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WITH XI PLATES.

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[THIRD SERIES.]

Art. I.—*Spiral Goniometry in its Relation to the Measurement of Activity*; by Carl Barus.

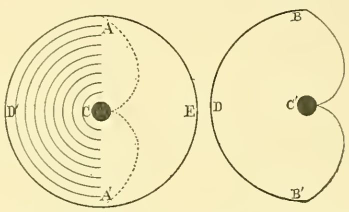
1. *Preliminary.*—Under this cumbersome title* I shall refer to the art of measuring variable angles between two coaxially rotating bodies by the displacement of a set of semicircles terminating in the same diameter in one body, relative to a set of spirals in the other; or by equivalent systems of spiral and straight edge. Problems which may be reduced to a measurement of the angular magnitude in question are of frequent occurrence in practical physics, and in most instances a moderate degree of accuracy will suffice because the quantity to be measured itself fluctuates within certain limits. As it is such cases which I have chiefly in mind, I will first give an account of the method in various stages of development, and then proceed with the more obvious applications to the evaluation of activity and speed.

2. *Dial and Index.*—In fig. 1, AA' is a circular disc (to be called the *dial* in this paper) capable of revolving around an axis passing normally through its center. On this disc a series of concentric, equidistant semicircles are inscribed, in such a way that the locus of their ends is the diameter AA'. BB' is a plate (to be called the *index*) bounded on one side of a diameter by the semicircle BDB', of the same radius as the dial,

* The instrument for measuring plane angles is the circular protractor; but the word "protraction" is not available. On the other hand the word goniometer like goniometry has been made to refer to solid angles like those between faces of a crystal. As I have no such purpose in view I use the above caption with misgiving and merely to express an operation which would consistently be called "circular protraction" in rotating bodies.

and on the other side by two symmetric confluent spirals BC' and $B'C'$. The plate BB' when in position, is placed immediately in front of AA' as shown by the dotted lines on the dial, and is capable of revolving normally around the same axis C independently of AA'. Since the curves BC' and $B'C'$ are by definition such that equal angular increments (in degrees of arc, say) correspond to equal radial increments (in millimeters, say) the number of ends of the semicircles visible beyond the spiral edge of BB' is numerically identical with the angular displacement of AA' relative to BB', reckoned

1.



from the fiducial position (no circles visible) given in the diagram, fig. 1. Now if the system AA', BB' revolves as a whole, the ends of the semicircles will tend to appear like complete circles, and this more fully in proportion as the speed is greater. It is therefore merely necessary to count the number of visible circles from the circumference inward, in order to measure the angle between AA', and BB', no matter whether the rotation be right-handed or left-handed, nor what its speed may be. Two spirals BC' and $B'C'$ have been provided in order to admit of changes in the sign of rotation.

The maximum angle measurable in this way is clearly greater than 90°, and clearly less than 180° in this simple contrivance (cf. § 4); for if the spirals be symmetrically prolonged in the directions $C'B$ and $C'B'$, and if the partial circles instead of terminating in a semicircle be similarly contained in a sector, the measurable angle will increase until the sector vanishes.

If $d\varphi$ be an angular increment and dr the corresponding radial increment of the spiral, then

$$dr \propto d\varphi,$$

and therefore the method is equally sensitive at all parts of the angular field, though perhaps the central parts are more fully controlled by the eye. The error in reading is in the most unfavorable case equal to the angular value of the distance between two consecutive semicircles on the dial, increased by the angular value of an arc, which is just visible on rotation. The latter quantity depends on the sharpness with which the semicircles stand out from the dial (§ 6). It is therefore expedient to tax the eyes in the smallest degree possible by using a *dull black* index and also a dull black dial, on which the semicircles are inscribed with white paint. I have availed myself of the black cardboard much used by photographers, upon which the circular lines could be inscribed with a ruling pen* by suitably thinning "flake white" or "Chemnitz white" with turpentine. In larger practice such dials could be printed on card board from a copper plate.

To guide the eye it is of course necessary to accentuate consecutive 5° and 10° circles in the usual way. Moreover a fixed narrow radial scale, containing the running numbers of each of the successive intervals of 10°, and placed directly in front of the whirling system of dial and index, further facilitates the reading. Indeed it is now quite as clear as an ordinary scale.

3. Instead of the arrangement given in figure 1, it is obviously admissible to allow the semicircles of the dial to terminate in spirals while the counting edge of the index is a diameter. If carried out in the plan of figure 1, however, such a goniometer if adapted to measure positive angles would not at once be available for negative angles seeing that a rotation of the index 180° around its diameter is necessary for this purpose. An auxiliary adjustment of this kind would, as a rule, be objectionable in practice; and therefore the design *A*, figure 2, in which the locus of the edges of the partial circles

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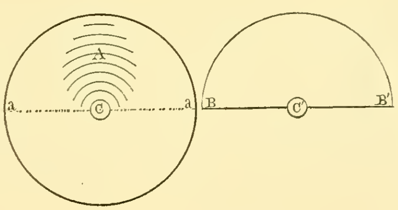

of the dials are symmetrically intersecting spirals, is preferable. The index in this case is the blank semicircle BB', and its initial position on the dial is shown by the dotted line *aa*. C' is a small circle used for attachment.

Remarks similar to those of § 2 may be made with reference to the measurement of angles greater than 90°. In this case the counting edges of the index BB' are to be made the bounding radii of a sector and the spiral loci of *A* are to be

* The convenience of a ruling pen for such purposes was pointed out to me by Prof. F. H. Bigelow.

prolonged and rotated in opposite directions until their initial radii subtend the same angle as the sector of the index. The limiting case is again reached when the sector vanishes. The reading is here made from the center outward. If however in figure 1, the area *AEA′* had been filled with concentric circles and the area *AD′A′* left blank, the readings for both positive and negative angles would be made from the circumference inward. It is in the direction of further progress to obtain two such readings simultaneously.

4. *Repetition.*—In figure 3 the spirals terminating the ends of the partial circles on the dial are no longer symmetric, but

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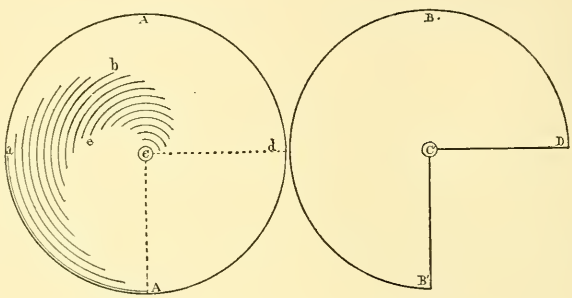

are so circumstanced that one spiral may be brought into coincidence with the other by rotating it about the center a stated number of degrees. In such a case if the reading of positive angles be from without inward, the reading of negative angles will be from the center outward. It is clear also that angles of any magnitude may be read by proportionately increasing the size of the dial. The same result may, however, be reached within a reasonably small area of dial by methods of repetition such as the following; and these methods are particularly appropriate for the present purposes, because they incidentally afford the means for reducing the error of reading to the smallest possible value. § 6.

In figure 3 let the spirals be 90° apart, and let each admit of a direct reading (as above shown) between 0° and 180°. Conformably with this arrangement let the index *BB′* be a full circle with a right-angled sector *B′C′D* cut out of it. The initial position of the sector on the dial is indicated by the dotted lines *A′Cd*. If therefore the index rotates on the dial counter-clockwise, the measurement is made in virtue of the spiral *Cba*, and the partial circles will gradually *emerge* from behind the index until with 180°, the ends of all are visible. On further rotation the circles beginning with the innermost will commence to *recede* behind the second limb of the index, until with 360° the last has disappeared, and the initial position of dial and index recurs. The procedure is therefore capable of indefinite repetition, all the readings being made from the center outward.

Similar remarks apply for clockwise rotation of the index on the dial, except that the reading now begins at the circumference.

6. *Eccentricity.*—Retaining the same dial, if an index of smaller angular opening were used, there would often be two readings simultaneously in view in different parts of the field, at an angular distance apart equal to the given angle of the open sector. Thus with a single sector of 60° there are two readings between 150° and 180° of the forward radius corresponding to 90° to 120° of the rearward radius, supposing the index to be twisted counter-clockwise. Repetition is necessarily interrupted for measurement must cease at 330° of the forward radius of the sector. The latter condition could easily be met by choosing a larger dial so that the spirals would sweep over an angle greater than 180°. But as increased size is not a desideratum, the end in view may be gained more satisfactorily by cutting two diametrically opposite sectors of 60° each, out of the index. In such a case there are always two readings in the field.

Leaving the ulterior advantages gained by this method to be considered in the next paragraph, I will here point out that the result obtained as a mean of the two simultaneous readings in question is essentially more nearly correct. For let the rotation of the index be as above: then at the advance radius of the sector, the reading will generally fall short of the true angle, seeing that the ends of the partial circles here emerge from behind the index; whereas at the other radius of the sector the reading will generally be in excess of the true angle, for here the partial circles recede behind the index. In all cases however *the latter reading will be as much in excess of the true angle as the former falls short of it*, and therefore the mean value will be free from systematic error (eccentricity as it may be called) to less than one-half of the angular value of the distance between two consecutive partial circles—in the most unfavorable case. It is thus that two readings virtually double the efficient size of the dial caet. par., or double the number of concentric circles.

Furthermore, if by reason of close graduation, or of indistinct demarcation, or the like, the projecting ends of a number of consecutive partial circles escape detection in case of a spinning dial, it is clear that the first of the visible circles will be symmetrically located on each side of the true angle. Even if certain of the circles on either side of the true angle are too faint to be visible, therefore, the error of a double reading need be no larger than has been pointed out above. For instance in a dial in which consecutive radial millimeters were each marked by a partial circle of 60°, in such a way that a millimeter corresponded to a degree of arc, the reading was made by an index containing open sectors of 30°. The following results were obtained :

First reading, a	17	27	37	47	58	68, etc., millimeters.
Second reading, $a+30°$	51	62	72	82	92	101, etc., millimeters.
Difference	34	35	35	35	34	33. etc., millimeters.
$\frac{1}{2}(2a+30)-15°$	19·0°	29 0°	39·5°	49·5°	60·0°	69·5°, etc.
True angle	20°	30°	40°	50°	60°	70°

In these cases the attempt was made to increase the angle in successive steps of 10° each by special adjustment, as shown in the last line. The angle found as the mean of the two readings does not differ from the true angle by more than a degree, part of which is referable to the preliminary adjustment as well as to actual irregularities of graduation. In spite of this good result it is seen that the differences (third row) of corresponding readings (first and second row) is in excess of the angle of the index (30°) by 3° to 5°. This shows, therefore, that when the system is spinning around, the projecting ends of about two circles on each side of the circle corresponding to the true angle, are so short as to escape detection.

6. *Multiple spirals.*—Although the preceding paragraph indicates that faintness of graduation does not necessarily vitiate the method, it is desirable to have the marks come out as early as possible. This end, together with all the suggestions of the preceding paragraph may be promoted at once, and even in a relatively *small* dial as follows : A smaller angular distance between the paired spirals is chosen and the advantages of continuous double reading and of repetition are secured by employing more than two open sectors on the index. In this case if the design is judiciously constructed as many systems of paired spirals may be traced out on the dial as there are open sectors on the index, the whole representing a set of equidistant whorls. If therefore when both dial and index are spinning around together, the protruding end of one of the partial circles which just escapes detection in the above designs is a, visibility has now been increased to the extent that a/n just escapes detection, where n is the number of sectors.

A good arrangement of this kind is shown in figure 4, in which the dial AA' contains three sets of paired spirals subtending arcs of 60° each, with a blank space of 60° between consecutive pairs. The index is shown at BB' and has three equidistant sectors of 30° each cut out of it, and its initial position on the dial AA' is indicated by dotted lines. All the spirals are produced until 120° of arc are swept over, and if a radial millimeter is to correspond to a degree, the effective

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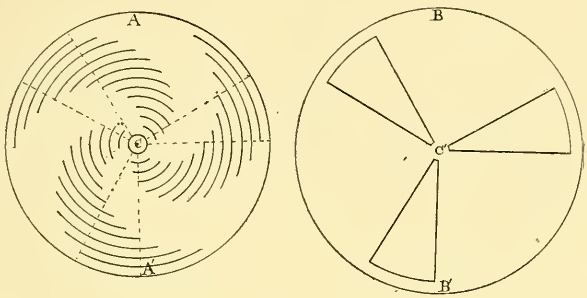

radius of the dial will be 120 millimeters added to the radius of the small internal circle of attachment, C. For practical reasons the diameter may be made somewhat larger than this in order that the removed sectors may appear as windows in the index plate.

Obviously all the sectors move over corresponding spirals in like manner, and hence the visibility of the protruding end of any partial circle is not only increased threefold but errors in drawing are reduced in value, no matter how fast the system may spin around its center. Again there are always two readings in view, one for the emergence of the front edge of the spiral band and the other for the recession of the rear edge. These angles (a) are 30° apart and from their mean value $\frac{1}{2}(a+(a+30))-15$, the eccentric error mentioned is the preceding paragraph has been eliminated. Other systems are easily devised.

7. *Measurement of activity.*—The present method of goniometry is peculiarly applicable to problems in which the quantity to be measured fluctuates about a mean value to a degree greater than the error of reading discussed above. Such is usually the case with the rate at which a motor works. In approaching this problem from the mechanical side, physicists have usually preferred to find the angular speed at which a measurable twist on the shaft is maintained, chiefly perhaps because the method is capable of great refinement, as for instance in Rowland's* researches on the mechanical equivalent of heat.

* Rowland: Proc. Am. Acad., xv, p. 157, 1880.

This is the method to which the above simple designs are tributary, and the diagram of an apparatus for measuring the work put out by a shaft in a given time is given in figure 5, in longitudinal section.

Let *ab* be a long rod whose torsion coefficient is of known suitable magnitude, and suppose the end *a* to be put in connection with the shaft of the motor and the end *b* with a tachometer or revolution counter, and let *cc* be the journals in which this rod revolves. The rod is concentrically surrounded throughout the greater part of its length by the stiff tube *ee*, one end of which may be rigidly joined to the rod near *a* by a set screw. The other end of the tube with the attached dial *dd* is capable of revolving around the rod in virtue of a journal, unless resisted by the set screw in question. Supposing the latter fixed and the shaft revolving, twist may be imparted to the rod by means of the friction pulley *p*, and its amount measured by the index *nn* fixed to the rod immediately in front of the dial *dd*, in the manner shown in the above paragraphs. *S* is the stationary scale with numerals to facilitate the reading, and it is attached to the base *B* together with the journals *c*, *c*. When no friction is applied at *p* the rod *ab* and tube *ee* spin around together in such a way that no angular deviation between index *nn* and dial *dd* is registered. When a suitable frictional resistance is applied, the index will be dis-

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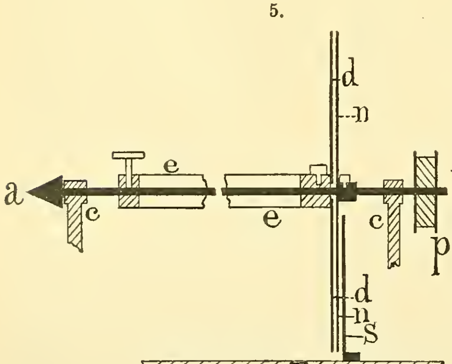

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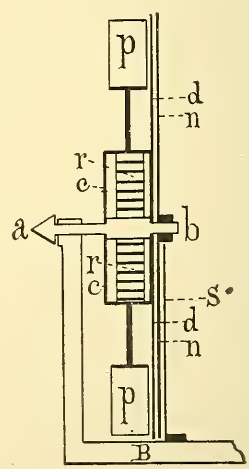


placed in angle relative to the dial, by an amount proportional to the frictional resistance. The efficient part of the torsion rod is clearly the length within the tube, and if by a preliminary calibration the intensity of the torsion couple per degree of displacement of index and dial is known, the moment of torsion for any observed displacement is given at once. This quantity multiplied by the angular speed is the activity sought. Thus if the number of revolutions is n per minute, the angular speed will be $\omega = 2\pi n/60$; and if the moment of torsion m be expressed in kilogram-meters

$$\omega m / 75$$

is the activity required in horse powers.

The calibration may be made once for all by twisting the rod ab in place by a known couple, and noting the corresponding deflection on the dial. Radial holes may be left in the pulley p for this purpose, in which spokes of known length are inserted. From the hookshaped ends of these, given weights are suspended so that if m' be the moment of the couple per degree of deflection at the dial and δ any observed deflection, $m = m' \delta$. To fix the ideas suppose a steel rod $0{\cdot}4^{cm}$ in diameter and 50^{cm} in efficient length were chosen: then one degree of deflection at 1000 revolutions per minute would correspond to about ·01 horse power.

8. *Tachometer.*—The construction of the speed indicator is easily inferred from the preceding paragraph. As shown by the diagram figure 6, ab is a short rod capable of revolving in a journal fixed to the bed plate B. The end a is suitably attached to the shaft. Near its middle parts the rod is doubly shouldered and surrounded by a cylindrical box or drum cc, which would be free to revolve around the rod but for a watch spring rr, one end of which is fastened to the rod ab and the other to the circumference of the drum cc. In this case the dial dd is attached to the front face of the drum, the index nn to the end b of the rod, and a scale S facilitates the reading as before. The outside of the box cc carries two vanes or propeller blades pp by which the rotation of the box is resisted. Suppose these removed or placed in the plane of rotation, no deviation would be indicated between the index and the dial however fast the system rotates. If however they are fixed in place (as in the figure), the angular deviation registered by the system of dial and index will in a general way be proportional to the square of the speed.

The instrument is capable of considerable adjustment so that it would appear to be adapted for measuring large ranges of speed. Thus one might alter the obliquity of the propeller blades, pp, relative to the plane of rotation, or by a suitable adjustment successively tighten or twist the watch spring rr. Consecutive notches would then correspond to given intervals of speed. The definite graduation would have to be made empirically, though it is seen that a subquadratic spiral is more in keeping with the purposes of this apparatus than the simple spiral discussed above.

9. *Summary.*—For the measurement of activity by the above simple methods one would therefore couple the instrument's figures 5 and 6 in series to the same shaft and read both dials. It is conceivable however that the propeller blades *pp* of figure 6 may replace the friction pulley *p* of figure 5, particularly if provision is made for rotating the propeller in a liquid instead of in air. Suppose therefore that the dial and index of figure 6 has been standardized both with reference to the twist corresponding to one in degree of deflection and to the speed corresponding to the deflections. Then in an instrument of the type of figure 6, *a single reading would* at once *give the activity of the motor.* This is the final outcome of the method sketched in the above paragraphs.

Washington, D. C., May, 1894.

ART. II.—*On the occurrence of a large area of Nepheline Syenite in the Township of Dungannon, Ontario;* by FRANK D. ADAMS.

WHILE engaged during the past summer in making a geological reconnaissance of a portion of Eastern Ontario previous to a detailed mapping of the district for the Geological Survey of Canada, a large area of nepheline syenite was unexpectedly discovered.

The district in question lies between Lake Ontario and the Ottawa River, near the southern edge of the Archean protaxis, in the counties of Victoria, Peterborough and Hastings, in the province of Ontario, and comprises 3500 square miles, being sheet number 118 of the series of geological maps of Quebec and Ontario now in course of preparation by the Geological Survey of Canada. This tract of country which up to the present time has been, geologically speaking, a *terra incognita* was found to be occupied almost exclusively by rocks of the Laurentian system. The Grenville series with numerous heavy bands of crystalline limestone is extensively developed in the southern portion of the district, while to the north great tracts are underlain by what is believed to be the fundamental gneiss. In the extreme southeast corner of the district certain rocks occur which have been referred by Mr. Vennor to the Hastings Series.

The stratigraphical relations of these several series in this district have not as yet been determined, but will it is hoped, be worked out as the detailed mapping is proceeded with.*

* See "Preliminary Report on the Geology of a portion of Central Ontario." Ann. Rep. of the Geological Survey of Canada, 1891-92-93. Part J.

It is in the southeastern portion of this district in the townships of Dungannon and Faraday, in the county of Hastings that the nepheline syenite was discovered.

The mass is crossed by the well known Hastings Road, near the village of Bancroft, and is—roughly speaking — about eighty-five miles in a straight line northwest of Kingston, Ontario.

