley, the glacial lake outlet which made use of this valley, and the work of the stream itself are each considered. Lakes

St. Croix and Pepin are due to recent and still progressing deposition of alluvium in valleys which were deeply eroded by outflow from glacial lakes.

MINNESOTA.

BROWER, J. B. *Kakabikansing*. St. Paul, Minn.: H. L. Collins & Co., Publishers, 1902.

Reviewed by T. C. Chamberlin in this JOURNAL, Vol. X, pp. 794–98.

UPHAM, WARREN. *Giant Kettles Eroded by Moulin Torrents*. Bull. Geol. Soc. Am., Vol. XII, pp. 25–45, 1901.

A description is given of very large potholes near Taylor's Falls, Minn., which are compared with other potholes both in North America and in Europe. Attention is called to the other ways in which potholes are produced (by subærial waterfalls and rapids), as well as by moulin torrents and subglacial streams. Those by the latter processes may have been formed in the early part of the glacial epoch, though some appear to date from the late part. It is thought they may be formed very rapidly, a single season perhaps being long enough to scour out one 20 to 50 feet deep.

WINCHELL, N. H. *Glacial Lakes of Minnesota*. Bull. Geol. Soc. Am., Vol. XII, pp. 109–28, Pl. 12, 1901.

This paper attempts to bring into one general view, with a brief description, the glacial lakes of Minnesota in their order of development. Twenty-six lakes are thus treated, many of which had not previously received names. The altitude of the outlet of each lake is given. The lowest is that of Lake Shakopee, 875 feet, and the highest, Lake Elftman, 1,700 feet. With this discussion of the lakes is given an account of the general manner of retreat of the ice-border. Attention is also directed to small glacial lakes along the Coteau de Prairie, which are not named, but have served to produce a remarkable topography. The paper closes with a reference to small lakes which laid in the deep gorges of the Mississippi within the driftless area and which owed their existence to glacial damming.

SOUTH DAKOTA.

TODD, J. E. *Moraines and Maximum Diurnal Temperature*. Science, Vol. XIV, pp. 794, 795, 1901.

From the fact that the moraines in the James River valley are wider and rougher on the west side of the valley than on the east, it is suggested in explanation that, the maximum diurnal temperature being higher after noon, the western half of an ice-lobe will receive more heat, and consequently be more active, than the eastern. As a general proposition it is stated that in the northern hemisphere the southern side of an east or west flowing glacier will be the more active and have its strongest movement toward the south. It is recognized that the influence of diurnal temperature may in certain cases be counteracted by other conditions.

TODD, J. E. *Hydrographic History of South Dakota*. Bull. Geol. Soc. Am., Vol. XIII, pp. 27–40, 1902.

The paper opens with a discussion of orogenic movements before the Pliocene, concerning which but little is known. The movements in the Pliocene are then taken up, and the development of the present streams in the portion west of the Missouri. These streams are thought to have made their way eastward to the James River valley, and several other peculiarities of drainage are mentioned. In the early Pleistocene the streams are represented as flowing over the same channels as in the Pliocene, for it is thought that the Kansan ice-sheet did not occupy the James River valley. During the later Pleistocene the James River valley was filled and the present course of the Missouri River is thought to have been inaugurated.

IOWA.

CALVIN, SAMUEL. *Geology of Page County*, Iowa Geol. Survey, Vol. XI, pp. 398–460, 1901.

The topography is characterized as an eroded drift plain, and the erosion is considered much more mature than in southeastern Iowa on the Kansan drift. The question is raised whether this drift may not be pre-Kansan. The valleys are partially graded up by a somewhat pebbly silt of loess-like aspect, and this grading up took place after the valleys reached their present large dimensions. Attention is called to a pebbly bed which occurs on the higher parts of the slopes at the base of the loess, which is thought to be the result of the removal of the fine parts of the surface of the till sheet and a resulting concentrating of pebbles. The statement that no such pebbly bed occurs in eastern Iowa is too broad, for the reviewer has noted it at the junction of the loess with the underlying Illinoian till sheet. (See JOURNAL OF GEOLOGY, Vol. VI, p. 181.)

CALVIN, SAMUEL. *Concerning the Occurrence of Gold and Some Other Mineral Products in Iowa.* Am. Geol., Vol. XXVII, pp. 363–72, 1901.

It is shown to be a fallacy that the topography of Iowa throws light upon the occurrence of valuable minerals deep in the earth. The presence of gold in the glacial deposits is also no indication of gold in the underlying rocks, since it has been derived from areas of crystalline rocks far to the north. It is also noted that gas, such as occurs in drift deposits near Herndon and Letts, is not to be taken as indication of larger amounts in underlying rock strata, for it appears to be formed from vegetation included in the drift.

CALVIN, SAMUEL. *Concrete Examples from the Topography of Howard County, Iowa.* Am. Geol., Vol. XXX, pp. 375–81, Pls. 27, 1902.

Descriptions and photographic views are given of the Loess-Kansan drift area, the loess margin, and the Iowan drift plain. The Loess-Kansan area presents a mature type of erosional topography, while the Iowan drift plain is very slightly eroded. The erosion contrasts are in line with other evidence, such as weathering and oxidation, in showing that the Kansan drift is many times older than the Iowan drift, or than its own coating of loess. It is considered a conservative estimate to give the Kansan drift an age fifty times as great as the Iowan.

FARNSWORTH, P. J. *When Was the Mississippi Valley Formed?* Am. Geol., Vol. XXVIII, pp. 393–96, 1901.

The present stream is in process of re-excavating a very old valley, whose floor was cut to a level more than 100 feet below the low water level of the river. The erosion is thought to have begun far back in Paleozoic times.

Finch, G. E. *A Terrace Formation in the Turkey River Valley, Fayette County, Iowa.* Proc. Iowa Acad. Sci., Vol. VIII, pp. 204–6, 1901.

The terrace is in a valley that heads in the drift covered, but passes into the driftless region of northeastern Iowa. The material found in the terrace is shown in the following section:

		Feet
1.	Surface soil of loess-like character	2–3
2.	Limestone fragments with a few glacial pebbles and with inclusions of blocks of loess	6
3.	Loess-like material with soil at top	8
4.	Iron-stained pebbly bed largely of local rocks, but containing green stones and quartz pebbles	3

Leverett, Frank. *Old Channels of the Mississippi in Southeastern Iowa.* Ann. of Iowa, Vol. V, pp. 38–51, Des Moines, 1901.

After calling attention to the several stages of glaciation that have influenced the course of the Mississippi, an attempt is made to outline the course the river took during each glacial stage.

Leonard, A. G. *Geology of Wapello County.* Iowa Geol. Survey, Vol. XII, pp. 439–99, 1902.

The physiography is discussed on pp. 443–48; the Pleistocene deposits, on pp. 472–75, and water supply and soils, on pp. 496–99. The part of the county northeast of a line running through Kirkville, Dahlonega, Agency, and Ashland is less deeply eroded than that southwest of it, but the entire county was originally a drift plain sloping southeastward. This difference in topography is explained by the relation to river systems and resulting gradients. The deeply eroded part is tributary to the Des Moines River, whose course to a given point on the Mississippi is more direct and the gradient steeper than that of Skunk River, which drains the less deeply eroded northeastern part. Attention is called to the greater width of the valley when in the soft Coal-measures than it is in the more resistant St. Louis limestone, the proportionate width being as 5 to 3. The Des Moines appears to be a re-established stream along a preglacial line. Its selection of the old course is thought to have been brought about by an incipient sag produced by the greater settling of material where the drift is very thick, an idea earlier brought out by Bain.[1]

The average thickness of the drift in this county is estimated to be not more than 100 feet, but the maximum may reach 200 feet. The county is entirely outside the limits of later drift sheets than the Kansan, though that drift is capped by a few feet of loess apparently of Iowan age. The surface of the Kansan drift is deeply weathered for 10 to 12 feet below the base of the loess.

MacBride, T. H. *Geology of Clay and O'Brien Counties.* Iowa Geol. Survey, Vol. XI, pp. 461–508, 1901.

The physiography is discussed on pp. 463–82; the Pleistocene geology, on pp. 482–89, economic products, on pp. 491–98, and forestry notes, on pp. 498–508. As these counties lie almost wholly within the limits of the Wisconsin drift, the drainage is very immature, and the chief contrasts in topography are such as are afforded by moraine and drift plain. The morainic topography is very largely comprised in the

[1] Iowa Geol. Survey, Vol. VII, p. 280, 1897.

eastern range of townships of Clay county. There are wide tracts of plane-surfaced gravel outside of this moraine, and the gravel is found to be covered by a loess deposit that must be younger than the loess of the eastern part of the state, which is correlated with the Iowan drift-sheet. The thickness of the drift in these counties is remarkable. A well at the county farm in O'Brien county, east of Primghar, is reported to have reached a depth of 700 feet, nearly all blue clay, and a well on the Boyd farm in Caledonia township, said to be 1,000 feet deep, is through the blue clay nearly all the way. The altitude of the drift surface at these wells is about 1,500 feet above tide.

MacBride, T. H. *Geology of Cherokee and Buena Vista Counties.* Iowa Geol. Survey, Vol. XII, pp. 303–53, 1902.

The physiography is discussed on pp. 306–16; Pleistocene deposits, on pp. 316–38; soils, clay industries, gravel, and water supplies, on pp. 338–43, and forestry notes on pp. 344–53. The contrasts in topography of the Wisconsin and the older drift of that region are clearly brought out. The drift, which in the report on Clay and O'Brien counties, was thrown into the Wisconsin, is here considered a possible early Wisconsin, while that bordered by the Altamont moraine is thought to be the probable limits of the Late Wisconsin. Further data are presented concerning the great thickness of drift in that region. A well at Marcus in the western part of Cherokee county, on ground standing 1,455 feet above tide, reached a depth of 680 feet without entering rock. This well is outside the limits of the Wisconsin drift.

Miller, B. L. *Geology of Marion County.* Iowa Geol. Survey, Vol. XI, pp. 127–97, 1901.

The physiography is discussed on pp. 131–40; Pleistocene deposits, on pp. 163–69; water supplies, on pp. 193–96; soils, on pp. 196, 197; the remainder of the report being devoted to the hard-rock geology. This county is outside the limits of the Iowan and Wisconsin drift-sheets, and has the topography of an eroded drift plain such as characterizes the Kansan drift elsewhere. The South Skunk and Des Moines Rivers are apparently re-established along the course of preglacial valleys. The remainder of the drainage is largely in new lines. It is noted that the streams have a tendency to flow along the base of the south bluff, and in explanation two causes are given, one being the influence of the rotation of the earth, brought to notice by Gilbert, the other the different rates of decomposition of rocks on the two sides, to which Calvin has given the preference in earlier reports of the survey, it being thought that freezing and thawing alternating rapidly on the north side of the valley break up particles, so that they are more easily transported into the valley than on the more shaded and longer frozen south side. Another cause brought out by John T. Campbell in 1884 is not considered.[1] This explains the low inclination of south-facing drift slopes to the creeping of the deposits on those slopes, which is favored by their deposition by a south-flowing current of ice.

Norton, W. H. *Geology of Cedar County.* Iowa Geol. Survey, Vol. XI, pp. 279–396, 1901.

The physiography is discussed on pp. 284–300; the Pleistocene deposits, on pp. 343–77; soils, on pp. 389–96. The Iowan and Kansas drift plains present marked contrasts in amount of erosion in this as in other counties of eastern Iowa.

[1] Am. Nat., Vol. XVIII, 1884, pp. 367–79.

The paha which are distributed near the border of the Iowan drift are found to be composed in part of Kansan drift, and are thought to be probable Kansan drumlins, though it is considered singular that they should be congregated around the border of a later sheet of drift. The deeply weathered surface of the Kansan, with its ferretto, is discussed very fully. Pre-Kansan drift is found in the deep part of the thick drift filling the preglacial valleys, but seems to be very sparingly represented on the uplands.

A preglacial channel called Stanwood River is traced through the county along a course parallel with and a few miles east of the Cedar River, the latter being largely in a postglacial course. From what seems to the reviewer to be an insufficient number of data, the gradient of the bed of this preglacial river is estimated to be 7 feet per mile, which is many times that of the neighboring portion of the preglacial Mississippi. As the valley of Stanwood River appears to have been a prominent tributary of the Mississippi, and since the valley of the Mississippi has a rock floor descending about one-half foot per mile, one would scarcely expect the gradient of this tributary to exceed one foot per mile. Attention is called to the incursion of some of the streams of the county into the edge of rock bluffs, which is thought to be due to an initial course given by the glacial drainage when the broad valleys were blocked by ice.

SAVAGE, T. E. *Drift Exposure in Tama County.* Proc. Iowa Acad. Sci., Vol. VIII. pp. 275–78, 1901.

A railway cut three miles west of Toledo, Ia., exposes what appears to be the Aftonian soil between sheets of Kansan and pre-Kansan till. The pre-Kansan till is thoroughly leached of its calcareous matter to a depth of 18 to 24 inches below the soil and partially leached to a depth of 6 feet. It is also changed to a reddish color to a depth of 3 or 4 feet, beneath which it is unoxidized. The soil is 1½ feet thick, dark brown in color, and carries numerous small fragments of wood and dark-colored bits of organic matter.

SAVAGE, T. E. *Geology of Henry County.* Iowa Geol. Survey, Vol. XII, pp. 237–302, 1902.

The physiography is discussed on pages 241–53; Pleistocene deposits, on pp. 289–95; soils, on pp. 297, 98; water supply, on pp. 301, 302; the remainder of the report being given to hard-rock geology. The effect of the Illinoian ice invasion in disturbing the drainage is discussed; also a probable post-Illinoian deflection of Cedar Creek into Skunk River. The Illinoian drift extends only a few miles into the southeast part of the county, the remainder being a Kansan drift area. In general the Kansan drift is greatly eroded, but in the northeast part of the county the channeling is very shallow, a feature which is explained by remoteness from a master stream. Gravelly deposits found at the surface of the Kansan drift are noticed and classified as Buchanan gravels. These gravels are of very limited extent compared with a deposit of gummy and slightly pebbly clay known as "gumbo," which caps the Kansan and also the Illinoian drift, and underlies the loess, but which is not noticed in this report.

SHIMEK, B. *The Loess of Iowa City and Vicinity.* Bull. Lab. Nat. Hist. State Univ. Iowa, Vol. V, pp. 195–216, 1901.

The loess at this locality, like that of much of eastern Iowa, is fine and homogeneous, and has a thickness of 12 to 15 feet. The loess fauna has perhaps been more fully studied here than in any other locality, and the paper deals mainly with this fauna. The molluscan fauna is found to point to comparatively dry, upland, terrestrial conditions during loess deposition, such as exist over the greater part of Iowa today.

UDDEN, J. A. *Geology of Louisa County.* Iowa Geol. Survey, Vol. XI, pp. 55–126, 1901.

The physiography is discussed on pp. 60–65; wells and water supply, on pp. 96–100, 125, 126; Pleistocene deposits, on pp. 101–14; clay industries, on pp. 119, 120; drift gas, on pp. 121–24; soils, on p. 125. In the discussion of drainage attention is called to divides which stand at the very brow of the west bluff of the Mississippi River, and of part of the Iowa River. It is thought that these large streams have widened their valleys sufficiently to reach divides separating them from small streams to the west. A contour map shows the altitude of the rock floor and levels reached by wells that did not strike rock. The rock surface of an upland in the southwest part of the county stands 650 to 720 feet above tide, while that of a lowland which occupies the remainder of the county averages scarcely more than 400 feet. The drift probably averages 300 feet in depth in the townships east of Iowa River, and ranges from 20 to 200 feet in townships west of the river.

Three sheets of bowlder clay are recognized—the pre-Kansan, Kansan, and Illinoian. The youngest, or Illinoian, covers all of the county except a narrow strip on its western edge. The pre-Kansan drift contains much wood, fragments of coal, and about twice as many fragments of local rocks as the higher drift sheets. Of the crystalline rocks it contains more greenstone, hornblende rock, and schist than are found in either of the other drift sheets, and a smaller proportion of dolomitic limestone, and of rocks common in the Kewenawan. This lowest drift sheet is poorly represented on the upland, but is a heavy deposit on the lowland tract and in preglacial valleys that traverse the upland. Between the pre-Kansan and the Kansan the Aftonian soil and a sand deposit have been found. The Kansan drift is jointed, with oxidized seams in the joints, and contains diabase, granite, and Kewenawan rocks, in larger amounts than the pre-Kansan. The Illinoian drift contains a large number of dolomitic rocks brought from neighboring outcrops to the east, and a comparatively few crystalline rocks. A few exposures of Yarmouth soil separating the Illinoian from the Kansan drift were noted, and a large number of exposures of the Sangamon soil between the Illinoian drift and the overlying loess.

Natural gas obtained near Letts is apparently from the Aftonian sand and soil horizon between the Kansan and pre-Kansan tills. The gas is probably partly from this soil, and partly from bituminous material in the pre-Kansan drift, which may include fragments of Sweetland Creek shale. The gas is in the upper part of the sand only, the lower part being filled with water. In fifteen different wells the pressure ranges from 4 to 10.5 pounds. The head of ground water is thought to be the principal factor which determines pressure. The depth of eight wells reported is 80 to 126 feet.

UDDEN, J. A. *Geology of Pottawattamie County.* Iowa Geol. Survey, Vol. XI, pp. 199–277, 1901.

The physiography is discussed on pp. 203–16; well records and water supply, on pp. 243–48, 273–76: Pleistocene deposits, on pp. 248–67; ice scorings, on pp. 268, 269; clays, on pp. 270–72, while the remainder of the report is devoted to hard-rock geology. This county is covered by a very thick deposit of drift which was apparently built up to a plane surface, with a slope, toward the south-southwest, of one to three feet per mile. The subsequent erosion has been so great that the surface is now nearly all embraced in the slopes toward the valleys. The valley bottoms are 50 to 200 feet below the upland plain, with a general depth of 100 feet. The grade of the steepest parts of the slopes is estimated to be about 13 feet to the 100, or 7° from the horizontal, but the average is much less. The drainage lines are apparently independent of preglacial courses, and it is suggested that the streams may radiate in conformity to glacial movements in this county. If the reviewer correctly interprets the hypothesis here advanced, the streams are thought to have had their start on the surface of the ice-sheet, and their courses determined by crevassing of the ice, but it is not made clear why the same kind of drainage may not have been developed on the drift surface after the ice had disappeared.

The average thickness of the drift is estimated to be 140 feet, exclusive of the loess, which has a thickness of about 60 feet. The surface of the till is not so much leached beneath the loess as in the Kansan drift in eastern Iowa. A dark blue-black till is found in the lower part of the drift which resembles the pre-Kansan till of eastern Iowa in color, structure, toughness, and position, and in containing vegetation, but the upper part of the till does not carry the distinguishing characteristics found in the Kansan of eastern Iowa. Its erratics appear to be of the same class as those of the blue-black till. The drift of this part of Iowa presents the rather anomolous and contradictory condition of being more eroded than that of the Kansan of eastern Iowa, and yet less weathered and leached. If one were to judge by the amount of erosion, it would be referred to the pre-Kansan stage of glaciation, but, judged by the amount of weathering and leaching, it would seem to be no older than the Illinoian, and possibly not older than the Iowan. It is well known that leaching progresses very slowly in arid districts, but it seems doubtful if the degree of aridity of western Iowa compared with eastern is sufficient to produce this difference in the amount of leaching. The rate of erosion should also be less in an arid than in a humid region, and yet the more arid western part of Iowa has the greater amount of erosion.

In the northern part of the county a "gumbo" separates the loess from the till on upland tracts, and the upper or gradual portions of the slopes. In places it appears to graduate upward into the loess, and downward into the till. It is more clayey than the loess, yet a mechanical analysis shows that about 95 per cent. of its material may be classed as loess. Interpretations concerning its origin are not reached, but it is suspected to be of diverse origin from place to place.

The loess is capable of separation into two distinct parts, especially the loess found in the valleys. The lower part is pebbly and shows clear evidence of water bedding. The upper part lacks these characteristics and appears likely to be a wind-deposited material. The reviewer would call attention to a feature which seems to indicate very clearly that the upper part of the loess on the borders of the Missouri valley in Iowa is wind-deposited. The topographic sheet of the Omaha-Council Bluffs district shows that the Iowa bluff stands considerably higher than the Nebraska bluff, and as the prevailing wind is from the Nebraska toward the Iowa bluff, it is thought that the latter has received the extra accumulation through the agency of the wind. A report on the loess mollusks made by Shimek (pp. 261–65) shows that the fossils are strictly terrestrial in nine out of the thirteen localities where collections were made, and in these remaining localities only two species of fresh-water pulmonates appear. In closing his report Shimek remarks that "the collection as a whole adds emphatic evidence of the fact, no longer to be doubted, that the loess was not of subaqueous origin." This unqualified statement appears rather singular in view of the fact that, in the report on this county, Udden calls attention to the presence of a water-deposited loess beneath the part of that formation thought to be wind-deposited.

UDDEN, J. A. *Loess with Horizontal Shearing Planes.* JOURNAL OF GEOLOGY, Vol. X, pp. 245–51, 1902.

The shearing planes here discussed were observed in Pottawattamie county, Iowa. They occur at the junction of the typical or pebbleless loess with a slightly pebbly deposit of loess-like material which underlies it. They appear to indicate a differential motion of the layers which they separate. The direction of movement is prevailingly from northeast to southwest, in harmony with the direction of general slope of the upland, but not in harmony with local topography. To account for the motion two hypotheses are suggested: (1) Tundra conditions may have prevailed, and the annual temperature changes caused creeping on a sloping plain; (2) there may have been glacial conditions. With a sudden onset of arctic climate, an extension of snow far beyond the margin of the ice seems probable, and an extra-morainic névé might develop. Such a snow-covered region would furnish ideal conditions for loess accumulation. A slow creeping of the entire field might take place in the direction of general slope of the land.

UDDEN, J. A. *Geology of Jefferson County.* Iowa Geol. Survey, Vol. XII, pp. 355–437, 1902.

The physiography is discussed on pp. 359–67; well records, on pp. 419–22; Pleistocene deposits, on pp. 422–29; glacial scorings, on p. 430; water supply and soils, on pp. 436, 437; while the remainder of the report treats of hard-rock geology. The drift of this county appears to have been left as a very smooth plain, with a gentle southeastward slope of 3 to 5 feet per mile. In this plain the rivers, creeks, and smaller streams have sunk their valleys 50 to 150 feet. It is estimated that from one-fourth to one-fifth of the total area of the county stands either at the original level of the plain or is included in the very gradual slope on the border between the plain and the steeper valley slope. The slopes are one-eighth to one-half mile wide, and show a rate of descent of 50 to 150 feet per mile, with the greatest pitch somewhat below the middle of the slope. The slopes facing the south are more gradual than those facing the north, and this is thought to be largely due to the rapid alternations of freezing and thawing to which the south-facing slopes are subjected. (See review of paper by B. L. Miller above, for other possible factors.) Terraces are found on Skunk River up to 125 feet above the stream, or 40 feet below the upland, and on Cedar Creek to 80 feet above the stream. The highest terraces have been shown by Leverett to be referable to drainage at the time of the Illinoian ice invasion. Udden doubts if they indicate a lower elevation of the land than now, for they seem, in Jefferson county at least, to have been dependent upon obstructions produced by rock sills in the valleys.

A list of twenty-seven wells shows a variation of but 110 feet in the altitude of the rock surfaee. If no deep-buried valleys occur which have been escaped in the borings, the reliefs of the rock surface are no greater than those of the drift surface.

The occurrence of weather-stained, leached, and partially indurated gravel beds at the base of the drift is noted. As these contain Archæan rocks, they appear to be glacial, but their age is not decided. A blue-black till 30–70 feet thick, which occurs in the lower part of the drift, is referred to the pre-Kansan stage of glaciation. Above this in some cases is a yellow sand separating it from the overlying Kansan drift. The sand is possibly of Aftonian age. A classification of the lots of 100 pebbles each from each of the drift sheets showed the upper or Kansan to have more hornblendic rocks, diabase, epidote, gabbro, red arkose, and chert, than the lower or pre-Kansan drift. The lower drift is found to have more of the greenstone, schists, slate, jaspilite, syenite, and Palezoic rocks than the Kansan drift sheet. A table shows to what different extent the several classes of rock suffered reduction in the glacial mill. The leaching of the Kansan drift surface varies within short distances from 4 to 12 feet in depth, because of the difference in texture or in drainage conditions. The thickness of the loess which covers the Kansan drift is about 12 feet, except on slopes, where it is 8 to 10 feet or less. Cross striæ were observed near Perlee bearing S. 35° E. and S. 70° W., but no attempt is made to explain this rather striking and unexpected feature.

WILDER, F. A. *Geology of Webster County.* Iowa Geol. Survey, Vol. XII, pp. 63–235, 1902.

The physiography is discussed on pp. 69–75; the Pleistocene deposits, on pp. 128–38; water supply, on pp. 185, 186; and soils, on pp. 189–91. There is thus but a small portion of this lengthy report devoted to Pleistocene features aud deposits. Webster county lies within the limits of the Wisconsin ice invasion, and the author calls attention to the slight amount of erosion and immaturity of drainage systems in this part of the Wisconsin drift sheet. The Des Moines River is thought to be in a pre-Wisconsin valley that was nearly filled with Wisconsin drift. The gravel terrace 150 feet above the river is thought to be of Wisconsin age. Attention is called to a recessional moraine south of Webster county, and two others in the north part of the county. There is also a weak one near Tara, previously noted by Upham.

MISSOURI.

MARBUT, C. F. *The Evolution of the Northern Part of the Lowlands oj Southeastern Missouri.* University of Missouri studies, Vol. I, No. 3, 63 pp. 6 Pls., 1902.

After describing the lowlands, with their intervening hills and ridges and the geologic formations of the region, the processes by which the lowlands were produced are considered. It is concluded that the streams which eroded the lowlands were the streams that now drain the region, and that the lowlands are so recent in their development that no complete rearrangement of drainage can have taken place since their erosion. It is thought that the Mississippi originally turned westward at Cape Girardeau and followed the course now occupied by the Advance lowland belt, and contemporaneously the Ohio eroded the Cairo lowland. The Ohio worked in loose sands and clays, while the Mississippi worked chiefly in hard limestone. The Ohio was therefore able in a given time to erode a much wider valley than the Mississippi. It is also probable that it was less burdened by silt than the Mississippi, and in consequence was able to bring its valley to a lower gradient. It is thought that the altitude at Cairo may have been 60 feet lower than at Cape Girardeau, points similarly situated on the parallel streams. This lower altitude of the Ohio gave it suffcient advantage over the Mississippi to result in the capture of the latter stream. The capture is thought to have first taken place through a gap between Benton Ridge and Crowley

Ridge, and later along its present course east of Benton Ridge. The paper also discusses the method by which smaller streams have been diverted or shifted from their old courses.

TODD, J. E. *River Action Phenomena.* Bull. Geol. Soc. Am., Vol. XII, pp. 486–90, 1901.

The phenomena discussed are mainly along the Missouri River. Attention is first called to the deep scouring which occurs at flood stages of the river, a depth of 50 to 100 feet being frequently reached. Several corrollaries are to be drawn from this fact: (1) that bed-rock 100 feet below present low water does not demonstrate a buried channel; there must be present some other deposit than river alluvium, such, for example, as till; (2) that estimates of discharge at flood stages should include this deepening as well as the rise of the water; (3) the transfer of sediment down the valley should include the moving river bed as well as the material in suspension; (4) recent objects may be deeply buried by river deposits. In this connection the reviewer would call attention to deep scouring at St. Louis noted by Woodward, (C. M.) in his treatise on the St. Louis bridge, published in 1881. Soundings off the east abutment of the bridge made in 1876 showed a depth of nearly 100 feet of water where there was but 15 to 20 feet when the abutment was constructed. Concerning this Woodward remarks: "It is clear that either the mighty river had at one time its normal bed on the rock or else it has in ages past, during its countless floods, again and again scoured down to the rock itself."

The second topic treated in this paper is that of mutual flood relief channels formed just above the junction of two streams. They have been noted on many rivers.

A third topic shows that a flooded stream has its velocity checked by overflowing its flood plain, and as a result fine material is deposited.

KANSAS.

CHAMBERLIN, T. C. *The Geologic Relations of the Human Relics of Lansing, Kansas.* JOURNAL OF GEOLOGY, Vol. X, pp. 745–77, 1902.

HOLMES, W. H. *Fossil Human Remains Found near Lansing, Kansas.* Am. Anth., N. S., Vol. IV, pp. 743–52, Pls. 31–32, 1902.

UPHAM, WARREN. *Man in Kansas in the Iowan Stage of the Glacial Period.* Science, Vol. XVI, p. 355, 1902.

——— *Man in the Ice Age at Lansing, Kansas, and Little Falls, Minnesota.* Am. Geol. Vol. XXX, pp. 135–50, 1902.

——— *Primitive Man and His Stone Implements in North American Loess.* Am. Nat., Vol. XXIV, pp. 413–20, 1902.

——— *The Fossil Man of Lansing, Kansas.* Rec. of the Past, Vol. I, pp. 272–75, 1902.

——— *Primitive Man in the Ice Age.* Bibliotheca Sacra, Vol. LIX, pp. 730–43, 1902.

WILLISTON, S. W. *A Fossil Man from Kansas.* Science, Vol. XVI, pp. 195–196, 1902.

——— *An Arrowhead Found with Bones of Bison occidentalis Lucas in Western Kansas.* Am. Geol., Vol. XXX, pp. 313–15, 1902.

WINCHELL, N. H. *The Lansing Skeleton.* Am. Geol., Vol. XXX, pp. 189–94, 1902.

These papers, with the exception of the second one by Williston, pertain to human remains found on the Concannon farm near Lansing, Kan., in a tunnel which had been extended into the Missouri River bluff. The remains were found just above a rock shelf which is covered to a depth of 25 feet or more by an earthy material which by Upham and Winchell is thought to be loess of Iowan age, but by Chamberlin is considered postglacial, and the product of aggradation at the mouth of a small tributary of the Missouri. Chamberlin's interpretation is indorsed by Calvin and Salisbury in brief statements which appear in connection with his paper. Williston's opinion, based upon the condition of the skeleton, would give it a respectable antiquity. Holmes considers the skeleton that of an Indian, and doubts if it is of great antiquity.

The second paper by Williston discusses the occurrence of an arrowhead and bison bones in a deposit which seems to be loess-like in character and possibly of Iowan age.

MISSISSIPPI.

SHIMEK, B. *The Loess of Natchez, Mississippi.* Am. Geol., Vol. XXX, pp. 279–99, Pls. X–XVI, 1902.

More than fifty exposures of loess were examined at Natchez and several at Vicksburg. It was found that the thickness had been overestimated by earlier investigators. Instead of 50 or 60 feet, its maximum thickness is only 25 or 30 feet. Like the northern loess, it mantles the slopes as well as the divides. Like the Missouri River loess, it is coarse and contains much lime. The molluscan fauna is, however, different from that of the northern loess, there being no pond species intermingled with the terrestrial species such as occur in the northern loess. The entire list of species are not only terrestrial, but all are now found living either on the hills in the immediate vicinity or in similar situations in other parts of the South. Some of the most characteristic and widely distributed species of the northern loess are wholly absent, and others very rare in the southern loess. Eighteen species are thus far known only from the loess of the South. The author holds that the Natchez loess furnishes weighty arguments against both the aqueous and glacial theories of the origin of the loess. The aqueous theory is unsupported by traces of beaches and shore lines, etc., and the fossils are so fragile that it is considered highly improbable that they were transported by water. There is also nothing in the molluscan fauna which would suggest even the remotest possibility of a glacial climate, for the species are in large part such as inhabit the warmer parts of our country today. The author therefore concludes that the æolian theory offers the best explanation of the origin of the southern loess. The paper is illustrated by photographs of the exposures and drawings of many of the loess fossils.

LOUISIANA.

HARRIS, G. D. *Quaternary Geology and Water Supplies in the Mississippi Embayment.* Geol. Survey of Louisiana, Rept. for 1902, pp. 32–39, 215–52.

The Orange Sand is a deposit thought to have been under conditions of rising shore or falling sea-level, without definite time in the geological scale. Port Hudson clay is apparently a deposit made in a broad marsh or in shallow lakes during a long-continued sunken or sinking condition, and it appears not to be separated from the recent alluvium by any sharp line of demarkation. The lower limits also are not clearly shown, there being a transition into the Lafayette. Loess is thought to be represented at a few localities. The loess and the Port Hudson have been raised to moderate altitudes above the sea, and the deposits made in trenches cut in these formations constitute practically the last geological formation.

The mud lumps at the mouth of the Mississippi are briefly discussed and shown to be unlike volcanic cones running down outside a gas vent. They represent upheavals, produced probably in large part by gas, though the origin and agencies are not fully understood.

The water supplies from the Quaternary are discussed on pp. 215–52. The Lafayette sands afford a strong supply, and if overlain by the Port Hudson clay, the water usually shows a rise when struck. The head declines toward the Gulf and also toward the axis of the embayment.

UPHAM, WARREN. *Growth of the Mississippi Delta.* Am. Geol., Vol. XXX, pp. 103–11, 1902.

The data collected from notes of early explorers lead to the conclusion that in the four centuries since the delta was seen by Vespucci it has been extended in the passes some 10 or 15 miles. The extension of the delta from an old to a new group of branches or passes is thought to have been effected by the growth of one of the old passes so far beyond the others that it became the chief, if not the only, channel in ordinary stages of the river. It is predicted that, instead of extending forward in a third stage, the main current will forsake this lower course and descend to sea level some shorter way.

GENERAL.

DRYER, CHARLES R. *Lessons in Physical Geography.* 430 pp., 347 text Figs., and 20 full-page maps. New York: American Book Co., 1901.

The subjects treated are the earth as a planet, the land, the sea, the atmosphere, and life.

The aim of the book is to develop a scientific habit of mind in the study of physical geography. No attempt is made to discuss exhaustively the physical features of the earth, or of any special region; but the best type-forms are selected and treated with sufficient fulness to give a clear and definite picture. General laws are developed from a study of the type which may be applied wherever the problems to which they apply may arise. This plan makes it possible to avoid the vague generalizations which characterize too many text-books. A large number of realistic exercises are introduced which appeal to the actual or possible experience of a student. They aim to give some idea of the methods of geographic research, and include both field and laboratory work. The illustrations, which are many, are frequently drawn from the interior part of the United States, which has been poorly represented in previous works on physical geography.

ECKHOLM, N. *Meteorological Conditions of the Pleistocene Epoch.* London Quart. Journ. Geol. Soc., Vol. LVIII, pp. 37–45, 1902.

The area of Pleistocene glaciation in Europe and America corresponds with the areas now traversed regularly by frequent storm tracks. There seems to have been the same difference in mean annual temperature of Europe and America in the Ice age as now, and it is thought a lowering of the temperature sufficient to put the snow line 1,000 meters lower would bring on glaciation. The effect of glaciation on cyclones and anticyclones is thought to be the same as a cold winter. Reference is made to a paper by F. W. Harmer (reviewed below), which is thought to overrate the effect of wind on climate.

GILBERT, G. K. and BRIGHAM, A. P. *An Introduction to Physical Geography.* 380 pp., 263 Figs. New York: D. Appleton & Co., 1902.

The several chapters treat the following subjects in the order named: the earth, the earth and sun, rivers, weathering and soils, wind work, glaciers, plains, mountains and plateaus, volcanoes, the atmosphere, winds, storms, and cyclones, the earth's magnetism, the ocean, the meeting of the land and sea, life, the earth and man.

The study of the lands is brought in early in the belief that here is the sure appeal to the students interest and previous knowledge. For the same reason the more familiar features of the land are treated before those that are less common. The treatment, so far as possible, is concrete, and wherever practicable each subject is opened with a type case, in the description of which terminology is called forth and the principles begin to appear. It is believed that physical geography is a subject which lends itself to this method with special effectiveness. The illustrations are especially well selected and are closely correlated with the text.

HARMER, F. W. *The Influence of the Winds upon Climate during the Pleistocene Epoch.* London Quart. Jour. Geol. Soc., Vol. LVII, pp. pp. 405–78, 1901.

Since changes of wind today cause sudden and marked changes in weather, it is thought that a long-continued change in the course of prevalent winds in the past ages would produce great changes in climate. At present continental areas are hotter than oceanic during summer, and are therefore cyclonic; they are colder in winter and are then anticyclonic. Regions covered by ice during the glacial period may have been to some extent anticyclonic at all seasons, low-pressure systems prevailing at the same time over the warmer regions south of them and over the adjoining ocean. With such a change oceanic winds with copious rainfall may have prevailed over regions now arid, and mild winters where they are now severe. The paper makes use of weather charts from all over the world in discussing the climatic conditions now prevailing, and draws upon paleontological and other evidence in support of changes of climate to which various parts of the world have been subjected. It seems difficult to explain how the northern hemisphere could have been wholly cold at one stage of the glacial period or wholly mild at another, and it is suggested that no difficulties would arise if there was an alternation of glacial and temperate conditions on the two continents, it being mild in America while glaciation was prevalent in Europe, and *vice versa.* The paper is naturally very hypothetical, and, as noted above (see Eckholm), the areas of Pleistocene glaciation in Europe and America apparently correspond with areas now traversed regularly by storms.

REID, H. F. *Variation of Glaciers.* JOURNAL OF GEOLOGY, Vol. IX, pp. 250–54, 1901; Vol. X, pp. 313–17, 1902.

The first paper gives a summary of records of glaciers for 1899, the second for 1900. The great majority of glaciers are in process of retreat, the world over, but historic evidence shows that their fluctuations are complex and dependent on several factors.

SCOTT, A. C. *A Brief Summary of Glacier Work.* Am. Geol., Vol. XXX, pp. 215–61, 1902.

This summary was written as a seminary paper in a course in geology at the University of Wisconsin. When attempting to arrange an outline of the work it was found that the literature nowhere included a summary, hence the publication of the paper. Although not exhaustive, it attempts to cover the important topics of the subject.

TRUE, H. L. *The Cause of the Glacial Period.* 162 pp. Cincinnati: The Robert Clarke Co., 1902.

The first 52 pages outline the main features of the drift, state the glacial theory, and discuss the several current hypotheses which aim to account for the glacial period. None of these, nor all of them put together, satisfy the author. Years ago he conceived the idea that a change of latitude might account for glaciation. In the remaining 110 pages the following topics are considered: (1) the inability of a change of the earth's axis to produce a glacial period; (2) the stability of the earth's axis; (3) time and climate; (4) causes of change of climate; (5) the glacial period still continues; (6) the glaciated region and probable thickness of ice during the maximum of glaciation; (7) the Champlain epoch; (8) evidence that the earth has toppled, together with a consideration of the objections; (9) an open polar sea.

The chief idea set forth in the book is that of a change of latitude or disturbance of the rotary motion of the earth produced by the weighting of the ice-covered region. The buried channels of the glaciated region, which are commonly interpreted to indicate a former high altitude of the land, are here interpreted to indicate that the land stands nearer the equator than it did when they were cut. The northward rise of the marine beaches and beaches of the great glacial lakes of the eastern part of North America are interpreted to indicate that the region is swinging away from the equator instead of undergoing an uplift. The reviewer would call attention to the fact that these beaches do not show a continuous northward rise, but stand higher for example, on the borders of Lake Champlain than they do considerably farther north on the borders of the Gulf of St. Lawrence, and even higher than at the extreme north end of the Labrador peninsula, as determined by A. P. Low (see papers reviewed above). The geological evidence appears to bring little or no support to the hypothesis that extensive changes of latitude have occurred. If there has been an oscillation of latitude as a result of the weighting of the glaciated region and subsequent melting, physicists and astronomers may be able to calculate its amount. The subject seems an inviting one for investigation.

ADDENDUM — CONNECTICUT.

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A probably expanded stage of Woodstock pond is noted, and neighboring glacial features consisting of kames, eskers, kettleholes, and drumlins are described. These features are largely restricted to the lowlands. The ridges, which in that vicinity stand about 300 feet above the lowlands, carry a smooth-surfaced drift.

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THE LAURENTIAN PENEPLAIN.

TABLE OF CONTENTS.

INTRODUCTION.

THE late director of the Geological Survey of Canada, Dr. George M. Dawson, in his address before the Geological Section of the British Association, at the Toronto meeting in 1897, mentioned, in passing, that the topographic features of the Archæan areas of North America were those of a peneplain. During the past seven summers the writer has had the opportunity of studying in more or less detail considerable areas around the southern portion of this Archæan region extending from Lake Champlain in the east to the Hudson Bay divide in central Keewatin. In a paper published two years ago (41)[1] attention was drawn to some of the geographic features of the southern margin of the Archæan belt within central Ontario. In the present paper, with the aid of the numerous accounts of travels and reports of explorations in various parts of these Archæan regions, these studies have been extended to the greater areas of central and eastern Canada

The purpose of the present paper is, primarily, to draw attention to the physiographic unit, the Laurentian Peneplain,[2] and to present a brief picture of its more salient features; and, secondly, to outline a few of the almost endless variety of geologic and geographic problems which the Canadian shield presents. Many of these problems, in the present state of our knowledge of the vast area here under discussion, are insolvable; many perhaps will never be solved; but none the less it is interesting to review the work already done and to consider that which lies before us.

[1] The number refers to the article listed with corresponding number at the end of this paper. A following number indicates the page reference to the article in question.

[2] The adjective "Laurentian" is here applied to this, the largest peneplain developed in Canada, to distinguish this topographic unit from others of a similar type also found in Canada or in the adjacent parts of the United States. For example, we have the Atlantic Coast Peneplain, parts of which, under the title of the New England Peneplain, and the Acadian Peneplain have been described by Davis and Daly respectively; the Tertiary Peneplain of British Columbia has been briefly referred to by Dr. Dawson, and the Peneplain of the Yukon basin has recently been described by H. C. SPENCER, *G. S. A.*, May, 1903. The relations of these minor plains to the greater area here under discussion are not yet definitely established. As will be shown in the succeeding paragraphs, the Laurentian Peneplain itself is not a single plain, but rather is made up of a series of facets intersecting at very low angles, three of which are distinguishable south of the main divide, so that there are probably at least five facets, and perhaps more. It has not been deemed advisable at present to suggest names for these facets.

Sketch map to show the area included by the Laurentian Peneplain. The peneplain area is shaded.

It is not proposed in the present paper to enter upon any discussion of the strictly geologic problems offered by the rocks of the area—such as a consideration of the stratigraphy, origin, and relations of the metamorphic and igneous rocks of the great Archæan complex.

THE CANADIAN OLDLAND.

In its general features eastern North America presents in a most striking manner and on a large scale what may be regarded as a typical development of physiographic forms characteristic of a belted ancient coastal plain centered around an oldland area. The Canadian shield of Suess, the area whose general physiographic features are to be more particularly described and discussed in the succeeding pages of this paper, marks the site of the oldland area from which the materials of the later sedimentary deposits were derived. A reference to the accompanying sketch map (inset) will show the general U form of this oldland area, which extends from Coronation Gulf in the extreme northwest, southward around Hudson Bay and northward through Labrador to Baffin Land and beyond. Its width varies from nearly a thousand miles in Labrador to about two hundred miles in the country southwest of James Bay.

Bordering the oldland on its convex side, and extending from the island of Anticosti in the Gulf of the St. Lawrence westward and northward as far as the Arctic circle, and probably beyond, we have a series of land forms presenting on the grandest scale the general features of an ancient belted coastal plain, in its present aspect much modified, it is true, from normal form —a modification probably due to the operation of relatively recent processes, differential uplift, and glacial action. The belted coastal-plain features are best preserved in the region of the Great Lakes. The most prominent topographic feature of this costal plain is the Niagara cuesta, which can be traced with varying expression from near Rochester, on the south shore of Lake Ontario, westward as far as the state of Wisconsin, beyond which it disappears for a time beneath the drift, but reappears to the west of Lake Winnipeg. Lakes Erie, Huron, Michigan, Manitoba, and Winnipegosis are situated upon the outer lowland;

Lake Ontario, Georgian Bay, Green Bay, and Lake Winnipeg lie upon the inner lowland in front of the cuesta. Lake Superior lies in a depression away from both lowland and cuesta. The portion of the ancient coastal plain in the vicinity of the Great

FIG. 1.—Sketch map of the Laurentian Peneplain and the country adjacent—west and southwest of Hudson Bay.