The area is a large one but its exact limits have not as yet been determined. It has however been traced in an easterly direction from a point in the township of Faraday, some distance west of Bancroft, to the York River on lots 12 and 13 or range XI of the township of Dungannon, a distance in a straight line of over seven miles. It also has a very considerable width.

As occurrences of nepheline syenite are rare, and this is the first one which has been found in the Laurentian system of Canada, and as, moreover, the rock presents a number of striking petrographical peculiarities, it has been thought that a preliminary notice of it at this time would be of interest.

Mode of occurrence and macroscopical character. — The mass occurs in the Laurentian and is flanked on the south, along a considerable part of its course by crystalline limestone. It is in many places intimately associated with a fine grained reddish biotite granite resembling aplite in appearance and which is apparently intrusive. The nepheline syenite is frequently massive in character, but usually possesses a somewhat streaked appearance, in places developing into a distinct foliation or gneissic structure, coinciding with that of the associated rocks. On the weathered surface little cavities are occasionally observed which are probably miarolitic druses. It is usually rather coarse grained, but in places becomes very coarse, as at the York River above mentioned, where nepheline individuals two and a half feet across were observed, with feldspar and mica crystals of corresponding size, while individuals one foot in diameter are numerous. On the weathered surface the nepheline and plagioclase which compose the great bulk of the rock can be readily distinguished, the former apparently dissolving away under the influence of the weather and presenting smoothly rounded surfaces of a gray color, like those so frequently seen in coarsely crystalline limestone. From these surfaces the plagioclase stands out in white chalk like grains or masses, while the other essential constituents of the rock are also readily recognized.

Microscopical character.—Under the microscope the essential constituents of the rock are seen to be nepheline and plagioclase, together with either a brown mica or a dark green hornblende. As accessory constituents, seldom absent and in some cases present in large amount, are scapolite and calcite, and as less important and less abundant accessory constituents are garnet, zircon, sodalite, magnetite, pyrite and apatite. These latter, with the exception of garnet, always occur in very subordinate amount. Two or three other minerals occur in small amount in individual slides, or can be seen on the weathered surface of certain specimens, as these however could not be determined with certainty, without prolonged investigation their true nature is as yet doubtful.

The rock is usually very fresh and has a true hypidiomorphic granular structure. Evidences of pressure are in most cases entirely wanting. In a few slides however slight strain shadows and bending of twin lines are to be observed, and in one specimen distinct cataclastic structure was seen.

Nepheline.—This is by far the most abundant of all the constituents of the rock. It always forms the greater part of the rock and in many places, over considerable areas, the rock is composed of this mineral associated with a little mica or hornblende. The mineral is clear and colorless and is usually free from inclusions. It has a low double refraction and parallel extinction. On basal sections it is seen to be uniaxial and negative. It is easily etched by hydrochloric acid in the thin sections and can then be stained with fuchsine. In a few cases it was observed to be altered to muscovite. In hand specimens the mineral is seen to possess a luster which is vitreous rather than oily, so that it has been referred to as nepheline rather than as eleolite. An analysis of it is given by Dr. B. J. Harrington in the accompanying paper.

Plagioclase.—The rock contains no primary orthoclase, but feldspar though seldom very abundant is in most cases present, often in considerable amount. It is twinned polysynthetically, the bands being usually narrow and often indistinct. When cut at right angles to an optic axis it is seen to be biaxial. Its specific gravity, determined on two fragments taken from the very coarse grained variety of the rock at the York River, is 2·6207 and 2·625, while in a separation of the constituents of a specimen of the rock from lot 25 of range XIV of Dungannon, it was found to have a specific gravity of not over 2·623. The extinction on either side of the twinning line, measured on a cleavage fragment from the York River was $2\frac{1}{2}°$. These facts prove it to be an albite, with probably a very small percentage of lime.

Mica.—This constitutes the iron-magnesia constituent of the rock in three out of the five localities from which specimens were examined. In these cases it occurs alone, while in the other localities where hornblende is present the mica is absent. It is nearly black when seen in the hand specimens and in the sections shows a very strong pleochroism, from pale yellow to a very deep brown. In basal sections it is seen to be distinctly biaxial but the axial angle is very small. It is usually quite subordinate in amount.

Hornblende.—Like the mica this constituent is usually present in comparatively small amount. It is always green in color and frequently presents more or less perfect crystalline outlines, with faces of the prism, clinopinacoid and domes. The prismatic cleavages at angles of about 124° are well seen. Two varieties have been observed. One of these from near the York River has a large axial angle and shows a pleochroism in tints varying from deep green to pale yellow, the absorption being $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. Before the blow-pipe it fuses with intumescence to a black glass, giving at the same time a strong soda flame. This variety probably contains a considerable quantity of soda, but approaches common hornblende in composition. The second variety, which occurs in an exposure about two miles east of the village of Bancroft, has a much stronger pleochroism in tints varying from very deep bluish-green to a yellowish-green and has a small axial angle and a high extinction. Hornblende is not common in nepheline syenite and the only occurrence in which I have seen this particular variety is that which forms part of the Montreal mountain. Here what appears to be exactly the same hornblende occurs intergrown with augite. It has a very high specific gravity and is probably rich in soda and allied to arfvedsonite. A chemical examination of this hornblende will be made by Dr. Harrington.

Scapolite.—This mineral is present in about one-half of the slides and occurs in large clear colorless grains. It has the appearance of an original constituent. Basal sections present the usual double set of cleavages crossing at right angles while sections in the prismatic zone show a single set of cleavages with extinction parallel to them. In convergent light it is seen to be uniaxial and negative. The double refraction is much stronger than in the case of nepheline, the interference colors being tints of red, blue and yellow. The two minerals are therefore easily distinguished. As the occurrence of scapolite in such a rock is very unusual and in order to make sure that the mineral was not cancrinite, a thin section was treated with concentrated hydrochloric acid at first in the cold and subsequently with hot acid. The nepheline was strongly attacked and when the slide was subsequently treated with fuchsine became deeply colored. The scapolite however remained quite unaffected, even after the acid had been actually boiled upon the section. In another section also in which, under the action of the weather, the nepheline was quite decomposed the scapolite was found to be still quite fresh. The uniaxial and negative character of the mineral together with the position of the cleavages, the strong double refraction, the parallel extinction and the deportment with acid, proves that the mineral is really scapolite.

Calcite.—The presence of this mineral in such a rock, as well as its mode of occurrence is very remarkable. The rock is quite fresh so that the calcite is not an ordinary decomposition product. Its mode of occurrence is that of an original constituent. It is found in well defined, more or less rounded, individuals, often of large size, occurring with, and often in, the other constituents of the rock. It has been observed completely enclosed by hornblende, nepheline, plagioclase, and garnet, the boundaries of the several minerals being quite sharp and the enclosing mineral being quite unaltered and normal in character. It shows the usual rhombohedral cleavages, is frequently twinned and sometimes has a fairly good crystalline form. It occurs in almost every slide, though usually in comparatively small amount. Individuals of considerable size are found in the very coarse grained variety of the rock at the York River. The origin of this calcite is a point which it is difficult to determine, although somewhat similar occurrences have been described in various other igneous rocks.* It cannot be a decomposition product in the ordinary sense of the term. Its mode of occurrence does not seem to indicate that it fills miarolitic cavities as Rosenbusch has supposed similar occurrences in certain granites to do. Had it been derived from the neighboring limestones some evidence of corrosion or alteration might be expected from the action of the very acid magma. Further study in the field may throw additional light on the question.

Garnet.—This is of a pale brownish or reddish-brown color and is always quite isotropic. It occasionally has a good crystalline form but usually occurs in more or less irregular shaped grains. It is present in most slides but seldom in large quantity.

Zircon.—Occurs in many slides and occasionally in the coarser variety of the rock in crystals of considerable size.

Sodalite.—At a number of places sodalite was observed in small grains or strings, scattered through the rock and it appears in one or two of the slides.

In certain parts of the area however it occurs in large masses.

* A. E. Törnebohm, "Om kalcithalt i graniter." Geol. Fören. i Stockholm Förh., 1882, 140. G. W. Hawes, "Mineralogy and Lithology of New Hampshire," p. 207. See, also, F. D. Adams, "On some Granites from British Columbia and the adjacent parts of Alaska and the Yukon District." Canadian Record of Science, Sept., 1891.

Good specimens have been obtained from lot 29 of range XIII and elsewhere, but on lot 25 of range XIV of Dungannon it was found quite abundantly in what appeared to be veins and irregular shaped lumps. From some of these, masses of pure sodalite 10 by 10 by 4 inches in size were obtained, while considerably larger masses could probably be secured by blasting. It is probable that no other locality hitherto discovered in America affords such large masses of this mineral, with the possible exception of the nepheline syenite of the Ice River in British Columbia. The sodalite is bright blue in color and is often associated with strings of iron ore and traversed by little reticulating cracks filled with a reddish mineral which presents every appearance of a secondary origin and which Dr. Harrington finds to be orthoclase feldspar. It is believed that the sodalite may occur in sufficiently large masses to enable it to be profitably extracted and employed for ornamental purposes.

Summary.—The following points in connection with the composition of this nepheline syenite from Dungannon seem to be especially worthy of notice. Nepheline is always very abundant and in many large exposures the rock is an almost pure nepheline rock, consisting of nepheline with a little hornblende or mica. This variety of the rock is really an Ijolite* rather than a nepheline syenite. No orthoclase has been discovered in the rock, although twenty-five thin sections have been studied and some of them etched and stained. The constituents of two specimens were also separated out by means of Thoulet's solution. Its place is taken by an acid plagioclase, which in those cases where it has been examined has proved to be albite.

If the distinctive character of the variety of nepheline syenite named Litchfieldite by Bayley,† be the replacement of the orthoclase by albite, this rock is a more typical Litchfieldite than that from the original locality. The propriety of defining nepheline syenite as a rock composed essentially of nepheline and an alkali feldspar instead of one composed of nepheline and orthoclase is also rendered evident, as otherwise it would be necessary to classify this rock as a theralite from typical specimens of which it would differ greatly in composition. Like the Litchfield rock also this Dungannon rock contains neither augite nor sphene, but unlike it often holds scapolite and calcite.

Some years ago Prof. A. P. Coleman when investigating the petrographical character of the bowlders of the drift in the

* W. Ramsay and H. Berghell, "Das Gestein vom Iiwaara in Finnland." Geol. Fören. i Stockholm Förh., 1891, 304.

† W. S. Bayley, "Eleolite-Syenite of Litchfield, Maine, etc. Bull. of the Geol. Soc. of America, 1892, 231.

vicinity of Cobourg on the north shore of Lake Ontario, found among these bowlders a number composed of nepheline syenite. The rock composing these bowlders strongly resembles in many ways that described in the present paper. Orthoclase and microcline although present are exceeded in amount by the plagioclase. Eleolite or nepheline usually forms from one-quarter to one-half of the rock, while the rock is sometimes a nearly pure eleolite. "Biotite and hornblende much outweigh all the varieties of augite." Calcite grains were found in about one-third of the slides, sometimes "in the midst of the eleolite where their existence is hard to account for. What appears to be a scapolite occupies a similar position in four specimens" and a flesh red garnet also occurs in a few places.*

Cobourg lies a little to the west of south from the townships of Dungannon and Faraday, and it is highly probable, in view of the marked resemblances between these bowlders described by Prof. Coleman and the nepheline syenite occurring in these townships that the bowlders have been derived from this vicinity. The presence of orthoclase and microcline in many of the bowlders would indicate that all of them at least had not been derived from the actual area described in the present paper, but there is every reason to believe, from the reported occurrence of sodalite at other points in this district, that other areas of similar nepheline syenite exist here, and some of these have probably furnished the bowlders in question.

Petrographical Laboratory, McGill College, Montreal.

Art. III.—*On Nepheline, Sodalite and Orthoclase from the Nepheline Syenite of Dungannon, Hastings County, Ontario;* by B. J. Harrington.

In a recent report published by the Geological Survey of Canada and also in the preceding paper, Dr. F. D. Adams has called attention to a remarkable mass of nepheline syenite discovered by him in the township of Dungannon and Faraday, Ontario. The rock is in places exceedingly coarse in texture and individuals of nepheline, as much as two and a half feet in diameter have been observed. Dr. Adams has kindly placed a specimen of this nepheline in my hands for examination. It is from near the bank of the York River in Dungannon and has been found to have the following percentage composition:

* Trans. of the Royal Society of Canada, vol. viii, 1890.

Silica	43·51
Alumina	33·78
Ferric oxide	·15
Lime	·16
Magnesia	tr.
Potash	5·40
Soda	16·94
Loss on ignition	·40
	100·34

Hardness nearly 6. Specific gravity at 17° C. = 2·625 as determined with the bottle and 2·618 as determined by suspension with a hair. The specimen analyzed was white, subvitreous or slightly oily in luster, translucent, and sub-conchoidal to uneven in fracture. Before the blowpipe it fused quietly at about 3·5 to a colorless, slightly vesicular glass. It is described as nepheline rather than elæolite because of the luster being only slightly oily. The two names also seem unnecessary.

At a number of points in the region in question Dr. Adams found the mineral sodalite in the form of veins, streaks and irregular masses in the nepheline syenite. The masses were of various sizes, the largest observed being 10×10×4 inches approximately. Specimens from lot 25 range XIV of Dungannon, which he has given me for analysis are weathered rusty superficially, but upon fresh fracture are of a fine smalt-blue color. They are traversed by a few little veins of a white and reddish mineral which proves to be orthoclase. The sodalite also contains scales of a dark brown to black mica. Some of the pieces were compact and microscopically showed no cleavage but one which was selected for examination showed distinct dodecahedral cleavage and vitreous luster. Its hardness was about 5·5 and its specific gravity at 16·5° C. was 2·295. On analysis the following results were obtained:

Silica	36·58
Alumina	31·05
Ferrous oxide	·20
Soda	24·81
Potash	·79
Chlorine	6·88
Sulphuric anhydride	·12
Water	·27
Insoluble	·80
	101·50
Deducting O = Cl	1·55
	99·95

The iron present was proved to be in the ferrous condition. On decomposing the mineral with nitric acid of 1·20 specific gravity, a residue was invariably left which did not consist of undecomposed sodalite. At first it was supposed to be silica which had separated from the sodalite, but on boiling with strong solution of sodium carbonate only a small proportion of it dissolved. This was included with the silica and the remainder, which contained a few minute grains of magnetite but which was not further investigated, was put down as "insoluble." What is given as water is the result of a direct determination, made by heating the powdered mineral in a combustion tube in a current of dry air and collecting the water in a chloride-of-calcium tube. A long piece of combustion tube was employed, so that if any sodium chloride were volatilized it would be condensed before reaching the chloride of calcium. The end of the combustion tube next to the latter was however found to be free from chlorides after the operation. Heated in a platinum crucible for half an hour at a low red heat, the mineral (after drying at 100° C.), lost 0·34 per cent of its weight. With increased temperature the mineral continued to loss weight slowly, and after heating to bright redness for about half an hour the total loss was 0·46 per cent. The sides and lid of the crucible were however coated with a film of sodium chloride. Heated in a closed tube the sodalite became perfectly white, while before the blowpipe it fused easily, with intumescence to a colorless glass.

As stated above the sodalite is in places traversed by little veins of a white and reddish mineral which proves upon analysis to be orthoclase. It is mostly dull but in places shows cleavage surfaces with a pearly luster. The reddish portions probably owe their color to the decomposition of iron pyrites, occasional grains of which still remain. The specific gravity at 18° C. was found to be 2·555 and analysis gave the following percentage composition :

Silica	63·00
Alumina	18·93
Ferric oxide	·59
Lime	·08
Magnesia	·09
Potash	12·08
Soda	3·67
Loss on ignition	1·00
	99·44

According to Dr. Adams the feldspar of the nepheline syenite in which the sodalite occurs is entirely plagioclase, and the occurrence of orthoclase as a secondary mineral in the sodalite is of special interest.

Chemical and Mineralogical Laboratory, McGill College, Montreal.

Art. IV.—*A new Design for large Spectroscope Slits*; by F. L. O. Wadsworth. With Plate I.

Of the various forms of double motion spectroscope slits which have been designed, the two forms in most common use are the parallel ruler form, as fitted to most German instruments, and that form in which the jaws slide in guides and are moved simultaneously in opposite directions by a right and left hand screw. The first form is very convenient but requires very careful work in order to secure accurate results and is moreover apt to stick if the working parts are not kept clean. Moreover the jaws must be made somewhat longer than the available width of slit and the plate upon which they are mounted must be still larger to admit of room for mounting the levers, etc., etc., so that the whole arrangement becomes somewhat bulky in the case of a large slit. Another difficulty lies in determining the exact width of slit from the reading of the screw which is used to open it. The second form mentioned avoids all these difficulties except the last, but introduces others of a different character. As the screw is necessarily at one side of the jaw a twisting strain is thrown on the latter by the friction of the opposite guide tending to make the slit of unequal width at the two ends, and as the motion of the jaws is positive in both opening and closing there is danger of injuring the edges of the slit by screwing them too tightly together. For the same reason and also because there is no spring to take up the lost motion in the two screws, the zero point of the screw reading is uncertain and it is therefore difficult to determine the exact width of the slit from the reading of the screw. Prof. Langley had previously designed on this plan a very large slit with jaws 5^{cm} in length for his bolometric work in the infra red solar spectrum, in which the above difficulties were reduced to a minimum, by the accuracy and care with which the mechanical work was done, but which nevertheless showed after some usage a decided bluntness and want of parallelism of the edges.

As the size of the slit increases these difficulties of course grow more serious. When it became necessary therefore to provide a new and still larger slit having jaws with 10^{cm} clear opening, I proposed a new design which I had previously used with advantage in a double motion micrometer, in which the thrust of the screw on both jaws is central. As it appears to be new and as it possesses several advantages over either of the two forms previously noted a brief description of it may be of interest. In fig. 1 is shown a rear view of the slit the back plate being removed to show the mechanism clearly. The two slit jaws slide between guides screwed to the front of the slit plate and each has a lug extending through this plate and projecting about 1^{cm} behind it. To the right hand jaw is screwed a] shaped bar *d*, the side arms of which pass around the ends of the slit and the center of which is opposite the lug on the left hand jaw. This lug is tapped to receive a screw on which are two threaded portions, one engaging with the thread in the lug and the other of just one-half the pitch of the first engaging in a nut *h* which is screwed to the slit plate. When therefore the screw is turned, say to the right, the jaws are separated by an amount equal to the motion of the point of the screw with reference to the threaded lug, say a distance x, while the whole jaw system is drawn to the right by the action of the fixed nut *h* a distance equal to $\frac{1}{2}x$ The center of the slit therefore remains fixed, the jaws opening out from it. A spring bearing against the lug on the left hand jaw provides for the return motion and takes up all back lash in the screw. The graduated head gives by its motion over the graduated drum the whole number of turns and fractions of a turn enabling the width of slit to be determined at a glance. It will be noted further that the accuracy of separation depends only on the accuracy of the screw which works in the slit lug, the screw at *h* serving only to keep the jaws centered. As the motion is positive in one direction only (on opening), as in the case of a single motion slit, there is no danger of injuring the edges of the slit by turning the screw too far.

Further and perhaps most important of all in a slit of this size, the thrust of the screw on both jaws is central and there is consequently no tendency to twist the jaws in their guides. The new slit has been constructed by Grunow, who has as usual admirably executed the work. A front view of the new slit is given in fig. 2 and to show its compactness and also its great size as compared with the usual spectroscope slits, two of these each having a clear opening of 2^{cm} and representing the two types already described are shown at its side.

Astro-Physical Laboratory, Smithsonian Institution,
Washington, D. C., March, 1894.

Chas. D. Walcott.

Fig. 2.

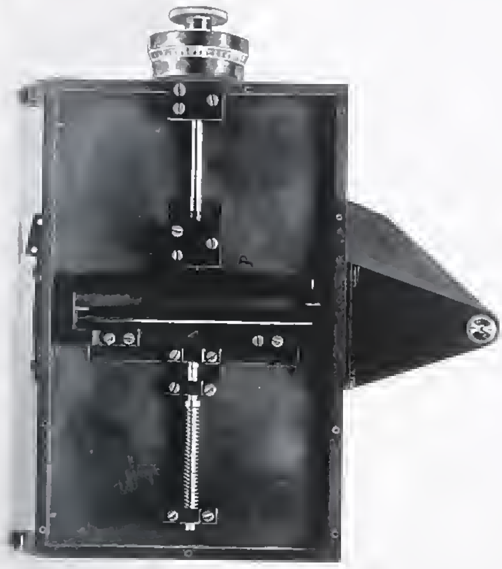


Fig. 1.

ART. V.—*Tertiary Changes in the Drainage of Southwestern Virginia;** by MARIUS R. CAMPBELL.

IT has been recognized for a long time that isostatic movements have been active in the Appalachian region throughout post-Paleozoic time. Their exact character has never been worked out, nor has their influence on the physiography and drainage of the region been fully appreciated. Certain phenomena have, by a few workers, been attributed to movements of this kind but in such cases they have been referred to broad epeirogenic rather than local orogenic movements. The writer is fully convinced that the local movements have been more important in shaping both the physiography and the drainage of the region than the broader and more general movements and offers the following observations concerning a reversal of drainage, in support of the statement.

Along the northwestern border of the Appalachian valley, from Cumberland gap northeast, there is a great synclinal trough of Coal Measures, bounded on the northwest by Pine mountain and on the southeast by Stone mountain or the Cumberland escarpment. The edges of the trough are formed by the Carboniferous conglomerate, a hard and resisting stratum which has been chiefly instrumental in turning the streams to subsequent courses. The change in drainage, here described, occurred within this syncline, about 70 miles northeast of Cumberland gap.

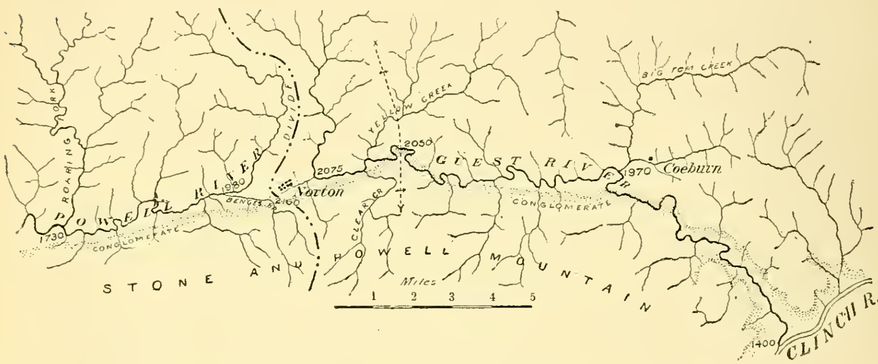
The region in question is drained by Guest and Powell rivers which rise in the Black mountains and flow south in parallel courses to Norton, where they encounter the conglomerate rising on the southern rim of the syncline. To avoid this, Powell river turns west, whereas Guest river turns east. They are but a mile apart at these bends and separated by a very low divide. Powell river flows westward within the synclinal rim to Big Stone gap which it has carved through the conglomerate barrier; through this gateway it enters the head of a broad, open valley eroded in the great Silurian limestones which it follows until it joins the Clinch river 15 miles north of Clinton, Tenn. Guest river turns eastward and flows around the end of Powell mountain, joining the Clinch river a few miles below St. Paul, Va.

In the basin of Powell River (fig. 1) the drainage appears normal, showing that mature adjustment to structural features which is found only in systems of great antiquity. The changes occurring in the past have been so remote that all traces are obliterated, both in the physiography and in the

* Published by permission of the Director of the U. S. Geological Survey.

arrangement of the drainage lines. Guest river, from the Norton divide to Coeburn, exhibits unmistakable evidence of a reversal of its course. All the tributaries, in this interval, turn westward to join the river which flows due east. They thus form a very acute angle where they unite. The present position of these tributaries is found to bear no particular relation to the geologic structure, but to be due to some condition affecting the stream alone.

1.



The tributaries which enter the river above the mouth of Tom creek from the south flow, throughout their upper courses, in gorges cut in the heavy conglomerate of Powell mountain and much of their irregularity is due to the way in which they cross its various hard beds. Before reaching the river they emerge from the mountain and flow, for perhaps a quarter of a mile, across the level surface of a shale valley. Their normal course in this plain would be northeast, but in every case they turn northwest. Below Coeburn there are several small branches which in general appear to follow the same law, but their courses were determined by the geologic structure and hence cannot be used as evidence of reversal.

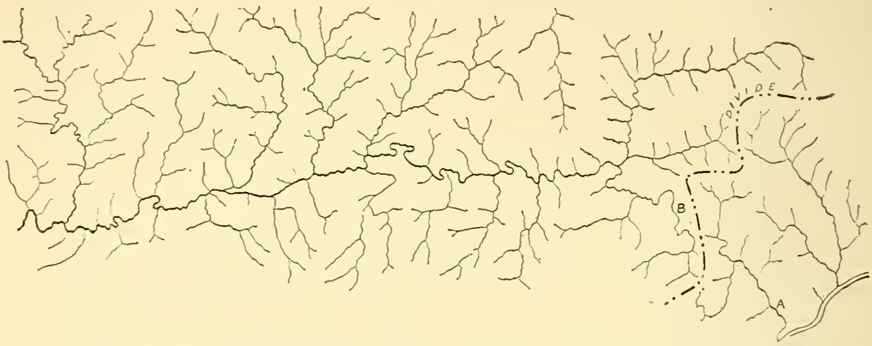
On the north side of the river there are three main branches which show this westward deflection even more strikingly than the southern tributaries. Big Tom creek, joining the river near Coeburn, has a decidedly westward course not in harmony with the present conditions. Geologic structure did not determine this bend in the creek, since the rocks are approximately horizontal except in the immediate vicinity of the mountain where there is a gentle northerly dip away from the anticlinal axis. Yellow creek also affords a good example of this westward deflection, for in persevering in its course the stream has been obliged to cut diagonally across a small anticline (x y, fig. 1) although the easier course would have been to join the river east of this fold. This cross anticline, pitching rapidly northward, has arched the strata in such a manner that the conglomerate, at this point, extends much beyond its general line of outcrop. Guest river originally flowed across this projecting point without coming in contact with the hard stratum, but in later ages it has removed the softer rocks and reached the main conglomerate. The stream has slowly migrated down the slope of the hard bed, forming a great northerly bend at the point where the axis crosses the river. No such formidable barrier intersects the course of Yellow creek, but in the measures above the conglomerate there are many hard sandstones which would doubtless have a tendency to shift the course of the stream.

The acute angle made by Guest river itself at Norton is equally remarkable and cannot be explained by the present course of the river, since there is nothing to prevent this stream from avoiding Norton altogether and joining the river near the mouth of Yellow creek. If Guest river were a mature stream this would certainly have been accomplished and Yellow creek also would have been shifted to the eastward in accordance with the present conditions. But the system is not adjusted to the surrounding conditions; it has the marks of immaturity, of adjustment to conditions which no longer exist and which were radically different from the present.

The divide between Powell and Guest rivers is no more conspicuous than that between any two tributaries of the same stream; but being quite narrow it has the appearance of exceeding them in altitude. The country is essentially a deeply dissected plateau with the water partings standing at or near the original surface. Along the northern side of Stone and Powell mountains there is a valley due to the combined effect of a line of outcrop of soft shale and great disturbance of the strata in the uprising of the Powell Valley anticline. This valley has been accentuated by the work of the rivers under consideration, for they have naturally availed themselves of the most favorable location and have carved deep channels throughout most of its extent. In view of these structural facts, we might expect to find a low gap in the divide between the two drainage basins, but it is even lower than would be expected. Furthermore a distinct channel across it is still visible and a deposit of white sand and clay rests upon its highest point at Norton.

Thus it seems certain that at no very remote time, geologically speaking, there was a large stream flowing across this divide; it seems equally certain that the direction in which it flowed was west; and that its drainage basin included the present basin of Guest river as far east as Coeburn. Figure 2 shows the ancient drainage reconstructed in accordance with the above facts. Powell river then had its source on the plateau east of Coeburn; it flowed along the present valley of Tom creek to Coeburn where it turned due west, receiving

2.



the various tributaries as they flow to-day and joined the present Powell river a mile west of Norton. Before the change occurred, Clinch and Powell rivers were flowing at about the same elevation, but this was probably very much nearer sea level than the streams flow at present. In the contest between their headwaters, the Clinch was retarded by the upturned edge of the Carboniferous conglomerate against which the main stream and its tributaries could make but little headway, while Powell river was not hindered by any obstruction. Under these conditions the divide between them had migrated back quite close to Clinch river as shown in fig. 2. Being thus adjusted to the surrounding conditions, the two rivers would have remained in equilibrium unless their balance was disturbed by an external cause. This cause must have been isostatic movement since no other kind of movement is known to have occurred in late geologic time. But was it an epeirogenic or orogenic movement that caused the change? A broad uplifting of the district could not have produced this effect for the relative position of the two streams would have remained unchanged, therefore it must have been caused by a local or orogenic uplift. Our conclusion however need not be based upon this negative evidence for the region abounds with positive proof of the warping of the earth's crust.

The upper portion of the Clinch valley presents the youthful features of a recently revived stream. Its character was first recognized by Willis in 1885 and later studied in detail by the writer. The river flows in a narrow channel 300 to 700 feet deep which it has carved in the calcareous strata of the Cambrian and Lower Silurian. Its larger tributaries have nearly kept pace with the river in the corrasion of their channels, but the smaller ones have only succeeded in cutting narrow V-shaped gorges through which they discharge their waters into the main stream. The Holston, a larger stream, flowing parallel to the Clinch and 20 miles southeast of it, has only cut from 50 to 100 feet below its ancient valley.

This shows greater elevation of the Clinch drainage basin or a differential uplift with its maximum development in the region northwest of Clinch river, sloping gradually southeast to a minimum in the valley of the Holston. While this uplift was purely orogenic in character, it must not be supposed that it formed steep slopes in both directions away from the axis of the fold, but rather that it raised the surface in a low broad ridge along a certain axial line which can be located only in the most general way. Judging from evidence obtained in a more extensive study of the field, this axis passes north of Norton but at what distance it is difficult to determine. Along the crest of the fold there was probably a broad belt where but little tilting occurred which accounts for the unaffected condition of the northern tributaries of Powell and Guest rivers.* The surface southeast of this axial line being thus tilted, those branches flowing southeast to the Clinch river would be accelerated, while the headwaters of Powell river would be retarded since they flow toward the axis of uplift. Clinch river having a greater volume of water than Powell river would more rapidly deepen its channel even though it had to contend against the upturned conglomerate. The branch A, fig. 2, flowing on the soft shales above the conglomerate, easily cut back along the strike and diverted the head branches of Powell river; first the small one B from the southeast was conquered which pushed the divide to Coeburn; Tom creek was captured at this point and the process of robbing was greatly accelerated by the increased volume of water derived from that stream; as time progressed, the conquest extended westward until at last it reversed the entire drainage east of Norton. This robbing could be easily extended so as to include Benges branch which comes out of the mountain upon almost the summit of the divide and flows west to Powell river. Should Guest river lower the divide but 20 feet this branch would flow to the eastward, bnt this change is not likely to occur since Powell river is much more actively at work on this divide than Guest

* A fuller discussion of this evidence is given in the Geomorphology of the Southern Appalachians by C. Willard Hayes and Marius R. Campbell. Nat. Geog. Mag., vol. vi.

river. The chances are in favor of the former stream recapturing some of its lost territory.

This career of conquest so well begun by Guest river was stopped short by an obstruction in its pathway. The river soon removed the soft shales upon which it was originally located and encountered the massive, horizontal conglomerate which soon absorbed all of its energies. This work has greatly retarded the development of its upper course which has remained almost stationary and has retained all of its inherited characteristics. In the great bend below Yellow creek, this massive conglomerate has again obstructed the course of the stream and still more retarded the development of its head branches.

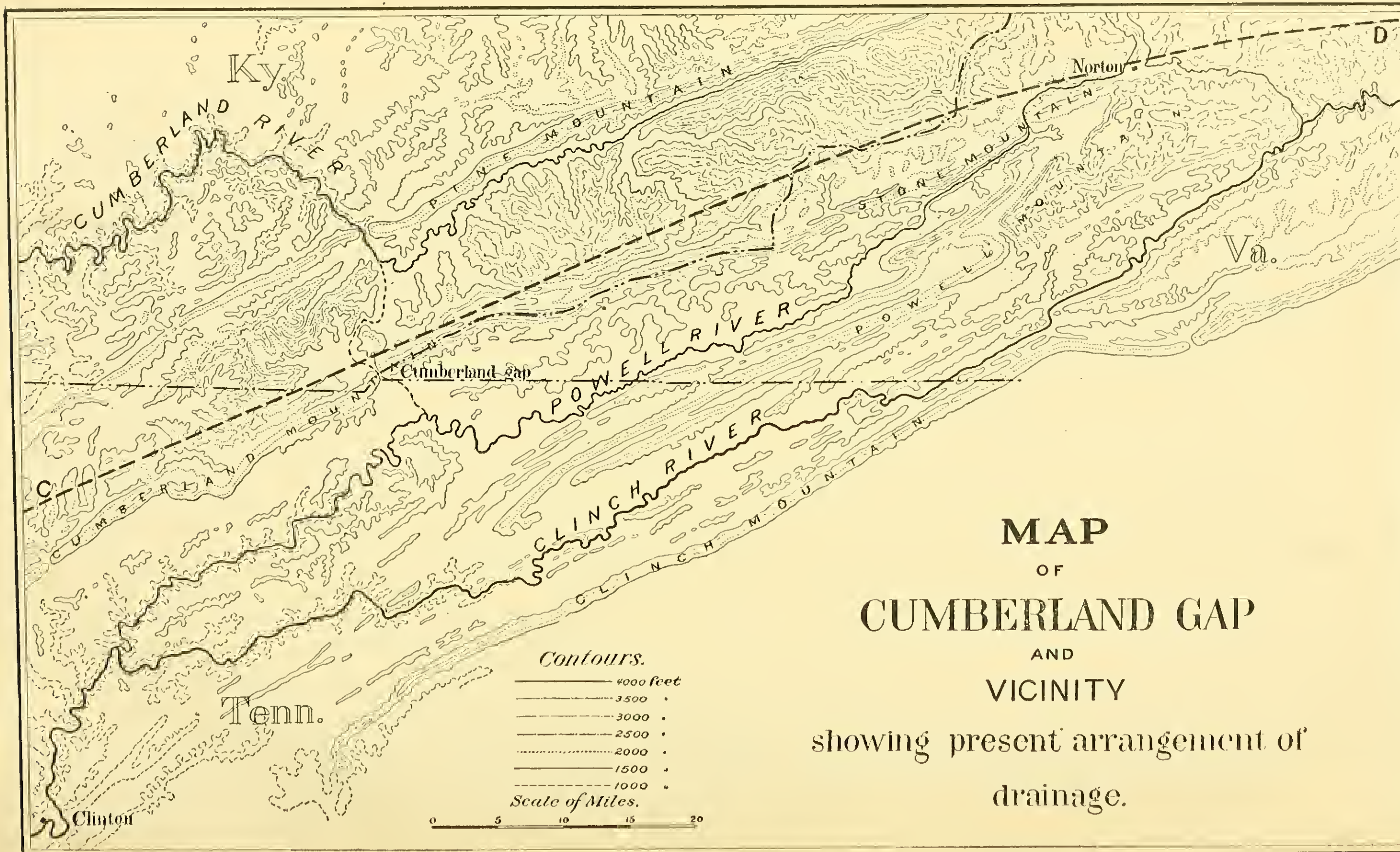
The reversal was accomplished after the Tertiary period of base leveling, for the uplift along the axis C D warped the Tertiary peneplain as described above and hence must have occurred after the completion of that topographic feature. The amount of corrasion accomplished by Guest river since the change, requires a large allowance of time; therefore it seems probable that the change occurred soon after the completion of the base-leveling period or in late Tertiary time.

Altogether the evidence seems quite conclusive (1) that such a change occurred; (2) that it was accomplished soon after the completion of the Tertiary peneplain; and (3) that its cause was the orogenic uplift along the axis C D.

In connection with the case above described, the writer wishes to call attention to another probable adjustment of drainage due to the same orogenic uplift; a change which accounts for some peculiar topographic features now apparently anomalous.

Cumberland gap, that historic gateway between the east and the west, is but a wind-gap in the Cumberland escarpment and is remarkable chiefly on account of the depth to which it is cut. That its history is different from the history of the ordinary wind-gaps in the ridge is apparent, but the only explanation yet offered regarding its origin is that by Shaler who attributes it to retrogressive erosion along a local cross-fault.* That a fault of this character determined the location of the gap seems quite probable but it is not so clear that sub-aerial erosion could reduce it to its present condition. The writer is familiar with several such cross-faults, but knows of no case in which a remarkably low gap has been produced by them unless corraded by a stream of water. If we assume for the present that Cumberland gap is due to stream corrasion, then there are three questions which must be answered. (1) What stream

* Kentucky Geological Survey, vol. iii, New Series, pp. 98–99.



MAP
OF
CUMBERLAND GAP
AND
VICINITY
showing present arrangement of drainage.

could have occupied the gap; (2) what conditions changed its course; and (3) when did this change occur?

The accompanying map shows in a general way, by means of 500 foot contours the configuration of the country. The great valley bordering the Cumberland escarpment on the southeast is called Powell valley and in this during the Tertiary period the limestones were reduced almost to baselevel. Since then the plain has been tilted so that at the northeastern corner of the area, covered by the map, its present elevation is about 2,000 feet, sloping gradually to about 1,500 feet at Cumberland gap and 1,200 feet in the extreme southwestern corner of the sheet at Clinton, Tenn. The Cumberland river valley was partially baseleveled at about this same elevation, but the rocks are harder and the reduction was not so complete. A very significant fact about Cumberland gap is that its elevation (1,383 feet)* is less than the Tertiary baselevel peneplain on either side. This shows that, after the completion of the peneplain, the stream occupied the gap long enough to reduce it at least 100 feet below the former baselevel. An uplift following a period of base-leveling would stimulate erosion very much and the streams would rapidly deepen their channels, but on the other hand the lower courses of a stream must be cut before it can deepen its channel near headwaters, so it is probable that considerable time elapsed between the completion of the peneplain and the diversion of the stream that carved the gap. This agrees with the probable date of change in Guest river and indicates that the same uplift is responsible for both.

Thus we can with considerable confidence establish the date at which this change occurred. Now it remains to be seen whether we can locate the stream that was then diverted from the gap. Did Powell river then turn north and join Cumberland river or did the Cumberland flow south and join Powell river? The headwaters of the Cumberland probably did not flow south, for the gorge through Pine mountain must have been occupied since Cretaceous time; therefore no change could have been made in that stream as late as the Neocene. In regard to Powell river there are some facts that support the idea of a northward flow. This stream as already described follows the Powell valley throughout most of its course. From Jonesville, Va., to a point opposite Cumberland gap, the river flows closely along the southeastern side of the valley in a normal course, but at the latter point it turns abruptly and flows toward the gap for a distance of five miles. In thus

* Elevation given by the profile of the Cumberland gap extension of the Louisville and Nashville Railroad.

deviating from its course, it leaves the soft Chickamauga (Trenton) limestone and cuts across the siliceous Knox dolomite to a point about four miles from the gap and on the axis of the anticline; here it makes another sudden change and follows the axis to the southwest. This peculiar bend in the river cannot be explained by existing conditions; it appears to be an inherited course from an older river which turned at this point and flowed northwestward through Cumberland gap.

The Cumberland river was probably one of the principal streams draining the Appalachian highlands before the close of the Paleozoic era and it held its antecedent course long after the Cumberland plateau was elevated above sea-level. The great river flowing southwest in the Appalachian valley encroached upon the headwaters of the Cumberland and gradually diverted its upper tributaries. In Cretaceous time Powell river was the sole surviving member of the Cumberland river system within the Appalachian valley. It held its antecedent course to the westward during the elevation which followed the Cretaceous period of baseleveling and carved deep gorges in Pine and Cumberland mountains. It maintained this course while the surface was again reduced to a peneplain, but in the succeeding uplift, it was diverted. Thus Cumberland river lost its last hold on the Appalachian valley.

The axis of orogenic uplift which affected the headwaters of Powell river so disastrously passes just west of Cumberland gap. Previous to the uplift, Cumberland river was barely holding its own against the encroaching Appalachian river; when the uplift occurred athwart its course it was forced to yield its last tributary to its more favorably located rival, Clinch river. A small branch working back along the axis of the Powell Valley anticline tapped Powell river above the rising fold and turned its waters into the Tennessee system.