Lakes presents in general aspect and in its present attitude the normal features of such a plain, with numerous drainage modifications due largely to differential uplift and glacial ice action. The portion of the plain which lies west of the oldland area is at present in such an attitude that practically all the streams flow against the dip of the rocks—a direction opposite to that normally found on a belted coastal plain—a modification in this case apparently due to the uplift of the Cordilleran system on the west.

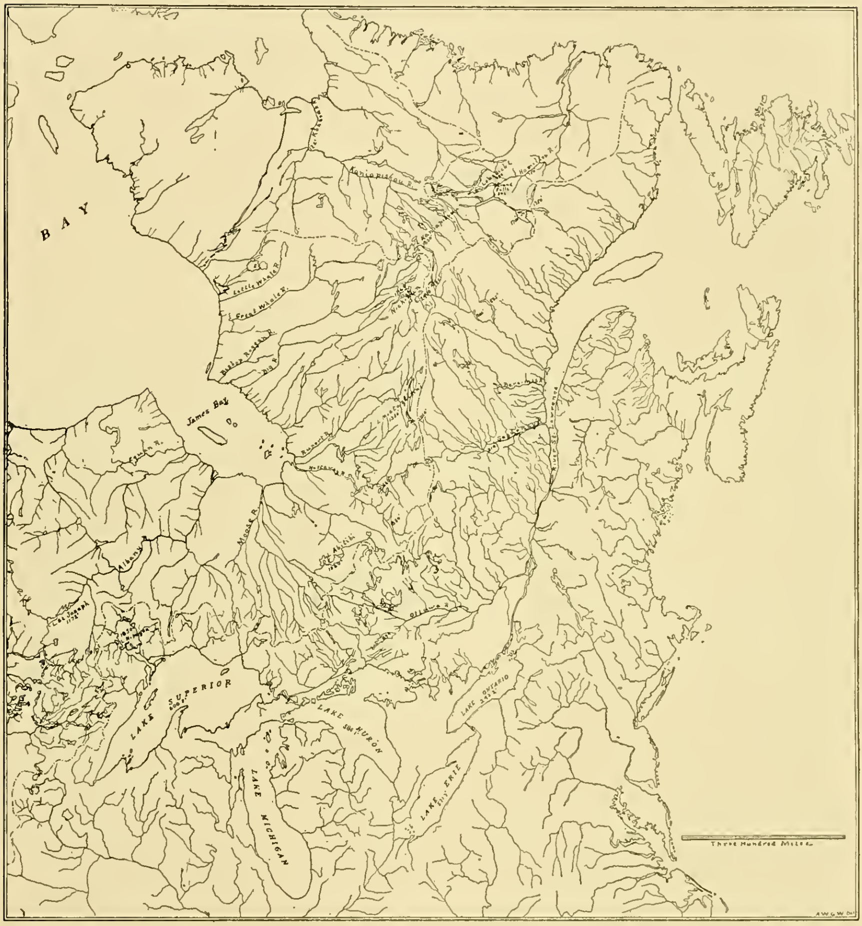

FIG. 1.—Sketch map of the Laurentian Peneplain and the country adjacent—south, southeast, and east of Hudson Bay.

On the southeast side of the oldland the valley of the St. Lawrence lies on a lowland cut on Paleozoic sediments, and shows at the extreme west in the valley of the Ottawa River, and at the east in the Mingan Islands and the Island of Anticosti, typical cuestas with inner and outer lowlands. In the central parts, in the vicinity of Montreal, the relation of the plain to the oldland areas, which stand boldly above it on either side, suggests that here the Paleozoic sediments may have been deposited in a pre-Paleozoic depression of the graben type. The well-known Monteregian hills, the stubs of post-Devonian volcanoes, form prominent buttes rising to a considerable elevation above the level of the St. Lawrence lowland.

On the concave side of the oldland area we find traces of an ancient belted coastal plain, convex southward, but for the most part its features are buried beneath the deposits which form the recent Hudson Bay coastal plain.

EXPLORATION AND SURVEYS.

The Laurentian Peneplain extends through about fifty-eight degrees of longitude and about twenty-three degrees of latitude, covering in all an area of over two million square miles. During the ten centuries that have elapsed since the first daring Norse mariner landed on its eastern shore, many explorers have traveled along the margins of the area, and not a few have traversed it in diverse directions. The early explorers, repelled by the bold and forbidding coast formed by the eastern edge of the uplifted peneplain, along the northwest shore of the Gulf and River St. Lawrence, chose rather the easy route offered by the free navigation of the great river, and penetrated to the heart of the continent and to the more inviting areas lying to the south of the great Archæan belt, long before traverses were made across the peneplain itself. At a later period the active searches instituted to discover a short route to China led to the discovery of Hudson Bay. The continued search for the northwest passage and the attractions offered by the profits of the fur trade resulted in the exploration of portions of the coasts of this inland sea, and in the establishment on its shores, more than two hundred years ago, of trading posts, some of which are still in existence at the present day. In the interests of the fur trade many traverses of the district were made by the employees of the great trading companies, both northward from the early French settlements and southward and westward from the English posts on Hudson Bay. Records of some of these exploratory journeys and records of the travels of the Jesuit missionaries are still extant. Later explorations, incident to the continued search for a northwest passage from Hudson Bay, led several parties across the far northwest portion of the area. Until quite recently the imperfect records of these travelers constituted the only available accounts of large areas of the interior.

The period of active geographic and geologic investigation of this region really began about fifty years ago with Logan's historic work on the geology of the Archæan districts north of the Ottawa River. Since that time more or less systematic geographic and geologic explorations have been carried on, chiefly by the Geological Survey of Canada, but in part by the Topographic Survey's branch of the Department of the Interior at Ottawa. At present we have at least a general knowledge of the main geographic features of the Laurentian Peneplain, although much still remains to be done.

The information used in the present paper, outside that from the writer's personal observations, has been derived chiefly from the reports of the explorations of A. P. Low in Labrador, of Dr. Robert Bell and Dr. A. E. Barlow in the districts to the south and southwest of James Bay, and of J. B. Tyrrell, and J. W. Tyrrell in the country to the east of Hudson Bay. In the papers by A. P. Low, J. B. Tyrrell, J. W. Tyrrell, and Dr. George M. Dawson, to which reference is made below, nearly complete bibliographies will be found dealing with the literature of the subject. It does not seem necessary to reproduce the bibliography here.

The writer is indebted to Mr. A. P. Low, of the Geological Survey Department, Ottawa, for some suggestions to which due reference is made in the text, and also for a number of photographs from central Labrador, from which Figs. 2, 3, 4, 5 and 13 were prepared. He wishes also to acknowledge his indebtedness to Dr. F. D. Adams, of McGill University, Montreal, and to Bailey Willis, of the U. S. Geological Survey, for critical readings of portions of the manuscript of this paper. To Dr.

Adams also the author is indebted for the photographs from which Figs. 6, 7 and 8 were prepared. He has also to acknowledge the kindness of Mr. James A. Smart, deputy minister of the interior, from whom the photographs to prepare Figs. 9, 10, 11, and 12 were obtained.

The original photographs from which the figures were made are deposited in the Collection of Geological Photographs of McGill University, Montreal.

PHYSIOGRAPHIC CONTROLS.

One of the most interesting problems for study presented by the Laurentian Peneplain is the control which the type of topography here developed has had upon the occupation and exploration of the region. Stretching, as it does, from the frozen Arctic to the temperate regions of central Ontario, and from the ocean border on the east to the mid-continental region of the great plains on the west, in its different parts it presents many phases of the operation of climatic controls, which affect its flora, its fauna, and its human occupation.

The uplands of Labrador and the far northwest of the region (north Keewatin, and northeast Mackenzie) are devoid of trees, the vegetation being confined to the lower orders of plants. Next southward we find the belt of conifers stretching all across the region from Hamilton Inlet to northwest of Great Slave Lake, the trees increasing in size and variety with decrease of latitude. In the central parts deciduous trees abound. Although, in general, throughout the region we find uniformity of features, in structure and development there is a great diversity of detail. The enormous number of the lakes and streams, the widespread distribution of the forests, the general uniformity of the topography, and the climatic characteristics of the region, have all contributed to make it the home of those animals whose flesh is valuable for food, and whose pelts are valuable for clothing or (secondarily) as an article of commerce. The remarkably even character of the region, the character of the flora, and the protection offered by climatic conditions even now make possible the existence of those vast herds of caribou (comparable to the herds of buffalo which roamed the great plains of the West until after the advent of the destructive white man) which at present roam over the barren grounds (see Fig. 8). The character of the country makes the continued existence of the fur-bearing and game animals possible. The widespread distribution of these animals, the chief support of the inhabitants, has led to the scattering of the people over the whole area, and to the development of more or less nomadic habits and customs.

The Indian inhabitants of the region, living chiefly on the products of the chase, have here, from time immemorial, found their hunting-grounds. The numerous lakes and streams, then as now, were the only lines of communication in all that vast area. Their distribution through all parts of it, and the comparative ease with which traverses from one body of water to the next can be made, enabled these people to wander unimpeded over the whole region. The customs of these people, in the several parts of the area, differ but little; in language there are greater differences, but over very large areas the speech is the same. Probably nowhere else, over so large an area, have scattered communities been found which have retained so well their communal characteristics. In language, customs, and culture they differ greatly from the various tribes found in the mountainous districts of British Columbia. In some of the still unexplored parts of the region there are Indians who have never yet seen a white man, unless perhaps some half-breed trader.

On the other hand, to the average white man, with his different modes of living, the region with its exceedingly limited agricultural possibilities, has always been inhospitable. He has displaced the Indian in the fertile plain regions which border the peneplain area to the south and west. The last remnants of some of these displaced tribes still survive upon these uplands, and still eke out a more or less precarious existence on the products of the chase. To the white man, however, the region offers other inducements which lead to the temporary occupation of local areas. The degradation which produced the peneplain has not only made possible the widespread forests, but has also exposed valuable mineral deposits that otherwise would not have been accessible. The region is thus of the utmost importance as the source of almost a world's supply of timber, and of the products of the mine, more particularly iron ore.

The journeys of the early explorers across the region were possible because of the character of its topographic features. They were undertaken by the early missionaries almost always, and by the fur-traders, frequently, to visit the wandering Indians scattered throughout the region. The fur-traders often undertook journeys solely for the pupose of hunting. The stories of the travels of these early missionaries as told by Parkman and others, and the history of the great fur companies, incidents of which form the historic foundation of many tales, afford some of the most fascinating chapters in the history of Canada, and in the study of the physiographic controls of this region. The early exploration of the eastern, central, and southern part of the western arm of the area were largely made by the early Jesuit missionaries and the employees of the great trading companies. The exploration of the far northwest, on the other hand, with the exception of three years' adventurous wanderings of Hearne, an employee of the Hudson Bay Company, were merely incidental to the continued search for a possible northwest passage.

The climatic conditions of the far northwest; and the absence of soil in any considerable amount from the Labrador areas and the country just north and west of Lake Superior, means that these regions will always be shunned by the majority of white men in search of a permanent abode. There are, however, considerable areas where there is a good soil cover, generally of fine glacial or lacustrine clays and sands, which are habitable and lie within the wheat belt. The largest of these lies between James Bay and the Lake Superior divide. Smaller areas, now partly occupied, occur in the vicinity of Lakes Temiscaming and St. John. The region is, however, one of great promise in another respect. Under progressive governmental control, and the competent supervision of trained forest engineers, it could be made an immense permanent forest reserve, a source of timber for many centuries to come. At present the timber resources are being rapidly exhausted, and practically no provision is made for the restoration of the forests.

Until the work of scientific exploration was undertaken by the government, little valuable information about the resources of the area was available, although much had been gathered in the preceding two hundred years by the employees of the great trading companies. This information was, however, kept buried in their archives, since the policy of these companies required that the richness and extent of their domain be kept secret as much as possible.

The beauty and diversity of the scenery, the innumerable lakes and waterways, the fascination of the dense forests, the salubrity of the upland climate during the summer season, and the opportunities afforded for exercising the innate hunting instincts present in nearly every man, will more and more make the accessible portions of the region the resort of those who would for a time leave the tiring, nerve-straining experiences of our modern cities behind them and find quiet, rest, and health in the peaceful wilds of the Laurentian Peneplain of Canada.

THE DATE OF EMERGENCE OF THE CANADIAN SHIELD.

The earlier studies of Walcott (39) on the Cambrian, and the recent investigations of Ulrich and Schuchert on the later Paleozoic, faunas of North America have led to the conclusion that

> the present North American continent was in existence and practically in full development as land at the close of Algonkian time, and that since that period, the Canadian shield and other smaller Archean land areas have never been wholly submerged. The periodic encroachment of the sea on the Canadian shield attained considerable extent on the north and west and more particularly on the south. The east shore, on the contrary, remained nearly the same till comparatively recent time—probably Post-cretaceous. (37, p. 659.)

Accepting these conclusions, it would naturally follow that a land area exposed for so long a time as has since elapsed would have undergone extreme degradation, and we should naturally expect to find it exhibiting all the features characteristic of the penultimate stages of the geographic cycle.

On the other hand, if we investigate the features of the region under discussion, we are led to similar conclusions. The very even surface of the area, in almost every part from Labrador south around Hudson Bay to the Arctic Ocean, is found to truncate the structure of intensely metamorphosed igneous and sedimentary rocks, irrespective of their hardness or attitude. The metamorphism is such as to imply that they have been at one time buried deeply beneath the surface of an overlying land mass, and have been subjected to the strains and stresses of intense orogenic movements. The removal of overlying mass of rock must have occupied an immense interval of time. How great it is impossible to say. For part of the area at least, this degradation took place before late Paleozoic time, for we find Paleozoic sediments resting upon a modified peneplain surface. It seems probable that for the central portions the interval was much longer.[1]

In brief, a study of the physiographic features of the Laurentian Peneplain must undoubtedly lead to the conclusion that the Canadian shield has been, for an exceedingly long interval of time exposed to processes of erosion which were chiefly subaërial; and a study of the relations of the central peneplain surface to the surface upon which the Paleozoic sediments around the margin rest shows that at least parts of the peneplain were produced before later Paleozoic times. It is only by stratigraphic studies, however, that approximate dates can be assigned for the origin of specific features.

FEATURES OF THE PLANATION SURFACE.

1. *Character of the sky-line.*—The most dominant and striking feature of the whole region, from the northern part of the interior of Labrador following approximately the median line of the region around to the south of James Bay and northwest toward the Arctic Ocean, is the remarkably even character of the sky-line. With few exceptions, to be noted elsewhere, almost everywhere in the interior it is found that from any slight elevation, which lifts the observer above the tree line, the bounding horizon is very even and almost circular. The many traverses

[1] It must be noted in this connection that Lawson, writing in 1888, dissents from the view that the Archæan rocks were ever elevated into mountains (18, p. 23).

which have been made across the different parts of the area show, particularly for the western portion of the peneplain between the Great Lakes and the Arctic Ocean, that for many miles the greatest elevation is often not over fifty feet higher than the

FIG. 2.—East coast of Hudson Bay, six miles up the Povungnituk River. Elevation 50′, looking inland.

(*Photograph by A. P. Low, 1899.*)

adjacent lowest depression, and as a rule the actual surface may be described as gently undulating. Occasionally the measure of relief may equal one hundred feet, but, particularly in the western arm of the peneplain, elevations of this amount are prominent

FIG. 3.—East side of Hudson Bay, thirty miles up Sorehead River. Elevation about 150′, looking inland.

(*Photograph by A. P. Low, 1899.*)

landmarks, visible for many miles, and from a distance are frequently seen to stand above the even sky-line of the adjacent regions, so that they may more properly be classed as monadnocks. In the country to the south of James Bay the measure of relief is somewhat greater, but the even sky-line, occasionally intercepted by residuals, is still the dominant topographic feature. In the eastern portion of the peneplain for long distances in the central parts the surface is practically the same as on the western half. Toward the margins it is more rugged or uneven, while toward the extreme northeast, close to the Atlantic coast, there is a narrow range of mountains rising prominently above the peneplain surface.

When the character of the surface is considered more in detail, it is found that, except for some very small areas, and in places where the peneplain surface is buried beneath the much younger glacial and alluvial deposits, the surface is nowhere quite flat, but is covered with low, rounded domes and ridges, which are roughly parallel to themselves and whose longer axes conform in general to the strike of the rocks.

The remarkably even character of the sky-line together with the universal distribution of many large and small lakes at levels little below that of the even sky-line, justifies the assumption that differences of elevation between different water bodies in the depressions upon the surface of the plain represent closely the differences in elevation between portions of the peneplain adjacent to each of these water bodies respectively. On this basis it will be found that the average gradient varies in different parts from one to about four feet per mile. For example, between Selwyn Lake (1,340′) and Doobaunt Lake (500′), along the line of the Doobaunt River, west of Hudson Bay, the average gradient is 2.8 feet per mile for a distance of approximately 300 miles. A section eastward from Cree Lake (1,530′) to the junction of the Churchill and Little Churchill Rivers shows an average gradient of 1.8 feet per mile for 450 miles. A study of the profiles of the Canadian Pacific Railway between Montreal and Winnipeg, where the line runs over the upland, shows between Buda (1,472′) and Brulé (1,355′) a fall of 117 feet in a distance of 146 miles; between Cartier (1,398′) and Lac Poulin (1,504′) the rising gradient is 106 feet in a distance of 129 miles. In central Labrador a section between Lake Nichikun (1,760′) and Lake Kaniapiskau (1,850′), and thence to Lobstick Lake (1,630′) above the Grand Falls on the Hamilton River, shows an ascending gradient of 90 feet in the first 100 miles, and then a descent of 220 feet in 200 miles, or a mean gradient of approximately a foot per mile. In a direction along the divide (1,550′) from southeast of Lake Mistassinni to Lake Kaniapiskau (1,850′) the rising gradient is almost exactly one foot per mile.

By way of comparison, from the profiles of the Canadian Pacific Railway between Winnipeg (757′) and Calgary (3,428′) in the foothills of the Rockies, the gradient is found to be 3.18 feet per mile. Between Edmonton (2,407′) and East Selkirk (744′), along the old location line, *via* the Yellowhead Pass, the gradient is 2.1 feet per mile. In each of the above cases, if shorter sections are taken on each of the three prairie steps, it will be found that for each step the gradient across the plains is much less than the figures here given.[1]

The comparison of the two gradients across the great plains with the gradients upon the peneplain surface, taken in conjunction with the character of the sky-lines in the two areas, shows the appropriateness of the term "peneplain" as a term to describe the principal geographic feature of this topographic unit.

2. *Departures from the normal peneplain type.*—On an area reduced to a peneplain one would expect to find a gently undulating surface, with the larger streams meandering in broadly open valleys. Their power to erode would long before have begun gradually to diminish, in part by reason of the lessened rainfall due to the reduced elevation above sea-level, in part because of the reduced grade. Their sluggish character, diminished water-supply, and low velocity will not enable them to transport the waste of the land except in a very fine state of division, or in solution. Hence the surface of a normal peneplain would be composed of mantle rock of considerable depth, at the surface very fine in texture, and gradually changing with depth to unaltered bed rock. A very even surface, deep soils, and streams which have long before lost the adjustments of early maturity, the absence of lakes, and an elevation little above sea-level must be characteristic features of a land area which has been reduced

[1] In the profiles taken along the lines of river valleys it is to be noted that the distances are estimated in straight lines, not along the stream courses. It will be found that the average gradient of the stream course is much less.

to the peneplain condition by the processes of subaërial degradation.

We have already seen that the Laurentian peneplain exhibits to a most marked degree the even sky-line and low surface gradients. We find, however, that it is almost devoid of mantle rock *in situ*. That which occurs, with the exception of an exceedingly small amount, almost too small to notice, was brought to its present location by glacial or aqueous processes of transportation. The drainage over most parts of the area is not well established; rapids and waterfalls are the most characteristic features of all the streams. The entire surface of the country is dotted with lakes, which are practically numberless; in places their area approaches 25 per cent. of the whole. And finally, parts of the peneplain are not now in accordant position with respect to sea-level. Thus, although the complicated and contorted rocks of the region are everywhere truncated by a surface which presents a remarkably even sky-line, in almost every other respect the features of the region are different from those characteristic of a peneplain. Since the production of the peneplain surface which traverses the rocks of the region, the surface of the plain has undergone profound modification, leading to the production of the present features.

In the descriptions which follow, the general nature of these departures from the normal type of peneplain will be described more in detail, and at the end of the paper a brief reference will be made to the processes which may have brought about these modifications. In general it may be said that the present attitude of different parts of the plain with respect to sea-level is due to a differential uplift, which, in parts of the area at least, is still going on. The later dissection of the plain, the carving of deep, broad valleys or of narrow canyons, seems to be a function of this uplift, though many of the first class of depressions here mentioned may antedate the peneplain. The absence of mantle rock *in situ*, the occurrence of the numerous lake basins, and the inmaturity of the drainage systems are usually attributed to the erosive action of glacial ice.

3. *Detailed descriptions of characteristic portions of the plain.*—

In the present attitude of the peneplain the highest part is found in central Labrador, where, to the south of Lake Nichikun, it reaches an elevation of approximately 2,400 feet above sea-level. The plain slopes outward from central Labrador toward Hudson Bay and the Gulf of St. Lawrence, the margins of the plain proper, near the coasts, being at considerable elevations.

In his report on explorations in James Bay and in the country east of Hudson Bay, drained by the Big, Great Whale, and Clearwater Rivers, Low describes the interior of this part of the peneplain as a

rough table-land having an elevation of about 700 feet above sea-level near its edge, and slowly rising inland to over 2,000 feet at its highest. The edge of this table-land leaves the coast to the north of Cape Jones, and runs in a S. S. E. direction, so that to the southward there is an interval varying from ten to thirty miles between it and the coast. In this portion the general level is not much over 100 feet above the sea, and the soil is of Post-Pliocene clays and sands, with alluvium. . . . . The land is rolling and broken by low rocky Archæan hills, which make up about one third of the entire area. (23, p. 16).

The same writer describes the area of country stretching from the Gulf of St. Lawrence northwestward to Hudson Bay as

a low-lying plateau of Archæan rocks. The height of this plateau averages about 1,500 ft. above sea-level, and rising slowly from about 1,000 ft. near the edge to about 2,000 ft. in the interior. The surface of this plateau is by no means flat, being covered by the low rounded hills, which are roughly arranged in a series of ridges more or less parallel to themselves and the general strike of the rocks. These hills are the stubs of extensive and elevated mountain chains which, from exposure to subaërial denudation, for countless ages, and from having been subjected to glacial action of later geological times, have been ground down to their present unimposing state. In the interior the difference of level between these ridges and the valleys separating them is small, the hills seldom rising 100 ft. above the general level. As the coast is approached the difference is more marked, the long action of ancient rivers having deeply cut out the principal valleys below the surrounding country, thus causing a more marked contrast in level, and at the same time much finer scenery. (24, p. 14.)

Summing up the statement of a series of levels in different parts of the Labrador area Low writes:

The interior of the peninsula is almost flat, so that in an area of 200,000 square miles, there is not a difference of general level of more than 300 or

400 feet, and the highest general level of the interior is under 2,500 feet. A belt of land somewhat higher than the general interior follows the St. Lawrence coast, a short distance inland. The northern half of the Atlantic coast rises in a chain of mountains considerably higher than any other portion of the peninsula. Along the northern and western coasts there is no evidence yet obtained to show the existence of a coastal ridge, but rather a probability that the general elevation increases towards the interior. (24 p., 23.)

FIG. 4.—Interior of Labrador, country north of Lake Michikaman.
(*Photograph by A. P. Low, 1894.*)

The divide between Hudson Bay drainage and that flowing into the St. Lawrence lies almost midway between the two water bodies. Throughout the greater part of its course the divide is frequently not well defined; at times it is well marked. Low describes it in the vicinity of Lake Mistassinni as a ridge of hills

FIG. 5.—View of the country on the Hamilton River, about fifty miles above Grand Falls, showing the character of the interior plateau.
(*Photograph by A. P. Low, 1894.*)

forming an escarpment about 300 feet high. Elsewhere he mentions that this divide is a prominent topographic feature for over fifty miles.

The St. Lawrence portion of the Labrador division of the uplifted peneplain does not slope uniformly from the interior divide toward the gulf. On the contrary, there seems to be, as it were, a sag in the surface of the peneplain between these two locations. The margin of the plain parallel and close to the St. Lawrence River, in the vicinity of the outlet of the Saguenay River, reaches an elevation of over 1,500 feet, and there is a well-defined gentle swell, whose height approximates to this elevation

FIG. 6.—Looking across Lake St. John from the discharge of the Saguenay, the margin of the upland makes the even sky-line in the background.

(*Photograph by Dr. F. D. Adams, 1884.*)

extending from southwest of the Saguenay in the neighborhood of Quebec, for a considerable distance along the southeast margin of the plain to below the St. John River. Between this swell and the interior main divide is a gentle depression. The lowest part of this depression forms the well-defined basin of

FIG. 7.—Central Ontario. The upland shows the less even sky-line of one of the pre-Paleozoic facets.

(*Photograph by Dr. A. E. Barlow, 1898.*)

(This photograph will accompany a detailed report on the geology of this area by Dr. F. D. Adams and Dr. A. E. Barlow.)

Lake St. John (314′), in this particular case probably located on a graben block. The majority of the streams rising near the interior divide are found to cross this marginal swell in the peneplain through deeply cut, steep sided gorges or canyons.

The best known, broadest, and deepest of these is the gorge of the Saguenay, a true fiord.

From the vicinity of Quebec westward to Lake Superior, and thence northward *via* Lake Winnipeg, Lake Athabasca, and Great Slave Lake, the convex margin of the peneplain is bordered by ancient sediments, Paleozoic for the most part; but in the extreme northwest Cretaceous deposits are found resting upon its surface. The inner or concave side of the peneplain to the south and west of James Bay, and extending as far north as Fort Churchill, is bounded by a narrow belt of Paleözoic sediments. North of Fort Churchill the ancient peneplain merges gradually with the modern coastal plain of Hudson Bay. The northern end of the western arm of the plain probably passes beneath Paleozoic sediments known to occur north of the Arctic circle. The surface of the peneplain north of the main divide and south of the lower waters of the Albany River and of James Bay, particularly that portion drained by the Moose River system, is almost completely buried beneath clays and sands, chiefly of glacial origin.

The divide on that part of the ancient peneplain south of James Bay lies nearly midway between the northern and southern boundaries of the plain, north of the city of Ottawa. From the vicinity of Lake Abitibi it runs westerly toward the most northern point of Lake Superior, so that in the longitude of Schreiber station, on the main line of the Canadian Pacific Railway, it lies not more than twenty-five miles north of the lake. From here it swings to the northwest, passing to the north of Lake Nipigon, and thence turns southwest toward Savanne on the Canadian Pacific, and continues southward, crossing the international boundary. A portion of the Archæan region lies to the south of the boundary in the states of Michigan and Minnesota, and portions of this area drain into Lake Superior. Following along the line of the western margin of the peneplain, however, from the international boundary as far north as Methy portage (lat. 56° 40′ N.; long. 109° 55′ W.) the main divide lies west of the peneplain and at the summit of the Rocky Mountain range. A subdivide, a little to the east of Lake Winnipeg, and on the peneplain, separates the headwaters of a few short, westerly flowing streams from the waters of streams flowing to Hudson Bay. All the waters from the river systems whose chief streams are the English, Red, Assiniboine, and Saskatchewan

Fig. 8.—Caribou on the banks of the Doobaunt River, Keewatin District.
(*Photograph by J. B. Tyrrell, July 30, 1893.*)

Fig. 9.—Great Slave Lake, looking north from Fort Smith.
(*Photograph by J. W. Tyrrell, 1900.*)

Rivers reach Lake Winnipeg (710′) just on the margin of the plain, and thence cross the plain in a broad shallow depression, *via* the Nelson River to Hudson Bay. North of the Nelson the Churchill River system also drains a considerable portion of the central plains across the ancient peneplain. Still farther north the main divide is again located on the peneplain, separating the Mackenzie River system from a number of river systems whose main direction of flow is a little to the east of north for nearly half their courses, and then eastward in broad, open valleys toward Hudson Bay.

It has already been noted that in central Labrador the main divide has a highest elevation of about 2,400 feet. South of James Bay the elevation of the main divide on the peneplain is about 1,400 feet above sea-level, as a maximum; in places it is somewhat lower. North of Schreiber it has an elevation of about 1,345 feet. East of Lake Winnipeg (710′) the sub-divide at the headwaters of the Berens River stands at about 1,400 feet above the sea. In the interior, north of the Churchill River, the elevation in places exceeds 1,600 feet. The divide north of Lake Athabasca stands at an elevation of about 1,400 feet.

Dr. A. E. Barlow, in his report on the Nipissing and Temiscaming map sheets, thus describes the topography of a portion of the central part of the peneplain to the south of James Bay:

The general character of the country may perhaps be best described as that of an uneven or undulating rocky plateau, with a gentle slope toward the east and southeast. Although in detail the surface of this plateau is far from uniform, consisting of a succession of more or less parallel rocky ridges, with intervening valleys occupied by swamps or lakes, still the district as a whole has a general elevation varying from 900 to 1,200 feet above the sea. There are no very prominent hills, the highest seldom attaining a greater altitude than 300 feet above the surrounding region, while throughout most of the district, hills of 50 to 100 feet in height are rather conspicuous topographical features. The highest land in the whole area is situated near the northwest corner of the Temiscaming sheet, immediately to the west of Lady Evelyn (Mus-ka-na-ning) Lake, where a range of hills, of which Maple Mountain is the highest peak, rises to the height of a little over 2,000 feet above the sea, according to Dr. Bell.

The influence exerted by the underlying rock on the general contour of the surface, is perhaps nowhere better exemplified than in the region embraced in this report. In the southern and southeastern portions, where the prevailing rocks are the various gneisses and granites included as Laurentian, there are no hills of any great height, the general surface presenting, as usual, a rather monotonous succession of low rounded hills, with corresponding shallow rocky valleys. In the northern and western portion, however, those areas in which the quartzites are present, as well as those in which the plutonic rocks, chiefly granite and diabase, are prevalent, rise into rather important elevations; while those regions which are underlain by the slaty member of the Huronian, are on the other hand low and flat. A remarkable resemblance exists between the contour of the surface, occasioned by the presence of the diabase rocks, and that produced by the heavy-bedded and massive quartzite, that forms the highest member of the Huronian exposed in this district, both rising into comparatively high rounded or broken ridges and rendering the stretches of country where such rocks prevail, exceedingly rough and hilly. . . . . This rough and broken contour is in marked contrast to the flat surface characteristic of the region in which the slates obtain. (4 p. 21.)

McOuat also draws attention to the general level character of the country south of Lake Abitibi, and mentions the occurrence of two remarkable hills which rise more than 700 feet above the general level. Lawson in his report on the Rainy Lake country also draws attention to the generally even character of the surface, and mentions the striking contrast offered by several ridges which rise prominently above the generally even surface. (19, p. 11.)

Farther northwest, near Lake Winnipeg we find "The country near the river (Berens) . . . . is made up of many low hummocky, gneiss hills, which seldom rise twenty feet above the water, and are partly covered with a heavy clay soil" (Low, 21, p. 5). Nearer the sub-divide we find "The surrounding country is a vast, level swamp, broken only by a few knobs of gneiss, that rise from ten to fifty feet above the general surface" (21, p. 11).

Bell, describing the country along the upper Albany, also draws attention to the generally level character of the district (7, p. 18). J. B. Tyrrell's description of the physical features of the district along the line of the Doobaunt, Kazan, and Ferguson Rivers is as follows:

The general relief of the whole country is very low and unpronounced, much of it having the appearance of vast undulating plains underlain by sandy or stony till and covered with stunted spruce and larch or short grass and deciduous northern plants. Here and there rise rounded rocky hills, the highest of which in the neighborhood of Kasba Lake have altitudes of about 1,700 feet above sea-level. Northeast of Doobaunt Lake some prominent hills of green trap and red conglomerate form conspicuous features in the otherwise monotonous landscape. From Kasba and Daly lakes the country has a general and moderately regular slope northeastward until it reaches the highest raised beaches or post-glacial shore lines, after which the slope is more directly eastward toward the present shore of Hudson Bay. (34, p. 158.)

Elsewhere he writes:

The northeastern part of this region is underlain by crumpled and distorted Archæan rocks, whose surface has, even in pre-Cambrian times, been reduced to an undulating plain, with very slightly accentuated contours. (35, p. 148.)

FIG. 10.—Sifton Lake and Cairn on Musk Ox Hill, District of Mackenzie.
(*Photograph by J. W. Tyrrell, 1900.*)

Again, in a note on the Pleistocene of the Northwest Territories of Canada, Tyrrell writes:

In general physical features the "Barren Lands" often closely resemble the great plains west of Manitoba along the line of the Canadian Pacific Railway, being undulating grass-covered country, underlain by till more or less thickly studded with boulders; but a hard granite knoll projecting here and there serves to remind one that the till is not here resting on soft Cretaceous shales and sandstones and at once accounts for the much greater abundance of boulders. In some places the surface is composed entirely of large subangular boulders, without any matrix of sand or clay, while the shores of Chesterfield Inlet, and part of the northwest coast of Hudson Bay, are bold and rocky. (33, p. 395.)

4. *Drainage features.*—A feature characteristic of the present drainage of the peneplain everywhere from Labrador to northern Keewatin and Mackenzie is that the upper courses of all the riv-

ers upon the plain consist of a series of chains of large and small shallow lakes occupying basins which are generally rock-bound, less often drift-blocked, and which spill over their lowest edge in a more or less ill-defined, sometimes braided stream, characterized by a succession of rapids or falls, to the next lowest

FIG. 11.—Junction of the Thelon and Hanbury Rivers, District of Mackenzie. (*Photograph by J. W. Tyrrell, 1900.*)

basin. The lower courses of the streams flowing across the Hudson Bay coastal plain are generally well defined, the streams lying in valleys incised beneath the surface level of the coastal plain and drift deposits.

In the Labrador area the main streams in their upper courses

FIG. 12.—View on the Upper Thelon River from Cairn Hill, District of Mackenzie. (*Photograph by J. W. Tyrrell, 1900.*)

upon the surface of the plain belong to the general type of streams upon the upland. When they approach the margin of the plain, however, they are found to occupy well-defined, often gorge-like valleys incised in the Archæan rocks of the plateau, often to a considerable depth beneath its surface. As a consequence of this, it is found that the lower courses of almost all the streams entering Hudson Bay on the east are characterized by a long series of falls and rapids, and are impassable by canoes, thus necessitating long portages when it is desired to reach the interior. This is equally true of most of the streams flowing outward from the interior of the plateau to the Gulf of St. Lawrence, to the Atlantic, and to Hudson Bay. The streams that flow southeast into the St. Lawrence River and Gulf all cross the St. Lawrence swell, before described, in deep gorges incised to a depth of several hundred, and in places more than one thousand, feet below the level of the plain.

Low states:

The rivers entering James' Bay from the east for their entire length, pass, so far as known, through Archæan country, and consequently present physical characters somewhat different from those on the west side. On their head-waters they flow on the general level of the country and are nothing but a succession of lakes connected by short stretches of rapid rivers. After they have attained considerable volume and as they approach the margin of the interior table-land they begin to assume a true river character; they flow with a moderate current, broken by short falls and heavy rapids, in old river valleys cut below the general level. Near the margin of the table-land the valleys become deeper, and the rivers are almost a constant succession of heavy rapids and falls until they reach the lower country, where they flow with a moderate current, with but few small rapids, in a distinct river valley between clay and sand banks of Post-Pliocene age. (23, p. 20.)

On the Stillwater River he notes that the country does not slope with the river, and consequently the bottom of the valley for several miles above Natuakami Lake is about seven hundred feet below the general level of the surrounding region. Referring to the Kaniapiskau, one of the streams flowing from central Labrador northward to Ungava Bay, he states:

For sixty miles below the lake [Kaniapiskau] the river, like all the streams of the central area, flows nearly on a level with the general surface, or rather fills all the depressions along its course, and in consequence is made up of a succession of lake expansions connected by short stretches of rapids, where the river is often broken into several channels by large islands. Below this distance the channel contracts and in five miles the river descends more than two hundred feet into a distinct valley well below the level of the surrounding country; and from there to its mouth always follows a distinct ancient valley cut down into the solid rock from 300 to 1,000 feet below the surrounding country. Between the first and the second gorge, which is about eighty miles lower down stream, the river is almost a continuous succession of heavy shallow rapids so bad that the stream is not used by the Indians. At the second gorge or Eaton Cañon, the river passes through a narrow cleft in the rocks and falls more than three hundred feet in less than a mile. Below Eaton Cañon the river continues with a very rapid current for one hundred and seventy-five miles to where it joins the Larch River, a very large branch from the westward. (24, p. 210.)

One of the best examples of this type of river valley is that of the Hamilton River. Low's description is as follows:

The Hamilton River like the Koksoak and all the other large rivers of Labrador flows in a distinct valley cut down far below the general level of the surrounding country. If Hamilton Inlet, which is only a portion of the ancient valley now sunk below sea level, is included, the main valley extends inland nearly four hundred miles, and its present bottom is from six hundred to twelve hundred feet below the surface of the surrounding table-land. The upper portion of the river flows nearly on a level with the lower portions of the central tableland, and like the Kanapiskau spreads out into lakes or in other places is broken into several channels by large islands, so that it is often difficult to define or follow the principal channel. Near the Grand Falls the river changes from a meandering stream that follows the lower levels of the general surface, and contracting into one channel is precipitated into the ancient deeply cut valley. In twelve miles this great river, with a volume nearly equal to that of the Ottawa where it flows past the Capital, falls seven hundred and sixty feet from where it issues from a narrow cañon into the wider valley. The first part of the descent is seven miles of rapids with a total fall of two hundred feet. The river then contracts into a narrow inclined, rocky trough down which it rushes with a tremendous velocity and is spurted out in a solid mass over a steep precipice into a circular basin three hundred feet below. The basin into which the river falls is about two hundred yards wide and is nearly surrounded with vertical rocky cliffs, that rise five hundred feet above the water . . . . From the basin the river rushes out through a narrow cañon cut vertically into the rock at right angles to the falls. This cañon on the level of the surrounding table-land is from one hundred to three hundred feet wide, but at its bottom is often less than fifty feet across. Down this narrow zigzag gorge the river rushes in a continuous rapid with a fall of two hundred and sixty feet from the basin to where it issues into the wider ancient valley eight miles away. (27, p. 212.)

In the report on the southern portion of Portneuf, Quebec, and Montmorency counties, Quebec, Low notes that

The rivers falling from the high interior plateau are much broken by rapids and falls, and owing to their rapid descent are liable to great and sudden variations in volume of discharge . . . . The valleys of the rivers and their tributary streams are deep, with almost perpendicular walls, rendering cross country travel very arduous, and in places impossible, while the dense forest growth adds to the difficulties and hides many of the rock exposures. (25, p. 7.)

The valley of the Betsiamites, described by Low (20, p. 7), and the well-known gorge of the Saguenay are two of the most striking of these deep valleys which traverse the St. Lawrence swell.

The drainage of the central portion of the peneplain south of James Bay presents somewhat similar features. Barlow draws attention to the fact that

Probably one of the most interesting of the physical features presented by the district is the valley occupied by Lake Temiscaming and the Ottawa River. The greater portion of this valley is a very steep rocky gorge, fringed on either side by lofty hills or perpendicular cliffs which rise abruptly

FIG. 13.— Post-glacial gorge of the Hamilton River, immediately below the Grand Falls. The vertical cliff on the left has a height of 500'.

(*Photograph by A. P. Low, 1894.*)

to a height of from four hundred to six hundred feet above the surface of the water, while the average of a large number of soundings indicate that the lake has a mean depth of over four hundred feet. The depression, therefore, occupied by these waters would be about one thousand feet below the level of the surrounding country, and as the bottom of the lake, wherever examined, consisted in the deeper portions of a very fine gray unctuous clay or silt, this depth may have been much greater before the accumulation of this material. From Mattawa to the mouth of the Montreal River these abrupt and rocky shore-lines prevail, but above the mouth of this stream the lake undergoes considerable expansion and the shores exhibit a more gradual slope towards the surface of the water. The traveler ascending the Ottawa River is thus usually impressed with the mountainous character of the district, but an ascent of the hills on either side at once shows that the adjoining country is comparatively level, and that what appeared as a range of hills are in reality the inclosing walls of this great valley. (4, p. 23.)

He also states that "the Mattawa and Montreal Rivers, in a lesser degree the Sturgeon and Temagami Rivers, occupy rather deep and important depressions in this rocky plateau."

On the western arm of the peneplain the upland still presents the same general features. The head-waters of all the rivers flowing to James Bay, where they flow over Archæan rocks, alternate between long lake-like expansions with little current, and short, contracted portions characterized by rapids and falls. Where they cross the ancient or modern coastal plains the fall is uniform, and usually, except at times of high water, they present an almost unbroken succession of small shallow rapids full of bowlders and gravel bars. (See Low, 23, p. 18.)

Tyrrell draws attention to the fact that

A particularly noticeable feature of the "Barren Lands" is the absence of valleys for the rivers. The Telzoa River probably the largest stream in all that country, is, through the greater part of its course from Daly Lake to the head of Chesterfield Inlet, merely a succession of lakes of larger or smaller size lying in original depressions in the till or rock, connected by stretches of rapid water flowing in one or more shallow, tortuous and often ill-defined channels frequently chocked with boulders. (33, p. 395.)

The deep, steep-sided gorges cut below the level of the plain are less in evidence on its western part. Shallower gorges occur, but generally only for short stretches along the rivers. There are, however, a number of broadly open valleys, more or less occupied by sediments, which have been provisionally classed as Cambrian. Tyrrell states

It would seem probable that the drainage has always followed the main valleys which still trench the surface, running more or less at right angles to the mountains. The pre-Cambrian valley of Chesterfield Inlet, extending eastward towards Hudson Strait, and westward towards Great Slave Lake, and the post-Cretaceous valley of the Saskatchewan, extending towards the lower valley of the lower Nelson River, and many other valleys running more or less parallel to these, go to prove the general correctness of this statement. (35, p. 149.)

The partial re-excavation of some of these depressions, occupied at least in part, by early Paleozoic sediments has given rise to the eastern extension of the basins of Lake Athabasca, Great Slave Lake, and Great Bear Lake. Reference has already been made to the valley of Chesterfield Inlet, and it is not improbable that Wager River (or Inlet) north of this owes its origin to a similar cause.

Valleys similar to these, containing sedimentary rocks, are also known to occur in the Labrador area. Low has reported the finding of sediments, provisionally classed as Cambrian, in the valleys of the Kaniapiskau and the Upper Hamilton Rivers. A somewhat similar series of sediments, the Manitounuck Series of Bell, occur along the east coast of Hudson Bay—lying below the level of the edge of the interior plateau, dipping seaward at low angles, presenting a well-defined cuesta front toward the plateau. In places the foot of the cuesta is submerged, but the unsubmerged portions form a series of coastal islands.

A series of sediments, for the most part classed as Cambrian, also occur in the Mistassinni basin. Ordovician outliers are found in the Lake St. John basin; Ordovician and Silurian strata occur in the northern part of the deep valley before noted as being occupied by Lake Temiscaming. Ordovician strata are also found in the Lake Nipissing basin. North of Lake Superior, particularly to the south and west of Lake Nipigon, is a well-developed series of non-fossiliferous ferruginous sandstones and dolomites resting upon the peneplain, and showing typical cuesta form. Subsequent to the development of the cuesta form on these sedimentary outliers they seem to have been overflowed with diabase sheets, and in some cases the earlier land form has been preserved beneath the more recent flow.