Thus in all probability a slight orogenic uplift was the direct cause of a complete change in the drainage of this region,—a change radical in its effect but now indicated alone by the deserted gorge of Cumberland gap.

ART. VI.—*On some Methods for the Determination of Water;* by S. L. PENFIELD.

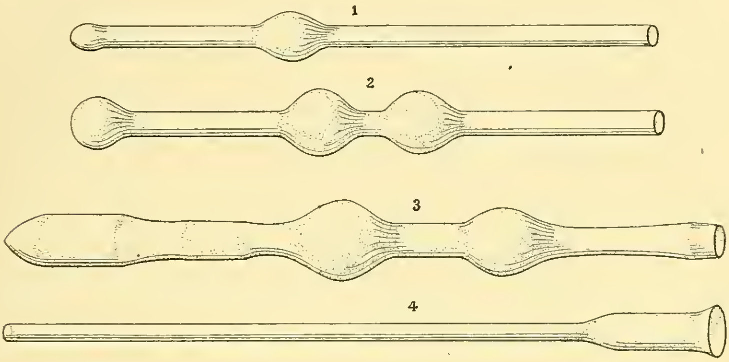
THE accurate determination of water is sometimes one of the difficult operations of analytical chemistry. This is especially the case when water is not completely expelled from a mineral at a temperature which can be obtained in a hard glass tube with an ordinary gas combustion furnace, and especially when either the loss of some volatile constituent or an increase in weight by oxidation renders it impossible to make the determination by loss on ignition. The tubulated platinum crucible described by Gooch* furnished a solution of the problem, but the apparatus is expensive, and the author has found it necessary to surround the crucible in which the fusion is made with an outer one containing some fusible salt like sodium carbonate, in order to prevent the passage of gases through the red hot platinum, which would render the results of the determination too high. This makes the apparatus more complicated, and the expansion and contraction of the fused salt between the crucibles strains the apparatus to such an extent that repairs are frequently necessary. The use of a platinum tube, wrapped with repeated layers of asbestus paper soaked in borax to prevent the passage of gases, has been suggested by Chatard,† but the apparatus is both expensive and complicated.

The author's experience in testing minerals for water has suggested the possibility of making an accurate determination by heating a weighed quantity of mineral in a closed glass tube, weighing the tube plus the water, then drying and weighing again. It has been found, as will be shown in the course of this article, that the method is very accurate and makes it possible to obtain direct water determinations without the use of absorption tubes, or any system of drying apparatus. The method is not altogether new, as it has been used by Prof. G. J. Brush‡ in the analysis of Sussexite, $H(MnMg)BO_3$. In this case after the water had been expelled and the tube weighed, the water was dried out in a vacuum over chloride of calcium, when the tube was again weighed and the percentage calculated from the loss.

From the author's experiments the following conditions may be recommended as favorable. The shape of the closed tubes depends upon the quantity of mineral that is to be experi-

* Am. Chem. Jour., ii, p. 247, 1880.
† Amer. Chem. Jour., xiii, p. 110, 1891.
‡ This Journal, II, xlvi, p. 240, 1868.

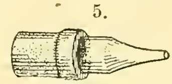
mented upon, the ease with which the water is given off and the necessity of adding some substance in order to retain a volatile constituent. A simple hard glass tube closed at one end, of about 6^{mm} internal diameter and $20–25^{cm}$ long can often



be used, while some of the forms that have been found more convenient are represented in figures 1 to 3.* Number 3 may be drawn out from ordinary combustion tubing. These tubes must be thoroughly dried inside, which is best accomplished by heating and aspirating a current of air through them by means of a glass tube reaching to the bottom. This is a necessary precaution and should always be taken even if the tubes are apparently dry. In order to bring a weighed quantity of the substance into the lower end of a tube without depositing any of the material on the sides, a thistle tube, fig. 4, is employed. This is conveniently cleaned by drawing through it a bit of dry cotton attached to a fine wire.

For heating, a Bunsen burner or blast lamp flame may be used, according to the temperature required. The water that is expelled condenses in the cold part of the tube, but cannot escape as there is no outward current to carry it along, except a very slight one caused by the expansion of the air when the tube is first heated. To guard against any possible circulation of currents of air however, which might carry off traces of water, a short piece of glass tube drawn out to a capillary, fig. 5, is joined on by a rubber and is removed before weighing. While being heated, the tube may be held by a clamp or in the hand, and if the quantity of water is considerable it should be expelled slowly and driven up into the first bulb, figs. 2 and 3, to prevent its flowing back upon the hot glass. To prevent

5.



* In making the ignition tubes considerable time may be saved by fusing new bottoms on to those that have previously been used.

the upper part of the tube from becoming heated by radiation from the flame, a screen of asbestus board can be used, or still better a strip of wet cloth may be wrapped about the bulbs and upper part of the tube, and this may be further cooled if necessary by applying water from a wash bottle. After the water has been expelled, the glass is fused down upon the substance, so as to make its volume as small as possible, and the end containing the substance pulled off. It is not always necessary to do this, but it usually is best. The tube containing the water is wiped clean, cooled and weighed. The water can be quickly removed by heating and aspirating out the steam and moist air, when the tube after cooling is again weighed. To test the accuracy of the method experiments were made with transparent, colorless gypsum from Sicily. The mineral, which is assumed to be pure and to contain 20·93 per cent of water, was ground and weighed out air dry from a weighing tube. The results are as follows:

	Gypsum taken.	Water calculated.	Water found.	Error.
1.	·20985	·0439	·0442	·0003 +
2.	·2417	·0506	‘0505	·0001 —
3.	·2642	·0553	·0553	·0000
4.	·3505	·0734	·0731	·0003 —
5.	.4913	·1028	·1028	·0000
6.	·6457	·1351	·1352	·0001 +
7.	2·0000	·4186	·4195	·0009 +
8.	5·0643	1·0600	1·0623	·0023 +

To these may be added some determinations made on calamine and natrolite, which by direct ignition in a crucible lost 7·76 and 9‘80 per cent of water respectively.

	Calamine taken.	Water calculated.	Water found.	Error.
9.	·5301	·0411	·0406	·0005 —
	Natrolite taken.			
10.	·1838	·0180	·0176	·0004 —
11.	·2553	·0250	·0247	·0003 —
12.	1·0000	·0980	·0980	·0000

These results indicate that the method is very accurate for the determination of both large and small quantities of water and experiments 7 and 8, which show the greatest apparent variation, are within ·045 and ·04 per cent of the theory respectively.

To test the method where substances have to be added to retain volatile products, experiments were made with pure recrystallized cupric and ferrous sulphates, containing 28·87 and 45·32 per cent of water respectively. To prevent the escape of SO_3 some strongly ignited lime was mixed with the powdered salts before heating. The mixing can best be done in the tnbe by means of a fine wire, bent into a corkscrew coil at the end. The results are satisfactory and are as follows:

	$CuSO_4 . 5H_2O$ taken.	H_2O calculated.	H_2O found.	Error.
1.	·2458	·0887	·0885	·0002 –
2.	·3532	·1274	·1270	·0004 —
3.	·3613	·1304	·1296	·0008 –
4.	·3779	·1363	·1359	·0004 –
5.	1·7587	·6347	·6343	·0004 –
	$FeSO_4 . 7H_2O$ taken.			
6.	·1138	·0516	·0516	·0000
7.	·2150	·0975	·0978	·0003 +

It frequently happens that water is to be determined in compounds which give off carbon-dioxide on ignition, as for example in rock analysis where calcite is present, and to test the application of the method in such cases experiments have been made with pure, recrystallized bicarbonate of potash, which yields 8·99 per cent of H_2O and 22 per cent of CO_2 on ignition, and also with gypsum mixed with calcite. It is evident that carbon-dioxide will displace the air in the tube and must be removed before weighing. This may conveniently be accomplished by holding the tube at an inclination of about 40°, with the cap removed and open end down, so that the heavier carbon-dioxide can flow out. At first the tube diminishes rapidly in weight, but after three hours the loss becomes almost constant and amounts to very nearly 0·0003 grams for every hour that the tube is left open. A correction therefore of that amount must be made. Moreover, the carbon-dioxide which passes out of the tube will carry water vapor with it, but if the amount of the gas that is liberated is known a correction may be made. Assuming that the gas is saturated with water vapor, and passes out of the tube at a mean barometric pressure of 760^{mm} and a temperature of 20° C., 1 gram of it would carry off ·0096 grams of water. In the following series of experiments the tubes were left open in an inclined position for three or more hours, and in addition to the time correction, one was made for the water carried off by the escaping CO_2, which amounts to ·0021 gr. for every gram of $HKCO_3$ taken.

	$HKCO_3$ taken.	H_2O calculated.	H_2O weighed.	Corrected weight.	Error.
1.	·2694	·0242	·0225	·0242	·0000
2.	·4641	·0417	·0395	·0418	·0001 +
3.	·5064	·0455	·0438	·0458	·0003 +
4.	1·0055	·0904	·0869	·0902	·0002 —
5.	1·0089	·0907	·0881	·0912	·0005 +
6.	1·5109	·1357	·1312	·1357	·0000
7.	2·0000	·1798	·1747	·1796	·0002 —
8.	2·7690	·2489	·2393	·2463	·0026 —

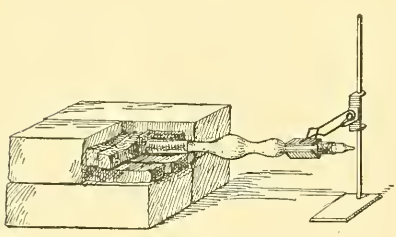
The greatest deviation from the theory in this series is in No. 8 which shows a loss of 0·10 per cent.

In the experiments with gypsum mixed with calcite it cannot readily be told how much CO_2 is expelled, since it is not known to what extent the calcite is decomposed. The only correction that has been made therefore is for the time that the tubes were left open.

	Gypsum taken.	Calcite taken.	H_2O calculated.	H_2O weighed.	Weight corrected.	Error.
1.	·2668	·1000	·0558	·0549	·0558	·0000
2.	·3503	·2000	·0733	·0712	·0721	·0012 –
3.	1·0000	1·0000	·2093	·2084	·2093	·0000

The results thus far given are very satisfactory, and they represent all the determinations made after the method was perfected. In the case of minerals, however, which give off water only on intense ignition, it was found that the tubes could not be heated sufficiently over the blast lamp. A long series of experiments was made with talc, chondrodite and staurolite, using lead oxide, bismuth oxide and a mixture of lead oxide and sodium carbonate in the tubes as fluxes, but the results were not satisfactory. It was evident that a more intense heat must be obtained, and accordingly the following method of heating was devised. A sort of oven was constructed of fire brick lined with pieces of charcoal,* fig. 6. The best tube to use with this furnace is one like fig. 3, made from combustion tubing. To protect the glass the lower end is surrounded by a cylinder of platinum foil. This is applied by first bending the metal about a tube considerably smaller than the one to be used, and then springing it over the end of the ignition tube. If properly adjusted the spring of the platinum will hold it securely in place. The tube is held in the furnace as shown in the figure. An additional piece of charcoal is placed on top of the tube and the blast lamp is turned to a horizontal position so that the flame plays upon the side of the apparatus. The temperature that can be obtained by this method of heating is very intense, bringing the apparatus

6.



* Where fire brick are not at hand ordinary brick will answer, but they soon crack with the intense heat. The charcoal that is most convenient to use is that which comes prepared for blowpipe purposes.

to a full white heat. The flame glances off from the charcoal and it is necessary to have the tube carefully screened by asbestus board, in addition to having a wet cloth around the bulbs. After the ignition is finished a glass tube is fused to the platinum to hold it, and the end of the tube is pulled off. The platinum foil can be separated from the glass by plunging it while hot into cold water, when the glass readily cracks away. For testing the efficiency of this method of heating, experiments were made with talc from Fowler, N. Y. The material was not absolutely pure and, therefore, the degree of accuracy must be determined by the agreement of a series of determinations.

	Talc taken.		Water weighed.	Per cent.
1.	·5000	Heated alone	·0232	4·64
2.	·5000	Mixed with 0·50 gr. CaO	·0224	4·48
3.	·5000	" " 0·75 " PbO	·0230	4·60
4.	1·0100	" " 1·50 " "	·0451	4·47
5.	·9637	" " 2·00 " "	·0426	4·42

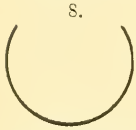
The talc contained some fluorine, since when heated alone the tube was slightly etched and the water distinctly acid, the percentage in No. 1 is certainly, therefore, somewhat high. A mean of Nos. 2, 4 and 5, 4·46 per cent is probably very nearly correct. The amount of lead oxide to be taken as a flux depends upon the fusibility of the mineral. With an infusible compound like talc, an amount equal to twice the weight of the mineral would be near the limit, while with a more fusible one very much less should be used. All that is necessary is to have the contents of the tube fuse so as to insure a complete decomposition, and if the mixture is too fusible it may eat its way through the glass, not only spoiling the experiment but probably injuring the platinum. Lead oxide, taken in small quantities, cannot always be relied upon to hold fluorine. Thus in trying to determine water in topaz, 1 gram of the mineral was fused with twice its weight of the oxide but the water that came off was very strongly acid. The lead oxide used in these experiments was a good quality of litharge, heated to near its fusing point to drive off water or any volatile matter. The material is not hygroscopic, and can be kept for a considerable time exposed to the air without suffering any appreciable increase in weight.

The intense heat which can be obtained with the charcoal furnace already described makes it possible to decompose a mineral completely by fusion with sodium carbonate in a combustion tube, and to collect the water in a weighed sulphuric acid or chloride of calcium absorption apparatus. For this purpose a piece of combustion tubing of 15^{mm} internal diameter is drawn out like fig. 7. The end is rounded and flared out a little. Two clylinders of platinum are next adjusted, one on the inside the other on the outside. These are made from pieces of platinum foil, about ·07^{mm} in thickness and

7.

8×11^{cm} in diameter, which have previously been bent around glass tubes of such a size that when applied to the combustion tubing the spring of the metal will hold them in place. A large platinum boat, 7 to 8^{cm} long and 11 to 12^{mm} in diameter with a cross section like fig. 8, should be used, since this will readily hold a gram of mineral mixed with 5 grams of sodium carbonate. Sodium carbonate dried at near its fusing point is not very hygroscopic. Thus 2·5 grams of it, spread out on a watch glass gained only ·0002 grams in 15 minutes.

8.



After the boat containing the mixture has been shoved within the platinum casing, the tube is connected with a suitable drying and absorption apparatus and heated in the furnace which is constructed like fig. 6 except that only three bricks are used. The tube is placed in the angle formed by the charcoal lining, some pieces of charcoal are placed at the sides in front, leaving an opening through which the flame may be directed, and an additional piece is laid on top. The tube can readily be brought to a full white heat, and by *forcing* a slow current of dry air through the apparatus the carbon-dioxide resulting from the decomposition can be removed, and the water carried over into the weighed absorption tube. The glass fuses between the platinum casings, and in a number of experiments that have been tried there has not been a single instance where the glass tube has broken or shown any indication of leaking. After heating, the tube will not crack if it is left to cool slowly on the charcoal, but it cannot be used a second time as it will be very apt to break where the platinum is fused on to the glass. At the high temperature to which the glass is subjected, it of course becomes very soft and the ends must be properly supported, also the rubber connections and absorption apparatus must be carefully screened by asbestus board. By constructing a cover for the boat no material need be lost by spattering, and after making the water determination the contents may be used for the remainder of the analysis. With some samples of topaz that were experimented upon, the escaping carbon-dioxide carried off traces of the mineral and sodium carbonate in the form of fine dust, but its passage into the weighed absorption apparatus was prevented by a loose plug of fine asbestus, slipped into the tube after the boat was in place.

Three determinations of water, made on the same sample of talc that was used for testing the previous method, gave 4·46, 4·37 and 4·44 per cent, a mean of 4·42. At the conclusion of an experiment the platinum foil can readily be removed from the glass by heating and plunging into cold water, and may be flattened by rolling with a glass tube. This method is one that is applicable for the determination of water in all cases of mineral analysis, and if carefully executed the results are very accurate. In its essential details, decomposition by fusing with an alkali carbonate and collecting the water in a weighed absorption apparatus, it is similar to the methods of Ludwig* and Sipöcz.† The former suggested the use of a specially constructed platinum tube in which the mineral was fused with a mixture of dry sodium and potassium carbonates, the latter made use of a porcelain tube and the fusion was made with the mixed carbonates in a platinum boat. The use of a glass tube has a decided advantage over platinum and porcelain, since the operation may be watched and the intense heat that can be obtained with the charcoal furnace renders it possible to use sodium carbonate for making the fusion, thus avoiding the use of the very hygroscopic potassium carbonate. The furnace may also be found convenient for other experiments where an intense heat is required.

This investigation was undertaken for the purpose of finding some simple means for the *direct* determination of water in refractory minerals, and the results that have been given indicate that the methods are accurate. The closed tube method is almost as simple as the determination by loss on ignition, and a direct weighing of the water is always a satisfaction, since otherwise there is a possibility that some volatile constituent may go off and render the result inaccurate. For example the sample of talc that was used in the previous experiments, and found to contain 4·42 per cent of water, lost 4·87 per cent by direct ignition the high result being due to the presence of a little fluorine and the liberation of acid water probably carrying some silica.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, Conn., April, 1894.

* Tschermak's Min. Mitth., 1875, p. 214.

† Sitzb. der K. Akad. der Wiss., Wien, lxxvi, p. 51, 1877.

ART. VII.—*The Detection of Alkaline Perchlorates associated with Chlorides, Chlorates, and Nitrates;* by F. A. GOOCH and D. ALBERT KREIDER.

[Contributions from the Kent Chemical Laboratory of Yale College—XXXII.]

THOUGH perchloric acid in the free state is an exceedingly active body, its combinations with alkaline metals are, as is well known, so characterized by inertness toward ordinary reagents that in order to effect its detection it has been customary to place dependance either upon the insolubility of the potassium salt in alcohol, or upon tests for the corresponding chloride derived by ignition.

In experimenting at high temperatures upon mixtures of potassium perchlorate with salts of the halogens we have found it possible to effect the liberation of the halogen to a greater or less degree by the oxygen of the perchlorate, but the amount thus evolved has never been sufficiently complete or regular to warrant the application of the reaction to the quantitative determination of the perchlorate. In two parallel experiments, for example, a mixture of the double chloride of aluminum and sodium with 0·05 grm. of potassium perchlorate evolved in fusion in a tubulated flask (which was fitted by a ground joint to an inlet tube carrying a constant current of carbon dioxide and connected with Will and Varrentrapp absorption bulbs filled with a solution of potassium iodide), an amount of chlorine corresponding to 0·0482 grm. and 0·0460 grm. of the perchlorate. A similar experiment conducted in an atmosphere of hydrochloric acid gas and carbon dioxide in mixture yielded chlorine amounting to 0·0477 grm. of the perchlorate. Fusion of the perchlorate with cadmium iodide resulted in the liberation of much oxygen accompanying the iodine, and a mixture of zinc chloride with potassium iodide (melting at about 200° C.), yielded a large evolution of oxygen which was somewhat diminished but not wholly prevented when manganese chloride was included in the mixture. A series of 14 experiments in which mixtures of the perchlorate with potassium iodide were treated with meta-phosphoric acid (made by heating the syrupy ortho-acid to 360° C.) in an atmosphere of carbon dioxide showed deficits in the amounts of iodine evolved amounting to 1·7 per cent on the average between extremes of 3·6 per cent in excess and 7·7 per cent in deficiency, and these particular experiments doubtless point to a more complete utilization of the oxygen of the perchlorate than was actually attained owing to the inevitable partial decomposition of hydriodic acid at the temperature necessary to effect the decomposition of the perchlorate.

We have, however, succeeded in developing a simple and delicate method of detecting perchlorates, and one which may be applied without great sacrifice in delicacy to mixtures of the perchlorates with chlorides, chlorates and nitrates. It is evident that for a rapid qualitative test conditions should be so chosen that the effect of atmospheric air shall not interfere with the certainty of the indication. Of the various salts which we have employed we choose by preference fused zinc chloride, chiefly because, while sufficiently energetic in its action upon the perchlorate, it does not, like manganese chloride or the double chloride of aluminum and sodium, evolve chlorine under the influence of ordinary air at the high temperature of the reaction.