5. *Topographic depressions.*—A comparative study of the various depressions which go to make up the relief of the peneplain surface, as it is today, suggest a provisional recognition of three distinct types.

a) The broad, shallow depressions between the more or less hummocky or undulating ridges which occur upon the upland itself, and which are probably in the main of contemporaneous origin with the surface of the peneplain, and are presumably due to local differential erosion, and subsequent denudation.

b) Broad, open depressions, which are generally in part occupied by sediments provisionally classed as Cambrian.

c) Deep, narrow channels, in places gorges, with steep, often inaccessible sides, distinctly incised beneath the level of the adjacent upland. (These are of two types, short and relatively shallow, and long and generally deep.)

a) *The upland depressions.*—In considering the drainage features of the whole peneplain, it is found that the drainage basins of the larger river systems indicate approximately the existence of large, amphitheater-like basins, each draining toward its own median axis. When the topography is considered more in detail, it is found that each of these drainage basins is divided into a number of minor basins, each with its local drainage system more or less imperfectly developed. For the most part the minor depressions of these local basins are occupied by small lakes, usually with rock basins, the water in each of these local basins spilling over the lowest edge to the next lowest one below. The depth of these minor depressions on the peneplain surface below the level of the water in the basin rarely exceeds, and is usually much less than, the elevation of the adjacent ridges above the same datum level. In parts of the area the surface of the peneplain submerged approximates as much as 25 per cent. of the whole.

The water filling of a number of the adjacent minor depressions may reach an elevation sufficiently great to unite many of them into a large lake or series of lakes, dotted with islands, where the ridges between the adjacent minor basins project above the surface of the water. These island-dotted lakes are one of the most characteristic features of most of the uplands. One of the finest and an easily accessible example of this type of lake is Temagami in "New Ontario." The eastern shore of Georgian Bay, with its "thirty thousand islands" marks the place where a small section of the peneplain passes beneath the water level of Lake Huron.

Upland lakes, in basins of the type here described, when occurring in the vicinity of divides, often have outlets in two directions. At the present time Temagami has two outlets, a portion of its water eventually reaching the Ottawa River, and another portion flowing to Lake Nipissing and Georgian Bay. A rise of a few feet would give the lake four outlets. Reindeer Lake in eastern Athabasca is a large lake on a divide between the Churchill and Mackenzie River basins. A part of its waters flow south and then eastward *via* the Churchill River to Hudson

Bay, and part of the waters flow *via* the Cochrane River and Wollaston Lake to Lake Athabasca, and eventually reach the Arctic Ocean. Similar lakes, both large and small, with outlets in two directions, are quite frequently found manywhere upon the peneplain.

b) *Depressions containing sedimentary deposits.*—The occurrence of valleys occupied by sediments which have been assigned to the Cambrian has been reported by Low in Labrador and by Tyrrell in northern Keewatin and eastern Mackenzie. Reference has already been made to some of these in a previous section; the occurrence of Paleozoic sediments in the basins of Lakes Nipissing, Temiscaming, St. John, and Mistassinni has also been noted.

Low in describing these valleys in Labrador mentions that the streams are often from 500 to 1,000 feet below the level of the plateau. The heads of the valleys are from 100 to 300 miles from their mouths, and at the upper ends the rivers descend from the level of the interior in a succession of heavy falls through narrow gorges, where processes of erosion are at present slowly extending and deepening the valleys. The valley of the Hamilton River he describes as being from 700 to 1,200 feet below the level of the plateau. In some cases these ancient valleys have been more or less filled with glacial débris, and the modern streams for parts or all of their lengths have taken new courses.

Some of the depressions in which these sediments occur seem to be ancient, broadly open valleys, and are considered by those who have had the opportunity of studying the region in the field as of pre-Cambrian age—In the case of Chesterfield Inlet, Tyrrell notes that the sides are deep and in places cliffed. Back's description of the country immediately north of the east end of Great Slave Lake would lead one to infer that the sides of this valley were also well defined.[1]

In the Labrador regions the margins of the depressions in which the pre-Cambrian sediments (so-called) occur are well defined. This is strikingly true of the lower and partly sub-

[1] See also Fig. 9.

merged valley of the Hamilton River. The Mistassinni depression is bounded by a well-marked scarp on the southeast, and a less definite, but still distinct, margin on the northwest.

The Lake St. John basin seems to be of a distinctly graben type; its margin is well defined, often cliffed or scarped; and all the streams tributary to the lake spill over the edge of the basin from the adjacent upland each in a series of waterfalls and cascades, often visible many miles away from the open lake.

The sediments in Lake Temiscaming and Lake Nipissing basins are in valleys lying below the level of the plain. The sediments in the vicinity of Lake Nipigon rest directly upon the plain, and rise above its surface.

In the greater number of cases it seems that there is a well-defined margin to the valley. In the case of some of those in the localities referred to above it may be possible that they antedate the peneplanation epoch, and that the sediments lying within them have been partly re-excavated since then. In the case of Lake Nipissing and Lake Temiscaming depressions, and possibly in the case of Lake St. John and Lake Mistassinni, the depressions may also be of a date antecedent to the peneplanation.

Barlow notes with regard to the Lake Temiscaming depression, and of others in that vicinity, that they bear no significant relation to the direction of the movement of the glacial ice, in fact, they lie at various angles up to as much as ninety degrees to the general direction of the movement of the ice-sheet. He also notes that many of them cut across hard and soft rocks alike, and are independent of the strike of the structure of the rocks.

The character of the bounding walls, and the preservation of Paleozoic sediments in the bottoms of many of these valleys, would suggest that they are graben formed after the deposition of the sediments, and that the sediments are preserved in them because they were below the base level of erosion at the time when the balance of the similar sediments on what are now the adjacent uplands were removed. The fact that in many cases streams cascade down the sides of these valleys in ungraded channels suggests that this faulting has been quite recent. It is doubtless possible that in some cases where these valleys open out on the coast, that hanging lateral valleys may be due to the deepening and widening of the main valley by an ice-stream; but many of the type of depressions here referred to not only lie in regions which can never have been at the edge of the ice-sheets when they were in motion (or at least at their points of discharge), but seem to be completely inclosed by the bounding scarps except for the narrow outlet through which the present drainage passes.

In the majority of cases there is not sufficient available evidence to warrant an extended discussion of this very interesting problem.

c) *Gorge and canyon valleys.*—Narrow, steep-sided valleys and gorges, sometimes many miles in length, sometimes only extending for short distances, are of frequent occurrence in various parts of the peneplain. Reference has already been made to a number of them which are known to occur in the Labrador area, through which the drainage of the interior upland passes down to Hudson Bay, to the River St. Lawrence or to the Atlantic Ocean. One of the most interesting of these is the gorge of the Hamilton River, described by Low[1] as occurring above the more broadly open, partly submerged pre-Cambrian valley (so-called) of the lower part of the same river. The numerous rivers which enter the Gulf and River St. Lawrence from the northwest in every case pass through deep, steep-sided valleys, often canyons with unscalable walls, at times cut to a depth of over one thousand feet below the level of the peneplain. The valley of Moisie has been described by Hinde, the Bersimis by Low, the Saguenay the best-known of all, by Laflamme and Dumais.

Farther west the depression occupied by the lower part of Lake Temiscaming and the Ottawa River as far down as Mattawa seems to belong to this category. In the immediate vicinity of Lake Temiscaming there are a number of other gorges and valleys, the former much narrower and smaller than the Temiscaming depression, cut beneath the surface of the plain, at times even across weak and hard rocks alike, independent of the structure.

[1] See above p. 641.

The edge of the plain along the north shores of Lake Huron and Lake Superior stands at a considerable elevation above these water bodies, and there are many south-flowing streams in this locality occupying steep-sided valleys incised well beneath the peneplain. In the northwest part of the area similar gorge-like valleys occur, but they are generally smaller, shorter, and are less prominent features.

So far as known, the valleys of this class are never found to be occupied by pre-Cambrian sediments and always have a well-defined "shoulder,"[1] where the gradient curve of the valley side intersects the flatter curve of the upland surface, and in their general relations suggest that they date their origin from a time subsequent to the period of planation.

6. *Monadnocks.*—In the various descriptions which have been quoted above it will be noted that frequent reference is made to the occurrence of residual domes and ridges which stand prominently above the generally even surface of the peneplain. In northwestern Labrador there is a narrow range of mountains described in part by Bell (5) and by Daly (9), reaching in places an elevation of about six thousand feet above sea-level. The range is narrow, having only a width of about fifty miles. The somewhat meager descriptions would lead one to infer that this range, like that of the less rugged Adirondacks in New York state, represents residual mountain peaks which have not been reduced to the peneplain condition. With the exception of these two small and widely separated areas, the residual elevations rising above the peneplained surface are generally more or less isolated domes and ridges, and they are found in all parts of the region. Their elevation and development seem to depend largely on the character of the material of which they are composed, and of the material by which they are surrounded. The most prominent monadnocks known within the area seem to be those mentioned by Barlow and McOuat as occurring in the region west and north of Lake Temiscaming, where hard quartzite ridges stand in places as much as seven hundred feet above the plain. The Baraboo ridge in Wisconsin,

[1] See 41, p. 155.

an outlying monadnock ridge rising through the Paleozoic sediments, is comparable with these, and it is not impossible that its height above the peneplain on which it stands, but whose surface in this vicinity is obscured by the sediments, may be even greater.

Another excellent example, and one of considerable historic interest in connection with Logan's early work on the geology of the Archæan, is Trembling Mountain, lying north of the Ottawa River, and to the northwest of the city of Montreal, The mountain is a domed monadnock rising over 800 feet above the general level of the plateau, and about 2,380 feet above sea-level.

7. *Lakes.*—Reference has already been made to the fact, characteristic of the whole area, that the majority of the minor depressions on the surface of the peneplain form innumerable rock-basins in which the water gathers to form large and small island-dotted lakes. In addition to lakes of this class, which are usually very shallow and with very intricate shore lines, we occasionally find several other types.

One of the commonest of these is longitudinal lakes occupying old valleys which are more or less blocked by débris or by other geologic causes, in some cases presumably differential uplift. There are other examples of long, narrow lakes whose depressions are ascribed to the erosion of softer dikes. Over fifty years ago Agassiz drew attention to the fact that many of the bays and points on the shores of Lake Superior owed their origin to the erosion of soft dike rocks. More recently Bell has explained the origin of certain channels along the Lake Huron shore, and the longitudinal basins of certain inland lakes north of Lakes Huron and Superior, by a similar process.

The most interesting of the lakes of the longitudinal type is that of Temiscaming and the "Deep River" of the Ottawa adjacent to it. Dr. Barlow's description of this lake has already been mentioned, and his description of the character of the depression which it occupies has been quoted above. Whether the depression is of the graben type, somewhat similar to Lake Tanganyika in central Africa, or whether it is to be ascribed to the blocking or warping of a preglacial gorge is at present impossible to say. The character of the walls and the occurence of silurian sediments within the basin certainly suggest that it is of the graben type.

THE PENEPLAIN FACETS.

The relations of the Paleozoic sediments around the southern border of the plain to the peneplain surface suggest several interesting problems. In a former paper (41) the writer drew attention to the fact that there seem to be some grounds for surmising the existence of at least two peneplains cut upon the Archæan rocks and meeting at a very low angle. The data on which this suggestion was based are in part repeated here, with the addition of a few facts since obtained which bear on the same subject.

In the earlier part of this paper attention was drawn to the remarkably even sky-line exhibited by the plain everywhere in the interior, and it was mentioned that the average gradient in the interior rarely exceeded four feet per mile. In the central part of the province ôf Ontario it is found that radially from the upland surface in the vicinity of Haliburton Lake (the highest point in this part of central Ontario) to a number of points along the base of the Ordovician escarpment between Georgian Bay and Kingston, the average gradient over the surface of the peneplain is nearly nine feet per mile. At Toronto a well boring has shown that the crystallines are about eleven hundred feet beneath the present surface. Two other borings — one at Cobourg and the other in the township of South Fredericksburg — indicate that the floor is over five hundred and over six hundred feet respectively below the surface at these localities. The average gradient beneath the sedimentary cover along a series of lines from the foot of the Ordovician escarpment to the bottoms of these borings indicates that the gradient beneath the cover varies from twenty-two feet per mile in the western portion of the district to over forty-one feet per mile at the eastern end. The relative attitudes of these two surfaces are represented in Fig. 14, where *AB* represents the edge of a cross-section of the plain beneath, and *BC* the edge of a cross-section of that outside the sedimentary area. Such a comparison is quite justifiable because the numerous outliers north of the edge of the escarpment indicate that the surface over which the average gradients on the Archæan have been taken has been at one time buried beneath the sediments, and this surface has a remarkably even sky-line.

In the province of Manitoba, at Deloraine, a well has been driven to a depth of 1,943 feet below the surface and 108 feet into the Dakota sandstone. The bottom of the well lies about 299 feet below sea-level and 1,009 feet below the surface of Lake Winnipeg. The Archæan surface beneath the sediments, making no allowance whatever for Silurian and Ordovician sediments which probably underlie this sandstone, must thus

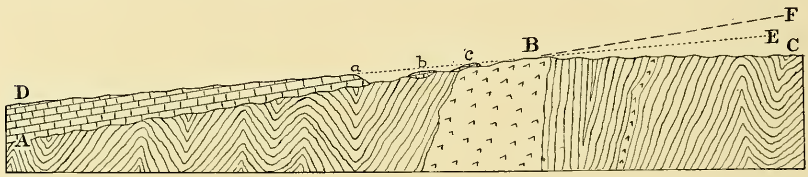

FIG. 14.

have a gradient of about six feet per mile, and probably it is actually more than double this amount. East of Lake Winnipeg the gradient upon the Archæan to the summit of the subdivide, along the same line, is less than two feet per mile.

The relative positions of these two plains (reference to a possible third plain upon the surface of the Paleozoic sediments is here omitted) suggest certain problems, which may be summarized thus:

1. Do these two plains represent two distinct periods of planation?

2. Are *AB* and *BC* of the same age, but now discordant by warping?

3. Did the former plain *AB* once extend upward in the direction of *BF?*

4. Is the discordance between *AB* and *BC* produced by warping?

It should be added that the data at present in hand are not enough to determine whether *AB* and *BC* represent two intersecting plains, or are portions of a continuous curve. It may also be noted that the data given above, taken in conjunction with the progressive overlap of higher and higher geologic horizons upon the peneplained surface, as one proceeds toward the northwest, suggest that there are even more than two peneplains. Each plain may be regarded as a facet cut upon the Canadian shield. During the long interval of Paleozoic time a succession of these facets intersecting at very low angles would be formed as the land slowly sank and the successive formations were laid down. The great central part of the area upon whose surface the remarkably low gradients have been observed would represent the youngest of the facets, the region upon which the planation processes had acted longest. The partial removal of the Paleozoic covering has already exposed several of the older facets.

Similar relations to those noted above as occurring in Ontario between two plains of degradation upon the crystalline rocks have been found by Van Hise in Wisconsin (38), and by Smyth in the region south of Lake Superior (31). Darton has described a somewhat similar case in Virginia (10). In the Grand Canyon of the Colorado we have an actual transverse section of two such intersecting plains, both older than the Cambrian, but meeting at a much higher angle than that noted for the two plains near the margin of the Canadian shield.

SUMMARY.

From a physiographic standpoint the Canadian shield can be described as an ancient peneplain which has undergone differential elevation; has been denuded, and subsequently slightly incised around the uplifted margin. At several places on the margin, as exposed today, the dissection may be regarded as submature. Around the southern margin between Montreal and Winnipeg there are traces of a peneplain (or probably more than one) of still earlier date, upon which Paleozoic sediments were laid down, and which has been uncovered by processes of degradation and denudation since the differential uplift of the latest

peneplain. The region is now in an extremely youthful stage of a new geographic cycle. It is bordered on the west and south by a belted ancient coastal plain whose mature drainage adjustments have been subsequently modified by glacial action, and in part by differential uplift. On the southeast the normal development of the ancient coastal plain has been in part retarded and modified by orogenic movement and dynamic process. Traces of the normal coastal plain development are, however, in evidence in a number of localities between Montreal and Anticosti.

The inner concave margin of the plain is marked by a depression occupied by the waters of Hudson Bay. To the south and southwest of the southern part of the bay there are traces of an ancient belted coastal plain with a convex south-facing cuesta development. For the most part this ancient coastal plain is buried beneath glacial débris and the sediments of the young coastal plain, the latter being superposed upon the former. This young coastal plain borders Hudson Bay on all sides, and the consequent drainage from the interior has incised well-defined valleys in the soft glacial and marine deposits, the interstream areas being little dissected. This modern coastal plain is of varying width up to a maximum of nearly one hundred and fifty miles.

The denuded peneplain surface, although destitute of mantle rock *in situ*, is strewn with glacial débris often of considerable amount. In the interior of Labrador this material is often very coarse, consisting of huge blocks and bowlders, with, however, considerable amounts of finer débris. In the parts to the south of James Bay, particularly in the Moose River basin and as far south as the height of land, the plain is almost completely buried beneath unmodified and modified glacial drift. Glacial drift in less amount, often fine-textured, at times coarse rock débris, occurs over the whole of the western portion of the peneplain. There are, however, areas of considerable extent where the amount of drift is very limited.

In the Labrador region there is a limited forest growth in the hollows. Most of the interior is bare and barren. In Quebec and in Ontario south of James Bay the region is densely forested.

The forests extend over the western portion of the plain to a short distance north of Great Slave Lake. Beyond this the region is treeless, moss-covered tundra. South of the forest line there are frequently large areas floored with glacial drift and forming numerous muskegs (or swamps) above whose surfaces the crystalline ridges and glacial kames and eskers project.

SOME PROBLEMS OF GENERAL INTEREST.

Aside from the strictly geologic problem of the origin and relations of the rock complex of which the Canadian shield is composed, there are a number of secondary problems of interest alike to the geologist and to the physiographer. Although it is not proposed to enter into an elaborate discussion of any of these problems at present, the time seems not inopportune to outline a few of those which are of general interest, and which are closely associated with one another.

1. *The former extent of the Paleozoic cover.*— The first of these which suggests itself is one to which reference has often been made. Did the Paleozoic sediments ever extend across the interior divide? Opinion seems somewhat divided on the answer to be given to this question. No doubt additional light will be thrown upon it when the fauna of the Paleozoic sediments occurring to the south of Hudson Bay can be adequately studied. The occurrence of the inlying areas of Paleozoic deposits, already referred to as occurring in the several depressions between Lake Mistassinni and Lake Nipigon, is generally regarded as strong evidence of the extension of these sediments at least across that portion of the plain which lies to the south of Hudson Bay.

To the physiographer the problem has an added interest from the fact that, if these sediments once extended completely across the peneplain, the questions arise: Is the present surface of that plain approximately the one upon which they rested; or has the surface upon which they were deposited been removed long since? Would it be represented by the extension of the peneplain of earlier date (which, it has seen shown above, probably exists) toward the locus of the present main divide?

The answer to these queries seems to be intimately associated with the second problem which suggests itself: What is the origin of the peneplain surface as to the time and process? At present it is quite certain that the evidence available is inadequate to solve the problem.

2. *The subaërial origin of the peneplain and the date of origin of the principal plain.*—As already noted, the stratigraphic studies of Walcott, Schuchert, Ulrich, and others have shown that at the beginning of Ordovician time the greater portion of the Canadian shield was above sea-level, and that since early Cambrian time it has never been wholly submerged. The work of Laflamme, Adams, Lawson, and others has shown that along the southern margin of the peneplain from Lake St. John to Lake Winnipeg, where the plain passes beneath the Ordovician sediments, it possesses the same hummocky character and fresh rock surface as it does in districts remote from the margin. Between the farthest outliers (exclusive of the outlying areas which may owe their preservation to the downthrow of fault blocks) there is a belt of the uncovered presedimentary surface, which shows all the features everywhere characteristic of the modified peneplain. Hence not only must the portion of the plain adjacent to the areas now overlaid by Paleozoic sediments be of pre-Ordovician date, but the dissection which it has undergone must also be pre-Ordovician. The dissection is regarded as of different date from the planation, because the gradient curves of the valley sides are not accordant with the flatter curves of the surface of the plain, often meeting the latter at an angle. The valleys are regarded as younger than the plain, because in no single instance do they contain sediments that have been derived from the adjacent plain. Along the margin of the plain their filling is always of the same materials as that with which the plain itself is covered—usually Ordovician limestone. The forms of the valleys and their relations to the plain are such that they would not be attributed to marine erosion.

During the transgression of the Ordovician sea it is conceivable that the earlier surface of subaërial origin may have been replaced by one of marine planation, assuming a time interval long enough. It is now generally admitted that during a time interval of sufficient duration to permit of the foundation of a plain of marine planation of any considerable breadth, the land of a very much larger area would be reduced almost to base-level by subaërial processes. If so, temporarily assuming that the margin of the peneplain, from which the Paleozoic sediments are known to have been removed, owes its plain character to marine planation, it would follow that the interior portions were principally of subaërial origin. If the marginal portion of the plain owed its plain character to marine erosion, we should expect to find the débris removed from the ridges deposited in the hollows, since the waves and currents tend always to produce an evenly graded floor. In the field no trace of this can be found. The Ordovician limestones often rest directly upon the plain surface and pass down into the adjacent hollows where the sides are not very steep. Where they are steep the lower beds abut against the valley walls and are conformably overlaid by beds which rest upon the plain. Nowhere has any accumulation which can be regarded as distinctively a product of marine planation been reported. Fossils (corals, crinoids, orthoceratites) are found in the lower limestone beds sometimes within a few inches of the Archæan rock, in some few cases actually attached to it. From the fact that these are not comminuted it may be inferred that the conditions of transgression, at least in the localities where they occur were such that the waters were moderately quiet; and from the absence of arenaceous deposits in many of the localities it may be concluded that the rate of transgression was comparatively rapid — presumably too rapid too permit of significant marine planation.

That the rate of depression was probably too rapid for significant marine planation is also suggested by the fact that everywhere beneath the surface of the sediments the Archæan rocks are found in a perfectly fresh and undecayed condition.

Thus although the area must have been exposed to marine planation at the time of Ordovician submergence there is reason to believe that the conditions of submergence were such that the pre-existing surface which must have been of subaërial origin can have been but little modified. The distribution of overlying areas of Paleozoic sediments suggests that the relatively rapid depression which continued through Ordovician time continued until near the close of the Silurian, and it is probable that the middle part of the plain was completely submerged. The eastern and western parts of the plain were still above water-level. If the middle portion was completely submerged at this time, it must have been re-elevated and the sedimentary cover in part removed, for Devonian corals have been found in the Hudson Bay basin with their bases attached to bosses of Archæan rocks. The Devonian sandstones flanking the peneplain on either side also suggest that the middle portions of the plain were subject to subaërial degradation during at least a portion of Devonian time. Of the history of the greater portion of the region from the close of the Devonian to the beginning of the Pleistocene there is no sedimentary record closely associated with the peneplain.

The late Mesozoic has been shown to have been a period of extensive peneplanation throughout most of North America. In New York and Pennsylvania to the south, in Wisconsin and Michigan to the southwest, the remnants of the planation surface have been recognized. In the far northwest strata classed as Cretaceous are found resting apparently upon the peneplain surface. The relations of Cretaceous sediments to a surface apparently coincident with the plain cut upon the Archæan rocks of Wisconsin also suggests that this plain is Cretaceous. It thus seems not improbable that the planation processes of the same period, working northward and eastward from these areas and southward from the Arctic regions, may have in part produced the younger of the two (or more) plains upon the Archæan areas in Canada.

The southern margin of the plain south of Methy portage and around nearly to the city of Montreal is probably of Paleozoic (and pre-Paleozoic) age, since there is little doubt but that it was once covered with Paleozoic sediments. Whether this is true of all that section which lies between the outliers before noted as occurring in the basins of a number of lakes near the central divide seems doubtful. The more detailed study of these basins may show that the Paleozoic sediments which they contain, and which are in every case, except that of Lake Nipigon, significantly below the level of the peneplain, are preserved because thrown into their present protected positions by the downthrow of graben blocks. If so, the probability of this plain being of Cretaceous age will be strengthened. What seems to be a comparable case is known in Scandinavia. The earlier sedimentary rocks were dislocated by a series of faults; later planation left only a few small patches at base-level upon the downthrown parts of the tilted blocks. Subsequent elevation of the whole area, and erosion of these softer remnants, produced a series of depressions in some of which are still found isolated patches of the soft rocks. The lower portions of these depressions frequently form lake basins, the most important of which are Boren, Roxen, Glau, and Braviken.[1]

So far as the geological record is known, it appears that the Labrador portion of the peneplain has never been submerged since Paleozoic time. To this long exposure to subaërial erosion may be attributed the extremely low average gradients of approximately one foot per mile, the lowest found anywhere upon the plain.

3. *The origin of the basins, valleys and gorges.*—The minor basins upon the upland surface, now forming the basins of small lakes, undoubtedly owe their origin to processes of differential disintegration and subsequent erosion and denudation by some agency. The last denuding agent in operation was, of course, the Pleistocene ice-sheets. There is some question, however, as to whether the denudation of the surface is due to these ice-sheets, or to some earlier ice-sheet, or to some other cause. Reference will be made to this in discussing the fourth problem.

The origin of the valleys and gorges incised beneath the plain to a significant degree presents some features of particular interest. Those in which the Cambrian sediments lie may be older than the sediments which they contain, and in that case would be of much earlier date than the main peneplain surface.

[1] See also Eighteenth Annual Report State Geologist of New York. Part V, pp. 143 ff.

The gorge-like valleys, free from Paleozoic sediments, and the canyons, one would be inclined to think, date their origin from a time subsequent to the planation period. Their immature form, as compared with the broader pre-Cambrian valleys (so called), and the absence of any Paleozoic sediments between their walls suggest this. Most of them are pre-glacial, but some few are post-glacial.

The processes by which they were excavated no doubt were various. Mention has already been made of the opinions of Agassiz and Bell that some of them owe their origin to the erosion of soft disintegrated dike rocks. This may be true in a few isolated cases. In the great majority of cases, however, particularly of the larger of these gorges, other and more general processes must have been in operation.

Given time enough, there can be no question but that the normal processes of river erosion could produce these deep canyons or steep-sided valleys. So far as we know at present, this seems to have been the process by which most of the deep gorges and canyons cut below the level of the Labrador peneplain were excavated. Low notes with respect to the canyon of the Hamilton, just below the Grand Falls, that the river in its erosion of this gorge has been guided by two series of joint fractures, so that the canyon has a somewhat zigzag course. Mr. Low has also drawn the writer's attention to the fact that there are several instance where an old valley has been blocked by glacial débris, and the streams flowing in the upper portions of the valleys are turned aside, and have already cut well-defined canyons, in some cases of considerable length, in the crystalline rocks. It is to be noted that the canyon of the Hamilton River enters the older valley, to which reference has already been made, from the north side. The old valley continues inland for a considerable distance beyond the junction of the present Hamilton River, *via* the canyon, with the lower part of the stream in the older valley. Mr. Low regards this canyon as of post-glacial origin and due to erosion by the large stream which now rushes through it.

The problem of the origin of the deep canyons across the

Laurentian swell by which the drainage from the main divide in the interior of Labrador reaches the St. Lawrence River is much more complex. One would expect the drainage of such a region to find its way outward toward the southwest, somewhere along the line of the present St. Maurice River. At the present time almost all the streams flow nearly at right angles to this apparently normal direction and cross the St. Lawrence swell in very straight courses by deep, steep-sided gorges or canyons.

The transverse drainage has been explained by assuming that the gorges through which the streams flow were produced by some cataclysm, either by the production of gigantic gaping fractures or by the down faulting of narrow graben blocks. The only evidence upon which this theory is based seems to be the existence of the gorges themselves, and the apparent difficulty of otherwise accounting for the courses of the incisions in a direction which is almost at right angles to what would be considered the normal one. There are, however, at least two other well-known processes by which features such as these could be normally developed.

In the first place, the swell may not have been in existence at the time when the streams were first beginning to flow and the gorges were not cut. The edge of the plateau may have been arched up slowly by the same forces which produced the Appalachian folds of the New Foundland and Acadian areas,[1] or by more recent dynamic processes. Provided this gentle arching proceeded slowly enough, the streams might have persisted in their original direction, apparently a consequent one (as suggested below) sawing their way into the ridge as rapidly as it rose. In brief, the streams may be *antecedent* rivers. While this process was going on in the southeast, the rivers on the other side of the main divide would, provided they had an equal capacity for work — a function of their volume and grade — have been competent either to have cut out longer and deeper gorges or to have widened their valleys. The information at present available is not sufficient to decide the question. Mr. Low has drawn

[1] Daly has recently shown that the post-Pleistocene beaches on the northeast coast of Labrador have undergone differential elevation since they were formed (9).

the writer's attention to the fact that the bottoms of the channels of the westerly and northwesterly flowing streams are almost graded, although, on account of the steepness and shortness of the descent from the plateau to the coastal plain, they are an almost continuous series of impassable rapids. On the other hand, in the case of the channels of many of the streams flowing to the St. Lawrence we find a series of step-falls or rapids with quiet reaches above and with steep canyon walls beside the falls, so that these latter, though they have cut out deep valleys, are yet in a less mature stage than those on the other side of the divide.

It should also be noted that the general direction along which the streams would develop by normal erosive processes would be determined, as in the case of the gorge of the Hamilton River, by lines of structural weakness in the rocks, not necessarily by lines of open fracture.

A second theory would regard the majority of these valleys as the incisions of *superposed streams*. The Paleozoic sediments in the basin of Lake St. John are usually supposed to indicate a transgression of the Paleozoic sea into this locality, and at least suggest that at one time the whole adjacent region was buried beneath the Paleozoic sediments. The small remnant of an ancient belted coastal plain found between Montreal and Quebec, and farther east in Anticosti and the Mingan Islands, show that there, where the Paleozoic sediments were undisturbed by the orogenic movements of late Paleozoic time, normal processes of erosion produced normal topographic forms. It seems not unnatural to suppose that consequent streams developed on the coastal plain would, when they reached the hard rock beneath, have still persisted in their initial consequent direction. In this connection attention may be drawn to a gorge on the Betsiamites River. Low writes:

> Next turning to the northeast, the river, for a distance of eight miles, breaks in a straight line through the Labradorite hills, which form almost vertical walls on either side, rising from two hundred to four hundred feet above the water (20, p. 7).

The description of the river course and the country on either side, below and above this gorge, would suggest that the Labradorite hills here referred to rise as a monadnock above the level of the plain, and that the stream to cut through them must have been superposed upon them.

Whether these gorges were developed by catastrophic processes, or owe their origin to antecedent or superposed streams, or to some other cause, a few of them have probably been modified by subsequent ice-action. In all cases they lie in a position transverse to the direction of ice-motion. In many cases, particularly toward the northeast, the probability is that the ice, retarded in its progress from central Labrador by the ascent of the main divide, had little effect. Toward the center and western part of this division of the plain, in the vicinity of Lake St. John and elsewhere, the effect of the glacial ice in modifying these valleys is more apparent. Writing of his ascent of the Betsiamites River, Low mentions incidentally a tributary of this river which "descends into the valley by a beautiful falls, over one hundred feet high" (20, p. 6). The main valley varies in width from a quarter of a mile to over a mile, and is more or less filled with glacial débris. The relation of this tributary lateral valley to the main valley certainly suggests that the main valley has been significantly widened and deepened by a glacial distributary from the interior. The best-known of the gorges is that of the Saguenay. It is a typical fiord valley with ice-scoured sides. Its relation to the St. John basin suggests that it owes its present form to the scouring by an ice-stream which made its way outward from the basin. The Labrador ice, although retarded in its flow by the ascent of the main divide, would attain a considerable thickness in this basin after it had passed the divide. Although it probably, at one time, passed over the St. Lawrence swell, the main ice-stream, after leaving the St. John basin, moved toward the southwest. If, however, there existed a deep river canyon leading outward from the basin, similar to the many found farther northeast, the depth of ice in the basin and the tendency for the pressure to force the ice outward in every direction along the lines of least resistance would cause an ice-stream to pass out in this direction toward the St.

Lawrence, even at a time when no significant amount was passing over the subdivide between the basin and the river. This ice-stream, moving in a well-defined channel, would deepen and widen the pre-existing river gorge. It thus seems probable that the Saguenay gorge may be regarded as the channel of a glacial distributary from the St. John basin, and that it was in existence prior to the advent of the ice, as a stream channel similar in form to those which exist farther northeast and show no significant modification of form due to ice-action.

With reference to the older valleys, north of the main divide in Labrador, containing pre-Cambrian sediments, the descriptions available are inadequate to enable one to determine whether they have been significantly widened and deepened by ice-erosion. In the case of the old valley of the Hamilton River lateral tributaries plunge or cascade over the margin into the main valley. This may be true of other similar valleys. It has already been intimated that the lack of adjustment between the tributary and the main valley may be due to relatively recent downfaulting of graben blocks.

Reference has already been made to the possible origin of the submerged gorge of Lake Temiscaming and the Ottawa River valley above Mattawa.

There are also a number of minor gorges, such as those mentioned by Barlow as occurring on the peneplain west of Lake Temiscaming, whose courses are in some cases transverse to hard and soft strata alike; or others, such as the gorge on the Upper Abitibi mentioned by Parks, which may be the channels of superposed streams, may have been eroded along the line of weak dike-rocks, or may be due to some other cause.

4. *The origin of the smooth fresh surface of the Archæan rocks.*—As has been intimated in the previous description of the peneplain, the old soil cover of subaërial origin has everywhere been removed. For this has been substituted a covering of material, much of which undoubtedly was derived from the Archæan terranes, but almost all of which has been brought to its present resting-place by the aid, direct or indirect, of the Pleistocene ice-sheets. Uncovered Archæan bosses often project above this

secondary cover. Everywhere that the bed-rock surface is known, whether covered or not, it presents a smooth, hard surface, free from the products of decay *in situ*. But not only is this true of the portion of the plain remote from the bordering Paleozoic sediments, but the work of Laflamme, Adams, Lawson, and others has shown that it is true of the localities adjacent to and *under* the Paleozoic cover.[1] Around the southern border of the peneplain, in the Lake St. John region, in the Moose River basin, and in a few other localities, the *actual contacts* between the Paleozoic sediments and the pre-sedimentary peneplain surface are known. In these cases it will be recalled that the peneplain facet upon which the sediments rest is probably that of an earlier cycle than the main Canadian peneplain. Now, in every case where these contacts have been met with and examined it is found:

1. That the crystalline rock surface under the sediments *in situ* is as little altered as in the ice-scoured surface perhaps twenty feet away.

2. In some few localities the pre-sedimentary crystalline surface retains some traces of decay, such as pits and pockets, now filled with small outliers of sediments, isolated more or less from the larger masses. Such pitted surfaces occur near Kingston. The best known case is that described by Bell as occurring on Benjamin Island, Lake Huron.

3. In only one locality south of the main divide has an actual arkose, which is presumably derived from the decay of near-by granitic rocks, been reported *in situ*. This forms the lowest member of the Ordovician series of the locality, and rests upon the fresh surface of a gneiss. The basal members of the pre-Cambrian rocks in northern Labrador are arkoses whose materials probably have not been transported very far.

As regards the apparently significant absence of arkose deposits (which might be regarded as old soils *in situ*) from beneath the Paleozoic sediments, it is to be noted that in almost all cases where the *actual* contacts between the sediments and the crystallines are known they occur at the summits or on the flanks of the crystalline ridges or domes. So far as the author

[1] For references and details see 41, pp. 146–53.

is aware, no case has been reported in which the *actual* contact between the two was located in or near the bottom of one of the characteristic pre-sedimentary basins. In fact, it unfortunately happens that most of these contacts must be below the present local water level. Hence at present we are only justified in stating that the summits and sides of the crystalline ridges beneath the sediments are as bare and as little decayed as are the similar ridges away from the sediments.

The condition of the surface beneath the sediments shows that processes which could produce a denuded fresh rock surface were in operation long before the Pleistocene. As to what these processes may have been there is considerable room for divided opinion.

Glacial erosion would seem to be competent to remove soft material from localities where disintegration had penetrated deeper than elsewhere. In the process it would scour the less disintegrated residuals and would thus produce the characteristic topography of the upland everywhere. The depth to which it would scour the bed rock itself is, of course, at present indeterminate away from the regions underlain by sediments, but it has produced no noticeable discordance between the parts of the buried crystalline ridges protected by the sediments and *closely* adjacent parts not thus protected. Again, if the bare, fresh surface has been produced by glacial scouring, it would seem that we must infer a pre-Paleozoic glacial period during which the sub-Paleozoic peneplain was scoured off. Of such a period, beyond the existence of the scoured plain itself, there is, in the regions under discussion, no known recorded evidence.

In this connection it may be well to recall that Dr. Geikie has described a somewhat similar surface occurring over a small area of Laurentian gueiss in northwest Scotland (Ross and Sutherland counties). He drew attention to the fact that this mammillated surface passed beneath the younger sediments, and notes that it is strongly suggestive of presedimentary glacial erosion.

The deep soils of the earlier peneplain might have been removed from the ridges, leaving them comparatively fresh, by some such process of erosion as McGee describes under the title of "Sheet flood erosion" (28). He describes the surface of a portion of the subarid Sonora district in southern California as being a plain cut on crystalline rocks, with little soil cover *in situ*. In some features this plain resembles that of the Canadian peneplain, but it has relatively a very limited area. On the Canadian peneplain, however, the basins as well as the ridges are free from rock débris *in situ*.

The normal processes of subaërial erosion or of marine erosion do not seem competent to remove the material from the basins as well as from the ridges; and, in addition, they do not produce residual land forms with surfaces so little decomposed as are the crystalline surfaces everywhere.

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RIVER TERRACES AND REVERSED DRAINAGE.

The south-central portion of New York state, or the plateau region, is furrowed by narrow north-south valleys. A study of a map made by combining the United States Geological Survey topographic sheets, representing the quadrangles lying between the Mohawk and the Susquehanna (Chenango-Chemung) valleys, draws attention to its peculiar drainage features and physiographic development. The presumption of reversed drainage, suggested in many instances by the map, is often borne out by a study of actual conditions in the field.

It is not the purpose of the present paper to consider the major features of a region extremely interesting and complex in its physiographic history, nor to correlate the analogous surface characters to be found in the numerous interrelated valleys. A future paper may consider these greater problems, and the presentation of many data gathered in field work extending over a large portion of the whole area.

These valleys of the dissected plateau region grow more trenchant in character and more rugged in their topography in passing from north to south. They all share in one common feature: that the preglacial floors are deeply covered with drift. The actual depth of filling may vary and fluctuate, but is from several hundred to something less than one hundred feet deep. Well borings of less than one hundred feet do not usually reach bed rock (Fig. 1). The locality herein considered is situated in Tioga county, N.Y., along the course of the Catatonk River. This stream heads in a flat, swampy divide on the valley drift, one mile east of the town of Van Etten, and, after flowing about nine miles in an easterly direction to North Candor, turns abruptly to the south. It maintains a practically southern direction for twelve miles, and, after uniting with Owego Creek, empties into the Susquehanna (Chenango) near the city of Owego.

The main stream follows a wandering course through the gravel-filled valley, never exposing rock *in situ*, except in one place, where by swinging it has undercut the valley wall. The surface of the valley presents the aspect of a flat, level plain of drift-filling from valley wall to valley wall, in which the Catatonk River has excavated a shallow trench (Fig. 2). For the most part this stratified drift in the valley bottom is composed of rounded pebbles and coarse gravel, with intercalated beds of sand and at some depth beds of clay.

In the fall and spring the Catatonk River is rapidly converted

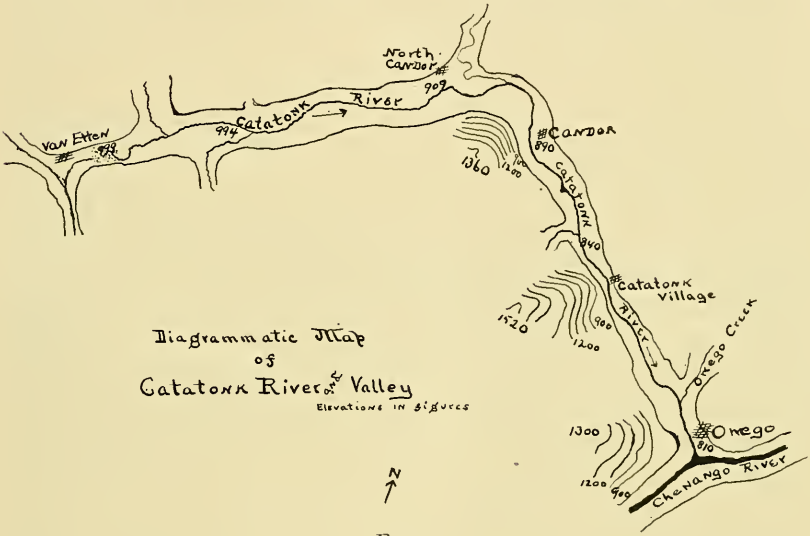

FIG. I.

into a flooded condition by the rains and melting snows decending rapidly from the high valley walls in a diversity of small streams. Some of these latter are more or less persistent streams, having a drainage heading back onto the plateau, or inter-valley areas. They carry considerable detritus from the upland, and plunge with a cascading rush down the escarpment of the main valley to the master stream. Much of their sediment is often deposited in alluvial fans, or cones, at the base of the valley wall, where the equilibrium between volume and load is abruptly broken. The residue, under a new adjustment, is strewn over the valley flood-plain or delivered to the main stream. The main stream is, therefore, for a part of the year essentially an aggrading rather than a degrading stream. The rest of the year the volume is extremely small, and the work accomplished proportionally slight. Such being the case the main stream, as at present constituted, is doing, and apparently has done, little work of vertical erosion.

In different parts of the valley, however, are remnants of well-developed terraces of destructional origin, which are out of all

FIG. 2.—Drift-covered floor of Catatonk Valley, N. Y.

proportion relative to present drainage conditions. The terraces are not continuous for any great distance, and often are entirely wanting on both sides of the valley. At some time during the preglacial period, and therefore previous to the deposition of drift, the valley was probably drained by two streams; one flowing to the north and one to the south from a common divide. In the lower half of the valley, as one proceeds from North Candor to Catatonk village, the valley grows gradually narrower, and a projection of the valley slopes intersect at a point much nearer the surface of the drift than toward the head of the valley, although one is proceeding toward the mouth of the present stream, and where the greater maturity should be expected. Near the village of Catatonk the valley walls also reach their highest elevation—somewhat over 1,500 feet. North and south from this point the inclosing hills slope gradually away in both directions to an elevation approximating 1,300 feet. That is, the upland elevation opposite North Candor is about 1,360 feet, and opposite the present mouth of the stream, near Owego, the elevation is 1,280 feet; while between these two points the elevation exceeds 1,520 feet. If the surface contour of the upland represents the old preglacial topography, then the height of land must represent an original divide, over which the present stream is now flowing in a reversed course to the south.

The slope of the buried rock floor was obtainable only at two points, but shows that between Catatonk village and North Candor it is toward the north. The rock bottom, or preglacial floor, of the valley is thus deeply buried, and its grade and development do not necessarily coincide with that developed by the present stream over the surface of the drift filling.

In studying the probable history of the valley, relative to other adjacent valleys, and their bearing on the physiographic development of the region as a whole, the terraces furnished an additional suggestion as to a change that the drainage may have undergone. Professor W. M. Davis[1] has brought out many pertinent facts as to the origin, pattern, and preservation of river terraces. Many ideas there expressed were applied to the study of the Catatonk River terraces. It has been shown by Davis that the carving of destructional river terraces does not necessarily imply a greater power in a stream during past time and that the present stream is one of diminished volume. On the contrary, he points out that such features may be produced by stream-swinging and the migration of its meanders down stream, now on one side of the valley and now on the other, the volume remaining constant. Each return of the meander at a lower level would mark a terrace plain. A stream, unthwarted

[1] Davis, "River Terraces in New England," *Bull. Mus. Comp. Zool.*, Vol. XXXVIII (October, 1902).

in its work and excavating in homogeneous drift, might also on a return vibration undercut one or more terraces left by a previous shifting of its meanders. This would leave its vertical downcutting, or erosion, expressed in a high escarpment, which would represent the sum of later terrace scarps combined into a single scarp coincident with one of an earlier terrace.