In the experiments recorded in Table I varying portions of a solution of potassium perchlorate were evaporated to dryness in a test tube and fused with anhydrous zinc chloride. A trap made by cutting off an ordinary two-bulbed straight drying tube was hung with the larger end downward in the test tube, after moistening the interior of the bulbs with a solution of potassium iodide. The chlorine evolved during the heating was registered by the iodine set free from the iodide and subsequently washed with a little water from the trap and tested with starch emulsion.

TABLE I.

$KClO_4$ taken.	Indication by the starch test.
0·00100 grm.	Strong.
0·00050 "	"
0·00020 "	"
0·00010 "	"
0·00010 "	"
0·00005 "	Distinct.
0·00005 "	"
0·00003 "	Trace.
0·00003 "	None.
0·00001 "	"
0·00000 "	"

The test for 0·00005 grm. of potassium perchlorate is sure and distinct; and it is, of course, evident that the presence of a chloride in the original test can in no way interfere with the certainty of the indication. All substances, however, which yield chlorine by decomposition or by the action of the air must be removed or destroyed before the application of the test. We find by experiment that 0·1 grm. of potassium chlorate is completely broken up by treatment with 5 cm^3 of the strongest hydrochloric acid and evaporation to dryness. Nitric acid does not yield so readily to the decomposing action of hydrochloric acid and may be detected in the residue after four similar treatments. To destroy nitrates, therefore, we followed the general plan of decomposition employed in a quantitative method for the determination of nitrates previously elaborated in this laboratory* and treated the dry substance to be tested with 2 cm^3 of a saturated solution of manganous chloride in the strongest hydrochloric acid. The liquid was evaporated to dryness, and the residue was again treated similarly with one or two cubic centimeters of strong hydrochloric acid. This method of decomposing the nitrate is peculiarly advantageous since the decomposing agent is itself an excellent indicator of the completeness of the work of removal. Two or three treatments serve to remove the nitrate entirely; but before proceeding with the test it is necessary to remove the manganese which has been introduced, inasmuch as manganese chloride will of itself evolve chlorine, by exchange for oxygen, when heated in air. Sodium carbonate in solution answers the purpose of removing the manganese (together with other interfering substances) and the filtrate from the precipitated manganous carbonate leaves on evaporation a residue, which, when treated with the anhydrous zinc chloride, gives indications for the perchlorate if it is present in appreciable amount. The results of a series of tests for potassium perchlorate associated with the chlorate and nitrate of the same element and recorded in the following table.

TABLE II.

$KClO_4$ taken. grm.	$KClO_3$ taken. grm.	KNO_3 taken. grm.	Treatment for the removal of chlorate and nitrate.	Indication of the perchlorate.
0·0005	----	----	By HCl	Strong.
0·0003	----	----	"	"
0·0002	----	----	"	Good.
0·0001	----	----	"	"
0·0001	----	----	"	Trace.
0·0005	0·1	0·1	By $HCl+MnCl_2$	Strong.
0·0003	0·1	0·1	" "	Good.
0·0003	0·1	0·1	" "	Good.
0·0002	0·1	0·1	" "	Trace.
0·0001	0·1	0·1	" "	Trace.
0·0000	0·1	0·1	" "	None.

It is plain that 0·0001 grm. of potassium perchlorate may be found with certainty when associated with 0·1 grm. of the nitrate or chlorate or both.

* Gooch and Gruener, this Journal, xliv, 117.

ART. VIII.—*The Upper Vicksburg Eocene and the Chattahoochee Miocene of Southwest Georgia and adjacent Florida;* by AUG. F. FOERSTE.

The Boundary Line between the Vicksburg Eocene and Chattahoochee Miocene in S. W. Georgia.

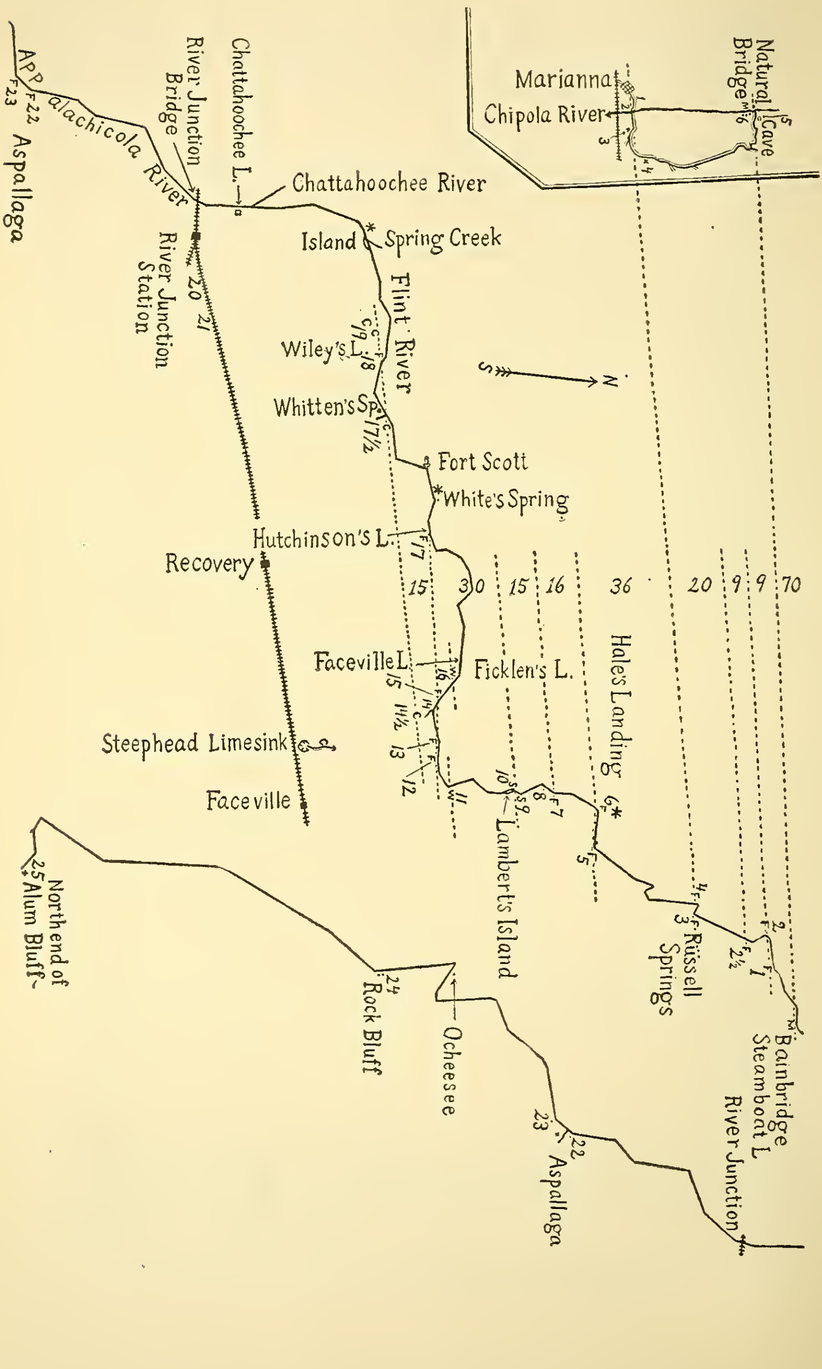
THE chief topographical feature of southwestern Georgia is the line of demarcation between the Eocene lowlands and the margin of the Miocene red clay plateau.* This line enters the State about 5 miles north of its southwest angle, follows the bluffs along the southern side of the Flint River for about 12 miles, continues in its direction across the country as far as Roseland Plantation, 4 miles south of Bainbridge, passes immediately to the north of Gasteropod Gully, Glenn's Well, and Powell's Limesink, the last locality being about 10 miles east of Bainbridge on the Thomasville road, and then turns more strongly toward the northeast, so as to leave the limesink and the Barrows plantation coral locality on the right. From its western extremity to Roseland Plantation this line is quite direct; it may be easily followed as far as Powell's limesink; beyond that point it seems to become more crooked and has so far not been accurately determined.

Method of Exposure of the Vicksburg.

On the northern margin of the red clay plateau the Vicksburg is found in limesinks, underlying the Chattahoochee, or Lower Miocene. In the lowlands extending from the plateau to the Flint River it occurs in the bottom of wells. Away from the river, very few surface exposures, which are evidently *in situ*, occur. Along the Flint River large blocks of siliceous Vicksburg rock are fairly abundant but it is evident that the greater part are only residual remains of the Vicksburg; the softer limestones and marls have disappeared or gone over into red clays, and in most places only the broken fragments of the silicified beds remain, let down as huge bowlders and slabs to the present limit of degradation,—the lower levels of the river banks.

At first it seemed impossible to use these blocks for stratigraphical purposes. However, during a trip down the Flint River, with Prof. Raphael Pumpelly, the localities where the bowlders occur were carefully platted on a sketch map of the river, and it became evident that these bowlders were distrib-

* That part of the plateau region lying south of Bainbridge is more fully described by Prof. Raphael Pumpelly, in this Journal, Dec., 1893, page 445.


Appalachicola River
Aspallaga
River Junction Bridge
Chattahoochee L.
Chattahoochee River
River Junction Station
Island
Spring Creek
Flint River
Wiley's L.
Whitten's Sp.
Fort Scott
White's Spring
Hutchinson's L.
Recovery
Faceville L.
Ficklen's L.
Hale's Landing
Steephead Limesink
Faceville
Lambert's Island
Russell Springs
Marianna
Chipola River
Natural Bridge
Cave
North end of Alum Bluff
Rock Bluff
Ocheesee
Aspallaga
Bainbridge
Steamboat L.
River Junction
S
N

uted along lines running a little north of east. These lines occurred at such distances apart as to suggest that they represented so many distinct silicified layers in the original Vicksburg section of this part of Georgia. It also seemed evident that even if not precisely *in situ* the lowering of these bowlders from their original position must have been of such moderate extent and must have taken place so gradually as not to confuse their position in the stratigraphic scale, otherwise the decidedly east and west character of these lines would have been marred, and there would have been a more evident commingling of rocks of different lithological character. Since these lines of bowlders furnish information as to the strike of rocks and promise to be of considerable value in working out the stratigraphy of the Vicksburg Eocene of this region the sketch map is here reproduced. It evidently offers materials for a section in which the soft white limestones are omitted and in which only the harder silicified courses appear.

Description of the Flint River section. Vicksburg.

(*a*) The base of the section so far examined is offered by a locality six miles north of Bainbridge, on the west side of the river, near a country graveyard east of the road in the woods. Here massive ledges of siliceous rock of unusual thickness occur, the section being at least 15 feet thick, the usual thickness of siliceous layers elsewhere being but 2 to 4 feet. This layer apparently occurs also on the east side of the river at various localities; in one case, one and a half miles east of the river, between the river road and the western Camilla road, near some plantation houses about 7 miles from Bainbridge; also still farther east, on the eastern or old Camilla road leading to the limesink, about 8 miles from Bainbridge. This horizon furnishes many fossils though chiefly in the form of casts, and almost all identical with forms found at Bainbridge and at Russell Springs. Owing to its massiveness this layer is more apt to occur as surface exposures and could probably be traced much farther east and west than has been done, thus offering an important datum line in the Vicksburg.

(*b*) Above this occurs the Bainbridge marl, exposed along the southern side of the river, at water level, east and west of the steamboat landing at Bainbridge. It is very calcareous, and contains many fossils, imbedded in a matrix composed of innumerable quantities of foraminifera, chiefly Orbitoides in all the various stages of development, the finer cementing material having in most cases disappeared to such an extent, owing to percolating waters, that it is possible to secure many shells and sea-urchins free from the surrounding rock.* This bed is the best collecting ground for Vicksburg fossils so far found in southwest Georgia; the variety and state of preservation of the fossils is excellent, and the bed has also decided value for purposes of correlation since nothing similar has so far been found elsewhere in the Vicksburg in southwest Georgia. It is with this layer that the bed dug up in the ditch near the Natural bridge on the Chipola River north of Marianna in Florida, is correlated. Immediately above the Bainbridge marl occur one or two silicified layers, represented at the Natural Bridge north of Marianna by the more massive silicified layer forming the top and the walls of the natural cave, a short distance east of the *bridge*, locality 5.

(*c*) The next silicified layer occurs at localities 1 and 2. The first presents many sponges, Orbitoides, simple corals, Hinnites, Pectunculus, including also a small, radiately strongly ribbed species of this genus, Cytherea, Cerithium Mariannensis, Melongena, and Mitra. At the second, Pectunculus, Pecten and Cytherea were found. It is possible that this layer is also represented by the massive silicified limestone at the cave near the Natural Bridge north of Marianna. At 2½ silicified rock occurs, containing many sponges, some massive corals, Pecten, and Cassidaria (Sconsia). Whether this forms a distinct layer or not, is undetermined.

(*d*) The next silicified layer is represented by localities, 3 and 4. The first of these is near Russell Springs, a picturesque limesink, surrounded by steep banks, filled with water, in which cypress trees grow abundantly. Numerous fossils were found here, the species being usually the same as those seen along the river at Bainbridge, either in the marl or in the silicified layers immediately above. At 4 there were many sponges, simple corals, Pecten, Hinnites, Pectunculus and Ampullina. This bed is probably represented at Marianna by the silicified beds above the level of water at the bridge across the Chipola River east of the town, locality 2.

(*e*) The next silicified layer is exhibited at localities 5 and 6. At 5, numerous small bowlders are carted together at the top of the bank; they contain Orbitoides, Lunulites, a Pecten with 7 or 8 broad ribs, numerous specimens of *Turritella*, the precursor of *T. variabilis* Conrad. This species occurs in the Vicksburg, Chattahoochee, Chipola, and Chesapeake of S.W. Georgia, and western Florida. It may be characterized as having a spiral rib a little posterior to the anterior suture, another rib a little posterior to the median line, a deep groove or con-

* Loc. cit., p. 445. with *Echinocyamus parvus*, *Scutella Lyelli*, *Pecten Poulsoni*, and unknown species of Amusium, Pectunculus, and Cerithium as frequent fossils.

striction between these ribs, and a slope from the last named rib to the posterior suture. By addition of other spirals both ribs assume later the form of elevated bands defined by two spirals each. By the adding of striæ in the groove and on the posterior slope the later formed whorls may become heavily ornamented. The Eocene form of this shell occurs at 5, two miles east of Marianna at the quarry, 4, and six miles north of Bainbridge on the west side of the Flint River, at the graveyard locality. At locality 5 at the river's edge is silicified rock more evidently in place and resembling that at locality 6. At 6, the silicified layer is well exposed and contains Orbitoides, sponges, massive and also simple corals, Ostrea, Pecten, a rock-boring lamellibranch, Strombus, and two species of Cerithium. A little farther up the river the soft white limestone which once filled in at least a part of the intervals between the various silicified layers, is still visible ; it occupies a slightly lower level and contains Orbitoides.

(*f*) At 7 occurred a silicified bed containing chiefly sponges, but also many massive corals, a concentrically striated Modiola 85^{mm} long, Cytherea, Ampullina, and the two species of Cerithium above mentioned. The layer bears evidently close faunal and lithological relations to layer *e*, but this does not necessarily imply the identity of the layers. At 8 a single large bowlder contains chiefly sponges, but also a stray Cytherea, and a large massive coral.

(*g*) The next layer is exposed at 9 and 10 and on Lambert's island. It is strongly characterized by being the only rock along the Flint River section here given, which look more like a sandstone than an ordinary silicified layer. At 9 it is more like sandstone and only a few small stray bowlders contained fossils, Pectunculus and Pectens. At 10 the more silicified material is full of Pectunculus and Pecten, and a stray astræiform coral was seen. At 11 and 16 the soft white limestone, which formed such a large part of the upper Eocene section, but which is usually worn away between the silicified layers along the river banks, is exposed. At 11 it contains Orbitoides and at 16 are found Orbitoides and a few Pectens.

(*h*) The highest silicified layer in the Vicksburg section is that found at 12, 13, 15, and 17. The deviation from parallelism between this line and the Chattahoochee outcrops is probably due to the difficulties in platting a river from a skiff. At 12 sponges are common and Pectens seem frequent. At 13, many Orbitoides and a sea-urchin occur. At 15, were found many concretionary looking sponges and a few Pectens. At 17 were abundant Orbitoides and stray Pectens.

Thickness of the Flint River section.

The data for an exact determination of the dip the Eocene southwards are not yet secured. Prof. Raphael Pumpelly determined the level of the base of the Chattahoochee to be 102 feet above the sea at Glenn's Well, and 155 feet above the sea in Powell's limesink. The first of these localities is 5 miles from the river almost directly east of Russell Springs, and 4 miles south of Bainbridge on the Coon-bottom road. The base of the Chattahoochee outcrops again along the Flint River at the localities 14½, 17½, 18, and 19, but little above the water's edge. The river localities are abont 6 miles south of the line of strike of the Chattahoochee at Glenn's Well. The precise level of the river where the Chattahoochee outcrops is not known, but a dip of 13 feet to the mile is considered at the present state of our knowledge to be amply sufficient to account for the facts.* At this rate the thickness of the Vicksburg section, from the Bainbridge marl to the Chattahoochee overlying it, would be 150 feet; the massive siliceous bed along the Flint River 6 miles north of Bainbridge would be 70 feet below the Bainbridge marl, making a total section of 220 feet, with the possibility that these thicknesses are overestimated. The figures on the accompanying sketch map will sufficiently indicate the intervals between the different silicified layers.

Chief characteristics of the Flint River section.

The chief characteristics of the Flint River section are: 1, the comparatively great thickness of the silicified beds 6 miles north of Bainbridge; 2, the Bainbridge marl with its abundant echinoids and other fossils loosely enclosed in a cement of which Orbitoides forms the main element; 3, the long interval between layers *d* and *e*; 4, the more sandy character of the layer *g* at Lambert's Island; 5, the great amount of soft white limestone in the upper part of the section, interrupted only by the siliceous layer *h*.

Correlation of the Marianna section with layers b to e of the Flint River section.

In a corner of the sketch map the Marianna section has been introduced. It shows the road leaving Marianna on the east, crossing the Chipola River, and then turning northwards, for several miles, after which a road through fields finds its irregular path to the Natural Bridge. It is better to secure a native as a guide here. The section was

* Loc. cit., page 445.

visited on a trip with Prof. Pumpelly and Mr. Alfred Brooks. At the Natural Bridge, about 3 miles north of Marianna, the Chipola River disappears under the ground, reappearing farther on. At present a ditch or canal (6) diverts a part of the water at this point, securing a partial surface flow. During the cutting of the ditch numerous echinoids and other fossils characteristic of the Bainbridge marl bed, in a similar state of preservation, and enclosed by a similar cement of Orbitoides shells as at Bainbridge, were unearthed. East of this ditch, perhaps a quarter of a mile distant, is a cave (5), the upper walls of which are composed of a hard siliceous rock, containing abundant Orbitoides. There is so much rock exposed at this cave that it probably represents not only the siliceous layers found above the marl at Bainbridge, but also the siliceous bed *c* (localities 1 and 2), and the siliceous bed at locality 2½ along the Flint River. At the edge of the river, where the road running east from Marianna crosses the Chipola (2), there is considerable siliceous rock which from its distance south of the marl bed should be correlated with layer *d*, the Russell Springs layer of the Flint River section. Above this layer is a whitish, porous, soft, pulverulent, silico-calcareous rock, 20 feet or more in thickness (1, near 2, 3, 4). This should correspond to the rock once filling the interval between layers *d* and *e* of the Flint River section though nothing similar has been noted there. It is well exposed between Marianna and the bridge crossing the Chipola (1, near 2), where a very thin form of Orbitoides, and a Pecten are very common; again, about one and an eighth miles east of Marianna, in a quarry south of the road (3) where in addition to a few of the fossils just named, a small shark's tooth with very broad base, and very short triangular tip was found; finally about 2 miles from Marianna, on either side of the road but especially in an old quarry east of the road (4) where—in addition to the thin Orbitoides and the Pecten—species of Lunulites, Cardium, Cerithium, Turritella, and other fossils were found. The same white pulverulent rock is found southeast of Marianna, along the north side of the railroad, containing the thin Orbitoides, but here a few siliceous beds are intercalated in the pulverulent rock series. At first sight this rock presents lithologically an appearance similar to many middle Chattahoochee exposures, such as those along the railroad east of Chattahoochee, or the exposures east of the landing of the same name, but the base of the Chattahoochee no doubt does not crop out for several miles down the Chipola River.