Davis also calls attention to the fact that the preservation of a series of terraces is due to the dominant influence and controling power of buried ledges. These latter have the character of an upland spur projecting transversely out into the valley. A degrading stream in alluvial deposits, finding itself superimposed upon a transverse rock spur, would tend to migrate farther toward the axis of the valley, and thus slip by the obstruction, provided it was not so far incised laterally as to be held fast by the spur. The succeeding meanders, degrading having gone on, would return at a lower level and impinge upon the intercepting ledge still nearer the axis of the valley at each successive swing. On the other hand, a down-sweeping meander having encountered the buried ledge, and having a curvature above it well developed through deep lateral cutting, might be held fast by the projecting rock spur and unable to slip by. Succeeding meanders having advanced down stream, and their curvature above the ledge having been highly compressed, they would undercut and scour out former terracing by the enforced increase in the radius of its lateral cutting. This might continue until the meander became so compressed that it would eventually destroy itself by a cutoff, and allow the stream to pass the ledge by straightening its course. The presence of such spurs and buried ledges would defend and preserve on its immediate lee, or down-valley side, any terracing cut at an earlier period in the drift covering above it. Thus a salient of terraces would be preserved above the rock defended cusps.

The Catatonk River terraces do not lend themselves to such interpretations, either as being the work of a stream of constant volume, or their preservation being due to the intervention of a protecting spur (Fig. 3).

If we agree that the radius of a meander curve is limited and proportional to a given stream flow, and when not interfered with will gradually bring itself to maturity, then the down-sweeping of an unobstructed meander must eventually result in its collapse and self-destruction through the medium of a cut-off. The present Catatonk River has obsolete meanders, now represented by more or less filled in cut-offs, or miniature oxbow lakes, that

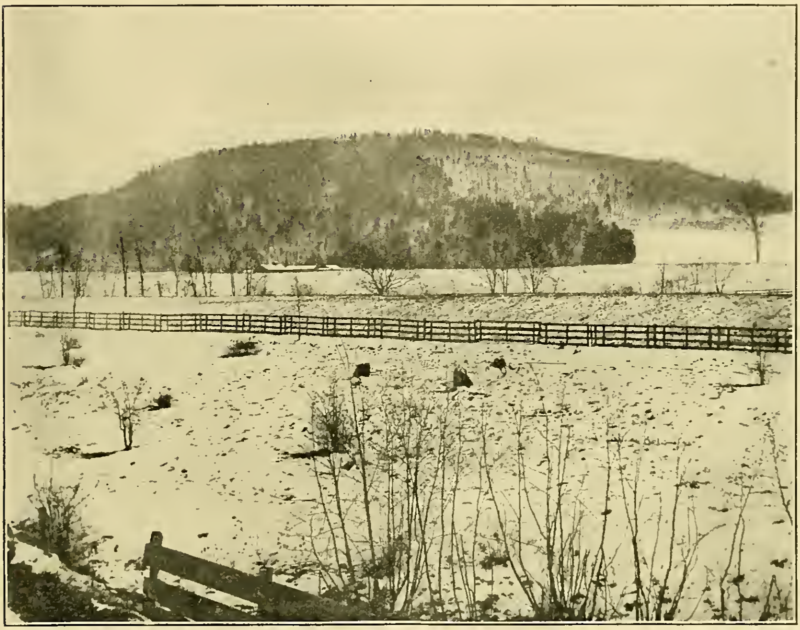

FIG. 3.—Terraces along Catatonk River, N. Y.

seem to gauge the limit of its radius in meander development. The full extent of its present mature meanders and the shifting of the meander belt is much less than the opportunity offered by the flat bottom plain extending across the valley.

To whatever state of maturity the valley development had attained preglacially, it was directly modified by the advent of the glacial epoch. The old valley floor and its grade must have been somewhat affected by the southward movement and erosion of the first ice advance, and a probable lowering of the preglacial divide. Upon a subsequent retreat of the ice it was aggraded by the fluvio-glacial débris. Later, the extra-morainic wash from the highly developed "kettle" morain, or the terminal morain of the second ice advance, lying only a few miles to the north, must have overwhelmed these intrenched valleys with floods of drift, under which their floors now lie deeply buried.

The proximity of the halted ice-front, and the immense load of detritus carried on, in, and beneath the ice, must have aggraded with tremendous rapidity the narrow valleys adjacent to it. The volume of drainage, fed by subglacial streams, by the general melting of the ice-front, by drainage from the land just released from the ice, and by the presumed greater precipitation of the glacial epoch, must have filled these valleys with streams of great volume, even after the continuity of the ice-sheet was broken by the melting upon hilltops and divides. Under such conditions it is not credible that the stream can be classed as one of either constant volume or load.

Drainage to the north was held in restraint by the blockage of the ice-front itself, and such conditions must have existed in north-sloping valleys as to transform them into temporarily ponded basins. The north-sloping valleys having become regions of more or less static water, the lower part (preglacially) of these valleys would be the points of greatest deposition. Helped in great measure by such aggrading and filling, the northward streams were compelled to flow over their former divides and adopt a southward outlet.

With the steady retreat of the ice two conditions of paramount importance must have been imposed upon the drainage: diminution in load, and a gradually diminishing volume. Both of these factors are of importance in the solution of these terraces, for a differential of either would affect the activity and scope of stream excavation. In the case in hand bold spurs do project into the valley flanked by terrace plains, but the interesting fact in regard to them is that the terraces appear on the *north* side, or up-valley, of the projecting spur, while the drainage flows to the south. It has been shown by Davis, both in text and by a variety of progressive illustrations, that terraces related to protecting spurs are removed by the stream on the up-valley side, and only by the rarest chance are destroyed in the curve adjacent to the down-valley side. That these terraces are preserved with a south-flowing stream, upon the north side, or up-valley, would seem to indicate that there had been a north-flowing stream since the drift deposition of glacial time.

It is evident that there has been a reversal of drainage since the initial development of the valley in preglacial time, but the position of the terraces would indicate that they were due to the postglacial meandering of a north-flowing stream, and that their preservation was due to the superimposition of the stream on the projecting rock spur. That there has been a second reversal since the inception of the close of the glacial epoch, subsequent to the drift deposition, does not seem rational. Though a post-glacial uplift may have taken place, it does not appear from any analogous development in the region that it was of a sufficiently revolutionary character to bring about such a change.

As both the highest level terrace plain and the lowest part of the valley bottom are a homogeneous, assorted, and glacio-fluviatile drift, from one end of the valley to the other, the possibility that the terraces are remnants of a flood plain developed previously to the glacial epoch is not great. If they are the result of lateral swinging by a south-flowing stream, of constant volume, they should have been undercut and concentrated, or else distinctly modified by its successive meanders.

It is not essential to the solution to discuss in detail the various causes of reversed drainage, whether by headwater piracy, ice erosion, aggrading, or land tilting, nor the evidences of the same as expressed in the Catatonk Valley; but, so far as either the negative or the positive evidence of the terraces suggests anything, it tends to strengthen the belief that neither slope, load, nor volume has remained constant since the drift-filling and aggrading took place.

There is some additional evidence in the fact that the terrace fronts have a vastly greater arc of curvature than is developed by the swing of the present stream.

It seems likely from the fragmentary evidences that the valley was occupied, for a time subsequent to the withdrawal of the ice, by a larger and more powerful south-flowing stream which had the potential of terrace-carving, either by diminished load or diminution of volume—possibly both. The accident of position and preservation is entirely independent of the presence of projecting spurs.

It is believed that an application of Davis's theories of terrace origin, pattern, and preservation, and their adaptation or non-adaptation to a given problem, may often afford suggestions as to the history of valley development by streams.

FRANK S. MILLS.

ANDOVER, MASS.

SILURIAN AND DEVONIAN LIMESTONES OF WESTERN TENNESSEE.

(*Concluded from p. 583.*)

C. DEVONIAN STRATA IN THE TENNESSEE RIVER VALLEY.

11. *The Linden bed; Perryville, Linden, Horse Creek, Pyburn Bluff, White Sulphur Spring.*—About half a mile northeast of the railroad station at Perryville, a large quarry has been opened into the top of the Brownsport bed. Immediately above is found the base of the Linden limestone, with *Orthothetes woolworthanus*, *Rhipidomella oblata*, and *Striatopora issa.* The lower third of the Linden bed, 10½ feet thick, consists of fairly solid crinoidal rock with comparatively few fossils. The middle third, 11½ feet thick, is richly fossiliferous. It consists of softer rock, partly crinoidal, partly fine-grained, and more or less interbedded with clay. At the base of this middle division, *Stropheodonto beckei*, *Strophonella punctulifera*, and *Orthothetes woolworthanus* are common. *Dalmanites micrurus* is not rare, but *Uncinulus schucherti* is very scarce. Above this *Stropheodonta beckei* horizon the limestones and especially the more weathered beds and clays are full of the smaller brachiopods identified from the Linden bed at Perryville. The upper third of the Linden bed, about 15 feet thick, consists of fossiliferous clay. It is exposed in the northwestern corner of the town, and is overlaid by thin layers of limestone, full of bryozoans, forming a section 1½ feet thick, followed by a sandy bed which may be the Hardin sandstone. The Camden chert fossils found at Perryville occurred loose, and were apparently derived from the iron-ore gravels of Safford.

A mile north of Linden, above the spring north of the home of William H. Patton, the Brownsport bed is overlaid by solid massive limestone, 5⅓ feet thick, containing few fossils; more shaly beds, 7⅔ feet thick, containing the characteristic Linden bed fauna; clayey beds, 6½ feet thick, not exposed; a total of 20 feet referred to the Linden bed. Above this occurs

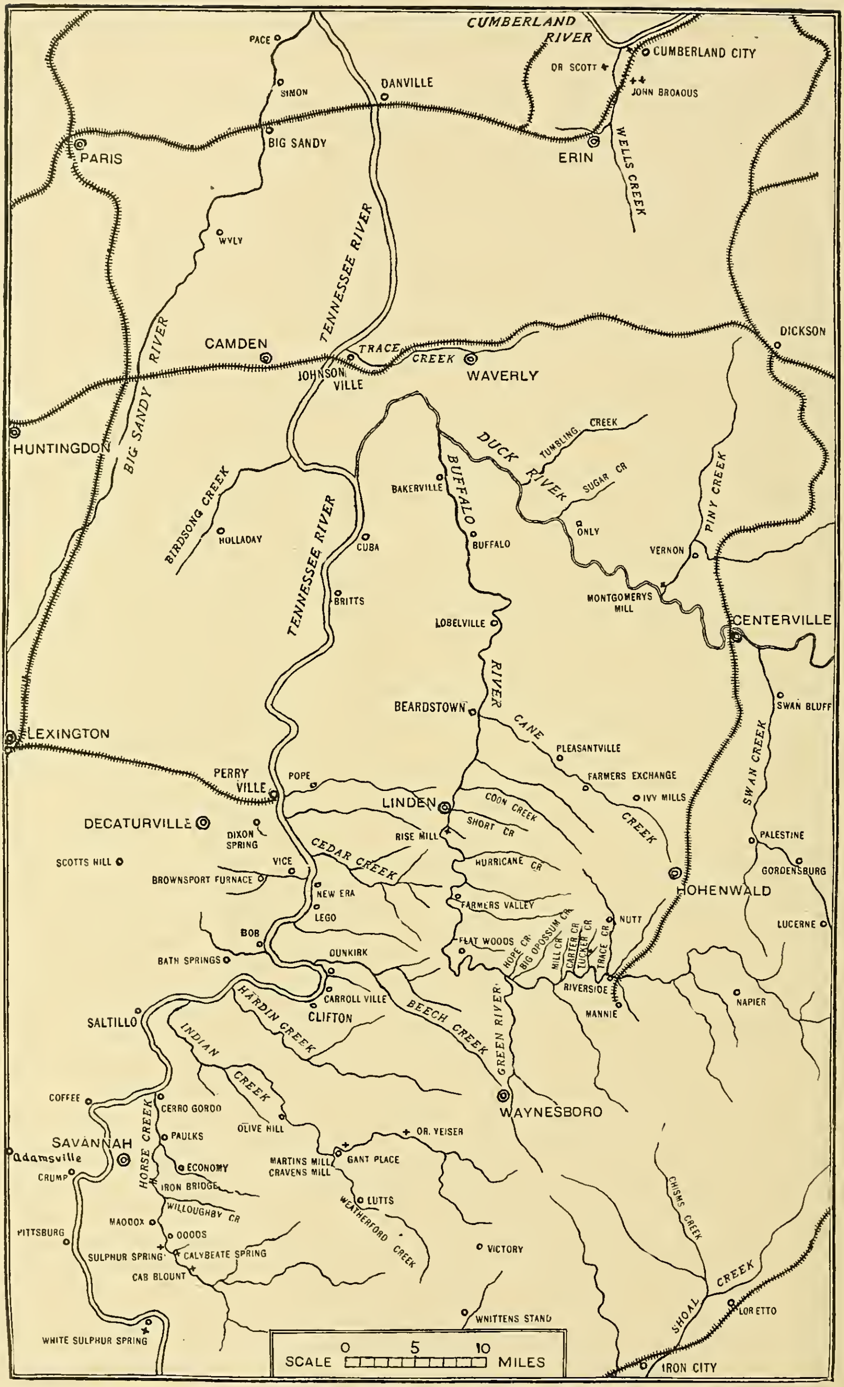

Fig. 7.—The Tennessee River basin.

(The name *Dunkirk* on the map should be read *Glenkirk*).

the Hardin sandstone, 1 foot thick, and the Black shale, 6½ feet thick. The fossiliferous part of the Linden bed is well exposed also about half a mile northeast of this locality, in the woods.

The Linden bed is exposed also on the eastern edge of Linden, below the level of the town spring at the foot of the hill, and thence eastward along the upper edge of the low bluff bordering the stream flowing from the spring toward the Buffalo River. The thickness of the Linden bed at this point is about 11 feet. Overlying it is a more massive rock, 2 feet thick, referred to the Camden chert; followed by the Hardin sandstone, 18 inches thick, and the Black shale, 6 feet thick, with numerous phosphatic nodules at the top.

About a mile east of Linden, on Short Creek, a quarter of a mile west of the home of J. S. Journey, the Linden bed is 11 feet thick. It is overlaid by the Hardin sandstone, 2 feet thick, followed by the Black shale.

The Linden limestone evidently thins out rapidly eastward. Half a mile east of the exposure west of the home of J. S. Journey, at the top of a bluff rising above a spring along Short Creek, east of the mouth of Jacks Branch, the Brownsport bed is directly overlaid by the Hardin sandstone, 2 feet thick, Black shale, 2 feet thick, and bluish sandy rock, 3 inches thick. No Linden rock is found at the home of William Goodwin on Coon Creek, 2¼ miles northeast of Linden, or at the Webb or Rise mill, half a mile south of Linden. It evidently thins out also southward, since it is absent northeast of Lego, along a creek also known as Short Creek. It is absent along the upper part of the Buffalo River between Flat Woods and Riverside, and along the upper part of Indian Creek above Olive Hill.

From the limited evidence so far secured it appears that the eastern line of outcrop of the Linden bed passes between Linden and the Rise mill, and then turns westward, crossing the Tennessee River somewhere north of Lego. There is no evidence of the presence of the Linden bed in the area between Brownsport Furnace and Bath Springs. It is possible that the eastern line of outcrop does not recross the Tennessee River north of the mouth of Horse Creek. The Linden bed is absent along the Headwaters of Indian Creek. but is present along the headwaters of Horse Creek. The chief difficulty encountered in attempting to trace the eastern line of outcrop of the Linden bed is the absence of exposures at the proper horizon in most of the territory contiguous to the Tennessee River, due to removal of the upper part of the Silurian section and of the overlying

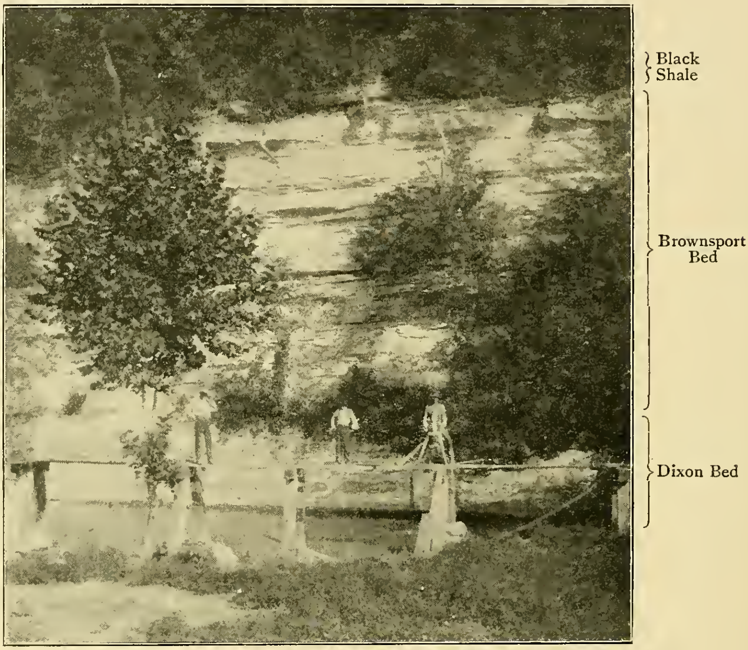

FIG. 8.—Bluff at Rise Mill.

paleozoic rocks by Cretaceous and Tertiary erosion. At most localities within this territory the Silurian rocks are directly overlaid by the Coffee sand or by the iron bearing gravels of Professor Safford.

The Linden limestone is well exposed at the Calybeate Spring on Horse Creek. Over a mile south of Maddox store, a road leaves the Florence road and passes through the woods eastward to the Sulphur Spring. Skirting the northern side of a large corn field, it crosses Horse Creek and follows the eastern bank for more than a mile, during the latter part of the distance along the upper edge of a low bluff, ending at a cultivated field at the mouth of a stream traversing a narrow valley. The base of the bluff on the east side of Horse Creek, just north of the mouth of this stream, is formed by crinoidal, massive limestone, apparently belonging to the top of the Brownsport bed. Immediately above is limestone and clayey rock containing, within 10 feet of the base, *Camarocrinus* and a number of brachiopods belonging to the Linden bed fauna. Among these are *Dalmanella subcarinata*, two forms, one coarsely and one finely striate, *Rhipidomella oblata*, *Bilobites varica*, *Strophonella punctulifera*, and *Spirifer perlamellosus*. About 200 yards south of the locality just described, on the same side of Horse Creek, is the Calybeate Spring. Here the exposure of the Linden bed is at least 60 feet thick. Specimens of *Camarocrinus* are abundant in the lower and middle part. Two miles above the Calybeate Spring, in a gulley southeast of the home of Cab Blount, on the east side of a branch of Horse Creek, the Linden bed is overlaid by a trace of Black shale, poorly exposed, followed by the Waverly. Within 10 feet of the top of the Linden bed it contains specimens of *Camarocrinus*.

Large exposures of the Linden bed line the northern side of the Tennessee River for more than a mile east of Pyburn Landing. Here was obtained the section described by Safford as occurring opposite White Sulphur Spring. At the eastern end of the exposures, west of the mouth of Bluff Creek, the exposure of the Linden bed is 101 feet thick. At the base of the section there is a series of cherty limestones, 11 feet thick, containing a species of *Chonostrophia* 23^{mm} wide related to *Ch. helderbergia*, *Rhipidomella oblata*, *Uncinulus nucleolatus*, *Uncinulus* (*Wilsonia?*) *schucherti*, *Meristella meeki*, and *Dalmanites pleuroptyx*. Unequal erosion of the cherty limestone forming the Linden bed has caused the formation of shelves at elevations of 11, 34, and 50 feet above the river. *Camarocrinus* occurs from the water's edge up to the 50 foot level. At the top of this part of the section, *Camarocrinus* is associated with *Favosites conicus*, *Favosites* with a convex base covered by the epitheca, *Pleurodictyum lenticulare*, *Rhipidomella oblata*, *Orthothetes woolworthanus*, *Leptaena* *rhomboidalis*, *Stropheodonta beckei*, *Strophonella punctulifera*, *Uncinulus nucleolatus*, *Atrypa reticularis*, *Delthyris perlamellosus*, *Delthyris* related to *D. perlamellosus*, but with a large, high, flat, triangular area on the ventral valve, *Spirifer cyclopterus*, *Spirifer* with 3 or 4 plications on either side of the mesial fold, ornamented with fine radiating striae, evidently closely related to or identical with *Spirifer tenuistriatus*, *Meristella meeki*, *Platyceras tenuiliratum*, and *Dalmanites pleuroptyx*.

No specimens of *Camarocrinus* were found above the 50-foot level, but the Linden fauna continues into the overlying rocks. It is abundantly represented in two cherty layers which immediately overlie the *Camarocrinus* beds, and in a layer of chert, about 1 foot thick, which occurs about 19 feet above the *Camarocrinus* beds. A large part of the section above the *Camarocrinus* horizon is soft and weathers readily, usually forming poor exposures, but the top of the Linden section at this locality is formed by more massive limestone, 17 feet thick, containing few fossils. Among these is *Dalmanites pleuroptyx*. The Black shale series is absent. The basal layer of the Waverly is 20 inches thick, and consists of sandy shaly rock belonging to the Hardin sandstone, and containing large specimens of *Spirophyton*.

The Linden bed dips westward; that part of the bed exposed in the eastern bluff apparently dips beneath the rock forming the western bluff, west of Anderson and Johnson branches. A study of the western bluff, however, suggests that the section here exposed is merely a repetition of the eastern section, just described. The massive limestone at the top of the Linden bed, however, has a thickness of only 6 to 10 feet, being unconformably overlaid by the Black shale series. It contains *Rhipidomella oblata*, *Spirifer cyclopterus*, *Uncinulus nucleolatus*, *Meristella princeps*, *Platyceras tenuiliratum*, *Dalmanites pleuroptyx*, and *Phacops logani*.

West of the store at White Sulphur Spring, 1 ½ miles southwest of Pickwick Landing, numerous Linden bed fossils occur in the residual chert along the middle and lower parts of the hillside. Exposures occur also in the vicinity of Decaturville, at Hollady, 5 miles south of Big Sandy station on the Lower Camden road, and at other points along the Big Sandy River. The Linden bed is exposed along the Cumberland River, a mile west of Cumberland City, and on the eastern side of the railroad, a quarter of a mile south of the home of John Broadus. Owing to faulting, it is impossible to determine the thickness of the Linden bed in the Wells Creek basin, but, as far as may be judged from the exposures seen, it does not exceed 30 feet. East of the home of John Broadus the exposure of the Linden bed does not exceed 10 or 15 feet. Mr. Charles Schuchert found three specimens of *Camarocrinus* in Benton county at an undetermined horizon.

As far as may be judged from the few sections so far studied, *Camarocrinus* is abundant in the lower half of the Linden bed, and is either much rarer or altogether absent in the upper half. The upper half, on the contrary, appears to contain a greater quantity of softer, clayey material, which weathers readily. It appears to give rise to the greater number of exposures at which the Linden bed fossils may be collected free from the rock. It appears possible to divide the Linden bed into two subdivisions, a lower, Camarocrinus or *Ross limestone*, and an upper, or *Pyburn limestone*. The exposures at Perryville, Linden, and Cumberland City appear to belong to the upper or Pyburn horizon. The upper bed appears to have a greater eastward extension than the lower, overlapping the latter. Very little attention has been given so far to the stratigraphy of the Devonian in western Tennessee. The chief results of the writer's efforts have been the conclusion that the Linden bed is absent in a large part of the territory east of the Tennessee River once believed to contain it. It is not known to occur anywhere between Rise mill, New Era, Bath Springs, Economy, and Martin's mill.

12. *The Camden chert.*—As in the case of the Linden bed, the thickest sections of the Camden chert are found at the more western points of outcrop. At Linden, on the eastern edge of the town, at the spring near the foot of the hill, it is represented by a massive gritty limestone, only 2 feet thick, immediately beneath the Hardin sandstone. In this rock were found two ventral valves of *Spirifer*, silicified, showing both the exterior and also the large muscular scars in the interior. They were identi-

fied by Schuchert as *Spirifer murchisoni*, a lower variety of *Spirifer arrectus*. They are evidently foreign to the Linden bed, and require the identification of the gritty limestone as part of the Camden chert series.

At Perryville, two silicified specimens of *Eatonia peculiaris*, and a single specimen of a large form of *Camarotoechia* (40^{mm} long, 36^{mm} wide, and 28^{mm} thick) belonging to the group of *Camarotoechia pleiopleura*, were obtained loose at the base of the sand and gravel overlying the Linden bed at the quarry. If the identification of the Hardin sandstone in the northwestern corner of Perryville is correct, the Camden chert bed can not exceed 2 or 3 feet at this locality, and it is probably altogether absent. It probably occurs, however, a short distance farther north. It is said, by Professor Safford, to occur in Decatur county, but it has not yet been recognized farther southward, in any part of Hardin county. The typical exposures occur at Camden, where the section is at least 60 feet thick. Five miles south of Big Sandy station, on the lower Camden road, the base of the Camden chert is said by Professor Safford to rest upon the Lower Helderberg. The writer has not seen any locality where it is possible to draw any sharp line between these formations. Lithologically, the formations are alike, and paleontologically, the change from the Linden bed fauna to the Camden chert fauna appears to be gradual rather than abrupt.

The chert derived from the Camden chert appears on the hillsides for several miles south of Big Sandy station. At the old Williams mill site, 5 miles above the mouth of Big Sandy station, there is a large exposure of the Camden chert bed. The thickness of the bed must be considerably in excess of 50 feet.

About 4 miles north of Bakerville, at the Whirl in the Buffalo River, the top of the Camden chert rises nearly 50 feet above the river. The exposure may be reached most conveniently by turning off from the Waverly road at the home of Clinton Burcham, following the lane along the northern edge of the hill for half a mile to the home of Henry McClure, and then crossing the field southeastward to the river bluff. The upper layers contain *Eatonia peculiaris*, *Amphigenia curta*, *Anoplotheca flabellites*, and a

Rhipidomella resembling *Rhipidomella oblata*. Two species of *Spirifer* occur which are related apparently to *Spirifer unicus* and *Spirifer arrectus*. The typical Upper Oriskany, characteristic of the Oriskany sandstone of the Appalachian region, does not occur, but a part of the Camden chert appears to belong to a higher horizon at least than at first supposed. A single specimen of *Edriocrinus* was found.

The same species of *Edriocrinus* occurs near the western end of the exposures along the Cumberland River, west of Cumberland City; on the eastern side of the railroad, a quarter of a mile south of the home of John Broadus; and on the rocky face of the hill southeast of the home of Christopher Schmidt, about a mile south of the home of Dr. Scott. At the western end of the exposures along the Cumberland River Professor Safford identified the top of the limestone section as belonging to the Camden horizon. The writer was not able to verify this in the short time at his command. No specimens of the species of *Edriocrinus* in question were found in the undoubted Linden bed exposures farther southward, but the genus is known to occur also in the Helderbergian elsewhere, although the species in question may have a more limited range.

13. *The Onondaga limestone.*—On the western flank of the Cincinnati geanticline, along the Harpeth River, between Newsom and the bridge west of Pegram, the Silurian is directly overlaid by a thin bed of Devonian limestone,[1] varying in thickness from 12 feet at the west to 3 feet at the most eastern point of outcrop. West of Pegram, at the bridge, it rests upon the soft clay forming the lowest part of the Brownsport bed. At Newsom, at the most eastern point of outcrop, it is underlaid by the equivalent of the Lego bed, 32 feet thick. *Nucleocrinus* (*Olivanites*) *verneuili*, is a characteristic species. *Stropheodonta demissa*, *Stropheodonta perplana* *Rhipidomella penelope*, and *Nucleospira concinna* are also found. This white and comparatively pure limestone is overlaid by a darker and more sandy limestone containing small grains or concretions of some black substance, similar to the black particles found

[1] Silurian and Devonian limestones of Tennessee and Kentucky, *Bull. Geol. Soc. Amer.*, Vol. XII, 1901.

in the beds containing fish-teeth in the Devonian of Kentucky and Indiana.

At the Whirl, 4 miles north of Bakerville, at the west end of the bluff exposing the Camden bed, there is a cultivated field. Almost directly east of the well and stable in the center of this field, near the lower part of the hillside, Devonian corals are very abundant. Species of *Heliophyllum*, and *Blothrophyllum* occur which closely resemble forms occurring in the Corniferous at the Falls of the Ohio River, at Louisville, Ky. Various species of *Cystiphyllum*, *Cyathophyllum*, and *Cladopora* also are found. In addition to a very large form of *Atrypa reticularis*, a single specimen of *Reticularia fimbriata* was present. The corals have been loosened by residual decay from a bed of limestone, about 3 feet thick. The top of this layer is formed by a darker, sandy layer, varying from a mere film to a little over 2 inches in thickness. This darker part resembles the darker layer at the top of the Devonian limestone section at the bridge west of Pegram. It contained a single, pointed fish bone, 45^{mm} long. This bed of limestone, 3 feet thick, is believed to be of about the same age as the Devonian limestone at Pegram. Both limestones are correlated with the Jeffersonville limestone of Kentucky and Indiana, which is the equivalent of the Corniferous or Onondaga limestone of more eastern sections.

The occurrence of the Onondaga limestone near Bakerville suggests that it may be expected at other localities in western Tennessee northwest of a line passing from Bakerville to Lexington.

14. *The Devonian Black shale series.*—The Chattanooga Black shale decreases in thickness from the north central part of the state southward and westward. Its thickness in the neighborhood of Cumberland City cannot be determined with accuracy, but it appears to reach at least 10 feet. At Montgomery's mill the shale has a thickness of 6 feet 3 inches; at Centreville, of 4 feet 6 inches; at Dean's quarry, of 2 feet. In the neighborhood of Linden the thickness varies between 1 and 6½ feet; at several exposures east of Linden a thin layer of sandy rock occurs in the shale, about 1 foot above its base. Along the Buffalo River it is

usually absent; one exposure, 1 foot thick, occurs on Tucker branch, and another, 2 feet thick, several miles west of the mouth of Green River. A trace of Black shale, not well exposed, was seen in a gully on the west side of Horse Creek, southeast of the home of Cab Blount. It is absent at Pyburn Bluff, opposite White Sulphur Spring. Five miles southwest of Mount Pleasant, at the Big Hill on the road to Waynesboro, the Black slate is absent, but a mile southeast of the hill it attains a thickness of 2 feet. At Dodson station and at Lynnville, 15 miles southeast of Mount Pleasant, it does not exceed 15 inches. At Iron City it varies from 6 inches to nothing.

From these and many other observations it may be seen that the Black shale is either very thin or is entirely absent in the southern parts of Maury, Lewis, and Perry counties, and in all of Giles, Lawrence, Wayne, and Hardin counties.

The Black shale occurs also on the western side of the Tennessee River. It was struck in digging a well north of the landing at Saltillo. A considerable quantity of Black shale was struck northwest of the furnace at Brownsport Furnace. A small exposure occurs near the bottom of a broad valley along the road half-way between Dixon Spring and Perryville. It probably occurs at other localities farther north. The scarcity of exposures is probably chiefly due to removal by erosion during Cretaceous and Tertiary times, the sands and gravels of these ages resting directly on Helderbergian and Silurian rocks in a large part of the area so far investigated.

At the more northern exposures the Black shale is usually underlaid by a sandy rock, 1 or 2 feet thick, and overlaid by another layer, usually only several inches thick, characterized by the presence of phosphatic nodules. Southward the sandy layer becomes thicker, developing into the *Hardin sandstone.* Owing to the thinning out of the Black shale in this direction, the *nodule layer* not infrequently rests directly on the Hardin sandstone. This is shown at a number of exposures along the upper part of the Buffalo River, between Riverside and Flatwoods. Farther south the phosphatic nodule layer is also usually absent, so that in the southern counties the Hardin sandstone is often the only representative of the Black shale group. The most southern localities at which phosphatic nodules were observed were at W. D. Holton's home, 3½ miles northwest of Waynesboro, and at the Taylor quarry near Iron City.

The Hardin sandstone frequently attains a thickness of 7 to 8 feet. The greatest thickness observed was 11 feet. About a mile northwest of Martin's mill, on Indian Creek, a fish plate, 4 inches long, was observed imbedded in this sandstone. At several localities *Barroisella subspatulata* was seen in the more shaley layers immediately above the Hardin sandstone. These layers form a transition to the Waverly, the Lauderdale cherty beds of the Alabama Survey. The eastward extension of the Hardin sandstone has not yet been determined.

D. SILURIAN AND DEVONIAN STRATA OF THE WELLS CREEK BASIN.

The Wells Creek Valley, southwest of Cumberland City on the lower part of the Cumberland River in western Tennessee, is 53 miles distant from Baker station, and 45 miles from Whites Bend, Newsom, and Centreville. Both lithologically and faunally the Silurian of the Wells Creek valley presents the facies of the Silurian of the Tennessee River valley rather than the appearance of the Silurian exposed on the western flank of the Cincinnati anticline.

About 3 miles southwest of Cumberland City, in a railroad cut northwest of the home of John Broadus, there is a considerable exposure of Ordovician rock, probably equivalent to the Saltillo limestone, originally consisting of frequent alternations of clay and clayey limestone, but now badly decayed and reduced in large part to shaly material. Owing to a local, overturned fold, the Silurian base is found south of the Ordovician exposure and apparently dipping beneath it. The base of the Silurian section consists of hard limestone, much faulted, estimated to be 22 feet thick. The lower half is massive and contains *Favosites favosus*. The upper half contains cherty layers. Next in order of succession is a red, clayey rock, also faulted, estimated to be 14 feet thick. At its base it is more whitish. At the top it grades into limestone, 7 feet thick, less red and clayey above, containing

FIG. 9.—View from home of Dr. W. B. Scott, east across the Wells Creek basin, showing the dome structure. The central area is the region of the Wells limestone. The water in the foreground, due to recent heavy rains, and the line of trees circling from the right across the background, indicates in a general way the location of the Saltillo limestone. Along the foot of the hills bordering the basin, Silurian and Devonian rocks are exposed. The upper part of the hills and the surrounding country consists of sub-carboniferous rocks.

Stephanocrinus osgoodensis and *Pisocrinus gemmiformis.* The red clay and reddish limestone is the equivalent of the Osgood bed as identified at Clifton and elsewhere, and the white limestone at the base of the Silurian section corresponds to the Clinton.

Next in order of succession is slightly crinoidal limestone, 2 feet thick, followed by reddish clay, 3 feet thick. Stratigraphically above this horizon belongs the crackled white and reddish limestone, the equivalent of the Glenkirk bed. Owing to the failure to identify the Waldron bed, the subdivisions of the Glenkirk bed, the Laurel and Lego limestones, cannot be recognized. This difficulty is increased by a considerable amount of very irregular faulting. Along the road east of the home of John Broadus the top of the Glenkirk bed is well exposed. It is overlaid by dark, brick-red clay rock, 32 feet thick, belonging to the Dixon bed. This is followed by a section 20 feet thick, not exposed. The overlying Brownsport bed dips strongly eastward. If not faulted, the section is 170 feet thick, but faulting is not improbable. *Astraeospongia meniscus* occurs near the base. At the top of the section a thin layer of fossiliferous limestone belonging to the Linden bed, is exposed. In a gully, southeastward, Black slate is exposed.

Along the railroad, a quarter of a mile south of the home of John Broadus, there is a considerable exposure of limestone. A part of it contains *Edriocrinus.* At the southern end of the exposure is a richly fossiliferous layer, apparently belonging to the Linden bed.

In the field south of the home of Dr. Scott, the layers at the top of the Osgood bed, containing *Pisocrinus gemmiformis*, and *Stephanocrinus osgoodensis* are found. Along the road southwest of the house and in the cedar glade west of the same, brachiopods and sponges belonging to the Brownsport horizon occur. About a quarter of a mile north of the house, along the road following the base of the hill, the Glenkirk bed is well exposed. A part of the Glenkirk exposure consists of a very hard and fine-grained, massive, red limestone. Another part is softer and white, followed by the red clayey rock belonging to the Dixon bed, well exposed. The Linden bed was not identified at this locality. About a mile southward, on a rocky hillside south of the home of Christopher Schmidt, *Edriocrinus* occurs in the limestone.

Along the Cumberland River, about a mile west of Cumberland City, a short distance beyond the exposures which line the bank, Black shale is exposed above the level of the road. At

FIG. 10.— Saltillo limestone, at crossing of pike from Cumberland City to Erin over the railroad.

the western end of the rock exposures along the bank, just below the level of the road, the Linden bed fossils are abundant. It is possible that some of the overlying limestones belong to the Camden chert horizon but the writer was not able to identify it in the short time at his disposal. The red rock forming the greater part of the exposures along the bank eastward toward Cumberland City appears lithologically to belong to the Glenkirk horizon. Faulting appears to be very frequent, bringing into contact all sorts of rocks, making stratigraphic work difficult. However, even a hasty examination of the field is sufficient to determine the fact that in all essentials the Silurian and Devonian sections of the Wells Creek basin strongly resemble those of the Tennessee River valley.

E. THE EQUIVALENCE OF THE CLIFTON, LINDEN, AND CAMDEN LIMESTONES TO OTHER BEDS.

In the *Geology of Tennessee*, published in 1869, Professor Safford included all Niagaran strata, from the Clinton bed to the Brownsport bed, inclusive, in his *Meniscus limestone.* He recognized, however, two subdivisions, each about 100 feet thick, the lower called the *Variegated bed*, the upper called the *Sponge-bearing bed.* The Variegated bed included the Clinton, Osgood, Laurel, Waldron, and Dixon beds of the present paper. The Sponge-bearing bed included the Brownsport bed. *Astraeospongia meniscus* is confined to the upper or Sponge-bearing bed.

In the *Elementary Geology of Tennessee*, published in 1876, Safford and Killebrew proposed the name *Clifton limestone* for the Meniscus limestone. This name is, therefore, equivalent to the name "Niagaran" as now defined.

At Clifton, the type locality, the section along the river below the landing includes the Clinton, Osgood, and Laurel limestones. The section along the river about three-quarters of a mile above the landing includes the upper part of the Laurel bed, the Waldron, Lego, and Dixon beds, and the greater part of the Brownsport bed. Immediately in the rear of the town, on the hillside north of the Waynesboro road, the upper part of the Lego bed, all of the Dixon red clay, and the base of the Brownsport bed are exposed.

As a synonym for the Niagaran, the name "Clifton limestone" will be found useful.

In the *Geology of Tennessee*, all strata in western Tennessee intervening between the Clifton bed and the Chattanooga black shale were included in the Lower Helderberg. In 1876, in the *Elementary Geology*, Safford and Killebrew employed the name *Linden limestone* for these strata. In 1899 Safford and Shuchert published an article in the *American Journal of Science*, entitled "The Camden Chert of Tennessee and its Lower Oriskany

Fauna," in which the Oriskany age of the upper part of the beds hitherto included in the Linden bed was shown. Therefore, in 1900, in a second edition of the *Geology of Tennessee*, Safford and Killebrew restricted the use of the name "Linden limestone" so as to include only beds belonging to the Helderbergian as now defined, while the name "Camden chert" was given to the Oriskanian strata formerly included in the upper part of the Linden limestone. The Linden limestone as now defined appears most nearly equivalent to the Delthyris or New Scotland bed.

The Camden chert was placed by Schuchert in the lower part of the Oriskanian. He called attention particularly to the absence of the characteristic upper Oriskanian species: *Hipparionyx proximus*, *Chonostrophia complanata*, *Spirifer arenosus*, *Rensselaeria ovoides*, *Meristella lata*, *Camarotoechia pleiopleura*, *C. barrandei*, and *C. speciosus*. Since his paper appeared a specimen related to *C. pleiopleura* was found loose in the sand above the Linden bed at Perryville, and a *Spirifer* resembling *Spirifer unicus* was found in the top of the Camden bed at the Whirl in the Buffalo River north of Bakerville.

The use of the name "Linden limestone" for the Helderbergian section in Tennessee is unfortunate, since at the type locality, Linden, the Helderbergian does not exceed 17 feet in thickness, while the maximum thickness in the state exceeds 100 feet. Moreover, the Helderbergian at Linden is overlaid by a thin section of Camden chert, 2 feet thick, hitherto included in the Linden bed. The Linden bed at Linden apparently belongs to the upper, more clayey part of the Helderbergian section as exposed in Tennessee, overlying the *Camarocrinus* beds. However, too little attention has been given as yet to the stratigraphy of the Devonian limestones of Tennessee to warrant a definite conclusion.

F. THE COFFEE SAND.

At various localities along the Tennessee River, in Hardin county, the paleozoic formations are overlaid by yellowish sands, sometimes interstratified with beds of clay. They have been called the Coffee sand by Professor Safford, and are believed to be equivalent to the Tombigbee sand, referred to the Lower

Cretaceous. The exposure at Coffee Landing is typical for the Tennessee beds. Silicified trunks of trees are not uncommon. One, 6 feet long and 2 feet in diameter, occurred in the sand directly above the Glenkirk limestone at the Welch or Maddox mill on Horse Creek. Another was found near Lutts, beyond the post-office, on the road to Waterloo. The locality is called Pin Hook Hill, and lies between Rutherford and Horse Creeks. A third trunk is seen on the Jack Martin farm, about seven miles north of Cypress Inn and five miles south of Victory, on the headwaters of Weatherford fork of Indian Creek. The trunk is found in the hollow in the field below the Martin house. The locality is fully twenty miles east of the Tennessee River. It has been suggested that the Gulf of Mexico once extended much farther north than at present, reaching the southern part of Illinois and covering southeastern Missouri. If the Coffee sand was deposited off its shores, the Gulf, during early Cretaceous times, must have extended east of the Tennessee River, at least in the southern part of Tennessee, in parts of Wayne and Hardin counties.

G. THE IRON ORE GRAVELS.

In western Tennessee, in the area lying between the Great Central Basin and the Tennessee River, the paleozoic rocks are usually overlaid by a great mass of sands and gravels, often cemented by ferruginous material. Sometimes the ferruginous material is in sufficient quantity to prove valuable as an iron ore. Thirty-five furnaces were in operation before the war, and the ore is still mined at a number of localities. The branches of railroad from Dickson to Mannie, from Summertown to Napier, and from Iron City to Pinckney owe their existence to the presence, at their terminals and at various points along the line, of ferruginous gravels, sufficiently rich in iron ore to be mined. The large furnaces at Florence and Sheffield in Alabama partly depend upon this source. The ferruginous iron-ore gravels extend west of the Tennessee River for a distance of ten or fifteen miles, resting upon the paleozoic rocks on all the higher hills. At lower levels, where the paleozoic rocks are covered by the Coffee sand, the iron-ore gravels rest upon the Coffee sand.

Along Horse Creek, the Ordovician and Silurian rocks have been reduced by Cretaceous erosion to a sort of base level and then covered by the Coffee sand. The Helderbergian exposures at the Calybeate Springs appear to have risen above the level of the Coffee sand (Fig. 3, p. 579). No careful study of the Coffee sand or of the iron-ore gravels has yet been made in the area in question.

II. THE AGE OF THE CINCINNATI GEANTICLINE.

15. *As determined by observations in Tennessee.*—Along the Cincinnati geanticline in Tennessee the Chattanooga black shale rests unconformably on Silurian and Ordovician rocks. Along the crest of the geanticline, for a width of 55 to 75 miles, the Black shale, where not removed by subsequent erosion, rests upon Ordovician strata. On either side of this area it rests upon the Silurian. Along the eastern line of outcrop of the Silurian, on the western flank of the geanticline, the Black shale rests upon the Clinton. Farther westward, proceeding to points more distant from the broad crest of the geanticline, the Black shale rests successively upon the Osgood, Laurel, Waldron, and Louisville beds, the higher subdivisions of the Silurian. On proceeding still farther westward, into the basin of the Tennessee River, this unconformity continues, so that the Black shale rests upon higher Silurian rocks in the Tennessee River valley than at Pegram, Centreville, Riverside, or Iron City. It rests upon higher layers of the Brownsport bed along the Tennessee River than at the more eastern exposures of this bed. East of Linden the Black shale rests upon the attenuated edge of the Linden bed. At Linden it rests upon the still more attenuated edge of the Camden chert. West of the Tennessee River both the Linden and the Camden beds are represented by thicker sections.

The Tennessee River region may be regarded as having formed, in times preceding the deposition of the Black shale, a broad geosyncline of Silurian and Devonian limestones, lying west of a broad geanticline of Ordovician strata. The axis of the geosyncline lay a considerable distance west of the Tennessee River. Both lithologically and paleontologically the Silurian deposits of the geosyncline differ sufficiently from those of the geanticline to form a distinct province. The Silurian deposits of the geosyncline extended northward into southern Illinois and the adjacent part of Missouri. The formation of this geosyncline was the first expression of the series of changes which finally resulted in the formation of the lower Mississippi valley.

Mesodevonic limestones are but scantily represented in the Tennessee River valley. At the Whirl in the Buffalo River, 4 miles north of Bakerville, they are 3 feet thick. Forty-five miles farther east, along the Harpeth River, they vary in thickness between 3 and 12 feet. At both localities, the Mesodevonic limestones belong to the Onondaga horizon. At Newsom, the Onondaga limestones rests on the equivalent of the Lego bed; at Pegram, on the lower part of the Brownsport bed; and north of Bakerville, on the Camden chert bed. The unconformity thus indicated suggests the existence of the Cincinnati geanticline in times preceding the Mesodevonic.

The Paleodevonic is absent along the western flank of the Cincinnati geanticline, in Tennessee, Kentucky, and southern Indiana. It is exposed, however, at numerous points in the Tennessee River valley, especially west of the Tennessee River. Both the Oriskanian and the Helderbergian are represented. Where more fully developed, the passage from the Helderbergian to the Oriskanian appears to be gradual, not indicating any unconformity between them. At their attenuated margins near Linden, the line of demarkation between the beds is very distinct. This suggests the growth of the Cincinnati geanticline during the Paleodevonic times.

Very few localities have so far been discovered where the contact between the Helderbergian and the Silurian may be studied. At all of these localities the Linden bed rests upon the Brownsport bed, and the change from the Silurian to the Devonian fauna is abrupt. It is impossible to determine at present whether the Linden bed rests upon higher horizons of the Brownsport bed westward than along the eastern line of outcrop. The faunus of the Brownsport have not yet been studied in sufficient detail to warrant any conclusions at present. If the

Linden bed fauna at Linden is the equivalent of the upper or Pyburn fauna at Pyburn Bluff, and overlies, stratigraphically, the lower or Camarocrinus fauna at that bluff, then the upper part of the Linden bed overlaps the lower part; suggesting the growth of the Cincinnati geanticline during the earlier part of the Paleodevonic. The studies so far made upon the Linden bed are insufficient to determine the matter.

No trace of the Upper Silurian or Cayugan has so far been discovered in the Tennessee River valley or in the Mississippi River basin.

From these observations it appears that the growth of the Cincinnati geanticline began in times preceding the Devonian, that its growth continued during early and middle Devonian times, and that it had reached considerable proportions in times preceding the deposition of the Chattanooga black shale.

The stratigraphic evidence secured so far is not sufficient to demonstrate the existence of the Cincinnati geanticline in Ordovician times. However, a study of the areal distribution of Silurian and Ordovician faunas suggests that the Cincinnati geanticline had its origin during Ordovician times, and that its effect upon the geographic range of faunas was considerable already during the earlier part of the Silurian[1] This method of determining the location of geologic barriers by means of a study of the distribution of faunas promises to be of the highest value, since it appears capable of demonstrating the existence and probable location of barriers even in cases where the stratigraphic evidence is defective, although, of course, it is eminently desirable that the results of paleontological research be corroborated by stratigraphical evidence.

Data are accumulating which suggest the existence of an elevation of land, or dome, in southwestern Tennessee during the later part of the Ordovician and at the beginning of the Silurian. According to the researches of Ulrich and Bassler, the Utica is absent in central and southern Tennessee; the Lorraine, however, is represented by equivalents of the Fairmount, Bellevue,

[1] ULRICH AND SCHUCHERT, "Paleozoic Seas and Barriers," *Report of New York Paleontologist* for 1901, No. 2.

and Corryville beds[1] of the Cincinnati section. The Utica is absent also in western Tennessee. The Swan Creek limestone is undoubtedly of Lorraine age; and analogy with the sections in central Tennessee, investigated by Ulrich and Bassler, suggests that the richly fossiliferous beds, containing *Platystrophia lynx*, below the Swan Creek limestone are probably equivalent to the Bellevue beds. No trace of the Fairmount, Bellevue, or Corryville beds has been recognized in western Tennessee, in the Tennessee River basin. This suggests a more rapid depression of the land eastward, permitting the invasion of the Lorraine sea, while in the Tennessee River basin no deposits belonging to the three horizons named are present. Moreover, the Richmond, although extending further southward and westward, is absent at Swallow Bluff, apparently also at Saltillo, and only a trace of Richmond clay, several inches thick, was found along Horse Creek, at Maddox mill. Again, the Clinton, which has a considerable development north, west, and southwest of Nashville, and which presents thick sections even as far south as Centreville and the Swan Creek valley, is less than 4 feet thick at Glenkirk, is 2 feet thick at Swallow Bluff, does not exceed 1 foot in thickness at Clifton, Riverside, and Iron City, is possibly represented by a few inches of decayed ferruginous material at the base of the Silurian section three miles northwest of Waynesboro, and possibly also by the more siliceous base of the Silurian section at the Maddox mill. Finally, the Osgood bed at Riverside is overlaid apparently unconformably by the Laurel, and south of Riverside and Clifton is either represented a much diminished section, not more than 3 feet thick, or cannot be differentiated as a distinct formation.

The identification of the Warren bed rests chiefly upon the presence of *Dinorthis retrorsa*. A variety of this fossil has recently been found in the upper third of the Lower Richmond or Waynesville bed, in Indiana, but it has fewer, coarser, and more distant radiating plications than the Warren bed form. However, the identification of a horizon should rest, not upon a single species,

[1] John M. Nickles, "Geology of Cincinnati," *Journal of Cincinnati Society of Natural History*, Vol. XX (1902), No. 2.

but upon the entire fauna. This will require further collecting. I desire here merely to call attention to the fact that even within the limited exposure at Clifton the supposed Warren bed runs out southward, and that this exposure also presents the thickest Richmond section so far discovered along the Tennessee River.

Recently Mr. Ray S. Bassler has identified *Hemiphragma imperfectum*, a characteristic species of the Upper Richmond in Illinois, from the coarse, cross-bedded ferruginous rock at the base of the Silurian section at Iron City. This necessitates also the reference of the cross-bedded, less ferruginous rock at the base of the Silurian section at Riverside to the Upper Richmond, the Clinton at both localities consisting of less than 1 foot of silicious or cherty limestone. The coarse conglomerate, half a mile east of Cedar Point at Iron City, is also probably of Upper Richmond age. While these rocks suggest deposition in shallow waters, and the probable vicinity of shore lines, their relation to a probable mass of elevated land toward the westward is unknown. The relation of this problematical mass of elevated land to the Nashville dome, as the southern half of the Cincinnati geanticline is sometimes called, also remains in doubt.

16. *As determined by observations in Ohio, Indiana, and Kentucky.* — In Ohio, Indiana, and Kentucky no unconformity has been noticed between any of the subdivisions of the Niagaran. The *Cayugan* is represented by a series of strata not sufficiently studied as yet to be divided into horizons. The *Salina* division is represented by the *Eurypterus* bearing beds at Kokomo, Indiana. In New York and adjacent Ontario these beds have been called the *Bertie or Lower Waterlime*. The *Manlius* division of the Cayugan is represented in part by the hydraulic limestone at Belleville, Sandusky county, Ohio, and the *Greenfield* limestone in the southern part of the state, as far as may be determined by the presence of *Orthothetes interstriatus* (*O. hydraulicus*), a fossil characteristic of the lowest or *Cobleskill* subdivision of the Manlius in New York, Pennsylvania, and Maryland. *Spirifer vanuxemi*, found on Put-in-Bay Island, Lake Erie, and *Leperditia alta*, identified at Bellevue, Sandusky county, Ohio, are characteristic of the *Manlius proper*, the upper member of the Manlius

division of the Cayugan of New York. Very little is known of the Cayugan in Ohio or Indiana beyond the fact that it is much thicker in the northern parts of these states and thins out southwards. It has not been detected south of the central part of Indiana, but in Ohio it it has been followed beyond Greenfield to the southern boundary of the state. It appears to cross the Ohio River into the northern part of the state of Kentucky. Recent observations suggest that the Cayugan (Greenfield or possibly Monroe) limestone of southern Ohio and northern Kentucky is unconformable to the Niagaran.

The Paleodevonic has not been recognized in Ohio, Indiana, or Kentucky. Various sandy beds have at different times been referred to the Oriskany, upon lithological rather than upon paleontological data.

The base of Mesodevonic is represented in central Indiana by the *Pendleton sandstone*, referred by Hall to the *Schoharie Grit*. The *Corniferous* or *Onondaga limestone* extends to the central part of the state of Kentucky, on both sides of the Cincinnati geanticline.[1] Indeed, in central Kentucky, the Corniferous is exposed at various points along the crest of the geanticline. East of the geanticline it extends as far south as the lower parts of Fishing Creek, west of Somerset. In Indiana and western Kentucky, the *Hamilton*, represented by the *Sellersburg* bed, is not known south of Louisville. In Ohio, on the eastern side of the geanticline, the Sandusky or Delaware limestone has been identified as the lower part of the Erian, and the Olentangy shales as the upper or Hamilton part. Neither of these beds has been identified south of the central part of the state. It does not reach the Ohio River, and certainly has not been seen in Kentucky.

There is no doubt about the presence of the Cincinnati geanticline in central Kentucky and in the neighboring parts of Indiana and Ohio, in times preceding the deposition of the Corniferous. The unconformity between the Corniferous and the various Niagaran and Ordovician strata is often very striking, con-

[1] CHARLES SCHUCHERT, "On the Faunal Provinces of the Middle Devonic of America." *Am. Geol.*, Vol. 32 (1903), No. 3.

sidering the comparatively small dips characterizing the strata along the Cincinnati geanticline. The absence of the entire Paleodevonic suggests the existence of a long period of no deposition between the Corniferous and Cayugan. During this time there may have been considerable erosion. Recent observations in southern Ohio and northern Kentucky, east of the geanticline, indicate the existence of a considerable unconformity between the Cayugan and the various subdivisions of the Niagaran. This suggests the origin of the northern part of the Cincinnati geanticline in times preceding the Cayugan. Observations are not yet sufficiently extended to lead to a definite conclusion.

There are indications of a rise of the sea bottom southward in Kentucky during the latter part of the Ordovician, accompanied by a slow sinking of sea bottom northward in Ohio and Indiana, but it has not yet been determined that these changes produced folding parallel to the Cincinnati geanticline. The absence of the entire Utica, of most of the upper Lorraine, and of all except the upper part of the Richmond, in Tennessee, suggests a relation between the facts observed in Kentucky and those discovered in Tennessee. The rise of the sea bottom appears to have begun much earlier in Tennessee than in central Kentucky, and to have been more pronounced in central Kentucky than in southern Ohio. It has, however, not been shown as yet that this elevation was more pronounced along the crest of the Cincinnati geanticline than on its flanks. The emphasis given to this lack of stratigraphic evidence at present may lead to future observations which may corroborate the deductions as to the very early origin of the geanticline, perhaps even in Ordovician times, based on paleontological data.

LOCALITIES MENTIONED IN THIS PAPER.

(Consult map on p. 30 of this volume.)

1. Paulk or Watson mill.

1*a*. Cave half a mile north of 1.

2. Junction of Turkey and Horse Creeks, a quarter of a mile above 1.

3. Iron bridge.

4. Lick Ford, at mouth of Willoughby Creek.

5. Willoughby Creek, above the mouth.
6. Welch or Maddox mill.
7. Dodds' mill.
8. Sulphur Spring, Ross and Arnold farms.
9. Calybeate Spring.
9*a*. Two hundred yards north of Calybeate Spring, north of mouth of branch.
10. Cab Blount.
10*a*. Pyburn Bluff, a mile and a half northeast of White Sulphur Spring.
10*b*. West slope of hill at store, White Sulphur Spring.
11. Cave Spring southeast of Cerro Gordo.
12. Cerro Gordo.
13. Saltillo.
14. Exposures along landing at Clifton.
14*a*. Hillside north of Waynesboro road, at eastern edge of Clifton.
14*b*. West of Eagle Creek, 3 miles from Clifton on road to Martin's mill.
14*c*. Three-quarters of a mile above the landing at Clifton.
14*d*. Swallow Bluff, on north side of river, half-way between mouths of Indian and Hardin Creeks.
14*e*. Bath Springs.
15. North of landing at Glenkirk, at mouth of Beech Creek; marked Dunkirk on the map.
15*a*. Short Creek, northeast of Lego, 300 yards southeast of W. E. Ashley and P. Denman.
15*b*. Along road leading east from New Era.
16. Glade southwest of Brownsport Furnace, 3 miles west of Vice Landing.
17. Glade northwest of Charles McClanahan's home, 2 miles west of Vice store.
18. Mound glade, ¼ mile north of Vice store, on Perryville road.
19. Mound glade, ½ mile west of 18.
19*a*. Series of glades southwest of Dixon Spring.
20. Northwest edge of Perryville.
21. Quarry northeast of Perryville, on Tennessee River.
22. William H. Patten, one mile north of Linden, at spring north of house.
22*a*. Exposure in woods at bluff northeast of 22.
23. East of William Goodwin, Coon Creek, 2.2 miles east of Linden.
24. Spring northeast of J. M. Goodwin, farther up Coon Creek.
25. Spring, eastern edge of Linden.
26. Quarter of a mile west of J. S. Journey, Short Creek, 1 mile east of Linden.
27. E. Duncan, 1.5 miles east of Linden, at mouth of Jacks branch of Short Creek.
28. Webb or Rise mill.
28*a*. Tate hollow, half a mile from Buffalo River, at forks of road, 3 miles south of Linden.

29. North of railroad bridge, northwest of Riverside.
29*a*. At station, Iron City.
29*b*. At Cedar Point, a mile north of station at Iron City, on west side of railroad to Pinckney.
30. Northeast of mouth of Trace Creek, west of Riverside.
31. Bluff on Buffalo River, east of Ezekial Cothran, 2 miles southwest of 30.
32. South of Ed. Walker, east side of Tucker Branch.
33. Road crossing over Carter Creek.
34. South of Old Mill on Mill Creek.
35. Between Big Opossum and Hope Creeks.
36. Half a mile west of Dr. Evans, west of Hope Creek.
37. Northwest of Flat Woods, at mouth of Little Opossum Creek.
38. John Henry Johnson, along Waynesboro road, 7 miles east of Savannah.
39. East of George Wilson, 7.5 miles east of Savannah.
39*a*. East of Jim Irwin, 8 miles east of Savannah.
40. Old Colonel Jim Smith place, 9 miles east of Savannah ; John Goodwin farm, 4 miles east of Economy.
41. Southeast of W. D. Helton on Beech Creek, 3.5 miles northwest of Waynesboro.
42. Six miles west of Waynesboro, at crossing of Martin's mill road over Brewer Branch.
43. West of Dr. Yeiser, 6 miles east of Martin's mill.
44. Hillside northeast of stables on Gant Place.
45. Half a mile north of Martin's mill on north side of Indian Creek, opposite site of Craven's mill.
46. Hillside at north end of Martin's mill.
47. A mile and a half northwest of Martin's mill, on north side of Indian Creek.
48. Half a mile west of 47, where road ascends the hill.
49. Four miles northwest of Martin's mill, on south side of Indian Creek, south of the home of Mr. Phillips.
100. Whirl of Buffalo River, 5 miles by road north of Bakerville.
101. Along railroad, northwest of John Broadus.
102. Hillside east of John Broadus.
103. Northwest of Dr. W. B. Scott.
104. Half a mile west of Cumberland City, along the river.
105. Christopher Schmidt, hill slope south of house, about 2 miles west of John Broadus.

WELLS (UPPER STONES RIVER) FOSSILS.

The fossils here listed were obtained about a mile and a quarter southwest of Cumberland City, along the railroad, about half a mile south of the crossing of the Erin pike:

Illaenus; glabellae slightly resembling *I. americanus*, but not accompanied by the characteristic pygidia of that species; probably identical with the forms listed by Safford from the Glade limestone as I. americanus.

Maclurea bigsbyi.

Crania; related to *setigera*, but with the surface of the upper valve crowded with minute pustules which may have been the bases of setae.

Orthis tricenaria.

Dinorthis deflecta.

Dalmanella subaequata, variety.

Strophomena incurvata (*filitexta*).

Rafinesquina minnesotensis (*incrassata* of Safford).

Plectambonites sericea.

Hallina nicolleti?

Zygospira recurvirostris.

Rhynchotrema related to *inaequivalvis*, but with a more triangular outline, and with the sides more flattened, producing a more angular shell; probably identical with *Rh. orientalis* of Safford.

Helopora spiniformis, identified by R. S. Bassler.

SALTILLO (LOWER TRENTON) FOSSILS.

Whiteavesia, identified by R. S. Bassler as identical with a species found in the Lower Trenton in Central Tennessee; W. D. Helton locality.

Leptobolus, resembling *insignis*, Clifton.

Trematis punctistriata, Clifton.

Schizocrania (*?*) *rudis*, Clifton.

Schizocrania, related to *filosa*, Clifton.

Lingula, Clifton.

Dalmanella, apparently an ancestral form of *D. emacerata* from the Utica group of the Cincinnati region; some of the specimens are 18^{mm} long and 28^{mm} wide, but usually the dimensions are 16 by 21. When compared with Utica specimens which have not been crushed flat, the similarity is striking. W. D. Helton, Clifton, Wells creek basin.

Zygospira modesta, with the four median plications of the ventral valve forming a distinct fold, the slightly more distinct median groove separating these plications into pairs; Clifton.

CLINTON FOSSILS.

Illaenus daytonensis, *glabellae* and *pygidia*; 14, 15, 29*b*.

Illaenus, *pygidia* resembling *madisonianus*, but with a less triangular outline; found in Clinton of Ohio and Indiana, 14*d*, 29.

Calymmene vogdesi, *pygidia* and *glabellae*; 14, 14*d*.

Lichas breviceps clintonensis, glabellae and pygidia; 14.

Cyrtoceras (*Glyptoceras*) *subcompressum*, showing surface marking and siphuncle; 14.

Orthoceras ignotum, showing smooth surface; 14.

Cyclonema daytonensis (published as *C. bilix* in Vol. VII, *Ohio Survey*, Pl. 30, Fig. 15; see also *Twenty-fourth Annual Report of Indiana Survey for 1899*, p. 77); 14.

Diaphorostoma (*Platyostoma*) *niagarense*; 14.

Cypricardinia related to *undulostriata*, found also in Ohio (*Ohio Survey*, Vol. VII, Pl. 47, Fig. 9); 14.

Orthis flabellites; 14.

Platystrophia daytonensis; 14.

Dalmanella elegantula; 14, 14*d*.

Triplecia ortoni; 14, 29*b*.

Leptaena rhomboidalis; 14, 14*d*, 29*b*.

Plectambonites transversalis elegantula; 14.

Stricklandinia (?) *dichotoma*; generic affinities uncertain, the interior being unknown; valve moderately convex, 23^{mm} long, 30^{mm} wide, marked by about 20 plications on the posterior half of the shell, of which all except the posterolateral ones branch once dichotomously on the interior half of the shell, crossed by very fine concentric striæ; 14, 29, 29*b*.

Pentameroid shell of unknown generic affinities; valves nearly equal, the beak of the ventral valve extending slightly beyond that of the dorsal valve; the interior of the ventral valve apparently supplied with a short septum supporting a very small spondylium; the interior of the dorsal valve does not show two parallel septa; form oblong; length 35^{mm}; width 28^{mm}; thickness 16^{mm}; valves with low, broad, radiating plications which increase in number anteriorly both by dichotomous branching and by intercalation, those along the center of the valve often raised on an almost imperceptible fold; 29, 29*b*.

Atrypa marginalis; 14*d*.

Favosites favosus; 14, 29.

Favosites niagarensis; 14.

Halysites catenulatus; 14, 29.

WALDRON FOSSILS.

Hyolithes newsomensis; length 25^{mm}, the convex side sharply striated longitudinally, the more prominent striæ being separated by 4 to 8 finer ones; the flat side nearly smooth; 14*d*, 29*a*.

Orthoceras amycus; 14*c*, 14*d*, 29*a*, 29*b*.

Orthoceras simulator; 14*c*, 14*d*.

Diaphorostoma niagarense; 15*b*, 29*a*.

Cypricardinia arata; 14*d*, 15*b*.

Dictyonolla reticulata; 14*d*, 15*b*.

Meristina maria; 14*c*, 14*d*, 15*b*, 29*b*.

Homoeospira evax; 14*c*, 14*d*, 15*b*, 29*a*, 29*b*.

Homoeospira sebrina; 29*a*.

Homoeospira, more convex than *sobrina*; found also at Newsom, 29*a*.
Whitfieldella nitida; minute, 15*b*.
Nucleospira pisiformis; 14*d*, 15*b*, 29*a*, 29*b*.
Spirifer swallowensis; resembling *crispatus*, but with only one well developed lateral fold on each side; 14*d*.
Spirifer eudora; 29*b*.
Reticularia petila; 14*d*, 15*b*.
Atrypa reticularis newsomensis; 14*d*, 15*b*, 29*a*, 29*b*.
Atrypina disparilis; 14*d*, 29*a*, 29*b*.
Anastrophia internascens; 14*c*, 14*d*, 15*b*, 29*a*, 29*b*.
Plectambonites tennesseensis; width 7–9^{mm}; convex valve with about 5 striæ, which are conspicuously stronger than the remainder, partly due to radiate plication; form as in *transversalis*; 14*c*, 14*d*, 15*b*, 29*a*, 29*b*; found also at Newsom.
Leptaena rhomboidalis; 14*c*, 14*d*.
Rhipidomella hybrida; 14*c*, 14*d*, 15*b*, 29*a*.
Dalmanella elegantula; 14*d*, 29*a*, 29*b*.
Macrostylocrinus striatus; 29*a*.
Lecanocrinus pusillus; 29*a*.
Eucalyptocrinus magnus; 14*c*.
Eucalyptocrinus elrodi; 14*c*.
Stephanocrinus gemmiformis; 14*c*, 14*d*, 29*a*, 29*b*.
Stephanocrinis tennesseensis; body approximately inversely conical, the sides diverging at angles varying from 50 to 60 degrees; constriction at base usually slight; base usually sharply pointed and triangular in cross-section; some specimens less acute, much larger than *gemmiformis* from the same beds; length to base of ambulacral grooves 6.5 to 7.5^{mm}, length of interambulacral projections of the body 2^{mm}; 14*c*, 14*d*, 15*b*, 29*a*.
Callopora elegantula; 14*d*, 29*a*.
Streptolasma radicans; 29*a*.
Astylospongia praemorsa pusilla; 14*d*.

BROWNSPORT FOSSILS.

Acidaspis, 1 species; spiny pygidium only; 46.
Calymmene niagarensis; 14*a*, 16. Gant bed at 46, Pegram, 14*eC*.
Ceraurus niagarensis; was found by Roemer in vicinity of Dixon Spring.
Dalmanites, 1 species; large, related to *D. verrucosus*; head 15, pygidium 16.
Encrinurus, 1 species; small pygidia; 14*a*, 35 Pegram.
Illaenus, 1 species; pygidia broad as in *I. armatus*; 14*a*, 15, 19*a*.
Phacops, 1 species; Gant bed 46.
Sphaerexochus romingeri; glabellae; 14*a*, 15, 14*eA*.
Amphicoelia ?, 1 species; large; 10 radiating plications in a width of 10^{mm}, 6^{cm} from the beak; 21.

Cypricardinia, 1 species; Gant bed 46.

Cypricardinia?, 1 species; small, related to *C. Caswelli*; 18.

Pterinea, 1 species; 16.

Cyclonema tennesseensis; not identified; type specimens found within several miles of Dixon Spring; 19*a*.

Holopea, 1 species; cast, 46.

Platyceras niagarense; 14*a*, 19*a*, 49.

Platyceras, brownsportensis vertically compressed at margin, more than in *Pl. sinuatum*; 12, 16, 14*eC*.

Diaphorostoma (*Platyostoma*) *niagarense*; 14*a*, 15, 16, 19*a*, 46, 49, 14*eA*, 14*eC*, 40.

Platyostoma, 1 species; general aspect that of a *Cyclonema*; 12, 16, 18.

Dictyonella gibbosa; Gant bed, 44, 46, 47; described by Hall from Perry county.

Dictyonella concinna; described by Hall from Perry county.

Dioryonella reticulata, 40.

Meristina maria roemeri; 15, 16, 19, 46, Pegram, 40.

Merista tennesseensis; 12, 16, 19, Gant bed 46, 14*eA*, 14*eC*, 39, 40.

Trematospira simplex; largest specimens 18^{mm} long; common at 12, 16, 14*eC*, 40.

Trematospira, 1 species; 6^{mm} long, with general outline and form of *T. tennesseensis*, but much smaller; Gant bed 44.

Homoeospira schucherti; largest specimen 13^{mm} in length, both valves with narrow median depression occupied by 1 or 2 narrow plications; type from Brownsport, 12, top 16, 18, 19, 44, 46, 47, 14*eA*, 14*eC*, 39, 40.

Homoeospira sobrina (?); 14*eC*, 38, 40.

Homoeospira beecheri; largest specimen 8^{mm} in length; shallow depression of ventral valve occupied by 2 plications slightly smaller than the rest; bottom of median furrow of dorsal valve occupied anteriorly by 2 narrow striæ, which are the bifurcated top of a low plication easily overlooked; type from Brownsport, 16.

Anoplotheca (*Coelospira*) *saffordi*; length 5^{mm}; ventral valve strongly convex, with 3 plications forming an indistinct median elevation, and with 3 distinct and 1 or 2 indistinct plications on each side; dorsal valve concave, especially anteriorly along the shallow median depression; depression occupied by 2 plications close together, more widely separated from the neighboring plications; Gant bed at 44, 14*eC*, 39.

Nucleospira concentrica; Gant bed, 44, 47; type from Decatur county, quoted by Whitfield and Hovey from Meniscus beds of Decatur county, and by Safford from Bath Springs in Decatur county; 14*eA*, 14*eC*, 39, 40.

Nucleospira, 1 species; probably *pisiformis*; 14, Gant bed 44, 14*eA*.

Cyrtia cliftonensis; height of cardinal area 6^{mm}, width 10^{mm}; margins of sinus of ventral valve distinct and angular, diverging at an angle of 52°, resembling *C. meta*; 14*a*.

Reticularia pegramensis; length 15^{mm}, width 19^{mm}; median fold low, but distinct, 5^{mm} broad anteriorly; median depression shallow; no lateral plications; concentric lines of growth distinct; found only at Pegram.

Delthyris, 1 species; 8^{mm} long, 10.5^{mm} wide; median plication of dorsal valve with faint depression along the axis anteriorly; 3 distinct and 1 indistinct plication on each side; cardinal angles acute; surface ornamentation similar to that of *Spirifer crispus*; 12, 16.

Spirifer oligoptychus; the radiating striæ are coarser than in *Sp. eudora* from the Waldron bed, and are not crenulated by transverse lines of growth, 14*a*, 19*a*.

Spirifer geronticus; 20^{mm} long; median fold and sinus distinct; 1 or 2 on each side at the beak, usually disappearing within 7^{mm} from the beak; radiating striæ; type from Dixon Spring; 14*a*, 19*a*, 49, Pegram.

Spirifer foggi; 14*a*, 19*a*, Pegram.

Spirifer saffordi; surface ornamented as in *Sp. crispus*, but the concentric striæ are much more distinct; cited by Whitfield and Hovey from the Meniscus beds of Perry county, Tenn., and by Safford from the Gant locality in Wayne county, and Bath Springs in Decatur county, formerly a part of Perry county, Gant bed 44.

Spirifer crispus; 12, 16, 19*a*, 40.

Spirifer crispus variety; concentric striæ finer and closer together; shell slightly narrower; 12, 16, 14*eC*.

Atrypa reticularis newsomensis; types from Waldron bed at Newsom, Tenn., 8 or 9 plications in a width of 10^{mm}; 16, 19, Pegram, 14*eC*, 39, 40.

Atrypa reticularis niagarensis; 12 to 14 plications in a width of 10^{mm}; 14*a*, 16, 19, 19*a*, 49, 103, Pegram, 14*eA*.

Atrypa reticularis arctostriatus; 28 plications in a width of 10^{mm}; top at 16.

Atrypa marginalis; 14*a*, 15, 16, 18, 19*a*, 49; similar forms included by Nettelroth under *C. Calvini*; 14*eA*.

Atrypina, 1 species; 16, 19*a*, 21.

Uncinulus stricklandi; 12, 16, 21, 43, 46, Gant bed 45, 46, 14*eC*, 40, 15*a*.

Uncinulus tennesseensis; shell smaller than *stricklandi*, usually with fold and sinus more distinct; 12, 14*a*, 16, 19, 19*a*, 20, Gant bed 46, Pegram, 14*eC*, 40.

Rhynchonella lindenensis; outline roughly circular; with three plications on fold, 2 in sinus, and 8 or 9 on each side; at 27 near Linden. A similar shell with only 6 or 7 plications on each side occurs at 16 near Brownsport Furnace; interiors unknown.

Wilsonia saffordi; 14*a*, 15, 16, 19, 19*a*, 49, 103, Gant bed 44, 46, 14*eA*, 14*eC*, 39, 40.

Camarotoechia; similar in form to *C. neglecta*, but 12^{mm} long and with the surface apparently smooth; 12, 16, 19, 19*a*, 27, Gant bed 46, 14*eC*, 38, 40.

Cāmarotoechia; cuneate in form, 11^{mm} long; sinus and fold almost imperceptible except on direct anterior face of shell; 12, 16.

Gypidula roemeri; 14*a*, 16, 18, 34, Gant bed 46, 14*eC*, 39, 40, 15*a*.

Conchidium littoni; described from Hardin county; identified by Safford from the Meniscus horizon.

Conchidium legoensis; length, 29 to 31^{mm}; width, 20 to 24^{mm}; thickness, 16 to 17^{mm}; 12 to 14 radiating plications; related to *C. crassiplica*; 15*a*.

Conchidium lindenensis; in form and frequency of radiating plications most nearly resembling *C. colleti*, but without frequent lines of growth, and only 50^{mm} long; not rare within 10 feet of base of section, east of house of William Goodwin on Coon Creek, opposite road leading off to Linden; 23.

Plectambonites, 1 species; Gant bed 44.

Strophonella roemeri; profile resembling Fig. 4*c*, Plate 23, Vol. III, *N. Y. Pal.*; striæ very fine and numerous in umbonal region, every fifth or sixth one distinctly more prominent; the more prominent striæ become more numerous in the pallial region, 12 to 15 in a width of 10^{mm}; length 43^{mm}, width 60^{mm}, outline triangular; about 35 feet above base of Dixon bed at Brownsport Furnace, 16; Gant bed 46; 12, New Era.

Strophonella prolongata; width 31^{mm}, length 15^{mm}; plications 18 to 21 in a width of 10^{mm} along anterior margin, numerous at beak; profile as in Fig. 6*c*, Plate 23, Vol. III, *N. Y. Pal.*; 16, 19*a*, Gant bed 44, 46, 39.

Strophonella laxiplicatus; plications consist of sharp narrow ridges separated by comparatively wide spaces, new plications are added along the middle of these spaces. Comparatively few plications (usually less than 10) begin at the beak. Related to *Str. semifasciata*, but plications more numerous, more prominent, and shell much smaller; 16, 12, 14*eC*, 39.

Leptaena rhomboidalis; 16, 14*a*, Gant bed, 46, 14*eC*, 39.

Orthothetes subplanus; 12, 16, 14*eA*, 14*eC*, 40.

Orthothetes roemeri; plications fewer, separated by wider spaces; shell much smaller; 19*a*, Pegram.

Dalmanella fissiplica; 19*a*, 14*a*, 36, 49, 103, 14*eA*.

Dalmanella elegantula; only 11^{mm} long, otherwise typical; 14*a*, 19*a*, 35. Larger form with usually finer striae, 20^{mm} long; top at 16, 14*eC*, 39, 40.

Dalmanella arcuaria; 14*a*, 15, 16, 18, 46, 49, 103.

Rhipidomella lenticularis; resembles *Rh. circulus*, but the striæ are much more numerous, largest specimens 28^{mm} long; top at 16.

Rhipidomella hybrida; variety, 12^{mm} long; 14*eC*, 38, 39, 40.

Rhipidomella saffordi; length 8^{mm}, dorsal valve strongly convex, but indented along the middle by a distinct depression which begins at the beak and is widest and deepest at the anterior margin; Gant bed 44, Pegram, 14*eC*, 39.

Bilobites biloba; 14*a*, 19*a*.

Allocrinus typus; Clifton and Decatur counties.

Callicrinus (*Eucalyptocrinus*) *ramifer*; Wayne and Decatur counties.

Caryocrinus ornatus; 14*a*, 16, 19*a*, 49.

Caryocrinus bulbulus ; Wayne county.
Caryocrinus milliganae ; Decatur county.
Centrocrinus tennesseensis ; Clifton.
Coccocrinus bacca ; 49.
Cystocrinus tennesseensis ; a parasitic growth on a crinoid stem ; 14*a*, 19*a*, 20.
Eucalyptocrinus ventricosus (= *E. caelatus* of Roemer); Decatur, Wayne and Perry counties ; 14*eA*.
Eucalyptocrinus milliganae ; Decatur county.
Eucalyptocrinus lindahli (= *wortheni* of Miller) ; Wayne county.
Gazacrinus tennesseensis ; Tennessee, locality unknown.
Glyptaster milliganae ; Decatur county.
Idiocrinus tennesseensis ; Clifton.
Lampterocrinus tennesseensis ; 15, 19*a*, 20, 49.
Lecanocrinus pisiformis (*Poteriocrinus*) ; 19*a*, 18, 49, 46, 39.
Lecanocrinus. 1 species ; identified by Springer as a form found at St. Paul Indiana; 21.
Lecanocrinus pusillus ; 16.
Marsupiocrinus striatus ; Decatur county.
Marsupiocrinus (*Platycrinus*) tennesseensis ; 14*a*, 16, 19*a*, 49.
Melocrinus (*Mariacrinus*) *nobillisimus* ; cited as occurring apparently in the Niagara of western Tennessee.
Melocrinus (*Cytocrinus*) *roemeri* (= *laevis*) ; 46. This may be *Actinocrinus verneuli* of Troost.
Myelodactytus gorbyi ; cited from Tennessee.
Periechocrinus tennesseensis (= *Saccocrinus speciosus* of Roemer) ; 14*a*.
Pisocrinus campana ; 15, 14*a*, 19*a*, 46, 49.
Pisocrinus gemmiformis ; 14*a*, 19*a*, 35, 39.
Pisocrinus milligani (= *gorbyi*) ; 14*a*, 15, 19*a*, 46, 49, 38.
Pisocrinus (*Synbathocrinus*) *tennesseensis* ; 14*a*, 19*a*, 49.
Taxocriuus ; genus identified by Springer, 14*a*.
Thalamocrinus ovatus ; Decatur county.
Thalamocrinus cylindricus ; Decatur county.
Thysanocrinus milliganae ; Decatur county.
Troostocrinus (*Pentatrematites*) *reinwardti* ; 15, 16, 18, 19*a*, 49, 14*eA*.
Zophocrinus howardi ; 14*a*.
Callopora elegantula ; 16, 19, 12, 14*eC*, 39, 40.
Fistulipora (*Thecostegites*) *hemispherica* ; 14*a*, 16, 32, 34, 35, 42, in Brownsport bed ; abundant also in Dixon bed, 14*eA*, 14*eC*, 14*eE*, 39.
Alveolites niagarensis ; 27.
Amplexus shumardi ; 14*a*, 16, 27, 46, 38, 39*a*.
Anisophyllum ; listed as An. agassizi by Prof. Safford, 14*eC*, 39.
Aulopora roemeri (= *repens* of Roemer) ; 27.
Calceola tennesseensis ; 14*a*, 15, 16, 27, Pegram.
Cladopora complanata ; 27.

Cladopora reticulata; 27.
Coenites verticillata; 27.
Ditoecholasma (*Petraia*) *fanningana*; 14*a*, 15, 16, 19*a*, 49, 14*eC*, 39*a*.
Enterolasma (*Petraia*) *waynense*; 14*a*, 16, 19*a*, 46, 49, 36, 14*eA*, 14*eC*, 14*eE*.
Eridophyllum proliferum; related to *E. sentum*, but corallites free, not connected laterally; the calyx of mature specimens not often seen, because usually filled by young corallets, invariably 4 corallets in each calyx; 16. 27, 39*a*.
Favosites cristatus; 14*a*, 15, 16, 27, 46, 14*eC*, 40.
Favosites cristatus major; 14*a*, 27, 46, 49.
Favosites discoidea; 14*a*, 16, 19*a* 32, 35, 49, Pegram, 14*eC*.
Favosites discus; 27, top of 16.
Favosites favosus; 16. 15, Pegram.
Favosites niagarensis; 27, 39*a*.
Favosites spongilla; 16, 27.
Favosites obpyriformis; growth globose or inversely pear-shaped, 12^{cm} in height; corallites 3 to 4^{mm} in diameter; 17.
Halysites catenulatus; 27.
Heliolites subtubulatus; 27, 16, 103.
Omphyma verrucosa; 16.
Laccophyllum acuminatum; Perry county, 14*a*, 16, 39*a*.
Plasmopora follis; 16, 27, 103, 38, 39*a*.
Platyaxum platys; corallum forming flat, very thin (1 to 3^{mm}) fronds, which are irregularly lobate; corallites very oblique; apertures sinuate, central part elevated, the sides adnate to the frond; probably congeneric with Alveolites; 15 corallites in a with of 10^{mm}; 16, 27.
Striatopora; related to Str. *flexuosa*; 12, 14*a*, 19, 19*a*, 16.
Thecia major; 14*a*, 27, 39*a*
Thecia swindernana; 15, 16, 27.
Ptychophyllum vulcanius; coral 65^{mm} wide, thin at the edges, 4^{mm} thick 17^{mm} from the center, maximum height 15^{mm} at 6^{mm} from the center, about 10^{mm} at the center. Top of coral flat; the base is not preserved, but, judging from what remains, its sides once spread at an angle of more than 45°, until it reached a diameter of about 35^{mm}, and then it spread almost horizontally. A basal view suggests the appearance of a model of a low volcano, with a distinct crater at the center. The septæ from this side have a striking resemblance to those forming the calyx in *Ptychophyllum ipomoea*; 36.
Astraeospongia meniscus; 14*a*, 14*b*, 22, 20, 35, 37, 43, 44, 46, 49, 102, 103, 14*eA*, 15*b*.
Anomoclomella zitteli; Decatur county.
Astylomanon cratera (*Palaeomanon*); figured by Roemer in his monograph of West Tennessee fossils on Plate 1; to Figs. 4 and 4*a* must be added also Figs. 1 and 1*a* on the same plate, according to Rauff. The following

varieties are established: *prototypum, aryballium, balantium, lecythium, promiscua, poterium, cantharium, cylix* which is the typical form, *patera*; 14*a*, 15, 19*a*, 28*a*, 103, 14*eA*.

Astylomanon pluriexcavatum; Decatur county.

Astylomanon verrucosum; figured by Roemer as *Astylospongia praemorsa* on Plate 1, Figs. 1*b*, 1*c*; 14*a*, 15, 16, 19*a*, 46, 103, Gant bed 46, 14*eA*, 39, 39*a*.

Astylomanon verrucosum bulbifera; Decatur county.

Carpomanon glandulosum; Decatur county.

Caryomanon roemeri; western Tennessee.

Caryomanon inciso-lobatum; 14*a*, 16, 46, 47, Gant bed 46, 14*eA*, 14*eC*.

Caryomanon stellatim-sulcatum; 14*a*, 15, 16, 19*a*, 22, 46, 49, 14*b*, 103, Gant bed 46, 14*eA*, 14*eE*, 38, 15*b*.

Caryomanon stellatim-sulcatum distorta; Decatur county.

Chiastoclonella headi; Decatur county.

Dendroclonella rugosa; Perry county.

Hindia sphaeroidalis (*Calamopora fibrosa* of Roemer); 14*a*, 15, 16, 27, 103, 14*eA*, 38.

Pycnopegma pileum; Decatur county.

Pycnopegma callosum; Decatur county.

Pycnopegma stromatoporoides; Decatur county.

Astylospongia imbricato-articulata; 14*a*, 15, 16, 46, 14*eA*.

LINDEN (HELDERBERGIAN) FOSSILS.

Favosites conicus; 10*a*, 10*b*, 21.

Favosites, with convex base covered by the epitheca; 9*a*, 10*a*, 10*b*, 21.

Pleurodictyum lenticulare; 10*a*, 10*b*, 21.

Striatopora issa; 21.

Brachiocrinus; 21.

Camarocrinus saffordi; 9*a*, 10*a*, 104.

Bilobites varica; 9*a*.

Dalmanites subcarinata, with coarse striæ; 9*a*, 10*b*, 21.

Dalmanites subcarinata, with fine striæ; 9*a*, 21.

Hebertella; 21.

Rhipidomella emarginata; 21.

Rhipidomella oblata; 9*a*, 10*a*, 10*b*, 21.

Orthothetes woolworthanus; 10*a*, 10*b*, 21, 22.

Leptaena rhomboidalis; 9*a*, 10*a*, 21.

Stropheodonta beckei; 10*a*, 10*b*, 21.

Strophonella punctulifera; 9*a*, 10*a*, 21, 104.

Chonostrophia, related to *Helderbergia*, but wider in proportion to length; 23mm wide, 11mm long; 10*a*.

Gypidula, without fold or sinus, plications narrow (as in Figs. 9–12, Plate 28, *The Paleozoic Fauna*, New Jersey Survey, 1903), but more obsolete towards beak and sides; 21, 104.

Uncinulus nucleolatus; 10*a*, 10*b*, 21, 104.

Uncinulus, with 2, occasionally with 4, plications on mesial fold, and 3 or 4 lateral plications; largest specimen 11^{mm} long, 11^{mm} wide, 10^{mm} thick, angular; 10*b*, 21.

Uncinulus, related to *vellicatus*, but smaller; the mesial fold only slightly elevated; ventral valve flattened toward the lateral margins and then abruptly bent toward the suture; 10*b*.

Uncinulus schucherti, resembling *Wilsonia saffordi*, but that part of the ventral valve occupying the fold projects far less beyond the lateral margins of the shell; the dorsal valve is more evenly convex; the anterior face of the shell is not flattened, so that a lateral view is less angular; plications on mesial fold vary from 4–5; of the lateral plications 7–10 are distinct, and 2–4 indistinct; largest specimen 15^{mm} long; globular or moderately elongated; 10*a*, 10*b*, 21.

Rhynchonella transversa; 10*b*, 21.

Rhynchonella bialveata; 21.

Rhynchotreta; cuneate triangular form without distinct sinus or fold; 21.

Atrypa reticularis; 10*a*, 10*b*, 21.