Strike of the Vicksburg indicated by the Bainbridge bed exposures.

The Bainbridge marl exposure at the Natural Bridge, 3 miles north of Marianna in Florida, lies about 40 miles west of Bainbridge in Georgia, or to be more precise, about S. 78 W. and this is so far the nearest approximation to an estimate of a strike for any great distance in southwest Georgia and adjacent Florida. Judging from this line of strike the Bainbridge marl should be exposed somewhere in the vicinity of Miriam's Landing on the Chattahoochee River. The line of outcrop of the Chattahoochee curves strongly northwards east of Bainbridge, but until the observations over that part of the area are accurate enough to determine the dip, and the elevation of localities above the sea, and from these data to calcnlate the real strike, it is only possible to say that strike of the Chattahoochee is probably very soon changed to strongly towards the northeast on passing Bainbridge, since the nearest point where the position of this horizon can again be approximately determined is near House Creek on the Ocmulgee.

Correlation of various exposures in Decatur County, Georgia, with the soft white limestone at the top of the Vicksburg, above layer g of the Flint River section, and the base of the Chattahoochee.

1. *The limesink on the Camilla road.*—Fifteen and a half miles northeast of Bainbridge, on the old Bainbridge-Camilla road, and west of the Whigham-Camilla road, is a very fine limesink, well known in the adjoining counties. On a trip with Mr. Alfred Brooks a short examination of the same was made. The depth of the sink was estimated at, at least, 45 feet. A rapid stream about 6 feet broad enters the sink on one side, where the walls are vertical, and at the base disappears again under a recess beneath the cliff. Elsewhere the walls of the limesink are very steep but can be descended. At the bottom the well known Orbitoides, Pectens, and other remains of the Vicksburg Eocene were discovered. The general mass of the rock is whitish and soft, turning to more drab and becoming more hard at certain levels, especially towards the top. The rock over which the stream flows before plunging into the limesink is lithologically dissimilar, light brown, soft, porous, argillaceous with fossils only as casts. Although fossils were not rare, most of them were poorly preserved, and while their general aspect was that of Chattahoochee fossils it would require more extended study to assert their position, since many of the forms appeared new to us, we having collected so far only in the more southern exposures

of this group. The finding of *Orbitolites Floridana* however strengthened us in our belief that this was the Chattahoochee. Three miles north of the limesink is a natural curiosity known as the Blowing Cave. One mile east of the same, 18½ miles northeast of Bainbridge, and 7½ miles north of Whigham on the Whigham-Camilla road, is Barrow's plantation house.* Here Prof. Raphael Pumpelly found abundant masses of coral, identical in species with those to be mentioned later as occurring in the basal Chattahoochee, along the Flint River. Their occurrence here strengthens the view that the upper layer at the limesink is also Chattahoochee. The coral layer is known to be present only at a few localities in the basal Chattahoochee in S.W. Georgia.

2. *Powell's limesink*, 7 miles east of Bainbridge, on the Thomasville road, and about 4 miles northeast of Climax has steeply inclined earth covered walls, at the base of which the Chattahoochee limestone is exposed. This is white or grayish white in color, and rather soft in texture, excepting in certain layers, especially at the very base of the Chattahoochee, where the rock is compact and hard and contains a few fossils similar to those at Glenn's Well and at Wiley's Bluff. The Vicksburg rock immediately below is very soft, and white, and forms a part of an almost vertical descent into a sort of well or shaft. Towards the top it contains characteristic Vicksburg echinoids and Pectens, such as are found at Bainbridge. At the base of this shaft were found the concretionary sponges, Orbitoides, and Pecten. Towards one side of the shaft an opening led down gradually into a sort of low long cave, followed by a stream of water. Here a hard rock corresponding perhaps to layer *h* of the Flint River section was noticed, below which was more soft white rock, with Orbitoides, Pecten, a long lamellibranch shell digging tubes 6 inches long into the rock, the bases and lower sides of these tubes being usually occupied by a thin layer of some astræiform coral, Cypræa, and Cerithium Mariannensis. Towards the lower point visited the rock became harder and light brown in color.

3. At *Glenn's Well*, 4 miles south of Bainbridge on the Coon Bottom road, there is only a thin layer of the Chattahoochee, the fossiliferous part of which is a white, siliceous, very friable rock. Only the very top of the Eocene is shown. It is hard, partly silicified, brown in color, and contains Orbitoides, Cerithium Mariannensis, a stray sea-urchin, and other fossils.

* W. H. Dall, Correlation Papers Neocene, under Georgia. Loc. cit., page 447.

4. *Sweigert's Well*, 2 miles north of the Thomasville road, and 3 miles northwest of Powell's limesink, shows the same brownish more silicified phase, and contains the so-called concretionary sponges, Orbitoides, Pecten, Lucina, Xenophora, and Cerithium Mariannensis.

*The Coral layer at the base of the Chattahoochee.**

On our trip down the Flint River, Prof. Pumpelly discovered at locality 14, on the bank, at the mouth of a small creek, a great heap of bowlder, containing, among other things, large massive corals. On a subsequent trip with Mr. Alfred Brooks I traced these bowlders to locality 14, where the stream cutting down the north slope of a long high ridge, exposes the Chattahoochee at the base. In the soft whitish rock near the base of the hill the massive corals occur scattered around very irregularly through the white limestone. When *in situ*, they do not command special attention on account of their numbers, but in the beds of the stream they have accumulated to such an extent, owing to their greater resistance to disintegration, that they at once attract the observer's eye. The rock below with similar lithological features, that is, soft and very white, with few fossils except the concretionary springs, is the Vicksburg.

On the trip with Mr. Alfred Brooks, abundant massive coral blocks were found in the river bed at locality 17½. On the trip with Prof. Pumpelly, the massive corals were found along a wood road leading southwest from Wiley's Landing. They were not numerous but at some localities more were found than at others. Their occurrence was beneath the brecciated limestone considered the base of the Chattahoochee. Taken together, these localities would indicate a sort of mild coral bank extending about east and west along the northern face of the present Chattahoochee outcrop along the Flint River. The coral locality on Barrows Plantation has already been mentioned. It suggests the presence there of the base of the Chattahoochee.

The Chattahoochee.

Wiley's Landing bed.—For paleontological purposes the base of the Chattahoochee can be studied at Wiley's Landing, or locality 18. At the river's edge are found pieces of a peculiar white limestone, irregularly cracked, breaking with a conchoidal fracture, usually quite hard, but also found with the exposed surfaces soft and friable, contain-

* Loc. cit., page 447.

ing fossils mostly in the form of casts. Lithologically this rock strongly resembles the upper Vicksburg. It occurs also at locality 14, among the blocks heaped up along the river bank. The situation and lithological character of these blocks seemed to be that of the upper Vicksburg, and the fossils were not satisfactorily identified but seemed to have a Chattahoochee facies. Above this level are a few silicified courses, and then in turn comes a massive bed of a grayish-white rock, quite firm, but readily broken by a hammer, in which occur those fossils which have been recognized at a number of localities as constituting the basal fauna of the Chattahoochee. This bed, which I shall call the *Wiley's Landing Bed*, may have a thickness of 20 feet, but at the Landing the actually exposed part hardly rises that far above the river level. Toward the base of this Wiley's Landing bed the rock is brecciated, the cracks being filled in with calcite of almost the same color and constituency. The coral blocks at locality 19, although loose in the stream beds, always occurred below this level of brecciation, and so were considered as of a lower horizon. The brecciated rock is as a rule unfossiliferous. It occurs also near the stream leading out of the sink at Steep Head, west of Faceville, northwards towards the Flint River, perhaps an eighth of a mile north of the sink on the west side of the stream. Also at Griffin's Creek, four and a half miles south of Bainbridge. Reasons are given later on for believing that the last locality does not represent the same horizon.

Chattahoochee bed proper.—Next in order comes the *Chattahoochee bed*, well exposed near the (Old) Chattahoochee Landing. This locality represents a southing of about three and a half miles from that of Wiley's Landing. Its main element is a peculiar gray limestone tinged with yellow, soft, friable, readily reduced to powder. At the Landing the fossils occurred chiefly at a level only a few feet above the river level, but the friable rock extends to a height of 30 feet above the river level. Rock of the same lithological character, and having a closely allied fauna occurs about a mile and a half east of the River Junction Bridge (called Chattahoochee Landing by W. H. Dall), along the railroad which crosses the river three-fourths of a mile below (Old) Chattahoochee Landing. Here the fossils occur at a higher level than at the Old Landing, and it is to be noted that the brecciated bed along the stream leading south from Steep Head, also seems to have a somewhat higher position than would be expected from its position at Wiley's Landing.

Thickness of Chattahoochee bed proper.—The position of the fossiliferous bed at the Old Chattahoochee Landing is estimated as being at least 40 feet above the base of the Chattahoochee as shown at Wiley's Landing. The top of the friable limestone of Old Chattahoochee would then reach a level of about 65 feet above the base, and the lowest exposure at Aspallaga Bluff about five and a half miles farther south, would be at least 80 feet above the base of the Chattahoochee. The main body of the rock exposed at Aspallaga is evidently closely related to the localities just mentioned farther north. The soft friable rock, here containing shark's teeth, and other teeth which we judged to be reptilian, also apparently fish bones, was abundantly represented. Harder courses contain the ordinary middle Chattahoochee fauna. More siliceous layers occur, but their presence is also familiar along the railroad exposures half a mile northeast of Chattahoochee Junction above mentioned. The top of these Chattahoochee limestones rises according to Dall and Stanley-Brown about 50 feet above the river level. This would place it at least 130 feet above the level of the base of the Chattahoochee, and would give the Chattahoochee bed itself a total thickness of at least 100 feet.

Griffin bed and Aspallaga clays.—The *Aspallaga clays* with its Oysters and Pectens we did not see. This is unfortunate since we found a hard rock full of Orbitolites and a few other shells at a level which seemed to us, judged only by the eye and the effort it required to reach the locality, to be much higher than 50 feet above the river level. This rock is lithologically and paleontologically identical with that at Griffin's Creek and seems to promise considerable as a valuable means of correlating various horizons. I shall call it the *Griffin bed*, and believe its location to be at the top of the Chattahoochee bed, and therefore about 50 feet above the river level or a hundred and thirty feet above the base of the Chattahoochee. Above the Griffin bed occur the Aspallaga clays.

*Griffin's Creek locality.**—At the Griffin's Creek locality, four and a half miles south of Bainbridge, on the west side of the road, about half a mile west of Griffin's house, and a little north of a plantation shed occurs an exposure of interest in this connection. The lowest exposure at this locality is a brecciated limestone, about 2 feet thick. Above this lies the peculiar Griffin bed, cavernous on account of the dissolution of the many gasteropod shells once contained in them, and still containing many specimens of Orbitolites. This bed may possibly be 6 to 8 feet thick at this point. In the calcareous clay, often already deep red, or clayey brown owing to decomposition, there are found the same Anomia and apparently the same Pecten as in the Aspallaga clays of Rock Bluff. This would place the Griffin Creek bed at the junction of the

* Loc. cit., page 447.

Chattahoochee bed and the Aspallaga clays, and would suggest that the brecciated limestone just below either represents a second horizon of brecciation, or that there must once have been a great Eocene island in this part of the country and that at the Griffin Creek locality the elevation was such that there was still a chance for shore work, at a time just preceding the deposition of the two beds of later age at that locality.

The elevation at Griffin's Creek is 180 feet above the sea; at Glenn's Well, 2½ miles southward, the base of the Chattahoochee is 102 feet above the sea level. This would give the Griffin bed at this point an elevation of 80 feet above the base of the Chattahoochee, instead of 130 feet, as given in the Flint River section. This may possibly indicate a thinning out of the Chattahoochee section towards the eastward.

Powell's limesink lies 7 miles east of Bainbridge. The elevation of the base of the Chattahoochee is there 155 feet above the sea level. So little has yet been done to trace out anticlinal axes, strikes and dips of these flat-lying rocks that it would be difficult to affirm much from known data. The more northern location of this locality and a low westward as well as southern dip might account in part for its greater elevation above sea level. But the belief in an uneven base of the Chattahoochee seemed the most natural at the time field observations were still being made.*

The *Aspallaga clays*, not seen by us at the type locality, are well exposed at Rock Bluff. According to Dall and Stanley Brown† the marl has here a thickness of 67 feet. Rock Bluff representing a southing of about four and a third miles from Aspallaga Bluff, the base of the Aspallaga clays being 50 feet above the river at Aspallaga Bluff,† and 12 feet above at Rock Bluff,† the dip of the rocks may be variously estimated at from 9 to 11 feet per mile southwards, according to the supposed fall in the river level. Alum Bluff lies about 6⅓ miles south of Rock Bluff, measuring across the supposed strike of the Miocene. At this rate it seems as though the Aspallaga clays must thin out more or less southwards, since otherwise they should be at about water level or slightly above, at Alum Bluff. No doubt they occur at no great distance below water level. At this rate the Chipola bed must be rather thin. Its base may be estimated as occupying a position at least 160 feet above the level of the base of the Chattahoochee as shown at Wiley's Landing. The question as to whether the Aspallaga clays belong in the Chattahoochee or in the Chipola will no doubt be settled as investigations go on. The Anomia in these clays was found in the Wiley's Landing basal Chattahoochee, as well as at the Griffins' Creek locality, but was not

* p. 447. † Cenozoic Geology along the Appalachicola River, p. 155.

seen in the Chipola around Bainbridge, at Alum Bluff, nor along the Chipola River. The oyster so common in these clays was also found at Wiley's Landing and the Griffin localities, but not in the Chipola. For that reason I am still inclined to consider the Aspallaga clays as the top of the Chattahoochee series, at least, until further collecting shows an assemblage of true Chipola fossils in these clays. Other collectors may have already secured this desired additional material.

The writer is under special obligations to Mr. Dall and Stanley-Brown, for more precise determinations of the thickness of the various Chattahoochee beds, and to Prof. Raphael Pumpelly and Mr. Alfred Brooks for the opportunity to accompany them during their various trips down the river and elsewhere, which made it possible to collect the material for these notes and utilize many of their observations. His obligations to various publications need not be expressed in detail since these publications are too recent to require recalling to memory and are sufficiently indicated in the publications of Mr. Dall.

On the accompanying sketch map* the course of the Flint and Appalachicola Rivers has been represented in two sections. The Marianna region is mapped and introduced into a corner of the page, so as to show its relations to the Flint River section. All of the mapping being the result of traverse work is sure to have its faults, but being done with considerable care, is certain to be vastly superior to the ordinary maps which fall in the traveler's hands. The railroad east of the River Junction station is only approximately located, so that the position of the Steephead Limesink is not accurately determined, excepting as regards its location west of Faceville. For the Eocene a slope of 13 feet to the mile is assumed, for the Chattahoochee, one of 9 feet to the mile. The question of dip still awaits more detailed study. Localities starred are suitable for camping when traveling in skiffs.

Art. IX.—*On Gabbros in the Southwestern Adirondack Region*; by C. H. Smyth, Jr.

The presence of large areas of anorthosite in the Adirondack region has long been known, although the igneous nature of the rocks has not been universally recognized. In a recent paper Professor J. F. Kemp† has described extensive developments of gabbro in the vicinity of Lake Champlain, which

* See page 42.

† Gabbros on the Western Shore of Lake Champlain, Bull. Geol. Soc. America, v, p. 213.

are connected with the anorthosites previously known. During the past summer the writer examined a group of related rocks, which, from their character, mode of occurrence and location, seem to merit description.

The locality is in the southwestern corner of Hamilton County, between the hamlet of Morehouseville and Wilmurt Lake, which lie about five miles apart on opposite sides of the valley of the West Canada Creek. The hills bordering the valley consist chiefly of two varieties of gneiss. One is a rather acid rock composed largely of quartz and orthoclase, with a peculiar spindle structure, giving to weathered surfaces the appearance of partially decayed wood. The second variety is of a brownish tint, which may be only superficial, and contains hornblende in some quantity. Its foliation is of the ordinary type and sometimes shows much crumpling. A third variety of gneiss, usually nearly black, coarse grained, often massive, and containing large lumps of garnet, is present in more limited amount. The relations subsisting between these gneisses have not as yet been determined.

The rocks with which the present paper is chiefly concerned are seen at several points between Wilmurt Lake and the creek below, the first outcrop being about a mile and a half down the road from the lake, and several others appearing at various points within the next mile. Then there is a break and no further outcrops appear till the village is reached. This break is doubtless simply the result of the covering of exposures by heavy stream deposits. The outcrops show a dark, fine grained rock, forming irregular patches in the gneiss, with the line of demarcation between the two very distinct. These patches often have a tendency toward rectangular outline, and may be nearly equilateral, or elongated into a dike-like form. Their extent is usually limited to a few yards or rods. The same rock occurs in what might be taken for an interbedded layer in the gneiss, some fifteen feet thick and dipping 10° south. At Morehouseville a coarser variety constitutes a knoll three or four acres in extent.

The true nature of the rock is best shown, so far as field relations are concerned, in the small patches. It is seen to be entirely different from the surrounding gneiss in composition and structure; it cuts directly across the foliation of the gneiss and the passage between them is as abrupt as possible; occasionally fragments of the gneiss are included in it; and the zone of contact between the two rocks is marked by a narrow band differing in aspect from either rock and evidently the result of contact metamorphism. From these facts it is clear that the dark patches are intrusions in the gneiss, the bed-like mass being an intrusive sheet. The large body of rock at

Morehouseville gives only limited indications of its relations to the gneisses and the determination of its intrusive character is based upon its composition and structure and resemblance to the rocks of the smaller patches, rather than upon its mode of occurrence. This being the case, the character of the rock from the undoubted intrusions will be first considered.

Specimens from these outcrops show variations in color from very dark blue-gray, to a lighter gray with brownish tinge. The grain is fine and even, with little variation from point to point. There are, however, decided differences in the structure of the rock at different outcrops, as in some it is almost completely massive, while in others it is distinctly gneissoid. In every case the foliation is parallel to the foliation of the enclosing gneiss, and both in the field and under the microscope shows plainly that it is a result of pressure and not a flow structure. Weathering produces a light brown crust which has not been found of any great thickness, but which greatly obscures the superficial difference between the intrusives and the surrounding gneisses. Differential weathering has not proceeded sufficiently far since glaciation to cause any marked difference in elevation between the two rocks, but there is often a slight projection of the intrusive patches above the gneiss. Jointing is more perfectly developed in the former than in the latter, giving an appearance like that of many dikes of diabase and related rocks.

The darker variety of the rock very strongly resembles some of the finer grained specimens of the Baltimore hypersthene gabbro described by Professor G. H. Williams.* In fact this resemblance is so strong that it is sometimes difficult to distinguish from each other specimens from the two localities. The same resemblance exists somewhat in the composition and structure of the rocks as seen under the microscope, but in a less marked degree. Sections of the Wilmurt rock show a holocrystalline granular aggregate of plagioclase, hypersthene, monoclynic pyroxene, hornblende, a little biotite, and magnetite. None of these minerals have crystal outlines, being in irregular grains which range, as a rule, from ·1 to ·5^{mm} in diameter. A rather conspicuous feature is the absence of apatite, which is seen only rarely and in very small quantity. In a single specimen several grains of garnet are shown. Variations in the rock result from the different proportions of constituents present, and, in less degree, from differences of structure. In nearly all specimens the minerals are extremely fresh, showing almost no effects of weathering.

* The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Md. U. S. G. S., Bull. 28.

The mineral composition and structure are characteristic of the gabbro family, but the variation in relative amounts of the constituents in different masses makes it difficult to include them all under one minor subdivision of the family. In the majority of cases hypersthene is the prevailing ferro-magnesian constituent, making the rock norite; but in other examples hypersthene is subordinate to monoclinic pyroxene, so that it must be classed as hypersthene gabbro. Less often hornblende exceeds the pyroxene in quantity, the rock thus approaching diorite in composition. In a single specimen hornblende entirely replaces pyroxene, the specimen being taken from near the edge of a small patch having the normal composition throughout most of its extent. In general these dioritic phases are quite limited and appear to be more common towards the contact with the gneiss. In view of this variation in composition the rock may be best treated under the broad term gabbro, which will serve to include the important varieties, hypersthene gabbro and norite.

The least variable and most abundant constituent is the feldspar. It is conspicuously clear and free from all traces of the dust-like inclusion so common in the feldspar of the gabbros. The polysynthetic twinning of plagioclase is usually present and the extinction angles on the lamellæ, ranging from 22° to 28°, show that the feldspar is a basic bytownite. Unstriated sections of feldspar are common, but the chemical analysis of the rock indicates, by the small amount of K_2O, that little or no orthoclase can be present. Undulatory extinction is very pronounced in the feldspar, and is never lacking. Further effects of pressure are seen in bending and breaking of the lamellæ and sometimes in considerable granulation. In the most gneissoid specimens there is a limited alteration of feldspar to muscovite.

In perhaps two-thirds of the sections examined hypersthene is next to feldspar in order of abundance. In very rare instances it shows an approach to crystal form, but usually is extremely irregular in outline. It is fresh and clear, and perfectly free from the plate-like inclusions so common in the mineral. It shows the usual pleochroism quite strongly; $\mathfrak{a}$, pale red; $\mathfrak{b}$, pale yellow or colorless; $\mathfrak{c}$, light green; with very slight differences of absorption. It is distinguished from monoclinic pyroxene by this pleochroism, by its parallel extinction, and by its rather low double refraction, together with a high mean index.

The monoclinic pyroxene is pale green, or, in very thin sections, colorless, and has no pleochroism. Like the feldspar and hypersthene it contains no inclusions other than the older magnetite. The pinacoidal parting and fibrous structure of diallage are lacking, the pyroxene being of augitic habit. The angle of extinction is about 40°. This pyroxene is often in somewhat larger grains than the hypersthene.

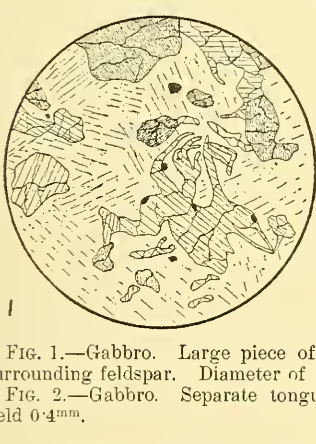
The hornblende, as already stated, is extremely variable in quantity, but is never entirely absent. It is compact, brown and strongly pleochroic; $\mathfrak{a}$ light yellow, $\mathfrak{b}$ deep brown, $\mathfrak{c}$ dark greenish-brown, with the absorption $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}$. It often contains small black inclusions, looking like magnetite. It is of considerable importance in making out the history of the gabbros and their relations to other rocks of the region to ascertain whether the hornblende is original or paramorphic. In favor of the latter supposition is the fact that the hornblende often partly encloses grains of pyroxene into which it seems to pass gradually. This intimate association is very common and often extremely marked. Paramorphism would, moreover, readily explain the increase of hornblende in some portions of the rock, even amounting to complete exclusion of pyroxene. On the other hand, the association of the hornblende and pyroxene clearly is often, if not always, the result of parallel growth and accidental juxtaposition. Further, in many cases the apparent gradual transition between the two is shown by careful observation to result from an approach to parallelism between the plane of their contact and the plane of the section. When this is not the case the line of junction of the two minerals is generally distinct and shows no indication of interpenetration. Then, too, the amount of hornblende in the rocks shows no close relation to the intensity of the mechanical force to which they have been subjected, as it is just as likely to be abundant in a massive rock as in one that is prominently gneissoid. Taking these points into consideration it seems probable that the hornblende is an original constituent of the gabbro and that the hornblendic phases of the rock are the result of local variations in the original magma, or of differences in the conditions of solidification.

Biotite is of very minor importance as a constituent of the gabbro, and need receive no special description. Its distribution is, however, of interest. Almost without exception in the finer gabbros the biotite occurs in close proximity to the plane of contact with the gneiss. The hornblende shows a tendency in this direction, but nothing like that of the biotite, which also tends to arrange itself parallel to the contact. The exceptions to this rule are few.

Magnetite is an unfailing and important constituent. It forms large irregular grains, plainly primary and in considerable quantity. Tested with H_2O_2 it shows the presence of some titanium, but as it is readily soluble in acids and strongly attracted by the magnet it must be a titaniferous magnetite rather than ilmenite.

The only macroscopic structural variations in the gabbros are differences in coarseness of grain and in degree of foliation. The grain as a rule remains nearly constant throughout any given body of the rock but varies somewhat in different patches. The hornblendic varieties are apt to be coarser than the normal rock, and as the hornblende is often more abundant toward the margins of the rock mass, these portions are sometimes decidedly coarser than the central portions, reversing the general rule in regard to intrusive rocks.

The gneissoid varieties when examined under the microscope show the effects of pressure in a greater or less amount of crushing of the minerals, besides the undulatory extinction, bending of twinning lamellæ, etc., which are seen in all sections. At the same time that the gneissoid structure becomes marked, the structure of the hypersthene undergoes a conspicuous modification. The mineral not only becomes shattered like the other constituents, but sends out long slender tongues into the surrounding feldspar. These tongues range from slight projections of the hypersthene to string-like extensions which radiate from a hypersthene core. In still more extreme cases this core is lacking and the hypersthene forms curious rosettes. It is often impossible to determine directly the nature of the mineral in the tongues, but it may be safely regarded as hypersthene as there is a complete gradation between them and the larger extensions plainly composed of this mineral. The larger tongues of hypersthene usually form a granophyric intergrowth with the feldspar presenting an appearance somewhat like that described by Bayley* in the augite of Lake Superior gabbros. It is impossible to deter-



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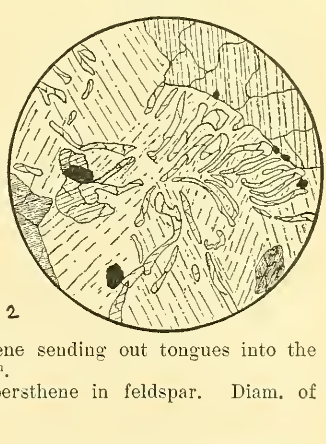

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FIG. 1.—Gabbro. Large piece of hypersthene sending out tongues into the surrounding feldspar. Diameter of field 0·7mm.

FIG. 2.—Gabbro. Separate tongues of hypersthene in feldspar. Diam. of field 0·4mm.

* W. S. Bayley. A Fibrous intergrowth of Augite and Plagioclase, resembling a reaction rim, in a Minnesota Gabbro, this Journal, III, xliii, p. 515.

mine whether the same regularity of orientation persists in the finer tongues, but such seems often to be the case. Again, the tongues wander irregularly through the feldspar, often extending between adjacent individuals. Figure 1 shows the first step toward this structure, figure 2 its more complete development though not approaching the fineness and complexity often seen. The extreme cases are often accompanied by an alteration of the feldspar to muscovite.

This stringing out of the hypersthene shows a most intimate connection with the development of gneissoid structure. When there are only slight traces of the latter structure the hypersthene occurs merely as irregular grains, but as soon as parallelism of constituents becomes marked the stringing out begins and becomes more and more conspicuous as the gneissoid structure increases. It seems a necessary inference that the phenomenon is a result of metamorphism but the rationale of the process is not clear, and it seems best to defer any attempt at explanation until more data are available.

The contact between the gabbro and the gneiss is quite distinct in hand specimens, being marked by a greenish gray band about 2^{mm} wide. Under the microscope the contact shows a narrow zone made up almost wholly of the pyroxenes with some biotite. Just within this band the gabbro consists chiefly of feldspar, and then gradually assumes its ordinary composition, though often containing an unusual amount of hornblende. The character of the contact zone is clearly due to the fact that the pyroxenes crystallized earlier than the feldspar and attached themselves to the solid face of the gneiss, leaving the adjacent layer of gabbro composed of nearly pure feldspar. The pyroxenes of the contact zone are almost completely altered to a green chloritic product, to which is due the color of this zone as seen in hand specimens. The gneiss shows no perceptible mineralogical changes at the contact, though its color is altered to a bluish gray tint.

The chemical composition of the gabbro is indicated by analysis I. The material analyzed was taken from a very fresh, massive specimen which showed under the microscope about the average proportions of minerals.

Analysis II gives the composition of a fresh specimen of the Baltimore gabbro described by Professor Williams* and III gives the results obtained by analyzing a mixture, in equal amounts, of specimens of this rock from twenty-three different localities.† The similarity in the results of the three analyses is striking and confirms the conclusion that the gabbro at Wilmurt is closely related to the Baltimore Rock.

* Op. cit., p. 37. † Op. cit., p. 39.

	I.	II.	III.
SiO_2	46·85	44·10	46·85
Al_2O_3	18·00	24·86	19·72
F_2O_3	6·16	7·89	3·22
FeO	8·76	6·53	7·99
MgO	8·43	3·89	7·75
CaO	10·17	11·90	13·10
Na_2O	2·19	1·66	1·56
K_2O	0·09	0·24	0·09
H_2O	0·30	0·60	0·56
Totals	100·95	101·67	100·84
Sp. gr.	3·097	3·044	

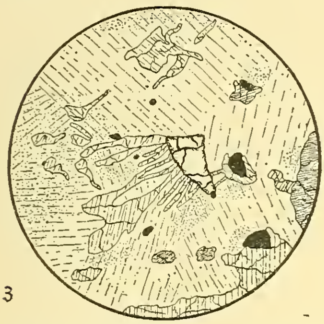
The gabbro of the larger area at Morehouseville, as already stated, gives only slight indications of its intrusive character. The rock is decidedly coarser grained than that of the small patches, and on the weathered surfaces closely resembles the ordinary hornblende gneiss of the region. In thin sections it shows the same constituents as do the finer gabbros, with the addition of considerable apatite, while biotite is quite abundant throughout the entire mass. The percentage of ferro-magnesian minerals is smaller than in the other rocks, and the augite is decidedly more abundant than hypersthene making the rock a hypersthene gabbro rather than a norite. In structure it varies from completely massive to slightly gneissoid. No crushing is apparent in sections, the undulatory extinction is less marked than in the finer rocks, and there is no sign of the stringing out of the hypersthene.

It seems probable that the facts above stated may prove of value in working out the geology of this region by giving a clue to the origin of the black hornblende gneiss previously referred to. Very little has been done as yet along this line, but a brief outline of the more important observations thus far made may well be recorded in this connection, leaving the details for a later paper. The black gneiss was first seen on the shore of Big Rock Lake, about a mile and a half northeast of Wilmurt, where it lies between acid gneiss below and brown hornblende gneiss above. As the shores of the lake are thickly wooded it is impossible to make out the character of the contacts between the rocks. From this point the black gneiss extends nearly or quite continuously along the strike, till the head of Metcalf lake is reached, a distance of three or four miles. Beyond this point the country has not been examined. On the north shore of Metcalf lake there is a series of cliffs rising one above another in which the black gneiss is seen alternating with layers of brown gneiss, sometimes with a rather gradual transition between the two, but often with a very sharp line of demarcation. As all the region is covered with dense forest it is almost impossible to get any more definite knowledge of the relations of the different rocks.

The black gneiss is coarse grained and usually more massive than the surrounding rocks, though by no means always so. Its most noticeable feature in the field is the presence of a great deal of garnet, ranging from small specks up to lumps two or three inches in diameter. Around the garnet there may generally be seen a narrow rim of dark green or black radiating plates. Freshly broken surfaces glisten with the brilliant luster of numerous cleavage faces of hornblende. From this normal type of the gneiss there are many variations. By a decrease in ferro-magnesian minerals it becomes light greenish-gray looking, very much like specimens of garnetiferous anorthosite from Essex County. In other cases the garnet disappears and the rock would then be taken for a basic gabbro. Rapid changes in the character of the rock often take place within the space of a few feet.

Sections of the gneiss show a mineral composition closely related to that of the gabbros. The feldspar is plagioclase, but in most sections is almost entirely changed to minute colorless scales, with the high double refraction, parallel extinction, absorption, and negative optical character of muscovite. In many sections this mineral wholly replaces plagioclase, but in others portions of the feldspar remain showing every stage of the alteration. Augite and hypersthene like that of the gabbro are abundant, together with hornblende of somewhat different character. This, though usually massive like the hornblende of the gabbro, differs from it in being pleochroic in green tints, sometimes with a decided bluish tone. It is intimately associated with both pyroxenes, and in such a way as to suggest that it may be derived from them, though positive proof of this is lacking. Magnetite and a little biotite make up the rest of the rock, aside from the garnet. The latter, as already stated, occurs abundantly in masses of varying size. It is sometimes perfectly clear, with a decided pink color and sharply defined, even boundary. In other cases its outline is very irregular with embayments and inclusions of the other constituents, particularly the hornblende and pyroxene.

The most conspicuous feature of the rock is its structure, due to the peculiar form of the hypersthene and hornblende. These two minerals, though often in irregular masses, show a decided tendency to extend out in radiating tongues, with a length often ten or twelve times their breadth. These tongues may start from any portion of the section, but commonly radiate from a mass of pyroxene or more particularly from garnet when it is present, thus giving rise to the radiating bands seen around this mineral in hand specimens. The tongues are usually curved and when developed from several centers give a remarkably beautiful effect under the microscope, impossible to describe or to figure with accuracy. An attempt in the latter direction is shown in figure 4. This



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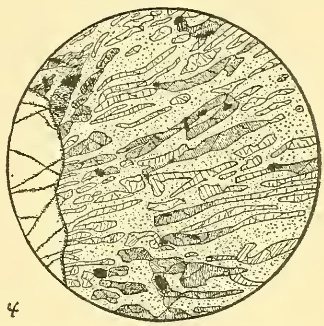

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Fig. 3—Gabbro. Tongues of hypersthene radiating from garnet. The feldspar somewhat altered. Diam. of field 0·7^{mm}.

Fig. 4—Black gneiss. Tongues of hypersthene and hornblende radiating from garnet. Feldspar completely altered. Diam. of field 2^{mm}.

structure is analogous in every respect to that described in the gneissoid gabbro, differing from it only in being on a larger scale, with all of the constituents coarser, and in the presence of tongues of hornblende as well as of hypersthene. The analogy is rendered even more complete by the fact, not previously stated, that in the sections of gneissoid gabbro which contain grains of garnet the latter are partially surrounded by radiating tongues like those around the garnet of the gneiss, but often so slender as to make difficult an accurate determination of the mineral composing them. This structure is illustrated in figure 3.

Thus, the black gneiss is closely related to the gabbro in mineralogical composition, showing such differences from it as might result from alteration and metamorphism. At the same time the gneiss has developed on a large scale a peculiar structure which is precisely analogous to a structure shown in the gneissoid gabbro. From these facts it seems justifiable to conclude that at least there is great probability that the black gneiss is a metamorphosed gabbro. The final establishment of the truth or error of this hypothesis will be an important step in unravelling the history of the gneissic complex of the region, for the bowlders of the drift indicate that the black gneiss is a rock of considerable importance. In fact, it may be said of all the rocks described that they are doubtless of much greater extent than might be inferred from the facts stated, for the dense forest covering the region, the scarcity of trails and the decided similarity in weathered surfaces of the different rocks combine to make it a matter of great difficulty to collect reliable data in regard to their areal relations.

The identification of rocks of the gabbro family in this locality is of interest in being one more piece of evidence indicating a much wider range for this group in the Adirondack region than was formerly supposed to be the case. In the early days of the New York survey the anorthosite was described by Emmons,* under the name hypersthene rock, as limited to Essex County. Colvin† speaks of finding it in another county, but does not state which one. Beecher and Hall‡ in describing the faults of the Mohawk valley speak of the labradorite at Little Falls, but give no description of the rock. Van Hise§ has stated recently that in company with Prof. G. H. Williams, he noted the gabbro in contact with limestone at Bonaparte Lake, Lewis County. Nason‖ mentions the occurrence of "frequent outcrops of the typical labradorite rocks" along the line of the Carthage and Adirondack railroad, in Lewis and St. Lawrence Counties. Finally, the work of Professor Kemp, already referred to, has shown a great expanse of the gabbros in the vicinity of Lake Champlain. In all of these recent papers, with the exception of the last, the reference to the gabbro is merely incidental, and no descriptions of the rock are given. They serve, however, to indicate that this group of rocks is by no means limited to Essex County, but, on the contrary, extends over a large portion of the Adirondack region. Of the various localities mentioned, Little Falls is the nearest to Wilmurt Lake, and is therefore of most interest in this connection. The rock so well exposed in the gorge of the Mohawk river at this place is very coarse grained, usually distinctly gneissoid, and of a greenish-gray color. It is composed chiefly of plagioclase, with some pyroxene, hornblende, mica, and quartz. Its most conspicuous feature is a highly developed cataclastic structure, showing great "augen" of feldspar lying in a mosaic of finely crushed fragments. In composition and structure the rock is precisely like the Canadian anorthosites, in fact the figures of cataclastic structure given by Adams¶ might have been drawn from sections of the Little Falls rock, so close is the resemblance. But more important is the fact that it is practically

* Geology of New York, 2d District, p. 32.

† Adirondack Survey, Second Report, p. 151.

‡ Fifth Annual Report State Geologist, p. 8.

§ Bull. 86, U. S. G. S., p. 399.

‖ Iron-Bearing Rocks of the Adirondacks, Am. Geol., xii, p. 28.

¶ F. D. Adams, Ueber das Norian oder Ober-Laurentian von Canada, Neues Jahrbuch für Mineralogie, etc., B.B. VIII, s. 419.

identical in character with the anorthosites of Essex County and must be regarded as a southward extension of this rock. Now, although Little Falls is nearly thirty miles from the Wilmurt locality, a line connecting it with the Essex County anorthosites would pass less than eight miles to the eastward of Wilmurt. Thus, if, as seems probable, the anorthosite of Little Falls is continuous with that of Essex County, it must approach within a comparatively short distance of the Wilmurt gabbro. The possibility of establishing a connection between the two rocks is thus rendered considerable, so much so in fact that there can be little doubt that the gabbros of Wilmurt Lake and vicinity are an offshoot of the great gabbro core of the Adirondacks.

Hamilton College, Clinton, N. Y., March 7, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a Titration method for determining Molecular Mass.*—It has been shown by Nernst that, when foreign substances are dissolved in a given liquid, the solubility of this liquid in another with which it is partly miscible, is diminished in accordance with the same laws as those which regulate the diminution of its vapor pressure when the second liquid is not present. The experimental confirmation of this law has been found difficult owing to the limited number of miscible liquids such as it requires. Küster, however, has succeeded in doing this, using for the purpose a saturated aqueous solution of sodium chloride on the one hand and phenol on the other. If we call L_0 and L the solubilities in water of pure phenol and of phenol containing a foreign substance, g_l and g_s the masses of phenol and of the foreign substance M_l and M_s their molecular masses and V_0 and V the volumes of phenol before and after the addition of the foreign substance we have for the value of the constant k

$$k = (L_0 - L)/L \,.\, g_l/M_l \,.\, M_s/g_s \,.\, V/V_0.$$

This value in Küster's experiments was 1·125.

To apply the results to the determination of molecular mass by titration, Küster uses two separating funnels, of about 100^{cc} capacity, each containing (1) 25^{cc} of a saturated aqueous solution of sodium chloride saturated with phenol at the temperature of the laboratory, and (2) 10^{cc} of phenol saturated with sodium chloride by contact with a strong solution of this salt. Into one of these funnels is now introduced a known mass of the substance whose molecular mass is to be determined. It must be soluble in phenol and only sparingly soluble in water. Both funnels are then shaken up for two minutes, care being taken to avoid rise in temperature, and they are allowed to settle for half an hour. A plug of cotton wool is placed in the tube of each funnel, and after drawing off 1^{cc} or so, the rest of the filtered aqueous layer is collected in a small flask and well closed. In this aqueous solution the phenol is estimated by titration with bromine; 10^{cc} of the solution being placed in stoppered bottles along with 25^{cc} of bromide-bromate solution and 10^{cc} of 10 per cent hydrochloric acid. After half an hour 10^{cc} of solution of potassium iodide (42 g. pr liter) is added and in 15 minutes the solution is titrated with twentieth normal thiosulphate solution. From the above equation

$$M_s = 1{\cdot}125 g_s 94/10 \,.\, L/(L_0 - L).$$

The author obtained for benzene values for the molecular mass ranging from 74·7 to 80·1 (theory requiring 78); for chloroform from 95·9 to 120·0, and for vinyl tribromide from 257·5 to 294; theory requiring 119·5 and 267 respectively.—*Ber. Berl. Chem. Ges.*, xxvii, 324, 328, February, 1894. G. F. B.