Cyrtina dalmani; 21.

Delthyris perlamellosus; 9*a*, 10*a*, 10*b*, 21, 22, 104.

Delthyris, related to *perlamellosus*, but with flat, high, triangular on ventral valve, giving the shell a slight resemblance to a *Cyrtina*; 10*a*, 10*b*, 21.

Spirifer cyclopterus; 10*a*, 10*b*, 22, 104.

Spirifer, with radiate striæ and 3 or 4 lateral plications; possibly identical with *Sp. tenuistriatus*, the horizon of that species not being definitely known; 10*a*.

Nucleospira; flatter than in *ventricosa*; 10*b*, 21.

Lissopleura; smooth, oblong, quadrangular form; 21.

Anoplotheca concava; 21.

Rhynchospira globosa; 10*b*, 21.

Rhynchospira formosa; 10*b*, 21, 22, 104.

Meristella Meeki; 10*a*, 10*b*, 21, 22, 104.

Meristella; related to *princeps*; 9*a*, 10*a*, 21, 104.

Platyceras tenuiliratum; 10*a*, 21.

Dalmanites pleuroptyx; 10*a*, 10*b*, 21.

Phacops logani; 10*a*.

AUG. F. FOERSTE.

DAYTON, O.

Reviews.

SUMMARIES OF THE LITERATURE OF ECONOMIC GEOLOGY.

I.

Edwin C. Eckel.

With the present issue the title of this section has been changed to conform to an enlargement in its scope. A brief outline of the plan which the writer purposes to follow may be of service to readers.

Papers and books relating to the economic geology of the United States will be summarized, so far as possible. Discussions of economic developments in foreign countries will be excluded, unless containing matter of general interest. Publications devoted largely or entirely to the technology of any mineral industry will not be summarized; but as such technologic papers appear to be of increasing interest to workers in economic geology, they will be listed by title, with occasionally a brief note to indicate their scope. Reports or papers containing statistical or compiled data only will be neither summarized nor listed.

The expansion of the scope of this series of summaries will necessitate the exclusion from it of many papers which would have been noticed under the old arrangement. The writer has planned, therefore, to continue the old series in *Municipal Engineering*, under the title "Recent Publications on Structural Materials."

Adams, G. T. "Principles Controlling the Geologic Deposition of the Hydrocarbons." *Trans. Am. Inst. Min. Eng.*, Vol. XXXII; advance separate, 7 pp.

The author notes the present unsatisfactory condition of the literature on the hydrocarbons, in so far as their geologic interlation and the principles governing the origin of their economically valuable deposits are concerned; and applies to these problems certain principles allied to those stated by Van Hise for ore deposits. The principal difference, in this regard, between hydrocarbons and ores is that the latter are carried in solution, while the former are largely associated with the transporting water merely in a condition of mechanical mixture. The author then discusses the effect of the inferior specific gravity of the hydrocarbons, as compared with water; the different effects which will be produced, according as the hydrocarbon is merely miscible with, or soluble in, the transporting water; and the possibility that separations of the hydrocarbons, equivalent to those accomplished by fractional distillation, may be effected by differences in degrees of solubility, or in the character of the rock traversed.

BRANNER, J. C., AND NEWSOM, J. F. *The Phosphate Rocks of Arkansas.* Bull. 74, Arkansas Agric. Exp. Station. 8vo, 67 pp.

Three phosphate-bearing areas are noted in Arkansas. The first, and by far the most important, lies north of the Boston Mountains and west of Black River; the second, in the Cretaceous area of the southwestern part of the state; the third, north and west of Hot Springs. The second and third areas may be dismissed with the remark that little appears to be known concerning the phosphate beds they may contain.

The principal area is that in the northern part of the state. The phosphates here occur as nodules associated with the Sylamore sandstone and Eureka shale. These two formations together have a maximum thickness of 90 feet, and represent the Devonian of the region. The phosphates are therefore at the same horizon as the Tennessee black phosphates. Average specimens gave a phosphoric acid content equivalent to 30 per cent. to 70 per cent. calcium phosphate, with 4 per cent. to 20 per cent. iron and alumina. Unless better material is found, the rock will evidently be unable to compete, except locally, with Tennessee or other southern phosphates.

CROSBY, W. O. "Geological History of the Hematite Iron Ores of the Antwerp and Fowler Belt in New York." *American Geologist,* Vol. XXIX, pp. 233–42; also in *Technology Quarterly,* Vol. XIV, pp. 162–70.

The author discusses certain of the red hematite deposits of the western Adirondacks and concludes that the "ore body of the Sterling mine is in a dike, 50 feet or more in width, of some highly altered basic rock, possibly diabase; that the ore was originally a magmatic segregation of this rock, chiefly in the form of sulphides, which have subsequently suffered more or less complete oxidation to a considerable depth, the ore now being virtually a gossan; and that this dike is, probably, continuous for the entire length of the belt of mines, although absolute continuity is by no means essential to the hypothesis."

[It will be remembered that the "dike" in which the ore bodies occur is bordered by granite on the southeast, and by crystalline limestone on the northwest; and that Smyth has considered the chloritic "dike" rock to be merely a highly altered phase of the granite.]

DICKSON, C. W. "The Ore Deposits of Sudbury, Ontario." *Trans. Am. Inst. Min. Eng.,* Vol. XXXII; advance separate, 65 pp.

The first part of this paper deals with "The Relation of Nickel to Pyrrhotite." The mineral associates, chemical composition, and nickel and cobalt content of pyrrhotites are discussed, particular attention being paid to the Sudbury and Algoma ores. The author states that "the nickel occurs in the pyrrhotite as the so-called pentlandite," but that, though "nearly all of the pentlandite can be separated from the pyrrotite by magnetic methods," "peculiar physical conditions seem to render its absolute elimination an impossibility." Magnetic separation is therefore a commercial impossibility. The further conclusion is reached that the Sudbury pyrrhotite conforms best to the formula Fe_8S_9.

The second part is entitled "Genesis of the Sudbury Ores," but contains in addition much material bearing on other districts. The Sudbury deposits and ores are discussed in detail, and the author concludes that the origin of the deposits is to be referred to replacement of the basic rock along crushed and faulted zones, and not to magmatic segregation. This conclusion is based upon the following line of argument:

Brecciation, with accompanying faulting and shearing, is noticeable both on a large scale and in slides. Most of this took place prior to the formation of the ore deposits, and the ore prevailingly occurs as a cement for the brecciated rock-fragments and along shearing planes. All the rock is now more or less altered; and the more complete the alteration of the rock, the more complete has been its replacement by ore. Pyrrhotite occurs, it is true, as an original constituent of the norite, but the amount of this original pyrrhotite is very small. The abrupt change from massive sulphides to barren rock, the angular form of the included rock fragments, and the comparative freedom from sulphides of these fragments are further adduced in support of the theory that the ore deposits are essentially and predominantly secondary.

FLUKER, W. H. "Gold Mining in McDuffie County, Georgia." *Trans. Am. Inst. Min. Eng.*, Vol. XXXII; also in *Eng. and Min. Jour.*, Vol. LXXIII, pp. 725, 726.

Of particular interest as describing a Georgia gold-mining district never before discussed in print, and far to the southeast of what is commonly considered the Georgia gold region. The veins carrying the auriferous pyrite are of the usual Appalachian type—stringers usually parallel to the lamination of the inclosing mica and hydromica schists.

HILL, B. F. *The Terlingua Quicksilver Deposits, Brewster County* [*Texas*]. Bull. 4, Univ. of Texas Mineral Survey. 8vo, pp. 74.

The rocks in the vicinity of the Brewster county quicksilver deposits are marine sediments representing the Lower and Upper Cretaceous and the Tertiary, with igneous rocks of late Tertiary age. The ores occur in the Cretaceous beds occupying fissures, either vertical or along bedding planes, marked by little or no displacement; and fault fissures marked by displacement with or without brecciated zones. Ore deposition in the district is supposed to have been due to the stimulus of the late Tertiary intrusions and flows. The common ores are cinnabar and native mercury, though other mercury ores occur in small quantity. The chief gangue material is calcite; aragonite and gypsum being next in importance.

McCALLIE, S. W. "The Ducktown Copper Mining District." *Eng. and Min. Journ.*, Vol. LXXIV, pp. 439, 440.

Description of the geography, areal geology, and ore deposits of the Ducktown district of southeastern Tennessee and its extension into northern Georgia. The original contribution of greatest interest in this paper is the determination of the occurrence of sheared igneous rocks in the vicinity of the ore bodies, a dark gray quartz diorite occurring in linear areas parallel with the trend of the ore deposits.

PRATT, J. H. "Gold Mining in the Southern Appalachians." *Eng. and Min. Journ.*, Vol. LXXIV, pp. 241, 242.

Summary of recent gold-mining developments in Virginia, North Carolina, South Carolina, Alabama, and Tennessee.

SPURR, J. E. "The Original Source of the Lake Superior Iron Ores." *American Geologist*, Vol. XXIX, pp. 335–49.

The author points out that, though Van Hise and Leith agree with him in considering the original source of the Mesabi ores to be a green hydrous ferrous silicate of organic origin, they refuse to call this material glauconite, because of its low content or entire lack of potash. Spurr gives analyses and descriptions of undoubted glauconites from various localities, comparing these with the Mesabi material. He decides that, though the Mesabi silicate carries less potash (0.31 per cent. and 0.41 per cent.)

than any of the others, it is nearer the Australian (less than 1 per cent.), the Paris basin (1.70 per cent.) and the French Creek, Pa. (2.23 per cent.) glauconites than they are to the Grodno, Russia, material (7.57 per cent.). Recalling Murray and Renard's observation that the potash content of recent glauconites depends largely on the composition of the coastal rocks, he shows that the surface, at the time of deposition of the Mesabi iron-bearing formation, consisted of rocks very low in potash. His final conclusion, therefore, is that the Mesabi mineral is entitled to the name glauconite.

SPURR, J. E. "A Consideration of Igneous Rocks and Their Segregation or Differentiation as Related to the Occurrence of Ores." *Trans. Am. Inst. Min. Eng.*, Vol. XXXII, advance separate, 53 pp.

The author discusses briefly the general relation of ore deposits to igneous rocks, pointing out that the ores were all originally derived from igneous rocks, and that most existing ore deposits are closely associated with areas or belts of such rocks. The sedimentary rocks, as a rule, contain a lower percentage of the metals than do rocks of igneous origin.

The differentiation of igneous rocks is then discussed, and the order in which the various minerals crystallize out of a molten magma is noted. The concentration of commercially valuable minerals by segregation within molten masses previous to their consolidation, is discussed in some detail, the metals being separately treated. The preference of concentrations of iron, chromium, nickel, copper, platinum (and probably cobalt) for the more basic igneous rocks, and that of molybdenum, tin, and tungsten for the acid rocks, is stated.

The author then takes up an original contribution to the study of ore deposits — the general preference of gold for the more siliceous igneous rocks, and the relationship of certain gold quartz veins to rocks of undoubted igneous origin. Studies in certain Alaskan and other districts have convinced him that many gold-quartz veins are to be regarded simply as extremely acid igneous rocks — the result of magmatic segregation — and correlative to the extremely basic rocks (pyroxenites, etc.) at the other end of the series. This theory is discussed in detail, and supporting observations, drawn from various districts, are given. This portion of the paper is summarized by the author in the statement that "although gold is present in all igneous rocks, and may be unequally distributed in any of them, yet the conditions for concentration by magmatic segregation become more favorable in proportion as the rock becomes more siliceous, and become *most* favorable in what has been shown to be the extreme siliceous product of rock-differentiation — in quartz-veins or dykes."

The merging of deposits formed by magmatic segregation into certain types of contact-deposits, and into deposits of gaseo-aqueous origin, is noted. The sequence of rock types in the volcanic eruptions of an area is then discussed, leading up to the relations between this sequence and the sequence of metalliferous deposits in the same area. The conclusion is then drawn that "by magmatic segregation the metals of commercial value, as well as the commoner rock-forming elements, are irregularly and to a certain extent independently concentrated in certain portions of the earth's crust. Such portions, characterized by the relative abundance of certain metals, may be called metalliferous provinces." These "metalliferous provinces" may be more or less closely identified with the different "petrographic provinces."

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THE AGE AND ORIGIN OF THE GYPSUM OF CENTRAL IOWA.

THE known gypsum of Iowa is confined to Webster county, which lies somewhat north and west of the center of the state. Here it occupies a tract about six miles wide and fifteen miles long, on the edge of which the city of Fort Dodge is located. The original gypsum area has been greatly reduced by the erosive and solvent action of the Des Moines River, which crosses it nearly at right angles, cutting completely through it and deep into the Coal Measures beneath. Some of the earliest geological work undertaken in the state was carried on in this region. The Des Moines River exposes along its banks the indurated rock and gives at times sections of rock and drift 200 feet in thickness, which greatly facilitate geological study. The unique deposit of gypsum has been attractive to the student on account of the theoretical problems that it presents, and to others it is interesting on account of its practical value.

In the year 1849 Owen[1] made a hurried trip up to the Des Moines River, noticed the gypsum, and made certain deductions in regard to its origin. After describing its remarkable thickness and purity, he adds:

> This plaster stone of the Des Moines does not appear to have been deposited in nests or conical heaps, as in the shales of the Onondago Salt Group of New York, but rather in continual horizontal beds, conformable to the underlying shale. The immense quantity of gypsum of this part of the

[1] *Geology of Wisconsin, Iowa, and Minnesota*, p. 126 (Philadelphia, 1852).

upper Des Moines can hardly be accounted for on the principle of double chemical decomposition between sulphate of iron and carbonate of lime, formerly existing where the plaster now is, since there does not appear to be an equivalent bed of iron in the vicinity, nor yet beds of limestone, except thin bands of black bituminous, calcareous rocks, by no means extensive, that are in immediate connection with the plaster-beds. It seems rather to have been an original deposit at the bottom of the ocean; the sulphate of lime having probably been derived, during the formation of the rocks, from submarine sources.

In 1856 Worthen[1] visited the region and came to the conclusion that the gypsum does not lie conformably on the Coal Measures. Hall[2] in 1858 and McGee[3] in 1884 considered the stratigraphic relationship and age of the gypsum. Webster county was included in the geological studies of C. A. White and references to coal and gypsum are made in his annual reports of 1868 and 1870.[4] In these reports White pointed out the great value of the Webster county gypsum, and urged that it be developed so that the state might furnish the stucco and land plaster used within its borders.

Keyes[5] reported quite fully on the gypsum area in 1893, describing the position and the extent of the deposit and its stratigraphic relationships, and with reference to its age concluding that it should be referred to the Cretaceous.

GENERAL RELATIONS OF STRATA.

Excepting limited Carboniferous outliers, Webster county contains the most northern of the Iowa Coal Measures. These lie just beneath the drift throughout the southern part of the county, and extend north to a point three miles above Fort Dodge. The Saint Louis limestone underlies the drift in the northern part of the county, and appears along the Des Moines well to the south, where the stream has cut through the Coal Measures. Upon the Coal Measures in the central part of the county lie the gypsum beds unconformably. The term "gypsum

[1] *Geology of Iowa*, Vol. I (1858), p. 177. [2] *Ibid.*, p. 142.

[3] *Tenth U. S. Census*, Vol. X, "Building Stones," p. 258 (Washington, 1884).

[4] *First Annual Report State Geologist* (1868), pp. 25–27; *Second Annual Report* (1868), pp. 135–40. *Geology of Iowa*, Vol. II, pp. 293, 254–56.

[5] *Iowa Geological Survey, Annual Report*, Vol. III (1893), pp. 259–304.

beds" includes the gypsum, red shales, and sandstone which often overlie it, and three or four feet of fine clay which commonly occur at its base. Two sections may be given to illustrate their stratigraphic relationships.

The exposure at what was formerly known as Kohle's Brewery near the mouth of Soldier Creek and within the Fort Dodge city limits has long been regarded as typical for the gypsum and associated red shales and sandstone.

		Feet
9.	Gravel, fresh, clean, well water-worn, containing much limestone	5
8.	Drift, slightly oxidized, unleached	28
7.	Gravel, rusted, many decayed fragments, showing only at certain points along bluff	2
6.	Sandstone, soft, friable, buff-colored, though at points not far away it is white and heavily bedded	5
5.	Shales, argillaceous, sandy layers alternating	5
4.	Sandstone, buff, friable	2
3.	Shale, gray	2
2.	Thin bands of gypsum and shale	7
1.	Gypsum, massive, exposed	11

SECTION IN THE PIT OF THE FORT DODGE CLAY WORKS.

3.	Drift, yellow, unleached, lower part a little darker than the upper	35
2.	Red sandy shale, with occasional thin bands of sandstone	0–10
1.	Gray Coal-Measure shales, often containing fossils of ferns, lepidodendrons. A few iron nodules present and crystals of selenite. Separated from red shales above by sharp line of unconformity. Along the line of separation there is a layer of gumbo, one foot thick	30

No. 2 includes the red shales found in so many places above the gypsum. These red sandy shales are so characteristic, and associated so conformably with the gypsum, that in this section, as elsewhere, they may safely be regarded as of the same age as the gypsum.

NATURE OF THE GYPSUM BEDS.

All of the gypsum in Webster county, except the scattered crystals of selenite in the Coal-Measure shales, is stratified in heavy layers which are rarely less than six inches thick, commonly twelve inches or more, attaining a maximum thickness of two feet. The layers are separated by traces of clay. In thickness the deposit varies from ten to thirty feet. Instead of thinning out gradually through a considerable area, it seems to diminish but slightly before it abruptly gives place to shale. At Kohle's Brewery, for instance, ten feet of gypsum appear, while half a mile further north, in the clay pit of the Fort Dodge Brick & Tile Co., only drift and Coal-Measure shales are found. Everywhere in the Webster county gypsum the laminæ alternate regularly in color from green to white. The gypsum is remarkably pure calcium sulphate ($CaSO_4 2H_2O$). The lower layers, generally the lower three feet, are not as pure as the upper and are not used in the manufacture of plaster. Even in these lower layers, however, the amount of the impurities is so small that they would hardly injure the plaster. An analysis of the upper layers shows:[1]

Calcium sulphate ($CaSO_4$,	78.44
Water crystallization (calculated)	20.76
Insoluble matter (impurities)	0.65

An analysis made by Professor J. B. Weems of gypsum taken from the lower, middle, and upper part of those layers that are rejected in making plaster shows:

Silicia, SiO	1.92
Alumina, Al_2O_3	1.00
Calcium sulphate, $CaSO_4$	76.28
Water	20.72
Total	99.92

With traces of magnesia and carbon dioxide.

When made into plaster this lower layer, while soft, will not adhere to the laths satisfactorily. After hardening it is as firm and durable as the plaster made from the upper layers. The gypsum is crystalline throughout, the slender needlelike crystals being arranged at right angles to the plane of sedimentation. Though the gypsum is now well preserved by the thick mantle of drift that overlies it, at one time it formed the surface rock, and in consequence suffered considerably from erosion and solution. When the overlying drift is removed, the surface of the gypsum everywhere seems deeply trenched, some of the trenches

[1]Analysis by G. E. Patrick, *Iowa Geological Survey*, Vol. III, p. 291.

cutting half-way through the entire deposit. At times the gypsum is wholly cut out, and records of drillings at points wholly surrounded by gypsum show only gravel. Trenches are frequently encountered in mining the gypsum when they cause considerable trouble. Where exposed along ravines, the gypsum is decayed on the surface to a depth of three or four inches, and picturesquely grooved and fluted.

AGE OF THE GYPSUM AND ASSOCIATED DEPOSITS.

In considering the age of the gypsum, the red shales which accompany it must be kept in mind, for they are very closely associated, as shown by exposures along Soldier Creek, where thin layers of gypsum are found in the shales. Wherever they were not removed by preglacial erosion, these shales overlie the gypsum conformably. Their extent is greater than that of the gypsum, and in the pit of the Fort Dodge clay works, as already described, they may be seen resting unconformably on the Coal-Measures. In Douglas township, sec. 8, there is a good exposure of these red shales which is six miles northwest of any known gypsum. Their color is striking, often brilliant, and for this reason they have been used to some extent as a natural pigment.

The fact that the gypsum and the red shales lie unconformably on the Coal Measures is good ground for believing that, if they belong to the Paleozoic era, they were formed near its close, during the Permian. The Permian beds of Kansas, Indian Territory and Texas, which contain quantities of gypsum, are so highly and so characteristically colored that they are known as the "red beds." These red beds, like the red shales and gypsum of Iowa, are nearly destitute of fossils, due probably to the fact that the climatic conditions favoring deposition of gypsum were hostile to organic life. Aridity is the climatic characteristic most essential for great deposits of gypsum, and the redness of the sandstones and shales usually accompanying gypsum deposits of all ages and localities may fairly be assumed to be an effect of climate, direct or indirect, on the iron content of the soil. All of these considerations—namely, the arid climate that prevailed during the Permian, shown by great gypsum deposits associated with red shales occurring in both Europe and America, and the striking resemblance which the series bears to the Permian only 300 miles to the west—carry great weight. The Iowa series might reasonably be interpreted as an outlier of the Permian of Kansas and Indian Territory. During the long interval between its deposition and that of the drift which now protects it erosion had an abundant opportunity to remove the Permian from the intervening territory. The gypsum was doubtless protected by heavy beds of the red shales, for, had it been exposed long, it must have yielded to the solvent and erosive action of water.

The gypsum has been referred to the Cretaceous and to the Eocene for stratigraphic reasons. In the region of the Mississippi valley and great plains there are two well-marked unconformities to be considered. One occurs at the base of the Cretaceous, and the other at the base of the Eocene. By an unconformity also, the gypsum beds of Iowa are separated from the Coal Measures. The Missourian, which farther west attains a considerable thickness, is here wholly absent, and instead of deposition, erosion was probably taking place in the Fort Dodge region during this stage. No unconformity has been recognized between the Permian and the Coal Measures in Texas and Kansas. The absence of an unconformity in these regions does not preclude the possibility of a local unconformity in Iowa. More striking unconformities, local in nature, between certain of the older formations in the state, can be positively demonstrated. The surface beneath the gypsum was plainly not brought down to a base level before the deposition of the gypsum, for the gypsum lies in an erosion trough which has rather steep slopes.

In view of the important climatic conditions which will be presently considered, which seem to have been particularly favorable during the Permian all over the world, a local unconformity may be admitted if it obviates the necessity of referring the gypsum to the Cretaceous, where these conditions were notably absent.

To regard the gypsum as belonging to the Eocene seems impossible, when the conditions under which it was formed, considered in a later paragraph, are taken into account. The evidence seems sufficient to show that a deposit so extensive and so pure could not have been formed in a basin without oceanic connection, and an oceanic connection during the Eocene for a basin in central Iowa seems impossible.

Attention has lately been called to a well boring at Cherokee which reached a depth of 800 feet. At the bottom, beneath a sandstone that was certainly Dakota, and at a depth below any possible Cretaceous beds in this state, sixteen feet of gypsum are said to have been found. The persons making the report are regarded as reliable. Gypsum is readily identified and the report has significance. An effort is being made to determine positively the nature of the material regarded as gypsum. If the report is correct it has a direct bearing on the question in hand, for the position of this gypsum would indicate that it belonged to the close of the Carboniferous.

The claims of the Cretaceous have been pressed also, on other than stratigraphic grounds.[1] Reference to the geological map of Iowa shows that Cretaceous deposits are present throughout the greater part of northwestern Iowa, and that they approach within thirty miles of Webster county, at Auburn in Sac county, where they appear as chalk. The Cretaceous in Iowa consists of sandstone of the Dakota stage, and shales, limestone and chalk of the Colorado stage. Sandstone, shales, and limestone have yielded abundant fossils which definitely fix their age. Other things being equal, it would be somewhat more natural to regard the Webster county gypsum series as an outlier of the Cretaceous than of the Permian which is farther away, yet the distance is not so great as to render a correlation with the Permian in any degree improbable, if the preponderance of other evidence favors such a view. A review of Cretaceous climatic conditions is first of all necessary, for if aridity is a more striking characteristic of the Permian than of the Cretaceous, the Cretaceous age of the gypsum can hardly be established. The Dakota sandstone is at times red, but this color does not everywhere prevail, and it does not characterize the Cretaceous shales and limestones in any degee. The Dakota sandstone abounds in fossils, as does the

[1]*Iowa Geological Survey*, Vol. III, p. 290.

limestone of the Colorado stage, in which *Inoceramus labiatus* is found in great numbers. The Benton shales, while not so rich in fossils as the limestones, contain *Ostrea congesta*, *Prionocyclus wyomingensis*, and other species, none of which are brackish water forms. They contain also some selenite, but, in view of the fossil content of the shales, it is probable that the selenite was not formed by precipitation from concentrated brine at the time that the shales were laid down, but is due to subsequent chemical reaction in which sulphuric acid, generated perhaps from iron pyrites, converted part of the lime carbonate of the shales into the sulphate. In barrenness of fossils, in color, and in association with gypsum the red shales which accompany the Iowa gypsum resemble the Permian of Kansas much more than they do the Cretaceous shales of Iowa. The presence of chalk in Sac county, close to what must have been the Cretaceous shore indicates that for a time sediments from land were at a minimum, and organic sediments unmixed with land waste were able to accumulate near the shore. This would indicate an absence of the barren surface usually attending aridity, or the absence of elevation, or both, so that climatic conditions favoring deposits of gypsum are not implied by the chalk of the Cretaceous. Regions devoid of rainfall are characterized by wind storms of great violence capable of transporting much earthy material as dust and carrying it out to sea, where it would ultimately be deposited. The arid regions of America are subject to brief but violent rain storms, during which erosion is vigorous on the surface barren of vegetation. Low land surfaces covered with an abundant vegetation are most favorable for pure chemical and organic accumulations in the neighboring seas. The great purity of many gypsum deposits presents a difficulty for this very reason, for land vegetation must have been limited during the concentration of the sea water and conditions favorable for dust storms seem likely to have prevailed. Microscopic examination of the Iowa gypsum reveals particles of sand scattered through the gypsum, probably by wind, but the total amount is small, amounting to about 1 per cent. of the whole.

The age of the great gypsum and salt deposits of the world is shown below:

FOREIGN.	AMERICAN.
PLEISTOCENE AND RECENT.	
Caspian Sea and Asiatic lakes.[1]	Great Salt Lake.
PLIOCENE.	
Transylvania, near Prague (salt).[2] Caspian Sea in Karabhogas Bay (salt and gypsum).[3] Austria at Wieliczka, Siebenbürgen (salt and gypsum).[4]	
MIOCENE.	
None.	
OLIGOCENE.	
Transylvania and Carpathian Mountains (gypsum and salt).[5] Germany, Sperenberg (gypsum).[6] France, Montmartre (gypsum).[7]	
EOCENE.	
None.	
CRETACEOUS.	
None.	
JURASSIC.	
None.	
TRIASSIC.	
Germany:[8] Hanover, Arnstadt. Erfurt, Thuringia. Lothringen (gypsum and salt). England:[9] From Scotland to Devonshire (gypsum and salt).	Black Hills (gypsum).[10]

[1] GEIKIE, *Text-Book of Geology*, 3d ed., pp. 737–39.

[2] *Ibid.*, p. 1018.

[3] *Ibid.*, p. 1004.

[4] CREDNER, *Geologie*, pp. 699, 700.

[5] GEIKIE, *op. cit.*, p. 993.

[6] CREDNER, *op. cit.*, p. 679.

[7] *Ibid.*, p. 675.

[8] *Ibid.*, p. 520.

[9] GEIKIE, *op. cit.*, p. 866.

[10] U. S. Geological Survey, DARTON's report on Black Hills, *Twenty-first Annual Report*, Part IV.

PERMIAN.

Germany:[11]
The Hartz (gypsum).
Stassfurt, Sperenberg (gypsum and salt).
South Tyrol (gypsum).
Russia (gypsum, salt).[12]

Iowa (gypsum).
Texas (gypsum).[13]
Kansas (salt and gypsum).[14]
Oklahoma and Indian Territory.[14]
Black Hills (gypsum)[15]

CARBONIFEROUS.

Lower Carboniferous.
Mississippian.
Lower Michigan (gypsum).[16]
Nova Scotia (gypsum and salt).[17]
Virginia (gypsum and salt).[18]
Montana (gypsum).[19]

DEVONIAN.

None.

SILURIAN.

Russia, Baltic provinces (gypsum).[20]

New York (gypsum and salt).[21]
Ohio (gypsum and salt).[22]
Pennsylvania (gypsum).[23]
Upper Michigan (gypsum).[24]

ORDOVICIAN.

None.

CAMBRIAN.

Punjab Salt Range, India.[25]

[11] CREDNER, *op. cit.*, pp. 503–11.

[12] GEIKIE, *op. cit.*, p. 853.

[13] Texas Survey, *Third Annual Report*, p. 212.

[14] *University Geological Survey of Kansas*, Vol. V.

[15] U. S. Geological Survey, DARTON'S report, *loc. cit.*

[16] *Geological Survey of Michigan*, Vol. V (1881–93), Part II, pp. 14–30.

[17] *Mineral Resources of Canada*, 1897, pp. 105–11.

[18] *Resources of Southwestern Virginia*, Boyd, 1875, pp. 260–304. The reference of Virginia gypsum to the Lower Carboniferous is exceedingly doubtful.

[19] U. S. Geological Survey, *Benton Folio*, p. 6.

[20] GEIKIE, *op. cit.*, p. 789.

[21] *New York Geological Survey*, Vol. III, No. 15, p. 550.

[22] *Geological Survey of Ohio*, Vol. VI, pp. 691–702.

[23] Geological Survey of Pennsylvania, *Summary Final Reports*, Vol. II, pp. 913–15.

[24] *Geological Survey of Michigan*, Vol. I (1869–73), Part III, pp. 29–31.

[25] GEIKIE, *op. cit.*, pp. 737–39.

Climatic conditions in both hemispheres, therefore, seem to have been favorable for deposits of gypsum during the Permian, whereas, if the Iowa gypsum were referred to the Cretaceous, it would be the only gypsum deposit of economic importance in Europe or America assigned to this period of geological history. The gypsum may therefore be reasonably regarded as Permian, though the possibility of its being Triassic cannot be denied.

ORIGIN OF THE GYPSUM.

Gypsum deposits are generally ascribed to two causes: (1) the transformation of deposits already formed by various chemical reactions, and to reactions between the salts in solution, or (2) to precipitation from sea water, due primarily to concentration by evaporation.

1. The most frequent transformation of deposits already formed is the change of limestone ($CaCO_3$) into gypsum ($CaSO_4 + 2\ H_2O$), through the agency of sulphuric acid, according to the equation $H_2SO_4 + CaCO_3 = CaSO_4 + CO_2 + H_2O$. The sulphuric acid may be generated by the oxidation of the sulphuretted hydrogen of sulphur springs or of volcanoes, or by the action of water on some sulphide ore like pyrites. The deposits which Dana attributes to the action of sulphuric acid generated from the sulphuretted hydrogen given off by sulphur springs in New York[1] are quite extensive. In certain instances the gypsum occurs in masses with irregular outline in limestone, and layers of shale in the limestone pass unaltered through the gypsum. In view of this evidence, the gypsum must be regarded as derived from the limestone. Deposits of this sort are exceptional, however, and it is probable that most of the gypsum of New York had a different origin.

Insignificant gypsum deposits occur about the fumaroles of craters and lava streams in Hawaii where sulphurous acid SO_2 is converted into sulphuric, and attacks rocks which contain lime. The frequent occurrence of small amounts of gypsum with hematite in the upper part of ore veins may be accounted for by the following reaction;[2] $Fe_2O_3\ (SO_3)_2 + 2\ CaCO_3 = 2\ CaSO_4$

[1] DANA, *Manual of Geology*, 4th ed., p. 554. [2] BECK, *Erzlagerstattenlehre*, p. 393.

$+ Fe_2O_2 + 2 CO_2$, the original form of the iron being FeS_2 Cerussite and smithsonite with gypsum in a mineral vein are similarly accounted for. Anhydrite when exposed to air containing moisture gradually takes on water and forms gypsum.

2. That great quantities of gypsum in all parts of the world and at different times in geological history have been derived from sea water by evaporation is generally recognized. Sea water contains 3½ per cent. of mineral matter, distributed as follows:

Chloride of sodium	77.758%
Chloride of magnesium	10.878
Sulphate of magnesium	4.737
Sulphate of calcium (gypsum)	3.600
Sulphate of potassium	2.465
Carbonate of lime	0.345
Bromide of magnesium	0.217
Total	100.000%

Gypsum is deposited from typical sea water when 80 per cent. of the water has evaporated, whereas common salt is not deposited until the bulk of the water is reduced more than 90 per cent. Gypsum deposits are more widespread than salt, but salt usually occurs in thicker beds. These facts, taken with the relative amount of each salt in sea water and the amount of evaporation necessary for precipitation in each case, accord with the theory which regards the evaporation of sea water as the cause of most salt and gypsum deposits. It is evident that conditions allowing the 80 per cent. of evaporation necessary for a gypsum deposit would occur more often than those giving rise to 90 per cent. of evaporation and a deposit of rock salt. When the amount of evaporation necessary for a salt deposit took place, however, the high percentage of salt in the water would yield a stratum of notable thickness as compared with gypsum.

The accompanying diagram indicates the relation of deposition to density in the case of the salts common to sea water. The magnesium chloride alone is not actually precipitated, but remains in solution always under ordinary atmospheric conditions. It may be precipitated, however, with potassium chloride as carnallite. Three-fourths of the gypsum is deposited between the densities of 1.1315 and 1.21, whereas the deposition of salt does not begin until the latter point is reached. The remaining one-fourth is precipitated with the salt, but constitutes so small a part of the whole that the commercial value of the salt is not appreciably lowered. The normal order of deposition on evaporation from sea water, beginning with the first which occurs, of course, at the bottom of the deposit, is:

1. Limestone with limonite, $CaCO_3$ and $2Fe_2O_3\ 3H_2O$.
2. Gypsum $CaSO_4\ 2H_2O$.
3. Sodium chloride (common salt) NaCl.
4. The bitter salts (in carnallite) $KCl\ MgCl_2\ 6H_2O$.

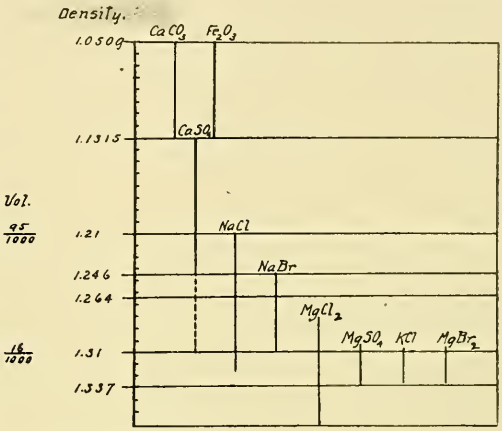

FIG. 1.—Sketch showing the order of precipitation of salts from sea water, with increase in density due to evaporation.

Practically this order is observed in the great salt deposits of Stassfurt, Germany.

While gypsum has been formed and is still forming in all of the ways described, most of these explanations are manifestly not adapted to the Webster county deposit. The definite lamination and layering of the gypsum indicate an aqueous origin. Pointing to the same conclusion is the fact that no limestones are associated with the gypsum which by alteration could yield gypsum. Salt may be regarded as absent from the Iowa gypsum area. If it existed, it would probably have been detected in some of the many wells and prospect holes. Its absence is not surprising, for the degree of concentration necessary for a salt deposit may never have been reached, or the salt, after having been deposited, may have been removed by subsequent erosion and solution.

The great thickness of some occurrences of gypsum and salt must be considered in seeking to determine their origin. The combined series of Strassfurt amounts to more than 1,000 feet, and at Sperenberg to more than 3,000 feet. To yield even fifteen

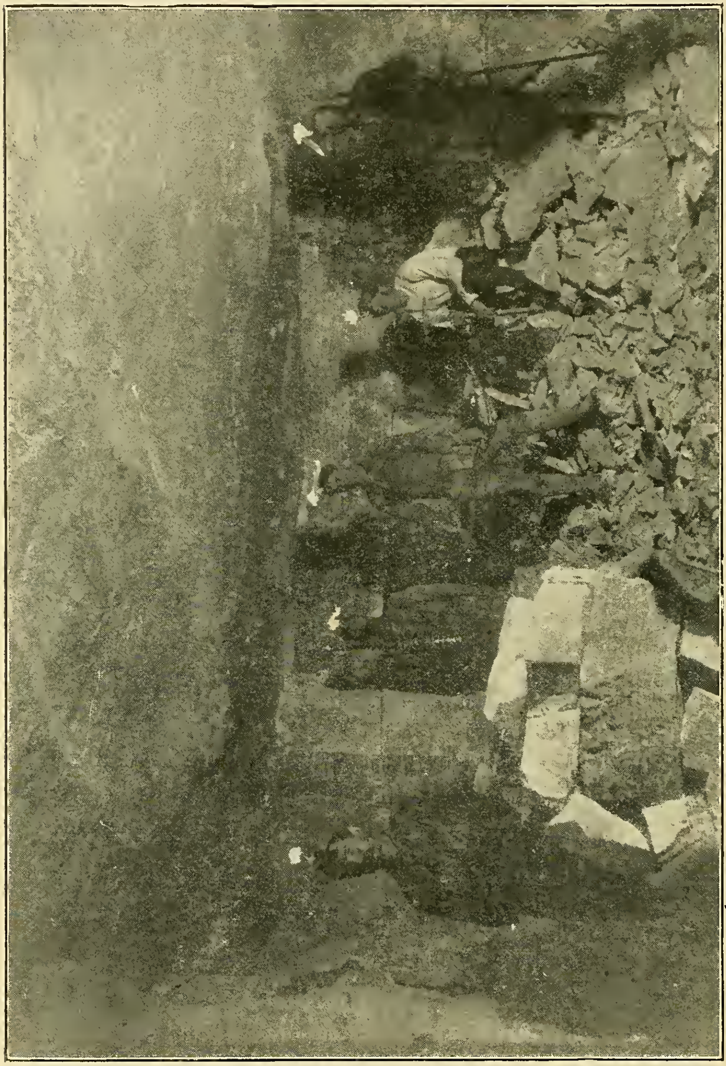

FIG. 2.—Interior of Crawford mine. The bedding and lamination of the gypsum show nicely in the pile in the foreground, and in the wall behind the men.

feet of gypsum, the average thickness in the Iowa field, an immense amount of water must have been evaporated. A cubic foot of gypsum weighs 140 pounds, and the amount of gypsum in a cubic foot of sea water today is three-fiftieths of one pound. The amount of water necessary to yield a cubic foot of gypsum, then, is 2,333.3 cubic feet. If the sides of the containing basin were vertical, the depth of the water necessary to produce fifteen feet of gypsum must have been 35,000 feet. If the average thickness of the Iowa gypsum be taken as fifteen feet and the gypsum area seventy square miles in extent, the amount of sea water necessary to deposit it, assuming that its content of gypsum was the same as in sea water today, was sixty-eight trillions of cubic feet. If a basin twenty miles wide be assumed. with two shores sloping to a center at an angle of 10 degrees, the length of the basin which would contain this amount of water must have been twenty-six miles and the depth at the center more than 9,000 feet, diminishing uniformly in depth from the center. Such a trough manifestly did not exist at the locality in question at the time of the deposition, and the hypothesis that the gypsum was deposited in a detached arm of the ocean, unaided by considerable supplies of salt from rivers or from the main body of salt water, is untenable.

There remain to be considered: (1) arms of the sea which were at least part of the time connected with the ocean, and which received more or less water from land; (2) inclosed seas fed wholly by rivers and without outlet except by evaporation.

Taking up the second case first, it will be instructive to review the conditions actually existing in inclosed salt seas in Asia and America. *The nature of salt deposits made in a lake not connected with the ocean and without outlet*, where evaporation is as great as, or greater than, inflow, may vary as widely as do the relative proportions of salts in the inflowing streams. The variation in the nature and amount of salts carried in solution by different streams is a natural consequence of differences in the mineral constitution of their drainage areas. In the Elbe and Thames chlorides predominate[1] (in the latter with gypsum), and the evaporation of these waters would give rise to lakes containing a large percentage of common salt. In the Seine, sulphate of lime (gypsum) predominates, while the waters of the Rhine,

[1] T. STERRY HUNT, *Chemical and Geological Essays.*

Danube, and Aar contain small amounts of chlorides and large percentages of sulphates of lime and magnesia. The Loire contains in 100,000 parts 13.46 of solid matter, of which 35 per cent. is calcium carbonate, while two-thirds of the soluble salts are carbonate of soda. In nearly all rivers bicarbonate of soda is present in large quantities. The solubility of calcium carbonate in water which is in contact with the air at 16°C. is 0.0746 grains per liter, which is six times its solubility in pure unaërated water. The $CaCO_3$ is for the most part present as the bicarbonate $Ca(HCO_3)_2$, only 3 per cent. of it existing as normal carbonate.[1]

ANALYSES OF SALTS IN THE WATERS FROM AMERICAN RIVERS.[2]

(Parts per 1,000,000 of water.)

Constituents	Ottawa	St. Lawrence	Mississippi	Missouri
K Cl	1.60	2.20	Not given	Not given
NaCl	....	2.25	8.57	32.03
K_2SO_4	1.22	....	Not given	Not given
Na_2SO_4	1.88	12.29	Not given	Not given
$MgSO_4$	...	....	15.41	125.20
$CaSO_4$	....	....	....	9.93
$MgCO_3$	6.96	25.37	19.63	....
$CaCO_3$	24.80	80.83	94.56	189.35
Na_2CO_3	4.10	.61	....	....

The water of the river Jordan gives the following analysis:[3]

Sodium chloride (common salt)	0.35
Magnesium chloride	0.03
Calcium chloride	0.07
Calcium sulphate (gypsum)	0.04
Water	99.50

The waters of the Dead Sea are the result of concentration by evaporation of waters containing salt. Quoting Bishof:[4]

In spring when the streams are turbid with the particles of carbonate of lime and clay, mere mechanical deposits take place, for at this period, when

[1] CAMERON AND BRIGGS, *Journal of Physical Chemistry*, Vol. V, No. 8, p. 548.

[2] BAILEY WILLIS, in JOURNAL OF GEOLOGY, Vol. I, p. 508. The waters of the Mississippi and the Missouri were sampled in the autumn during low water, near their junction.

[3] BISCHOF, *Chemical and Physical Geology*, Vol. I. [4] *Loc. cit.*, p. 397.

large masses of water are carried into the Dead Sea, and the saline solution thereby diluted, while at the same time the evaporation is but slight, no common salt is deposited. During the ensuing warmer months the chemical deposition of common salt and carbonate of lime take place. Should the stream become turbid at this season in consequence of continued rain, deposits are formed which contain a less amount of common salt. In this way there must arise a constant alternation of different irregular layers of greater or less thickness. All these layers must contain gypsum, since in a water which contains so much chloride of magnesium as is present in the Dead Sea, gypsum, as we shall subsequently see, is dissolved with difficulty, as is also shown by the small proportion in which this salt exists in that sea.

Lake Elton, a brine pool of the Russian steppes, may once have had an oceanic connection. If this is true, the calcium carbonate and gypsum of the original sea water have been deposited, for the water now contains but small quantities of lime salts, but chlorides of sodium and magnesium with sulphide of magnesium are present in abundance.[1] Bischof describes the lake as follows:

The Elton lake, whose greatest diameter is 20 and its smallest 16 versts, lies 19 feet below the level of the ocean. It has flat banks and may be waded through almost anywhere. On its margins and upon its bed there is almost everywhere crystalline salt. This forms layers from one to two inches in thickness which are separated from one another by layers of mud and earth. The streams which empty into it are eight in number. They all contain more or less salt, and consequently carry supplies of this substance into the lake. The most considerable among them is the Charisacha, which is also the only one which continues to flow during the whole year. In the loamy soil which surrounds the lake numerous small crystals of gypsum are imbedded.

A deposit of salt is formed in this lake every summer. In the winter and spring the water is diluted by the rivers which are then copious, and a layer of silt, probably carrying some gypsum, is formed. The decrease or complete disappearance of $CaSO_4$ from the water of Lake Elton into which it is being constantly conveyed by the Charisacha River, the waters of which have been analyzed, shows that the gypsum goes down with the salt.

Great Salt Lake in Utah furnishes an excellent example of salt deposits in a lake without oceanic connections. The present

[1] Analysis by Gobel, quoted by Bischof, *loc. cit.*, p. 404.

lake is but a remnant of the much larger Lake Bonneville, which was at one time fresh and was drained by a stream flowing into the Snake River. Its present salinity is high, the specific gravity of the water being 1.1[1] and its saline contents, varying with the seasons from 14 to 22 per cent., is distributed as follows, as shown in five analyses:[2]

Sodium chloride	90.7	79.1	65.9	81.3	80.5
Potassium chloride	....	....	14.1	....	....
Magnesium chloride	1.1	9.9	8.9	6.7	10.3
Sodium sulphate	8.2	6.2	8.1	8.5	5.4
Potassium sulphate	....	3.6	....	2.6	2.4
Calcium sulphate	....	0.6	1.5	0.9	1.4
Chlorine (in excess)	....	0.6	1.5	....	....

Russell regards the analysis made by E. Waller,[3] of water, taken from Great Salt Lake in August, 1892, as the most complete and satisfactory that has been published.

Analysis by E. Waller, expressed in grams in a liter:

Specific gravity, 1.156.

NaCl	192.86
K_2SO_4	8.75
Li_2SO_4	0.16
$MgCl_2$	15.04
$MgSO_4$	5.21
$CaSO_4$	8.24
Fe_2O_3 and Al_2O_3	0.004
SiO_2	0.018
Surplus SO_3	0.051
Total	230.333

In these analyses the absence or the very small content of calcium, both as sulphate and carbonate, is remarkable. Analyses of the fresh waters tributary to the lake show that the lake could accumulate its total content of calcium in eighteen years, while the accumulation period for the chlorine would be 34,200 years.[4]

[1] Specific gravity in

1850	Summer 1869	Aug. 1873	Aug. 1889	Aug. 1892
1.17	1.111	1.102	1.157	1.156

—Compilation by RUSSELL, *Lakes of North America*, p. 81

[2] U. S. Geological Survey, *Monographs*, "Lake Bonneville," p. 254.

[3] *School of Mines* (Columbia College) *Quarterly*, Vol. XIV (1892), p. 58.

[4] U. S. Geological Survey, *Monographs*, "Lake Bonneville," p. 256.

Manifestly the lake is disposing of the calcium as fast as it is received. Deposits of tufa occur on the old Bonneville, Intermediate, and Provo shore lines, on their weather faces, and a few feet below their crests. It is absent in sheltered bays and most abundant on points that were especially exposed to wave action. Calcareous oölitic sands are now forming along certain parts of the shore of Salt Lake "between the delta of the Jordan and Black Rock, where it constitutes the material of a beach, and is drifted shoreward in dunes."[1] Of the three important fresh-water tributaries of Great Salt Lake, the water of Utah Lake is characterized by sulphate of lime, over 60 per cent. of the total solids held in solution by it consisting of this salt, while the waters of Bear River and City Creek are characterized by carbonate of lime.[2] The deposits of tufa and oölite alone may account for the absence of calcium carbonate from the water of the Great Salt Lake, yet it is possible that both the calcium carbonate and sulphate are precipitated in the ordinary manner by evaporation. Yet the fact that the calcium carbonate is, at least in a measure, taken from the water by the aëration due to wave action and deposited on the shores as tufa and oölite is interesting and, taken with other conditions, may account for deposits of pure gypsum from waters which contain a certain amount of lime carbonate.

Basins which are in some degree connected with the ocean may next be considered. The Bessarabian coast of the Black Sea furnishes an example of salt deposits in bays slightly connected with the open sea and fed from the landward side by rivers. From the Danube to the Dnieper the rivers before emptying into the ocean expand into lakes which are separated from the sea by natural dams. Under ordinary circumstances the water flows into the sea through an opening in the dam, while during storms the water of the sea enters the lakes. Three of these lakes become partially dry every summer and deposit salt which in places amount to a layer a foot thick.[3] This salt is used for commercial purposes. The calcium sulphate of the river water and of the sea water which is driven in during storms must also be deposited, but the quantity, being small, readily escapes notice.

[1] *Ibid.*, p. 169. [2] *Ibid.*, p. 207. [3] BISCHOF, *op. cit.*, Vol. I, p. 392.

Many writers on gypsum and salt have called attention to the fact that the Mediterranean Sea furnishes conditions which, if but slightly modified, would result in deposits of these substances.[1] Although it receives the waters of many rivers, some of them of considerable size, evaporation takes place faster than inflow, and if no water entered through the Strait of Gibraltar, or if the supply entering were considerably reduced, much of the mineral matter held in solution would be deposited. A steady current pours in from the ocean, however, and the density necessary for precipitation is not reached. The bottom of the sea rises sharply near the Strait of Gibraltar, cutting off communication between the lower part of the sea and the ocean, but permitting a free interchange of water in the upper level. The depth at the strait is less than 200 fathoms, while the average depth of the Mediterranean is 1,000 fathoms. The accompanying diagram roughly illustrates existing conditions:

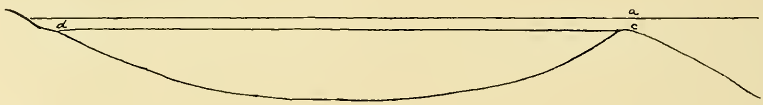

FIG. 3.

The amount of salt in the water of the Atlantic is 3.6 per cent., while in the Mediterranean it is 3.9 per cent. The specific gravity of the water of the Atlantic off the Strait of Gibraltar is 1.026, while at the west end of the Mediterranean, near the surface, it is 1.028, increasing in the east end to 1.03. At a depth of 300 fathoms the density is considerably greater than at the surface. A current of water flows in constantly at the surface of the strait (Fig. 3, *a*). This water is concentrated by evaporation and sinks. The bottom below the line *c d* has been previously filled by this dense water, and the water above this line is being constantly condensed and sinking causes a portion at the bottom water to flow out at *c* as a lower current into the ocean. The outlet at the strait is so free that the condensation does not reach the point which results in the deposition of lime, gypsum, or salt.

[1] *Geological Survey of Michigan*, Vol. V (1881–93), Part II, pp. 1–13; *University Geological Survey of Kansas*, Vol. 5, "Gypsum," Introduction.

It is quite conceivable that the opening could be so restricted that the outflow would be greatly diminished and the density of 1.05 to 1.13 which is necessary for the deposition of limestone be reached. If this were maintained for a long time and the outflow were enough to prevent further concentration, a thick bed of limestone without gypsum and salt would be formed. If the opening were still further restricted, gypsum would be precipitated and at length salt. In this case, however, the calcium carbonate in the inflowing sea water would be precipitated with the gypsum, unless converted into gypsum or a more soluble salt by reaction with other salts, or isolated during deposition, as is the case today in Great Salt Lake. The amount of the calcium carbonate (one-tenth as much as the gypsum), if present, would be easily recognized. If, instead of a small opening, the inland sea were shut off from the ocean by a low barrier, over which the sea water passed only in time of great storms, the deposits might be more varied. The water would be diluted at times so that precipitation of the more soluble salts would cease, and after a period of evaporation, if the amount of calcium carbonate in the newly added water were considerable, there would be a deposit of limestone succeeded by gypsum. A series of limestone and gypsum beds occurs in the northern peninsula of Michigan near St. Ignace.

In applying "inclosed sea" conditions like those now prevailing about Great Salt Lake to the Iowa gypsum, two questions arise. Was there a supply of gypsum in the rocks of the region subject to the solvent action of stream water sufficient to yield the existing deposit? If this question may be answered in the affirmative, do the deposits formed in inclosed seas structurally and chemically resemble those of Webster county? The Coal-Measure shales and sandstones, with here and there a limited area of St. Louis limestone, formed the land surface when the gypsum was deposited. There is a considerable amount of gypsum in all of these strata which appears frequently in large selenite crystals. Rivers flowing over this surface would carry a large percentage of gypsum in solution, provided the gypsum now contained in these strata was present at that time. It is hardly probable that the gypsum of the Coal-Measure shales was formed at the time of their deposition, for the presence of great numbers of ferns indicate fresh water. A more probable origin lies in the action of water on pyrites, giving rise to ferrous sulphate, which in turn changed part of the lime carbonate of the shales into gypsum. This may have taken place before the great gypsum deposit was made, and, if so, the gypsum dissolved out of the Coal Measure shales may have been sufficient to form it. The same waters which carried the gypsum would, however, carry much lime carbonate and mud, and it is difficult to conceive of fifteen feet of pure gypsum forming in an inclosed basin fed by streams. It is true that at the top in one or two localities thin layers of limestone, sandstone, or shale occur with thin layers of gypsum, but the presence of fifteen feet of gypsum containing only 1 per cent. of sand and clay practically precludes the possibility of its origin in an inland basin fed by land streams.

Turning to the "Mediterranean hypothesis," there are two apparent difficulties. In the series of deposits due to deposition on account of evaporation in such a basin, limestone would be the lowest member. If the amount of calcium carbonate in the waters tributary to the basin was small, limestone might not appear beneath the gypsum as a distinct formation, but, mixed with the finer impurities, would still be present as a notable calcareous element in a clay or shale. The Iowa gypsum overlies a fire clay, the analysis of which shows but a very limited amount of lime. Moreover, the lime carbonate in the inflowing water, after the density necessary for the deposition of gypsum had been reached in the basin, would, it would seem, be deposited with the gypsum. The phenomena observed about Great Salt Lake perhaps relieve us of these difficulties. As already stated, the water of the lake is almost free from calcium carbonate, while deposits of calcareous tufa and oölite have been and still are forming along the shores where water action is violent. This localizing of the calcium carbonate, if it were complete, would render possible deposits of pure gypsum like that of Iowa, in which no calcium carbonate appears. Unfortunately, calcium carbonate due to precipitation from solution appears widely distributed in the marl of the old Bonneville bed, as well as along the shore.[1] Still, the fact that calcium carbonate deposits were favored at the shores by the aëration associated with wave action is particularly significant. Even more significant is the fact that near the streams which contribute to the lake the greatest amount of lime carbonate, the calcareous oölite already mentioned, accumulates as a shore deposit in considerable quantities. If in this or some similar way the lime carbonate was localized, the Mediterranean hypothesis would appear satisfactory.

The experiments of Thoulet, quoted by Bailey Willis,[2] seemed to show that carbonate of lime in the form of marble, shells, coral, and globigerina ooze are much less soluble in ocean water than in fresh water. If this is true, when river water enters a salt sea, conditions for unstable equilibrium of the bi-carbonate of lime might arise which would result in the formation, and probably the deposition, of the neutral carbonate, and the greater the salinity of the sea, the more prompt and complete would be the precipitation. In this way streams on entering a salt sea might precipitate all of their calcium carbonate near their mouths, while gypsum would be deposited on subsequent evaporation in more remote parts of the basin. Willis calls attention to the limestone deposited beyond the delta of the Rhone. He says:[3]

> This is referred to by Thoulet and described by Lyell who says: "In the Museum at Montpelier is a cannon taken up from the mouth of the river imbedded in crystalline calcareous rock. Large masses also are continually taken up of an arenaceous rock cemented by calcareous matter, including multitudes of broken shells of recent species." Lyell attributes the precipitation of lime to the evaporation of the Rhone water, which, when it is spread upon the salt water, he compares to a lake. But this one cause is no doubt combined with the chemical and mechanical conditions which have been suggested in the preceding discussion. These conditions are favored at the mouth of the Rhone by the salinity of the Mediterranean and the absence of strong currents.

The experiments of Cameron and Seidell[4] gave results which differ radically from those of Thoulet. These chemists found

[1] U. S. Geology Survey, *Monograph 2*, "Lake Bonneville," p. 190.

[2] Journal of Geology, Vol. I, p. 510. [3] *Ibid.*, p. 516.

[4] Cameron and Seidell, in *Journal of Physical Chemistry*, Vol. VI, No. 1, p. 52.

that a maximum solubility for calcium carbonate was reached in a solution holding 50 grams of sodium chloride per liter, when its solubility was 2.36 times greater than in water without sodium chloride, but in equilibrium with air. In view of these experiments, which were conducted with great care, the experiments of Thoulet and the conclusions based on them must be questioned.

It is possible also to assume that chemical reactions took place between the salts in solution, which resulted in the elimination of this lime carbonate, by converting it either into gypsum or into a salt that is more soluble than gypsum, thus keeping it in solution until after the gypsum was deposited. It is well known that reactions between various salts contained in sea water may causes divergence from the series which results from evaporation alone. According to Usiglio, sea water deposits limestone abundantly when the density reaches 1.0506, and again at 1.1304. The last deposit he ascribes to the decomposition of sodium carbonate and gypsum with the formation of sodium sulphate and calcium carbonate.[1] Oschenius holds that sudden and well-marked deposits of gypsum may be caused by the addition of sodium or calcium chloride.

The solubility of gypsum in a sodium-chloride solution increases with the strength of the solution, as shown in the following table by Cameron:[2]

$NaCl$ AND $CaSO_4$ IN WATER AT 150° C.

Grams $NaCl$ per Liter	Grams $CaSO_4$ per Liter
0.6	2.3
1.1	2.5
5.1	3.1
10.6	3.7
31.1	4.8
51.4	5.6
139.9	7.4

So when the solution contains 140 grams of the $NaCl$ per liter, the solubility of $CaSO_4$ is more than three times as great as in water without sodium chloride. In solutions containing less than

[1] HUBBARD, *Geological Survey of Michigan*, Vol. V, Part II, pp. 1–33.

[2] *Journal of Physical Chemistry*, Vol. V, No. 8, p. 559.

140 grams of NaCl per liter the solubility of gypsum is affected but slightly by changes of temperature. In a sodium-chloride solution the presence of calcium carbonate up to 8–10 per cent. is scarcely a factor in determining the amount of gypsum that will be dissolved.[1]

At low temperature in Salt Lake a double decomposition takes place between magnesium sulphate and sodium chloride, resulting in the formation of sodium sulphate which is deposited and magnesium chloride which remains in solution.[2]

All of the facts cited in regard to the solubility of gypsum and calcium carbonate in mixed solutions and double decompositions probably have little bearing on chemical deposits from sea water, though they might be determining factors in the order of deposition in inland lakes. Assuming that the composition of sea water in the past did not differ greatly from that of the present, in the course of its evaporation there is little reason for supposing a departure from the normal order of precipitation found in all salt pans where sea water is used. If a marked difference in composition existed, however, it might become a prime factor in the problem. Given an excess of sulphates (such as Na_2SO_4); or an excess of calcium ions (as regards calcium carbonate) from calcium sulphate, and it *may* be found that the curves plotted to illustrate the solubility of calcium carbonate and calcium sulphate in mixed solutions, will cross each other in such a way as to allow the calcium sulphate (gypsum) to come down first.

A change in the amount of atmospheric carbon dioxide, or a considerable change in temperature, might seriously change the order of deposition from that which now occurs when sea water is evaporated under ordinary conditions. A further study of these conditions during periods of great gypsum deposition may make clear the reason for vast deposits of gypsum due to evaporation of sea water which contain at the most only traces of calcium carbonate.

The same line of reasoning which is used to explain great

[1] Cameron and Seidell, in *Journal of Physical Chemistry*, Vol. V, No. 9, p. 653.

[2] Russell, *Lakes of North America*, p. 75.

deposits of gypsum may be applied to many limestones. Calcium carbonate in sea water is one-tenth as abundant as calcium sulphate, and for every twenty feet of gypsum two feet of limestone must be precipitated, unless the calcium carbonate is converted into some other substance. Since the density required to precipitate limestone is far below that required for deposition of gypsum, it is highly probable that in many shallow seas but slightly connected with the abyssmal ocean limestone was continuously and abundantly deposited. Such deposits must be more wide-spread than gypsum, for the same reasons that gypsum deposits must be more abundant than salt. While laying stress on this point, the fact probably remains that most of the limestone of the earth is of organic origin.

While conditions like those now existing in the Mediterranean Sea, when somewhat intensified, may in the main be regarded as giving rise to gypsum deposits, this sea presents one peculiarity which could not have characterized many of the regions where gypsum occurs. Structural conditions indicate that most of the gypsum deposits were formed in arms of a shallow epi-continental sea. The Mediterranean Sea with its average depth of 1,000 fathoms is truly abyssmal.

Although there may be some doubt as to the exact manner in which the calcium carbonate is removed from the brine during concentration, the fact that it is removed in some one or more of the ways suggested, or by some process not yet brought to light, may be assumed. This removes the only serious difficulty in conceiving of extensive and very pure deposits of gypsum forming in basins only slightly, yet continuously through long periods, connected with the ocean. The Mediterranean hypothesis, with the modifications pointed out, may be accepted as accounting for the Iowa gypsum, as well as similar deposits in various periods of geological history. It must be admitted, however, that further chemical investigations in regard to the reactions between salts in solution during the process of brine concentration must be undertaken before the problem can be regarded as fully solved.

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Iowa City.

THE RECENT ERUPTIONS OF COLIMA.

THE *Volcán de Colima* with the *Nevado de Colima* together form a magnificent mountain mass at the extremity of a branch of the Sierra Madre, known, at no great distance from the volcano, by the name *Sierra de Tapalpa* (Fig. 1). Colima lies in latitude 19° 30′ 25″ N., and longitude 4° 37′ 55″ W. from Mexico. Its altitude is $3{,}960.90^{m}$, while that of the *Nevado* is $4{,}334.57^{m}$. The two peaks are seven kilometers apart. The volcano is thirty-three kilometers from the city of Colima and twenty-five kilometers from Zapotlan. Both *Volcán* and *Nevado* are in Canton 9 of the state of Jalisco, Mexico.

From Zapotlan the volcano presents the form of an elegant cone with slopes of 45°; the *Nevado*, seen from there, appears upon the west flank of the cone and a little to the north (Fig. 2). The volcano has long been active, and during the last century made notable eruptions in 1804, 1806, 1808–18, 1869, etc. (Fig. 3).

The above description is condensed from a paper by Padre José Maria Arreola which was printed in the monthly bulletin of the Mexican meteorological observatory in 1896.[1] In this article Father Arreola described the work of observation being conducted by himself at Colima and his colleague Castellanos at Zapotlan. Rarely has any volcano been subjected to such careful scrutiny and record as has Colima by these two devoted observers. Three times daily, from 1893 through a period of seven or eight years, the conditions of the volcano were carefully recorded and sketches made, if there were any signs of activity. Precise terms were employed in description. Vapor was "dense" or "thin;" "dense," when emitted rapidly, as if in eruption, and in volutes; "thin," when issuing slowly, continuously, as if filtered out. For force, degrees from 0 to 10 were recognized, running parallel with the verbal terms—"little,"

[1] J. M. ARREOLA, "El Volcán de Colima," *Boletin mensual del Observatorio meteorológico central de Mexico*, 1896, p. 10.

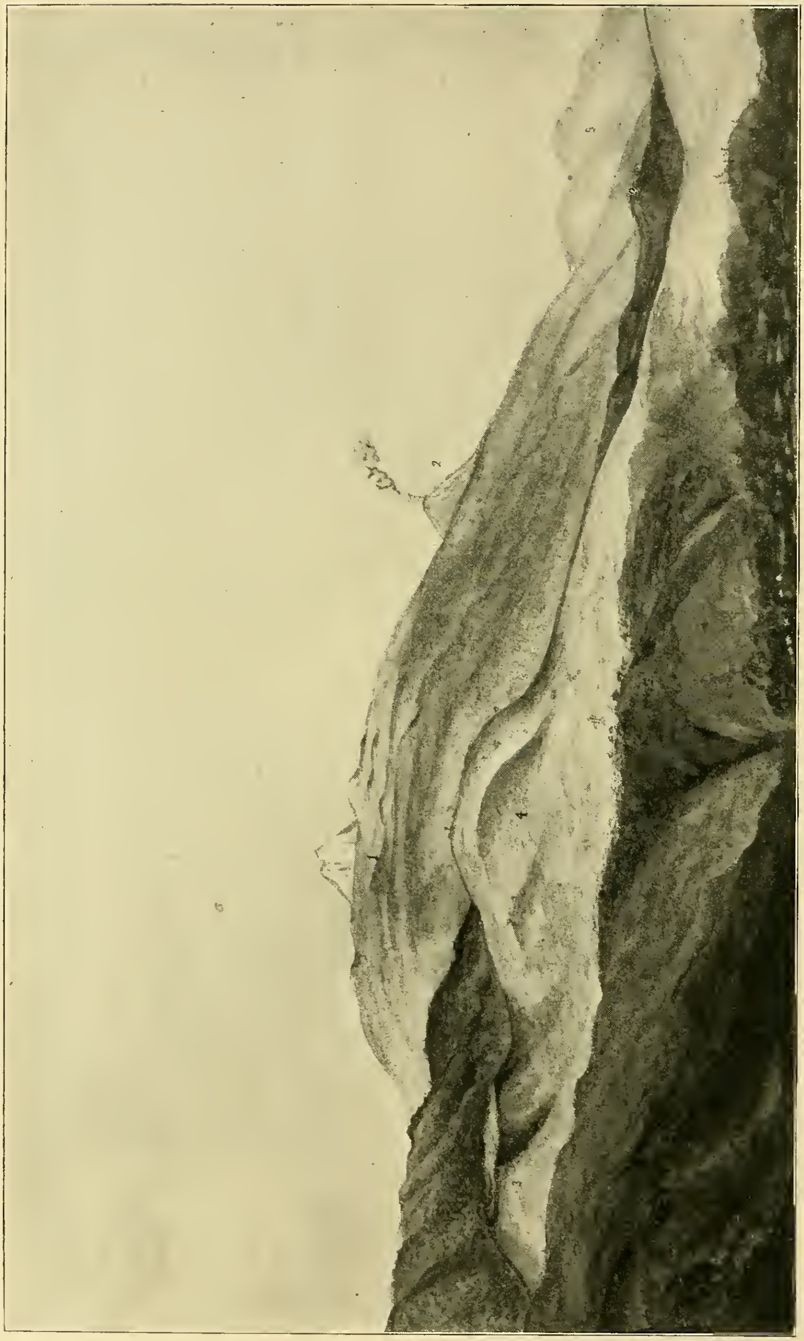

Fig. 1.—View of the volcano Colima from San Gabriel; seen looking southwest. (1) Nevado; (2) Colima; (3) and (4) Los Gallos small, extinct volcanoes; (5) Montiules.

"regular," "moderate," "great," and "maximum." Some of these records of observation have been published in the various issues of the bulletin already mentioned. It is greatly to be desired that the whole mass of them, together with the tri-daily sketches, might be published in one volume. During February and March of the present year (1903) the volcano has been notably active. Father Arreola, though no longer living within observation distance of the volcano, visited it during this time of

Fig. 2. —Photographic view of Nevado and Colima, taken from the observatory of the Seminary of Zapotlan. The volcano lies to the southwest; the little Apaxtepetl is at the extreme left. The summit of the volcano is visible behind the crest of the Nevado.

eruption and secured the records kept by others. He has printed a pamphlet, in Spanish, presenting the facts.[1] As this pamphlet is practically inaccessible to students, I have translated so much of it as is descriptive, retaining the author's arrangement and headings. Father Arreola has loaned the original photographs and drawings for reproduction.

Frederick Starr.

BRIEF NOTICE OF THE OBSERVATIONS OF COLIMA.

Passing over the history of the eruptions, which, for several years past, Colima has given — which is to be found elsewhere

[1] *Las erupciones del volcán Colima en Febrero y Marzo del corriente ano.* Guadalajara: Luis G. Gonzales, 1903; 8vo, pp. 26; seven cuts.

— it is my intention to summarize the condition of the volcano during the past eleven years. In a note entitled "Datos de los temblores, erupciones, lluvias y otros fenomenos observados en Zapotlan," which I sent to the Central Observatory, and which was printed in its *Boletin*, in the year 1894, among other matters, I gave notice of a great eruption in the early days of March, 1892, which produced an abundant fall of dust, carried by a current of air from the southwest. No other notable eruption was observed during that year. In 1893, with the opening of the meteorological observatory of the Seminary of Zapotlan, began systematic and continuous observation of all the manifestations of the volcano, reinforced, from the beginning of 1896, by the similar labors of the observatory of the Seminary of Colima.

Through the whole space of time since, the condition of the volcano and the character of all its manifestations have been noted, day by day. The records of the two stations form an inestimable treasure for science, which before could only deal with isolated data, which were often of uncertain character. By an examination of these records . . . . it is seen that Colima, during this period of eleven years, has been in a condition of constant, irregular, and feeble activity.

From a study, presented by Severo Diaz, presbyter, at the Third National Meteorological Congress, in December last, we may summarize this period in the following statement:

From 1893 to 1898 the volcano continuously emitted thin vapors, forming streaks, varying in direction with the wind, attaining a length of from forty to fifty kilometers, and losing themselves on the horizon. In the midst of this constant, but feeble, activity it was not rare to see, from week to week, an eruption — regular or moderate.

From 1898 to 1899 this continuous activity was converted into eruptive emission; during this period about eight little eruptions were often observable in the space of two hours.

Finally, from the end of 1899 to 1902, the continuous activity gave way completely to eruptive emission. During this period little eruptions were repeated at intervals of three or four hours;

during the intervals the volcano remained completely inactive. Through these years there were recorded some thousand little eruptions in each year; these at times produced light showers of fine sand in the vicinity of Zapotlan.

From the beginning of the present year a notable diminution was observed in the eruptions; these no longer followed the periods determined in the previous years; the intervals of

FIG. 3.—Photographic view of Colima from the Hacienda de San Marcos, March 11, 1901. The volcano lies to the west; the cone and the secondary cone being in the center; the Nevado at the right, and Monticules at the left.

inactivity were longer, apparently preluding the new period of great activity.

RECORD OF THE OBSERVATIONS OF COLIMA DURING THE PERIOD OF GREAT ACTIVITY (1903).

February 15.—At 3 A. M., from the Hacienda de Santa Cruz de Duque, a great eruption was observed, after which fire was seen upon the volcano. . . . . At 11 A. M. ashes fell at the same hacienda, probably proceeding from a second eruption. From Zapotlan there was no report, on account of rain. From Colima, at 1 P. M., a great eruption was seen.

February 16.—Insignificant escape of vapor.

February 17.—At 7:45 A. M. and 11:45 A. M., moderate eruptions, borne to the west and the southwest. During the rest of the day insignificant escape of vapor.

February 18.—At 12:45 P. M. an explosion was heard from the volcano, and immediately a maximum eruption burst forth with great force, completely filling the crater and covering the slopes with its products; it continued for more than a half-hour, during which the west wind bore the gaseous and sandy products toward the villages of Tuxpan, Tecalıtlan, etc. Another eruption followed. The hot stones and scoriæ, which were poured out in great quantity over all the slopes of the volcano, set fire to trees on various parts of the summit of the mountain. . . . . The great quantity of matter thrown out in these eruptions, and in those of the 21st and 24th, was almost wholly material which had been accumulated gradually, above the crater, during its time of slight activity, as may be shown by a comparison of photographs taken before and after the events. Once the crater was disembarrassed, no such abundant outflows were recorded, from which it may be inferred—at least in the present period—that there is no risk of a greater invasion of scoriæ.

February 19.—At 6:15 and at 10 A. M., moderate eruptions. At 12:15 and at 1:30 P. M., little eruptions, all drifted by strong west winds.

February 20.—Inactivity all day.

February 21.—At 9:30 A. M., regular eruption. At 12:15 P. M. a heavy detonation was heard which threw the air into commotion, even shattering the walls of houses. . . . . The noise had been heard for some seconds, when a great eruption broke forth, the colossal proportions of which could not be fully appreciated on account of the products being violently swept by the west wind to the east of the volcano. The rain of sand over this region was distinctly visible from Zapotlan. At 3:30 P. M. there was another great eruption. Its products were drifted by the west wind into the state of Guanajuato.

February 22 and 23.—Insignificant issue of vapor, carried by the west wind.

February 24.—At 3: 15 P. M., a great eruption, with characters similar to those of the 21st. The products were promptly distributed to the east, sand raining over Tonila; in their descent, however, they were drifted by the lower air-current from the south, so that the sands were carried to Zapotiltic, Zapotlan, Sayula, Guadalajara, etc. The rain of fine sand—commonly called ashes—began at Zapotlan, at 4 P. M., and was so heavy that persons could not be distinguished at a distance of fifty meters. The fall lasted more than two hours, forming a sheet one millimeter in thickness. On this day, by telescopic observation of the volcano, a change in form of the upper part of the crater was noticed. The sands which fell in Tonila were as coarse as common sand, those falling in Zapotiltic were finer, those of Zapotlan and Sayula were like ashes, and so decreasingly with increasing distance. . . . . At about 7 P. M. was observed a little overflow of glowing scoriæ. A great eruption was reported for 10 P. M.

February 25.—At 4 A. M. there was a great eruption, preceded by a report.

At dawn the volcano was wrapped in a cloud of its own erupting. During the rest of the day there was a constant emission of thin vapor, which sallied as if filtered through the west side of the crater.

February 26.—Until 3 P. M., enveloped in cumulus clouds; after that hour, inactive. There must have been an eruption during the night, since at dawn the summit of the *Nevado* was covered with sand.

February 27 and 28. — Almost inactive.

March 1.—Completely inactive.

March 2.—At 6:50 P. M., a maximum eruption, less, however, than those of the 18th, 21st, and 24th past; it was so spread by the southwest winds that at 8 P. M. it reached the opposite horizon. After this eruption, grains of porphyritic stone rained down upon the fields situated at twenty kilometers southeast of the volcano. Of these grains I collected in Piaya and in Platanar some of the size of grains of corn. At places nearer the volcano stones fell. From the ranch of Cauzentla, one of the nearest to the volcano, three were found weighing one hundred and thirty-six, thirty-four, and thirteen grams — the two larger being of the same nature as the grains of Piaya and the sands of other localities. The nature of these pebbles, of the grains, and of the sands gives reason to believe that all are derived from the rocks constituting the cone, broken and reduced by heat and the force of projection. The fine dust, commonly called ashes, which exists in great quantity over the flanks of the volcano and which is also distributed by the eruptions, is of pumiceous nature and proceeds from the solid and broken lavas of the interior of the crater.

March 3. — At dawn Mr. Diaz observed with the telescope a new change in the form of the crater. . . . . From this alteration it appeared that the crater, which had become almost completely clogged during the period of little activity (Fig. 4), had been thoroughly opened (Fig. 5). Little columns of vapor were seen ascending from the bottom of the crater. During the middle part of the day the volcano was covered with atmospheric clouds. At 5:45 P. M. there was a great eruption, almost maximum; as the air was calm, the vertical cloud could be long observed. The cloud was driven by a high current from the southeast, until, at 9 P. M., it touched the northwest side of the horizon of the valley of Zapotlan.

March 4.— At 6 P. M., a great eruption, driven by the southwest wind, until it promptly disappeared. This eruption produced an overflow of scoriæ on the eastern flanks.

March 5.— At 10:45 A. M., a great, almost maximum, eruption, borne toward the east.

March 6.— Insignificant emissions.

March 7.— At 7:10 A. M., a maximum eruption, preceded by an explosion (Fig. 6). A great eruption at 8:20 and another at 8:45 A. M. All of these drifted to the east. During the rest of the day there were moderate eruptions, some of which lasted several minutes.

FIG. 4. — Cone of the volcano Colima as seen in December, 1902. Drawn with the aid of a telescope at the observatory of the Seminary of Zapotlan. The crater rises behind the crest of the Nevado.

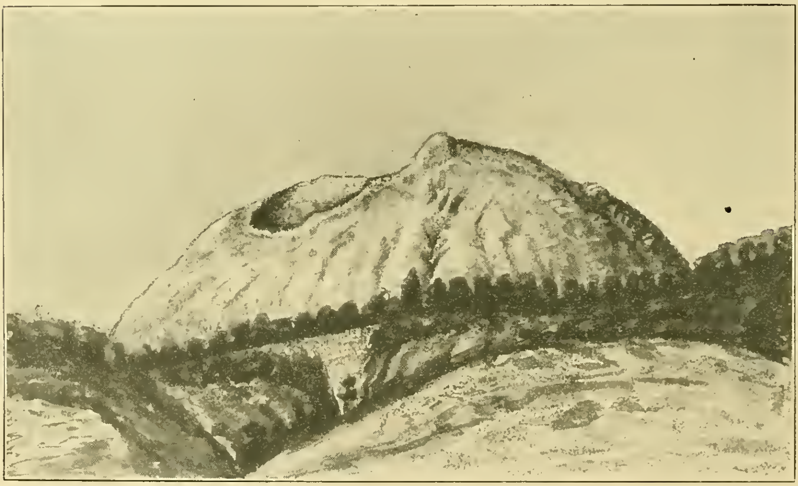

FIG. 5. — Crater of the volcano Colima after the eruption of March 2, 1903.

FIG. 6 — The volcano Colima in eruption, March 7, 1903, at 7 : 10 A. M., as seen from Colima, the volcano lying to the north. (R. R. Rivera.)

March 8. — Almost inactive.

March 9.—At dawn completely inactive. During the day there were seven little eruptions — at 9:18 and 11 A. M., and 12:24, 1:20, 1:40, 2:20, and 2:47 P. M. During the intervals there was complete inactivity. At 7:45 P. M., preceded by a heavy rumbling, there was an eruption, during which there was an abundance of fire and flashes, through the mass. There was a moon, and its white rays, reflected upon the edges, gave the cloud clean and immaculate outlines with which the black and red tones at the center sharply contrasted. The spectacle was indescribably beautiful. The cloud directed itself to the northeast, over the city of Zapotlan; the vapor mass had already passed the zenith of that city when, with an almost clear sky, there began a rain of coarse sand, the fall of which made a sound like the pattering of an ordinary rain. Of this sand two hundred and fifty grams were collected to an area of a square meter, on an average. In some parts of the city pieces of stone, up to the size of a grain of barley, were collected. This fall began at 8 P. M., and lasted about an hour.

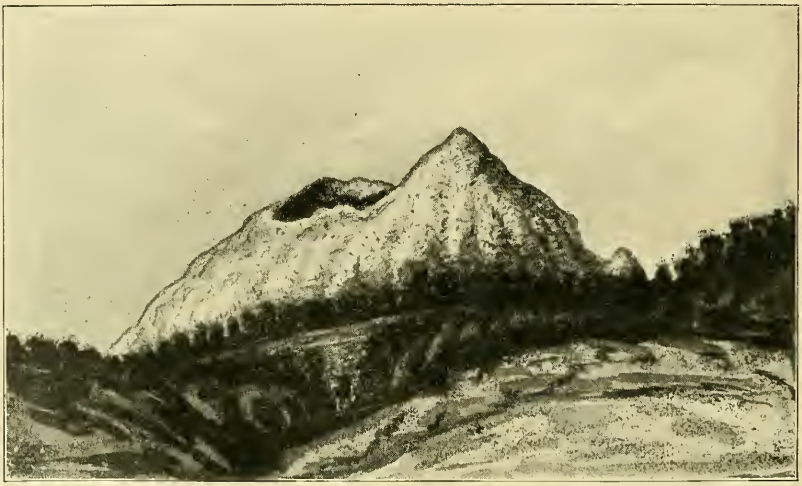

FIG. 7. — Crater of Colima after the eruption of March 10, 1903.

March 10. — Little clouds were observed at 6:15, 7:05, 7:27, 9:34, and 10:47 A. M. At 1 P. M., a maximum eruption, borne by the southwest wind toward the valley of Zapotlan, where some coarse sand fell — and, later, very fine sand like that of February 24. The quantity collected this time averaged about one hundred and seventy-five grams to the square meter, and the fall lasted some twenty minutes. At this time the crater suffered an alteration of form on the west border (Fig. 7); presenting thereafter on all sides an irregular border, with projecting points, in the form of a crown.

FIG. 8.—Colima in eruption on March 24, 1903, at 12:55 P.M., as seen from Colima, the volcano lying to the north. (R. R. Rivera.)

March 11, 12, and 13. — Almost inactive.

March 14. — At 1 A. M., a great eruption, with fire in the cloud and overflow of glowing scoriæ on the flanks. It produced a rain of fine sand to the east, in Tonila, and to the southwest in the Hacienda de San Antonio, estimated, at the latter place, at ten grams to the square meter. Inactive the rest of the day.

March 15–23. — Almost inactive.

March 24. — At 1 : 55 P. M., a maximum eruption, in six impulses, during the period of thirty-five minutes (Fig. 8). At the beginning frequent rumblings were heard, during some five or six minutes. The cloud directed itself east-northeast; and produced a rain of coarse sand in Tuxpan, Tecalitlan, etc.

March 25–31. — Almost inactive.

CONCLUSIONS.

1. The volcano of Colima has been from time immemorial an active volcano, the eruptions of which gain force, in some periods, until they assume a violent character.

2. The intervals between the periods of great activity, and the duration of these periods, are irregular . . . .

3. The characters of all the violent eruptions recorded in history are similar to those of the present time. The only notable incident is the appearance of a secondary crater, to the northwest of the principal, at the beginning of the 1869 period, which functioned until 1872.

4. From the examination of the flanks of the volcano and from recent superficial observations, it is inferred that the volcano has never thrown out lavas. All that lies upon the constituent rock mass of the cone, and all lately ejected, are fragmentary material—pebbles and sands of various grades of fineness, some with marks of having been exposed to heat and to the emanations from the crater. It appears, then, that they do not proceed from the internal reservoir.

5. The reason that this volcano has never belched forth lava is that its impulsive force has never been sufficient to overcome the height—3,960 meters above sea level. The lava rises to a level lower than this in the crater, and only the hot scoriæ, floating upon its surface, overflow.

6. The heavier products erupted fall upon the higher slopes

of the volcano, no more than four or five kilometers from the crater, where they do no harm. The pebbles and the sands, which have rained upon the low and populated districts, have caused no damage to persons or to cultivated fields.

7. The existence of *solfataras* in this volcano has not been proved; sulphur probably forms no part of its emanations.

8. The scoriæ and sands which issue from the crater are stopped in their course by the *barrancas* (gorges) which exist about half-way up the cone; these *barrancas*, existing on all sides and at various altitudes, serve as receptacles and protectors. If the higher ones are filled up, the lower ones receive the discharge. As the material is uncompacted, it is easily removed and the *barrancas* are cleared by the later rains. . . . .

9. As there are no signs that the eruptive power of Colima is augmenting, the inhabitants of the neighboring country may live tranquil. . . . .

10. The most violent eruptions have agitated the air sufficiently to produce loud explosions, but have not caused earthquakes.

José Maria Arreola.

THE DIVERSITY OF THE GLACIAL PERIOD ON LONG ISLAND.[1]

As pointed out by Professor Shaler some years ago, the region between, and including, northern New Jersey and Cape Cod is admirably situated for the preservation of the records of the glacial period.[2] The work of Woodworth on the New England islands has brought forth the complexity of the glacial records there, and the results of the last field season on Long Island and Gardiners Island have connected this work with that of Salisbury in New Jersy and given a basis for a tentative correlation with the deposits of the Mississippi valley.

GARDINERS ISLAND.

Gardiners Island, situated between the two eastern flukes of Long Island, presents many of the features shown on Nantucket, Marthas Vineyard, and Block Island. The succession is essentially the same and the correlation evident. It therefore forms a ready point of reference between Long Island, on the one hand, and the New England islands, on the other.

The structure of the island can best be worked out on the northeast shore, where the bluffs are quite high and are kept clean by the constant encroachment of the sea. Here the succession of strata is:

4. Gravelly till (Wisconsin).
3. Interglacial clays and fossiliferous sands.
2. Glacial gravel and bowlders.
1. Black lignitic clay and white and gray to red sand (Cretaceous).

The first three beds are very much folded and the last one deposited irregularly on their eroded folds (Figs. 1 and 2).

1. *Cretaceous.*—The older beds appear only in a few places where they have been brought up by folding. They are commonly black to dark gray clays and very fine sands with consid-

[1] Published by permission of the director of the United States Geological Survey.

[2] U. S. Geological Survey, *Seventeenth Annual Report* (1896), Part I, p. 957.

erable pyrite and muscovite. They were seen in four places on the northeast shore, and their presence was inferred in as many more by the large springs which occur along the line of parting between this formation and the gravels above. On the east shore the dark-colored older beds were seen at one place in the bluff

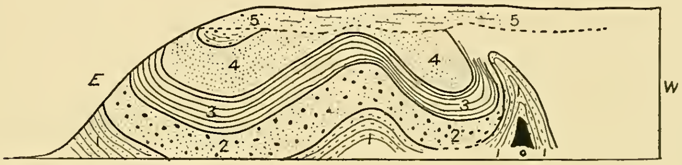

FIG. 1. — Section near middle of northeast shore of Gardiners Island, N. Y. (0) black Cretaceous clay; (1) fine gray micaceous sand (Cretaceous); (2) old glacial gravel; (3) red clay; (4) laminated yellowish-gray silty sand; (5) Wisconsin glacial deposits. Height of section, 60 feet.

at the southern end of Tobacco Lot Bay, here likewise associated with a fold. The white clayey sands, which characterize the Cretaceous on Long Island, were seen in one place in the bluff on Bostwick Bay. They show here in a small overturned

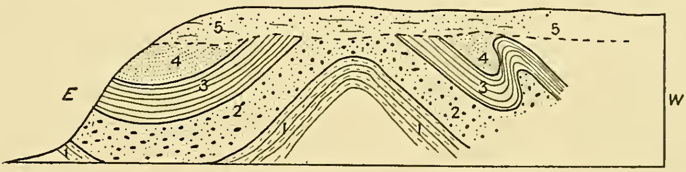

FIG. 2.— Section on west side of the hollow which afforded the figure in sec. 1. About 200 feet farther west. The figures indicate the same beds as in Fig. 1.

fold. These beds, in the absence of definite proof of age, are regarded as probably Cretaceous, and are so correlated.

2. *Old glacial gravel.*—Overlying the older beds, and involved in the same folds with them, are reddish glacial sand and gravel which, where best exposed, have a thickness of 10 to 15 feet. These beds are for the most part composed of iron-stained quartz, very much disintegrated and in sharp angular pieces. Intermingled with these are many pebbles and bowlders of mica schist, hornblende granite, and granitite, some weighing several thousand pounds. The larger of these compound rocks, while

very much stained with iron, and covered with a coating of pebble-conglomerate, which renders their composition unrecognizable, are not greatly decayed; the smaller ones show very great weathering. When not masked by recent deposits, the lithological character of this bed is quite distinctive.

3. *Red clays and associated beds* (*Sankaty*).— The red clay bed which overlies this gravel is perhaps the most easily recognized and persistent bed on the island. After its stratigraphic position has been definitely fixed in a number of exposures, it becomes a key bed to the whole series. It is a very finely laminated red clay, with occasional sand partings, especially in its upper portion,

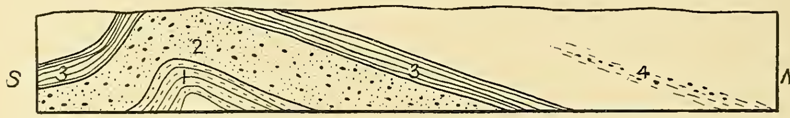

FIG. 3.— Section at Tobacco Point, east side of Gardiners Island, N. Y. (1) Cretaceous; (2) old glacial gravel; (3) red clay; (4) fossil bed with bowlders.

where it grades into a fine gray to yellowish-gray silty sand. The red clay has a thickness of about 15 feet. Overlying the red clays are very finely laminated gray and yellowish-gray silty sands, which, although somewhat eroded on the north shore, are still 15 feet thick. On the east shore, at Tobacco Point, they apparently grade upward into a peculiar mixture of sandy clay and fossiliferous sands with lens-shaped masses of glacial pebbles in their upper portions. These lenses of glacial gravel are perhaps to be accounted for by floating ice from the approaching glacier which disturbed these beds. The fossiliferous beds are clearly stratigraphically above the red clay, and are involved in the same fold (Fig. 3).

A small collection of fossils from the outcrop on Tobacco Lot Bay, and from another near the western point of the island, have been identified by Dr. William H. Dall as follows:

West point of Gardiners Island:
- Cyprina islandica, Gmelin.
- Crenella arca.
- Modiola sp.

Tobacco Lot Bay:

Chrysodomus decemcostatus, Say.
C. pygmaeus, Gould.
Natica (Lunatia) heros, Say.
Astarte elliptica, Brown.
Pecten magellanicus, Gmelin.
Cyprina islandica, Gmelin.
Thracia conradi, Coutony.

Dr. Dall remarks: "The material appears to be practically identical from both localities, and to represent the fauna now existing in the gulf of Maine or on the coast north of Cape Cod, a little colder water being indicated than is now found south of the cape." Smith[1] and Merrill[2] have both published lists of fossils which they collected at the Tobacco Lot Bay locality.

These beds present all the characteristics described by Woodworth in the Sankaty beds farther east, and, as already indicated by him, are to be so correlated.[3]

Folding and erosion of Sankaty beds.—Considerable time will be required to completely work out the very complex system of folds developed on this island, but the following points regarding them are of interest. Involving as they do, preglacial, glacial, and interglacial deposits, they are clearly of Pleistocene age, and their irregularity is strongly suggestive of a glacial origin. Near the center of the northeast shore a series of four folds was worked out whose axis is north 20° west. A little farther east, near Eastern Plain Point, there are three or four sharp, partially overturned folds, whose axes are almost due east and west.

Manhasset deposits.—Although the similarity of the Manhasset to the Tisbury beds[4] would lead us to expect them to appear on Gardiners Island on the top of the eroded folds of the older

[1] SANDERSON SMITH, "Notes of a Post-Pliocene Deposit on Gardiners Island, Suffolk County, New York," *Annals of the New York Lyceum of Natural History*, Vol. VIII (1867), pp. 150, 151.

[2] F. J. H. MERRILL, "On the Geology of Long Island," *Annals of the New York Academy of Science*, Vol. III (1886), pp. 354, 355.

[3] J. B. WOODWORTH, *Seventeenth Annual Report* (1896), U. S. Geological Survey, Part I, p. 976.

[4] *Ibid.*, p. 977.

beds, they have not as yet been definitely recognized, but certain thick beds of stratified gravels, whose position could not be satisfactorily determined in the short time that was spent on this island, may prove to be its equivalent. The fact that beds of Manhasset age have been recognized by Mr. M. L. Fuller on Montauk Point and Shelter Island greatly strengthens this supposition. On Shelter Island the beds are, moreover, known to be underlain by fossiliferous clay.

4. *Wisconsin deposits.*— The whole surface of the island is covered with recent morainal deposits. These have so masked the older topography that it is quite morainic in character, though the major topographic features are doubtless due to the distorted older deposits. Where seen in clean sections they are sharply nonconformable to the older deposits. They differ very little from the normal deposits of the same period on Long Island, and have a maximum thickness of about 50 feet.

LONG ISLAND.

For the purpose of this discussion the geologic succession on Long Island may be stated as follows:

- Pre-Pleistocene.
- Pleistocene.
  - Pensauken (glacial).
  - Jameco (glacial).
  - Sankaty (interglacial).
  - Manhasset (glacial).
  - Wisconsin.
    - Ronkonkona moraine.[1]
    - Harborhill moraine.

Pre-Pleistocene.—The pre-Pleistocene formations concern us mainly in that they form the surface on which the Pleistocene beds were deposited. On the western part of the island, about Astoria and Long Island City, on the East River, the crystalline rocks out-crop. Eastward and southward they occur at increasing depths beneath the unconsolidated beds. Such boring records as have been collected in this part of the island indicate a very irregular rock surface sloping southeastward at an average

[1] Name proposed by Mr. M. L. Fuller in manuscript discussion.

rate of about 100 feet per mile. These records are not numerous enough to do more than indicate roughly the general position of the rock surface (Fig. 4), and the extreme irregularity of the

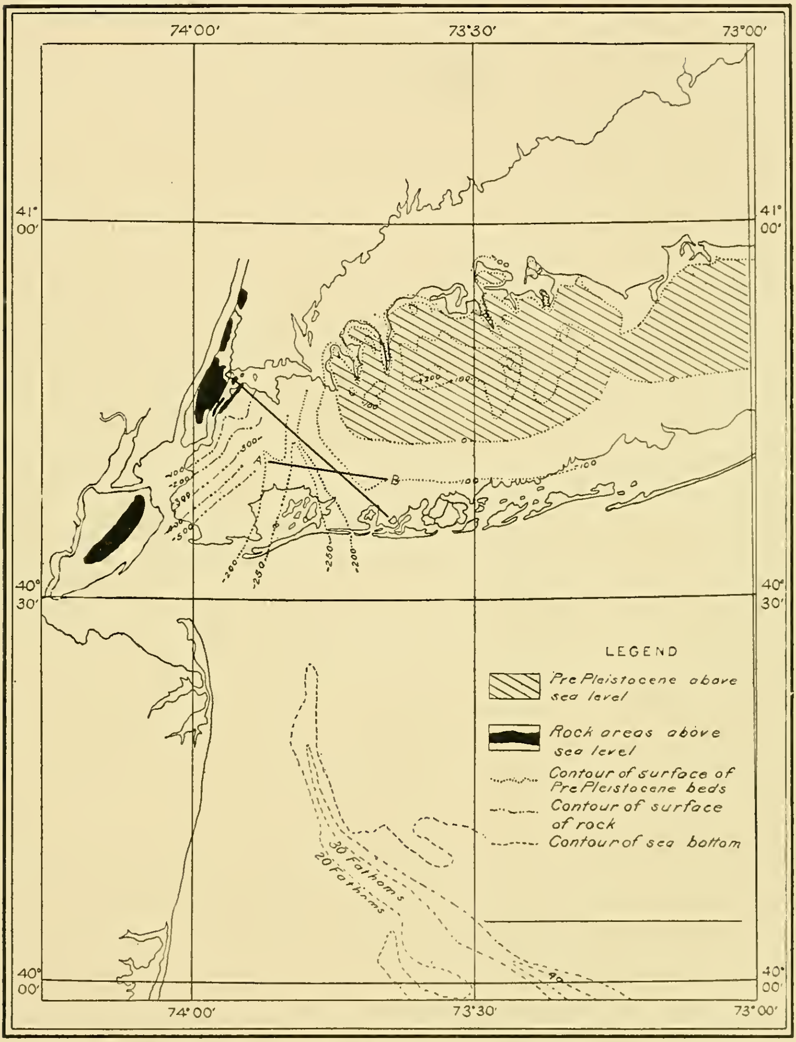

FIG. 4.—Sketch map showing the approximate position of the surface of the Pre-Pleistocene formations on Long Island and vicinity.

rock surface in New York city, where enough records have been collected by Mr. W. H. Hobbs to make its detailed mapping possible, leads us to believe that a like number of records on Long Island would show a like irregularity.

The pre-Pleistocene unconsolidated beds, represented by sands, gravels, and clay, for the most part Cretaceous, outcrop at many points on the north shore and in the West and Half Hollow Hills. Well sections show that they are present at no great depth under the glacial material in the highest part of the island, and they are now known to form a core about and over which the Pleistocene beds have been deposited. Although involved in sharp folds in many of the bluffs on the north shore, this folding does not appear to extend to any great depth, and the beds in the higher hills are essentially erosion remnants with a small coating of glacial material. On the north shore, between Peacock Point and Lloyds Neck, a number of wells, having a depth ranging from 200 to 500 feet, show a very regular dip of about 65 feet per mile S. 20° E., which contrasts markedly with the crumpled condition of the beds at the surface above them.

The preliminary map (Fig. 4), showing the approximate surface of the pre-Pleistocene unconsolidated beds, as far as they are known from well sections and outcrops, emphasizes two points: (1) the presence of a deep valley passing beneath Jamaica and Jamaica Bay, with a maximum depth exceeding 280 feet below present sea level, which seems to be the logical continuation of the deep channel shown by the soundings of the Coast and Geodetic Survey off New York harbor; and (2) the fact that the older deposits form the greater part of the highest points on the island.

All these beds, so far as known, are Cretaceous, with the exception of a thin bed of "fluffy sand" in the top of the West Hill section, which Mr. G. N. Knapp has referred to the Miocene because of its lithological resemblance to some of the near-by New Jersey beds.

Pensauken.—The oldest of the Pleistocene deposits on Long Island are coarse yellow quartz gravels, which contain a few very much weathered compound crystalline pebbles and cobbles. They are found capping West Hills and underlying the Wisconsin moraine in the Wheatley Hills at no great depth. In the

West Hills they have a thickness of over 35 feet, and reach an altitude of over 325 feet above sea level. These beds are sharply different from the underlying Cretaceous, and are lithologically identical with the Pensauken of New Jersey. Mr. G. N. Knapp, who has spent much time on the Pensauken of that state, has examined the West Hills beds and believes them Pensauken, notwithstanding their rather considerable altitude.[1] Mr. Fuller reports an additional locality on Lloyd's Neck which may belong to these beds. Here the percentage of erratic material is considerably greater, but the state of decay is much the same.

Post-Pensauken erosion interval.—The amount of erosion which belongs to the high-level interval which followed the deposition of this gravel is difficult to determine, but the fact that all the wells that have penetrated the Jameco gravels in the Jamaica-Jamaica Bay valley pass into the Cretaceous without any intervening yellow gravel bed suggests that a portion of the erosion of this valley belongs to this interval.

Jameco gravels.—The borings of the Brooklyn water works and of private parties in the old Jamaica-Jamaica Bay valley have revealed beds of multicolored gravels beneath beds of blue clay. These gravel beds contain only 10 to 20 per cent. of quartz, the remainder being dark-colored shale, red sandstone, trap, granite, and gneiss. The material in these beds varies in size from fine sand to small cobbles. The samples preserved by the Brooklyn water works contain much more erratic material than is generally found in the recent moraine. In the first sample tube[2] examined it was believed that some careless clerk had accidentally inverted it, the upper part of the tube showing yellow gravel, with only a few erratic pebbles, and the lower part, below a thick bed of dark lignitic clay, dark multicolored, highly erratic sands and gravels. The section seemed more correct when reversed, but, as sample after sample was examined, this idea proved incorrect. Records and samples collected the past summer from many wells

[1] Though I have not seen the beds at this locality, I am disposed to doubt their correlation with the Pensauken of New Jersey, unless, indeed, they are the glacial equivalent of the aqueo-glacial Pensauken of New Jersey.—R. D. S.

[2] Samples of the Brooklyn water works are preserved in glass tubes, a miniature reproduction of the strata being attempted.

in the same region have fully confirmed the conclusions from the samples of the Brooklyn water works' test borings. The gravels have a maximum thickness of more than 100 feet near the axis of the old valley, but thin out rapidly in passing eastward, the last wells in which they are known to occur being at Barnums Island and Long Beach. Farther east, the south shore, protected as it was by the Cretaceous upland, received none of these glacial gravels, but still farther east they again appear at Riverhead, here likewise overlain by clay beds. The local name proposed for these beds is from the Jameco pumping station of the Brooklyn water works, which is a few miles south of Jamaica, New York. . It was here that borings first revealed these beds.

Blue clay (*Sankaty*).—Overlying these gravels on the south shore are dark-colored clays, having a normal thickness of about 50 feet, and containing considerable lignite and occasional fragments of shells. These beds were laid down as a marginal coast deposit around the nucleus of older material when the land stood about 50 feet higher than today. On the north shore, where erosion has been more active, these beds exist, at present, only as remnants, associated with somewhat similar Cretaceous clays, and, except where brought up by folding, always below sea level. Their differentiation in well sections and small outcrops is, therefore, neither satisfactory nor certain. In no place on the north shore have sections been seen in which this clay bed and the older gravel are clearly shown—a result not to be wondered at when the fragmentary and folded character of these exposures is considered. In the southernmost of the sand pits, just northeast of Plum Point, near Port Washington, beds of laminated gray clay of probable Pleistocene age are exposed in slightly overturned folds. These may be of the Sankaty age.

The greatest thickness of this clay in the Brooklyn water works test borings, 150 feet, is believed to be greater than the true thickness of the deposits of this period. The clay bed is perhaps divisible, the portion below a more or less well-defined sand and fine gravel bed, which separates the section when the clay is of considerable thickness, belonging to the last outwash from the glacier which deposited the Jameco gravels. These greater thicknesses in the clay are generally associated with more or less well-defined valleys in the older gravels (see wells 5, 8, and 18 in Fig. 5), and the wood in the lower portion is rounded, or waterworn in distinction from the compound pieces of lignite found in the upper portion, indicating the true swamp character of the latter deposits. This would leave a thickness of about 50 feet definitely assignable to the Sankaty period in western Long Island—a thickness which is very similar to that found on Gardiner's Island.

Merrill reports the clays at the brickyard west of Greenport very much folded, and they, as well as the clays of Robbins Island, may belong to this age. Similar concretionary clays are found in the high hills between Bridgehampton and Sag Harbor, often very near the surface, and sometimes reaching a height of over 100 feet above sea level—a height doubtless due to folding similar to that shown on Gardiners Island.

The similarity of the stratigraphic position of these beds on Long Island, Gardiners Island, Marthas Vineyard, and Nantucket leaves no doubt of their equivalence to the Sankaty of Woodworth.

Gayhead interval.—There is nothing on Long Island which can clearly be referred to this interval except by inference. While there are many cases of folding on the north shore, the time of the folding is not so clearly fixed as in the small islands to the eastward. Still we feel, from the great similarity of the Pleistocene succession in each case, an assumption that the major folding took place at the same time is not unfounded. The main folding on the north shore occurred before the deposition of the typical Manhasset (Tisbury), as is the case in the New England islands. Some slight folding has doubtless occurred since that time, but it is of small consequence when compared with the older.

Manhasset.—The Manhasset of Woodworth[1] consists of a series of yellow quartz sand and gravel, with an intercalated bowlder bed, and on the north shore lies horizontally on the

[1] J. B. Woodworth, *Bulletin of New York State Museum*, No. 48, 1901, Plate I.

truncated folds of the older beds. It differs from the older Jameco in the small amount of erratic material it contains, and from the still older Pensauken in the very slight weathering of the compound pebbles. On the north shore Woodworth has shown that it was deposited as a very level plateau-like plain, reaching a height of over 200 feet. Mr. M. L. Fuller has now proved that it underlies the moraine and occurs south of the moraine in the Half Hollow Hills and the southern end of the West Hills. It is known to underlie the Wisconsin outwash in the plain to the south at an inconsiderable depth and to occur at

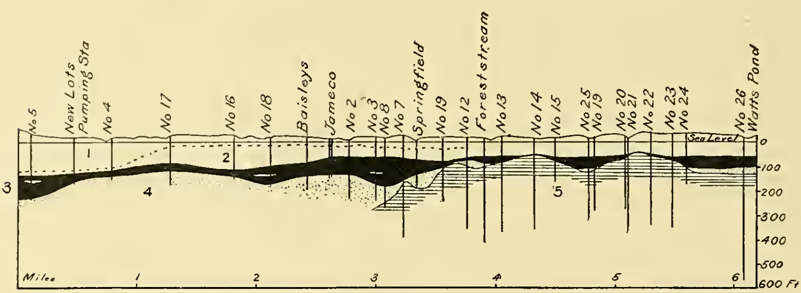

FIG. 5.—Section along the line *ab* of Fig. 4, showing portions of (1) Wisconsin; (2) Manhasset; (3) Sankaty; (4) Jameco; (5) Cretaceous beds, and east side of old valley. Numbers refer to the Brooklyn water-works test wells.

Far Rockaway. It is in this region that its position is definitely fixed between the Sankaty and Wisconsin (see Fig. 5).

This formation seems to represent waterlaid material when the ice was at no very great distance to the northward. The greater part of it is regarded as the equivalent of the Tisbury of Woodworth for the following reasons: (1) deposition between the Sankaty and Wisconsin; (2) deposition after the main folding of the older beds; (3) marked nonconformity between it and the overlying Wisconsin; (4) similarity of formation; (5) similarity of elevation.

A portion of the folded Manhasset of Woodworth may be referable to the Jameco, but the evidence is not sufficiently clear at present to warrant such a reference.

The Vineyard interval.—As in the New England islands, the Manhasset is separated from the Wisconsin by a period of uplift and subaërial erosion of very considerable extent. The land probably stood somewhat higher than at present. Much erosion occurred on the north shore, but it is hardly believed that the whole of the erosion of the deep re-entrant valleys can be referred to this period.

Wisconsin.—This period is represented on Long Island by two sharply defined terminal moraines and the accompanying ground moraines and outwash plains. The two terminal moraines exhibit some little shifting of the ice lobes, the younger one, as pointed out by Woodworth,[1] crossing the older one near Lake Success. This is quite in accordance with the dual character of the Wisconsin worked out by Leverett[2] in Ohio with its shifting of the ice lobes.

RÉSUMÉ AND CONCLUSIONS.

Having presented briefly such facts as have immediate bearing on the question in hand, the following résumé and statement of conclusions is pertinent. In this the several epochs are treated in ascending order, beginning with the oldest, the scheme of classification shown on p. 766 being followed:

1. The Pensauken has not been recognized on the New England islands, but its outcrop on Long Island near the Jameco gravels makes it possible definitely to refer the "first glacial" of Woodworth to a stage younger than the main body of the extra-

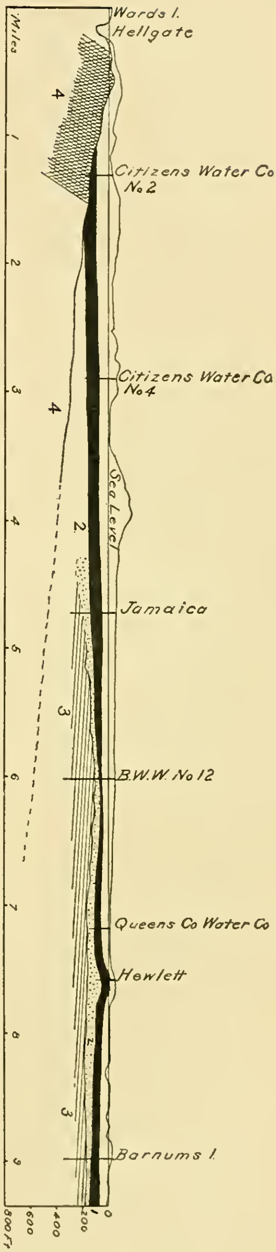

FIG. 6.—Section along the line *cd* of Fig. 4. (1) Sankaty; (2) Jameco; (3) Cretaceous; (4) "Bed Rock."

[1] *Loc. cit.*, p. 642.

[2] FRANK LEVERETT, *Monograph U. S. Geological Survey*, Vol. XLI (1902), pp. 41, 352, 353.

morainic drift in New Jersey. The deposition of the Pensauken on Long Island indicates submergence of something over 300 feet.

2. In the erosion interval which followed the land stood higher than at present, the absence of Pensauken gravel in the old western Long Island valley indicating that the elevation was something over 250 feet above the present sea level.

3. Following this erosion, the Jameco gravels were laid down in this old valley. These gravels are essentially continuous from the New England islands through Long Island possibly to eastern New Jersey. The ice seems to have about reached the northern part of Long Island and the Jameco gravels to be an outwash from the ice in this position. The very large bowlders at Gardiners Island and at Gayhead indicate that the ice was not far distant at these points.

4. Regarding the relative position of the land during the deposition of the following Sankaty beds we have evidence only in western Long Island, the folding in the other islands preventing any conclusions. On Long Island the land stood 50 feet higher than today, and these beds were laid down as marginal coastal deposits about the older island-like nucleus. The climate, as indicated by the fossils, was not much different from that existing now, and a long period of deglaciation seems indicated.

5. All the evidence which has thus far been collected regarding the greatly contorted folds which involve all the beds between and including the Cretaceous and Sankaty, points strongly to a glacial origin. No evidence of the ice advance besides the folding exists other than the glacial gravels which occur associated with the fossil bed on Gardiners Island and suggest an approach of the ice. The fact that no glacial deposits have been recognized on the mainland which correspond in age to this folding can hardly be regarded as proving that such an advance did not occur. Other ice advances clearly shown on the island have not been recognized on the mainland, the older deposits apparently having become so involved in those of the more recent advances as to make the exact time of their deposi-

tion uncertain. Separated as this is from the preceding glacial epoch by heavy beds of clay and fossiliferous sands, and from that following by marked erosion, this period seems to deserve the rank of an epoch.

6. The exact nature of the erosion in the interval between the folding and the deposition of the Tisbury beds is difficult to determine. That suggested by the outcrops is a decapitation of the folds by wave action, the land standing somewhat lower than today. The nonconformity shown is very marked and forms a ready plane of reference.

7. The Tisbury or Manhasset beds represent glacial outwash when the land stood at least 200 feet lower on Long Island, and 140 feet lower on Marthas Vineyard, than it does today, and the bowlders in the Marthas Vineyard and the bowlder beds in the Long Island deposits perhaps represent the deposits of floating ice.

8. In the Vineyard interval, which separated the Tisbury from the Wisconsin, there was widespread erosion; the land stood somewhat higher than today, and the surface of the preceding deposits was greatly trenched by stream erosion.

9. In the last ice advance the change in the shape of the ice lobes, shown by the crossing of the two outer Wisconsin moraines, suggests the twofold division of the Wisconsin found by Leveret in Ohio.

CORRELATIONS.

The correlation of the Pleistocene succession here shown with that in the Mississippi valley is necessarily more or less tentative, but cerain points are worthy of note: (1) the number of glacial epochs is in each case the same, and (2) the correlation of the Pensauken and extra-morainic drift of New Jersey with the pre-Kansan, or sub-Aftonian, which will follow if these glacial epochs in each case are to be regarded as synonymous, is supported by a growing feeling among Pleistocene geologists that the old extra-moranic drift of New Jersey is rather older than the Kansan; hence the growing tendency to say Kansan or pre-Kansan in speaking of these deposits. These results are remarkably in accord with this idea, and if the oldest and youngest beds of the series are equivalent and there are the same number of epochs, the feeling that the intervening epochs are more or less synonymous must be very strong, and the following correlation suggests itself:

<table>
<tr><th>North America</th><th>New Jersey</th><th>Long Island</th><th>Gardiners Island</th><th>New England Islands</th></tr>
<tr><td>Pre-Aftonian</td><td rowspan="8">Extra-Morainic Drift and Pensauken[1]
(Not differentiated)</td><td>Pensauken</td><td>Wanting</td><td>Wanting</td></tr>
<tr><td>Aftonian</td><td>Erosion interval unnamed</td><td>Not separable from pre-Pleistocene erosion</td><td>Not separable from pre-Pleistocene erosion</td></tr>
<tr><td>Kansan</td><td>Jameco</td><td>Jameco</td><td>"First glacial"</td></tr>
<tr><td>Yarmouth</td><td>Sankaty</td><td>Sankaty</td><td>Sankaty</td></tr>
<tr><td>Illinoian</td><td>Folding</td><td>Folding</td><td rowspan="2">Gay Head interval</td></tr>
<tr><td>Sangamon</td><td>Erosion interval unnamed</td><td>Erosion interval unnamed</td></tr>
<tr><td>Iowan</td><td>Manhasset</td><td rowspan="2">Not recognized</td><td>Tisbury</td></tr>
<tr><td>Peorian</td><td>Vineyard internal</td><td>Vineyard interval</td></tr>
<tr><td>Wisconsin
Early
Late</td><td>Wisconsin</td><td>Wisconsin
Ronkonkoma
Harbor Hill</td><td>Wisconsin
Ronkonkoma</td><td>Wisconsin</td></tr>
</table>

A. C. VEATCH.

WASHINGTON, D. C.,
October 16, 1903.

[1] I have no adequate reason for regarding the extra-Wisconsin-morainic glacier drift of New Jersey as pre-Aftonian, though, on the other hand, I think this is as probable as any other correlation. Neither is it certain that the extra-Wisconsin-morainic glacier drift of New Jersey is a unit, nor that it is all the time-equivalent of the Pensauken, which is not of glacier origin, though it is believed to be aqueo-glacial. Neither is it certain at the present moment that all which has been regarded as Pensauken can be grouped together as a unit, in the sense of corresponding to a particular glacial epoch. It is a composite formation ranging through a somewhat protracted interval.—R. D. S.

OBSERVATIONS ON PLATYGONUS COMPRESSUS LECONTE.

In the museum of the University of Michigan there is a collection of bones of a fossil peccary, found in the peat-bog near Belding, Ionia county, Mich. The late Professor Alexander Winchell correctly identified the material as belonging to *Platygonus compressus*, first described by John L. Leconte (1848, 1848*a*). Professor Winchell published nothing on the subject, and there is now no record of the exact relations the bones had to each other when found.

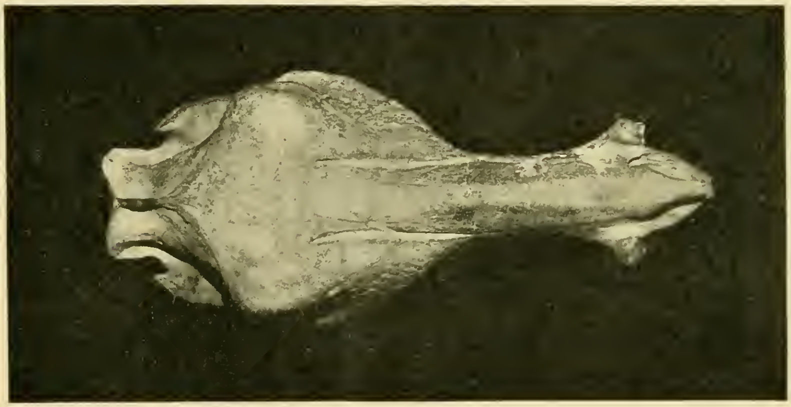

Fig. 1.—*Platygonus compressus* Lec. Skull of adult male, from above.

According to Professor Winchell's labels, five specimens are represented in the collection. One series, comprising a nearly complete skeleton, was by him referred to one individual; the only reason for doubting this collocation is that the skull seems to be of a male, while the sacrum agrees well with that referred by Williston to a female (1894, p. 36). In all probability the differences shown in the sacra figured by Williston are merely individual. The other bones of this series clearly belong together, and the bones are in excellent preservation. The other skeletons are represented by much less complete material.

The only skull in the collection is the one above mentioned, belonging to the nearly complete skeleton. It is that of an adult male, judging from the strong, protuberant flange of the mandible. All sutures are obliterated, and the teeth are much worn—the third premolars much more deeply so than the others. The prenasal ossification, figured by Williston (*loc. cit.*) in a similar skull is missing.

Because of the question of specific identity of the specimen with others, I give the measurements of this skull rather fully, as follows:

	mm
Length of skull from top of inion to end of nasals in median line	293
Length from anterior margin of foramen magnum to end of premaxillaries	260
Breadth of postorbital processes	109
Breadth of face at middle of zygomas	136
Breadth of face at lachrymal eminences	103
Height of supra-orbital margin from a level	107
Height of face at posterior end of infra-orbital foramen	82
Height of face at middle of canines	59
Width of face at first premolar	37
Width of face at canine alveoli	68
Width of premaxillaries	42
Depth of zygoma from end of postorbital process to end of preglenoid process	76
Depth of zygoma at middle below the orbit	39
Length of temporal fossæ from inion to postorbital process	85
Height of inion	93
Breadth of upper part of inion	59
Breadth at glenoid fossæ	118
Height of occipital foramen	21
Breadth of occipital foramen	21
Distance between the ends of the paroccipital processes	(?)58
Width between molars of the two sides	21
Length of upper molar series	78
Length of hiatus in advance of latter	44
Height of canine tuberosity	44
Length of mandible from condyle to symphysis	223
Height of mandible at condyle	85
Height of mandible at coronoid process	98
Depth of mandible below premolars	39
Depth obliquely at symphysis	79

Width at canine alveoli	40
Length of lower molar series	77
Length of hiatus in advance of latter	53
Transverse diameter of the condyle	26

In comparing this skull with those described by Williston from the Pleistocene of western Kansas, the following points of interest may be noted: In our specimen the diastema between the incisor and the canine of the mandible is five millimeters in length, as compared with eleven in the Kansas specimen. In the

FIG. 2.—*Platygonus compressus* Lec. Skull of adult male, from the side.

specimen described by Leidy as the type of *Euchœrus macrops* Williston supposed the diastema to be nearly absent, as indeed it seems from Leidy's figure in Plate XXXV. But a comparison of this figure with others of the same specimen on Plate XXXVI convinces me that the former is anything but accurate, and that the diastema is really very considerable. Our specimen further differs from the one described by Williston in having the peculiar asymmetrical *cul-de-sac* below the anterior margin of the nares, as described by Leidy for *Euchœrus macrops*. Nothing is to be seen of fossæ above the infra-orbital foramen.

It will be seen that all our measurements fall well within the range of those given by Williston, and the same is true of other measurements not here given. A comparison of these, as also of other characters of the various skulls so far figured, has convinced me that *P. leptorhinus* Williston is a synonym of *P. compressus*, as the author believed to be probable (1896, p. 303). There would seem to be little doubt that the differences given between these eastern and western specimens are merely individual. I am further convinced of this by Leidy's comments upon the variations in the skull of *Dicotyles torquatus* and by the differences shown in the dentition of specimens of *Dicotyles* and *Platygonus*.

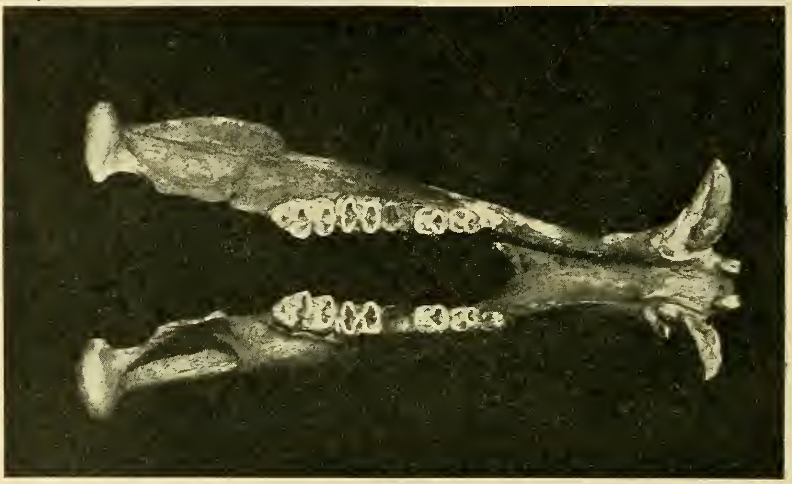

FIG. 3.—*Platygonus compressus* Lec. Lower jaw of adult male.

Platygonus compressus, therefore, seems to have had a very wide distribution during Pleistocene times in North America, ranging at least from New York to the extreme west of Kansas, and from Michigan to Mexico.

It will be of interest here to note some of the other related forms described from North America:

Platygonus striatus Marsh (1871). The type consists of portions of two lower jaws from the "Pliocene" (Pleistocene?) of Nebraska, with a few anterior teeth. The characters distinguishing this from *P. compressus* do not seem to be important.

Platygonus condoni Marsh (1871). The type consists of portions of two maxillæ with three posterior molars, from the "Pliocene" (Pleistocene?) of Oregon. Cope and Wortman (1884) referred this to *Dicotyles*. The posterior molar is larger than in *P. compressus* (26^{mm}).

Platygonus rex Marsh (1894). Based upon three lower teeth from the "Pliocene" of eastern Oregon. Gidley (1903) says "the horizon is almost certainly Upper Miocene." If so, there will be no question of the validity of the species. The last lower molar has a length of 27^{mm}.

FIF. 4.—*Platygonus compressus* Lec. Lower of jaw adult male

In addition, other species referred to this genus have been described by Marsh (1871, *P. striatus*, Eocene of Wyoming), Cope (1894, *P. calcaratus*, Blanco beds of Texas), and Gidley (1903, *P. texanus*, Blanco Pliocene of Texas). In comparing *P. vetus* and *P. alemanii*, it is noticed that the two species, if they are distinct from each other, are of larger size than *P. compressus*, and they may represent a species distinct from the latter, with practically the same geographical distribution, and they were probably contemporaneous.

Some years ago Newberry (1875, p. 6) mentioned a lot of a dozen nearly complete specimens of *Platygonus compressus*, found within the city limits of Columbus, O., and belonging to the

Ohio Geological Survey. Professor Marsh was expected to write a report upon them, but none such has ever appeared. If these specimens have been preserved, a careful study of them, with especial reference to individual variations in connection with what has already been published, may be of much interest.

George Wagner.

University of Wisconsin.

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GLACIER CORNICES.

In recording observations concerning the glaciers of Greenland, Professor T. C. Chamberlin[1] describes a jutting of certain layers of clear ice over dirt-stained layers in the vertical escarpment at the lower end of Tuktoo glacier. The projections or cornices referred to overhang from a few inches to ten or even fifteen feet. As to their origin, two hypotheses are discussed; one, to the effect that they are due to a greater rate of motion in the projecting layer of ice than in the layer immediately beneath; and the other, that the exposed edge of a dirt-stained layer melts back more rapidly than the similarly exposed edge of a stratum of clear ice. Either of these two explanations is considered as being applicable to the observed examples, and a choice between them does not appear to have been practicable.

While examining the glaciers on the Three Sisters, Oregon, on August 16, 1903, I found jutting layers of névé ice, on the vertical wall of a crevasse which seem to be a counterpart of those described by Chamberlin, a photograph of which is here reproduced.

The wall of ice, or rather granular névé, referred to, occurs near the head of a small glacier at the east base of West Sister, and occupies an amphitheater-like depression between West and North Sister. It is the upper or hanging wall of the highest crevasse which intersects the glacier or a *Bergschrund*, the lower wall of which had in part fallen previous to my visit, so as to leave its companion fully exposed. The wall faces east and is in shadow after midday, when melting ceases on its face. In reference to the stratification of the snow, presence of dirt bands, exposure to the sun, etc., the conditions present are similar to those pertaining to the glaciers of Greenland on the vertical walls of which cornices have been observed.

The escarpment shown on the accompanying photograph is

[1] *Bulletin of the Geological Society of America*, Vol. VI (1895), pp. 206, 207; JOURNAL OF GEOLOGY, Vol. IV (1896), pp. 589–91.

about twenty-six feet high, and is composed of the edges of layers of clean, stratified, granular snow, between which there are dirt bands ranging in thickness from a fraction of an inch to three or four inches. On the central part of the precipice, where fully exposed to the sun until noon each day, there are two conspicuous cornices which project beyond the surface below them in each instance from six to seven inches. The under surfaces of

FIG. 1.—Wall of a crevasse in the névé portion of one of the glaciers on the Three Sisters, Oregon, showing cornices above dirt bands. Looking northwest. August 16, 1903.

the projecting beds, where exposed, are slightly fluted at right angles to their length, but this is not a conspicuous feature. The precipice at its north end passes under an arch of snow which forms the roof of a cavern, and in the portion sheltered from the sun there is no jutting of the layer of snow above the lower of the two principal dirt banks, which is the only one extending into the cavern. Near the south end of the precipice, but not shown on the accompanying picture, the dirt bands are bent abruptly upward and become vertical, near where the névé joins the steep face of the mountain. In this portion of the precipice, which is also fully exposed to the sky, melting is equal on each side of the dirt bands, and they appear as black streaks in the bottom of vertical V-shaped grooves five or six inches deep.

In the instances deseribed above it is evident that the cornices are due to the more rapid melting of the layer below a dirt band than of the layer above it. The evidence sustaining this conclusion is, briefly, that when a horizontal dirt band is traced from where it is exposed to the sun, and has a cornice above it, into the cavern where the sun's rays do not exert a direct influence the cornice disappears; and when followed to where it is vertical and fully exposed to the sky, melting is equal on each side.

The more rapid melting of the snow below than above a horizontal dirt band is evidently due to the absorption of the sun's heat by the dark material, as it is dislodged and washed downward so as to stain slightly the surface beneath. The dirt exerts this influence during its passage over the surface of the exposed edges of the layers of clear snow in the face of the precipice.

In addition to the direct evidence just presented favoring the hypothesis of differential melting to account for the development of cornices, indirect testimony in opposition to the hypothesis of differential motion is furnished by the fact that the distance from the *Bergschrund* to the head of the névé where it meets the steep upward slope of the mountain ranges from 50 to 200 feet, and, as is probable, there is practically no motion in the wedge of snow thus left clinging to the rocks. ISRAEL C. RUSSELL.

NOTE.—That differential melting is the chief factor in the formation of ice cornices, in most cases, may be accepted as established by such evidence as is presented in this article, and concurrent evidence elsewhere given. It is much less safe to assume that shearing motion is not a *contributing* factor in many cases, especially in the basal and terminal portions of ice tongues. It is quite unsafe to infer that this bears adversely on the doctrine of shearing, which rests on other grounds. It is altogether wholesome, however, to check, by such evidence as that presented in this paper, the too free inference of shearing motion to which the striking features of the cornices are liable to lead. T. C. C.

Reviews.

Elements of Geology. By Joseph Le Conte. Revised and partly rewritten by Herman Le Roy Fairchild. Fifth edition. New York: D. Appleton & Co. Pp. xii+667.

For a quarter of a century Le Conte's *Geology* has been largely used as a text-book in colleges, and as a work for the general reader. The high standing which the author had as a geologist and as a teacher, the literary excellence of his writings, and the even balancing of the divisions of the subject have all conspired to make Le Conte's text-book a popular one. Students and teachers of geology will be pleased to know that the book has lately been revised and in part rewritten by Professor H. L. Fairchild, head of the department of geology at the University of Rochester and for a long time secretary of the Geological Society of America.

In its general appearance, form, and style very few or no alterations in the book have been made. Advancing knowledge has required, of course, that many changes be made in the text, some of them of minor import and scarcely noticeable in a casual examination, while other changes are profound and indicate radical departures from what has heretofore been taught. Among the latter may be noted the substitution of the planetesimal theory of Chamberlin to account for the origin of the earth, instead of the Laplacian hypothesis that has been so long accepted.

The paging of the new edition practically conforms to that of the previous one. This has been done largely by a judicious withdrawal of some paragraphs and sections, and the addition of new ones that correspond in length. Many new cuts have been added, and a number of the sketches and drawings in the previous edition have given way to photographs. A few of the graphical illustrations or mathematical diagrams have been omitted. In the chapter on metamorphic rocks a number of changes have been made. Some additional varieties of these rocks have been described, the section on the origin of granite has been omitted, and the theory of metamorphism has been rewritten. In the historical division some new figures have been added, and changes in classification have been made to conform to later researches.

The section which treats of the glacial epoch has been rewritten and enlarged, and a number of cuts have been added. Professor Fairchild has shown much skill in preserving the spirit and style of the book, and yet by a series of deft touches he has been able, in most instances, to bring the subject-matter up to date and well to the forefront of the rapidly advancing science. HENRY LANDES.

Geology. By THOMAS C. CHAMBERLIN AND ROLLIN D. SALISBURY. Vol. I, Geologic Processes and Their Results; Vol. II, Earth History. (American Science Series — Advanced Course.) Henry Holt & Co., 1903.

VOLUME I is just issuing from the press. Volume II is to follow closely. The following extract from the preface indicates the controlling ideas of the authors :

In the preparation of this work it has been the purpose of the authors to present an outline of the salient features of geology, as now developed, encumbered as little as possible by technicalities and details whose bearings on the general theme are unimportant. In common with most writers of textbooks on geology, the authors believe that the subject is best approached by a study of the forces and processes now in operation, and of the results which these forces and processes are now bringing about. Such study necessarily involves a consideration of the principles which govern the activities of geologic agencies. These topics are presented in Vol. I, and prepare the way for the study of the history of past ages, which is outlined in Vol. II.

The general plan of the work has been determined by the experience of the authors as instructors. Little emphasis is laid on the commonly recognized subdivisions of the science, such as *dynamic geology*, *stratigraphic geology*, *physiographic geology*, etc. The treatment proceeds rather from the point of view that the science is a unit, that its one theme is *the history of the earth*, and that discussions of dynamic geology, physiographic geology, etc., apart from their historical bearings, lose much of their significance and interest. The effort has, therefore, been to emphasize the historical element, even in the discussion of special themes, such as the work of rivers, the work of snow and ice, and the origin and descent of rocks. This does not mean that phases of geology other than historical have been neglected, but it means that an effort has been made to give a historical cast to all phases of the subject, so far as the topics permit.

Throughout the work the central purpose has been, not merely to set forth the present status of knowledge, but to present it in such a way that the student will be introduced to the methods and spirit of the science, led to a sympathetic interest in its progress, and prepared to receive intelligently, and to welcome cordially, its future advances. Where practicable, the text has been so shaped that the student may follow the steps which have led to present conclusions. To this end the working methods of the practical geologist have been implied as frequently as practicable. To this end also there has been frankness of statement relative to the limitations of knowledge and the uncertainty of many tentative conclusions. In these and in other respects, the purpose has been to take the student into the fraternity of geologists, and to reveal to him the true state of the development of the science, giving an accurate and proportionate view of the positive knowledge attained, of the problems yet unsolved, or but partially solved, and of solutions still to be attained.

The theoretical and interpretative elements which enter into the general conceptions of geology have been freely used, because they are regarded as an essential part of the evolution of the science, because they often help to clear and complete conceptions, and because they stimulate thought. The aim has been, however, to characterize hypothetical elements as such, and to avoid confusing the interpretations based on hypothesis with the statements of fact and established doctrines. Especial care has been taken to recognize the uncertain nature of prevalent interpretations when they are dependent on unverified hypotheses, especially if this dependence is likely to be overlooked. If this shall seem to give prominence to the hypothetical element, it should also be regarded as giving so much the more emphasis to that which is really trustworthy, in that it sets forth more frankly that which is doubtful. Hypothetical and unsolved problems have been treated, so far as practicable, on the multiple basis; that is, alternative hypotheses and alternative interpretations are frequently presented where knowledge does not warrant positive conclusions.

In many cases the topics discussed will be found to be presented in ways differing widely from those which have become familiar. In some cases fundamentally new conceptions of familiar subjects are involved; in others topics not usually discussed in text-books are stated with some fulness; and in still others the emphasis is laid on points which have not commonly been brought into prominence. Whether the authors have been wise in departing to this extent from beaten paths, the users of the volumes must decide.

The work is intended primarily for mature students, and is designed to furnish the basis for a year's work in the later part of the college course. By judicious selection of material to be presented and omitted, the volumes will be found useful for briefer courses, and by the use of the numerous references to the fuller discussions of special treatises they may be made the basis for more extended courses than are commonly given in undergraduate work. The attempt has also been made to make the volumes readable, in the belief that many persons not in colleges or universities will be interested in following a connected account of the earth's history, and of the means by which that history is recorded and read. Antecedent elementary courses in geology will not be necessary to the use of these volumes, though such courses may be helpful.

The arrangement of themes adopted is such as to bring to the fore processes with which all students are immediately in contact, and which are available for study at all seats of learning. The commoner geologic agents, such as the atmosphere and running water, have been elaborated somewhat more fully than is customary, and the common rather than the exceptional phases of the work of these agents have been emphasized, both because of their greater importance and their universal availability. The text has been so shaped as to suggest field work in connection with these topics especially, since work of this sort is everywhere possible.

After the preliminary outline, which is intended to give some idea of the scope of the science, and of its salient features, and to show the relations of the special subjects which follow, the order of treatment is such as to pass from the commoner and more readily apprehended portions of the subject to those which are less readily accessible and more obscure. Following the same general conception, the treatment of the topics is somewhat graded, the earlier chapters being developed with greater simplicity and fulness, while the later are somewhat more condensed.

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