2. *On the Use of the Lummer-Brodhun prism in Colorimetry.*—The Lummer-Brodhun prism which has proved of so much service in photometry has been applied by KRÜSS with equal satisfaction, in colorimetry. This double prism consists of one ordinary total reflecting prism with its hypothenuse-surface plane, and of a second such prism having its hypothenuse-surface spherical, with the exception of a small circular plane surface at the center. The second prism is so adjusted to the first that its plane circle is in the center of the plane hypothenuse side of the other, the two being pressed together so as to leave no air between them. The double prism thus obtained permits light to pass unchanged through its central contact surfaces, while those rays which are incident upon the outer portions of the plane surface are totally reflected. It follows that the transmitted beam appears as a central luminous circle while the totally reflected one is a bright ring surrounding it. If the central image and the annular one are given by different sources of light the point where, on moving away the brighter source, the intensities become equal, can be very exactly determined. In Krüss's colorimeter, the light traversing the prism comes through the one solution, and that reflected by the prism through the other; the arrangement of auxiliary prisms being such that each ray has to pass through an equal thickness of glass and suffer the same number of reflections.—*Zeit. anorg. Chem.* v, 325, November, 1893. G. F. B.

3. *On Electrolysis by Alternating Currents.*—An investigation has been untertaken jointly by HOPKINSON, WILSON and LYDALL in order to determine first, the energy dissipated by the so-called electrolytic hysteresis, and second, the quantity of an ion per square centimeter of an electrode, required to change the properties of the electrode to that of the ion during alternating current

electrolysis. The experiments were made by passing an alternating current through an ordinary non-inductive resistance and through an electrolyte, the difference of potential at the extremities of these two resistances being measured at different phases of the current. Accompanying the paper are curves of current and potential differences with different frequencies, and also curves showing the dissipation of energy per cycle. As a result it appeared that with platinum electrodes 150$^{sq\ cm}$ in area, the ion being hydrogen, the maximum electromotive force due to polarization was reached when one-tenth of a coulomb had passed through the cell. That is to say, when 0·00001 gram of hydrogen had been liberated. It appears therefore that 0·00000007 gram of hydrogen is sufficient to polarize one square centimeter of platinum. If we may assume the density of this hydrogen to be comparable with that of liquids, the thickness of the film of hydrogen necessary is of the same order as this number—0·00000007^{cm}—a number comparable with the distance between the molecules.—*Proc. Roy. Soc.*, liv, 407; *J. Chem. Soc.*, lxvi, ii, 178, May, 1894. G. F. B.

4. *On the Source of the Hydrogen Peroxide in the Atmosphere.*—From his experiments, Bach has been led to the conclusion that under the action of sunlight carbonic acid undergoes decomposition, yielding percarbonic acid and the elements of formaldehyde according to the equation

$$(H_2CO_3)_3 = (H_2CO_4)_2 + \boxed{C + H_2O}$$

The percarbonic acid may subsequently decompose, yielding carbon dioxide and hydrogen peroxide $H_2CO_4 = CO_2 + H_2O_2$. It is to these reactions in his opinion, that the presence of hydrogen peroxide in the atmosphere is due. If a cold saturated and filtered solution of uranium acetate, containing one per cent of freshly distilled diethylaniline, be exposed to the simultaneous action of carbon dioxide and strong sunlight, a violet coloration is developed; although the solution is not thus affected by either of these agents separately. The result, therefore, must be due, the author believes, to the production of formaldehyde and of a compound (percarbonic acid) which will oxidize the leuco-base produced by the action of the formaldehyde upon the diethylaniline.—*Ber. Berl. Chem. Ges.*, xxvii, 340, February, 1894.

G. F. B.

5. *On the Explosive Haloid Compounds of Nitrogen.*—Pure nitrogen trichloride NCl_3 was first prepared by Gattermann in 1888, as an oily liquid, so explosive that sunlight or even the light of burning magnesium caused its detonation. Associated with it, the crude product contained other chlorides of nitrogen. Last year Szuhay produced the compounds NHI_2 and $NAgI_2$, both explosive. The whole subject has now been studied by Seliwanow who shows that the production of the chloride or the iodide of nitrogen by the action of the halogens upon ammonia takes

place in two stages, hypochlorous or hypoiodous acid being first produced. When a dilute instead of a concentrated solution of iodine is employed, no separation of nitrogen iodide occurs and the solution contains both ammonium iodide and hypoiodous acid HIO; this latter substance being readily detected by means of its reaction with potassium iodide. As the strength of the iodine solution is increased, nitrogen iodide begins to be deposited its formation taking place at the expense of the hypoiodous acid. The reactions are: $NH_3+I_2+H_2O=NH_4I+HIO$, and $NH_3+(HIO)_3=NI_3+(H_2O)_3$. The author has shown that a similar explanation holds with reference to nitrogen chloride. The fact that he proves the presence of hypoiodous acid in a solution of ammonia, is interesting in view of the basic properties of this substance as recently established by Victor Meyer.—*Ber. Berl. Chem. Ges.*, xxvii, 1012, April, 1894. G. F. B.

6. *On the Preparation of Phosphorus by the Action of Aluminum upon the Phosphates.*—It has been observed by ROSSEL and FRANK that on heating sodium metaphosphate with aluminum in a current of hydrogen, 28 to 31 per cent of the phosphorus distills over, leaving a residue consisting of alumina, sodium aluminate and aluminum phosphide. The same is true of the phosphates of calcium and magnesium; all of them yielding phosphorus when heated with aluminum. When aluminum is heated in the vapor of phosphorus, aluminum phosphide Al_3P_5 is formed. It is obtained as a gray powder by continuing the heat until the excess of phosphorus is drive off. If silica be added to the mixture of phosphate and aluminum the whole of the phosphorus may be obtained:

$$(Ca(PO_3)_2)_3+Al_{10}+(SiO_2)_3=(CaSiO_3)_3+(Al_2O_3)_5+(P_2)_3.$$

On heating a mixture of calcium metaphosphate and calcium sulphate with aluminum a violent explosion took place which the authors believe to be due to the sulphate; since barium sulphate or calcium sulphate acts with explosive violence when heated with aluminum setting free sulphur.—*Ber. Berl. Chem. Ges.*, xxvii, 52, January, 1894. G. F. B.

7. *On the Production artificially of the Diamond.*—The experiments of MOISSAN upon the production of the diamond in his electric furnace have been continued. In order to cool the melted iron, it is poured into melted lead. Small globules of the iron rise to the surface and are cooled and solidified before reaching it. When these globules are treated with acids in the usual way the yield of diamonds is somewhat better and they are very limpid, have no black enclosures and some of them show distinct crystallization. In many cases they also show parallel striæ and impressions of cubes similar to those seen on native diamonds. Two specimens thus prepared broke spontaneously after a time. One of them showed distinctly curved faces. Some of these diamonds show smooth and brilliant surfaces while others have a granular surface. In some cases they were found to be trapezohedrons

with twelve faces. In convergent polarized light, some crystals showed no coloration, while others showed feeble colors though less intense than is sometimes seen in natural crystals. Hence the author thinks it probable that carbon like iodine and arsenic, changes at the ordinary pressure and at a sufficiently high temperature from the solid to the gaseous state but under a very high pressure can be liquefied and remain in surfusion taking a crystalline form when it solidifies.—*C. R.*, cxviii, 320; *J. Chem. Soc.*, lxvi, ii, 189, May, 1894. G. F. B.

8. *Electrical Condition of the air in high altitudes.*—The results of experiment by Weber, Elster and Geitel appear to confirm the hypothesis of Peltier that the earth has a negative charge and is also surrounded by an electrostatic field. The equipotential surfaces are approximately parallel to the earth's surfaces, and the positive charge increases with the height as far as previous observations have extended. The amount of vapor in the air, the presence of clouds modifies notably this electrostatic field of the earth. Various measures of the potential of the air at different heights have been made in balloon ascensions. Thus Lecher found at 440, 550 and 660 meters height a potential of 193 voltmeters, while at the surface of the earth 92·2 voltmeters was obtained. Tuma obtained at the height of 410 meters, +40 voltmeters and at a height of 1900 meters +70 voltmeters. R. Börnstein has made, however, two balloon ascensions and obtained results which appear to disprove the theory that the potential increases with the height. The first ascension was made August 18, 1893, near Berlin on a clear day, with still air. The height of 3790 meters was reached, and the electrometer indicated a potential between +88 and −52 voltmeters. The instrument showed marked variations and on the whole, diminution of the potential with the height. At 3000 meters, the potential difference was too small to measure. The results of this ascension however may have been complicated by unusual atmospheric conditions, possibly by the prevalence of an aurora. A second ascension was made from Charlottenburg, September 29. The height of 3943 meters was attained. The potential varied somewhat, attaining a maximum value of +100 voltmeters, and did not reach negative values. It decreased as the balloon rose, at 3300 meters it was not measurable, but became greater as the balloon sank. Feb. 17, 1893, Baschin attained a height of 4000 meters, and also noted a diminution of the potential with increasing height. At a certain height measures were no longer possible. Similar results were obtained in August, 1893, by French observers. Börnstein remarks that five observers, thus independently of each other, have found that the potential decreases with increasing height. The observations seem to point to the conclusion that masses of electricity of positive sign are present in the atmosphere. In the discussion of Börnstein's paper Professor Bezold pointed out that our knowledge of atmospheric electricity can be gained better from balloon ascensions than from observations

from high points on the earth's surface, for at such high points it is impossible to obtain conditions of uniformity. If we had numerous observations at different heights taken in balloon ascensions, we could construct curves which would show at a glance the electrical conditions of the atmosphere.—*Proc. Physical Society Berlin*, March 16, 1894. *Ann. der Physik und Chemie*, No. 6, 1894, pp. 35-50. J. T.

II. Geology and Mineralogy.

1. *The United States Geological Survey.*—The recent resignation of Major J. W. Powell, and the appointment of Charles D. Walcott to be his successor as Director of the U. S. Geological Survey, mark the completion of the first fifteen years of this important Government Bureau.

Congress did not organize this survey, but in a couple of clauses of the Appropriation bill of March 3, 1879, established the office of "Director of the Geological Survey," made the necessary appropriations for his salary and for the expenses of the survey, and placed upon the Director the duty of "directing the Geological Survey, the classification of the public lands, the examination of the geological structure, mineral resources and products of the national domain."

Clarence King was the first Director and performed the important function of organizing the Survey and setting it in motion. In 1881 Mr. King resigned and Major J. W. Powell took up the task of directing the survey, and it is largely due to the energetic directing of the survey by these two officers that such grand results have been accomplished in so short time. In fact the criticism of the administration of the survey has been directed chiefly against the too energetic extension of its investigations into fields thought, by the critics, to be outside the legitimate province of the survey.

The broadening of the area of the survey from the "national domain," to which it was at first restricted, to include the whole territory of the United States has resulted in opening the grander problems of the geological structure and development of a continent to scientific study, and has already been found entirely practicable—aiding and not interfering with local state surveys.

The great attention paid to topographical surveys has been criticised both by those calling for more thorough work than has been done, and by those jealous of enroachments upon the more specific province of a geological survey—i. e. the elaboration of the geology of the country. Topographic maps are undoubtedly necessary to the minute study of the geology of a region, but their construction should not be made the chief work of a geological survey.

The segregation of lands in the arid regions for irrigation reservoirs, however important for the regions concerned, is not the legitimate function of a geological survey, and the transfer of this work either to a separate organization, or to the individual States to be benefited thereby, would relieve the survey from both criticism and expense.

The paleontological work of the Survey has been done on a scale which has excited the admiration of the scientific world. When we consider the marvelous revelations which American paleontology has made in the past few years any undue expenditure in this direction may be charged to the lavishness of our rocks in paleontological wonders rather than to any wastefulness on the part of the survey. Paleontology is the basis of all interpretation and classification of the geology of stratified rocks, and we hope that the selection of one of our ablest paleontologists to be Director will result in the application of the thorough methods of research, used by Mr. Walcott in his interpretation of the Cambrian, to all the departments of the United States Geological Survey.

H. S. W.

2. *An Introduction to the Study of the Brachiopoda*, intended as a Handbook for the Use of Students. By JAMES HALL, assisted by JOHN M. CLARKE. (Report of State Geologist of N. Y. for 1891.) Pp. 135–300, plates 1–22, 1894.

It is seldom that the authors of special monographs devote their time and knowledge to the preparation of a general elementary work which will enable the student to gain a comprehensive view of a given subject. The Brachiopods are an especially favored class of animals. Davidson, in 1851, published his well-known and able "Introduction," which showed what might be expected when the recent and fossil forms had been more thoroughly studied. Œhlert, later, in 1887, prepared the section relating to Brachiopods for Fischer's "Manual de Conchyliologie." It has been considered the best modern treatise on the class, and is in every way an admirable resumé. Zittel has also given an excellent review of the group in his "Handbuch der Palæontologie."

The authors of the present work are especially fitted for the task through their long and intimate investigation of the Genera of Palæozoic Brachiopoda (vol. viii, Palæontology of New York), and it is safe to assume that this handbook embodies a more critical knowledge of the class than it has hitherto received in similar elementary works.

The introductory portion treats of the leading characters of the Brachiopoda, together with their geographic and bathymetric distribution. The features of the shell are then discussed, with the variations in form, ornamentation, and the special characters of the cardinal area and delthyrium. The internal configuration of the valves receives considerable attention, and includes features of the articulating apophyses, muscular scars, pallial sinus, genital markings, and structure of the test. The portion relating to the animal itself gives a summary of the structure of the mantle and pedicle, the muscular, alimentary, neural, and reproductive systems, and the numerous modifications of the brachia in various groups of genera. The last of the general introductory matter is on the embryology and especially the early and post-embryonic stages in the development of the shell.

These observations are followed by succinct descriptions of the genera, with mention of their geological range and the type species. The genera are well illustrated in the twenty-two lithographic plates accompanying this work which were drawn in the most perfect manner by Philip Ast, the well-known artist of the Palæontology of New York.

The present volume includes the inarticulates with the orthoid, strophomenoid, and productoid genera of the articulates. The authors propose to complete the work with plates and descriptions of the spire- and loop-bearing forms, together with a general chapter on the classification of the Brachiopoda. C. E. B.

3. *Bibliotheque Gèologique de la Russie*, vol. viii, 1892, par S. NIKITIN, pp. 1–215, St. Petersbourg and Paris, 1893.

The eighth volume of this valuable digest of Russian geological literature contains titles and brief synopses of contents, in both Russian and French, of the literature of 1892. Its value is increased by the addition of full indices, arranged according to subjects, geographic, biologic and authors' names.

4. *Illustrations of the Fauna of the St. John Group*, No. VIII; by G. F. MATTHEW. (Trans. Roy. Soc. Canada, Section iv, 1893.) pp. 85–129, Plates xvi, xvii, 1894.

In the closing number of this important monograph, which has been issued serially, is added a "list of the Fossils of the Cambrian and Ordovician rocks in and near St. John, being those of the Basal or Etcheminian series and of the St. John Group," in which are listed 220 species and varieties.

The following thicknesses are given of the rocks of the St. John Basin, viz:

Basal series (Etcheminian) at Hanford Brook, St. Martin's,	1,200 ft.
Division 1 (Acadian) at the Alms House, Simonds,	650 "
Division 2 (Johannian) at King's Square. Carleton,	1,000 "
Division 3 (Bretonian) at Straight Shore, Portland,	700 "
	3,550 ft.

At the close of the paper the author remarks on the use of the name St. John group as follows:

"Since the range of the terrain is now known, the name St. John group cannot be used as synonymous with Cambrian; nor is it of value as that of a group with a specialized fauna of local import only. It is rather to be regarded as presenting a phase of the Cambrian and Ordovician faunas of regional value, and especially as showing a succession of American faunas of those times, having close relations with the co-temporaneous faunas of Europe. Its claim to general use has been abrogated by the discovery of its faunas, and it now stands on much the same footing as the Quebec group of Sir Wm. Logan. These names must give place to the older ones, Cambrian and Lower Silurian

(=Ordovician), since both the St. John and the Quebec groups include strata of two great geological systems." (pp. 120–121.)

5. *Fossil resin.*—The following chemical analyses of specimens of a fossil resin of black color from two horizons in the Tertiary formation in Alabama, viz: the base and the summit of the Eocene, imbedded in impure limestone, are reported by EUGENE A. SMITH, the State Geologist, in a letter to the editors.

The analyses were made by Dr. Wm. B. Phillips.

No. 1. Marengo Co., Ala. Base of Eocene.
No. 2. Barbour Co., " " "
No. 3. Choctaw Co., " Top "

PROXIMATE ANALYSES.

	I.	II.	III.
Volatile matters	57·65	62·85	62·90
Fixed carbon	41·00	36·20	34·50
Ash	·15	·85	2·30
Moisture	1·20	·10	·30
	100·00	100·00	100·00

ULTIMATE ANALYSES.

	I.	II.	III.
Carbon	63·88	59·86	54·47
Hydrogen	9·07	7·90	7·72
Oxygen by difference	20·21	26·17	29·71
Nitrogen	0·37	0·63	0·22
Sulphur	5·12	4·49	5·28
Ash	·15	·85	2·30
Moisture	1·20	·10	·30
	100·00	100·00	100·00

6. *Papers and Notes on the Glacial Geology of Great Britain and Ireland;* by the late HENRY CARVILL LEWIS, M.A., F.G.S., Professor of Mineralogy in the Academy of Natural Sciences, Philadelphia, and Professor of Geology in Haverford College, U. S. A. Edited from his Unpublished MSS. with an Introduction by Henry W. Crosskey, LL.D., F.G.S. London: Longmans, Green & Co. 1894. 8vo, pp. lxxxi, 469.—The sudden death of Professor Lewis in July, 1888, just as he was beginning to revise his field work on glacial geology in Great Britain and Ireland, led many to fear that the world had lost the greater part of the work already done by him, for there are few observers whose field notes can be safely published without the author's own revision; but those who knew the habits of Professor Lewis expected that his notes upon this subject would prove of inestimable value. They are not disappointed. The present volume of 550 elegantly printed 8vo pages, is really one of the most important contributions to glacial geology which has yet been made. The late Rev. Henry W. Crosskey has furnished an introduction

of great value, and Prof. Percy F. Kendall has added an appendix ably supplementing the observations and inferences of Professor Lewis. But the main work is still that of Lewis in which we are permitted to travel with him over almost the whole of Great Britain and Ireland and see what he saw of the glacial facts upon which his theories were based. Professor Lewis' eye was both sensitive and highly trained, and he records fully the separate facts as they are. In this respect the volume very much resembles the separate volumes of the Second Geological Survey of Pennsylvania, and reflects the good judgment of Professor Lesley who furnished the pattern for the reports of the Pennsylvania geologists in whose company Professor Lewis began his scientific work. The volume contains ten elaborate maps and one hundred or more illustrations. The author's minute acquaintance with the glacial phenomena of Pennsylvania enabled him through comparison to see the meaning of the English facts as no local observers had been able to do. He was led to believe in the continuity of the glacial period and to reject the theory of an extensive submergence of the British Isles in connection with it. His greatest triumph is what may be called a *reasonably complete demonstration* that the high-level shell-beds at Macclesfield and Moel Tryfaen were not deposited during a period of submergence, but consisted of material which had been incorporated into the till, pushed up by the glacier from the Irish Sea. The work of Professor Lewis marks an epoch in English glacial geology, and Alfred Russel Wallace has recently given his adhesion to the most important of the revolutionary views so ably defended in this volume. Great credit is due to Mrs. Lewis for the expense and pains which she has bestowed in making the unrivalled work of her husband available to the scientific public. G. F. W.

7. *Brief notes on some recently described minerals.*—Under the name of *Knopite*, Holmquist has described an apparently isometric mineral from Alnö which is very near to perofskite but differs in containing cerium as shown in the analysis.

SiO	TiO_2	ZrO_2	FeO	MnO	MgO	Ce_2O_3	CaO	K_2O	Na_2O	H_2O	
1·29	58·74	·91	3·23	·31	·19	5·80	26·84	·75	·29	1·00	= 99·35

Two types of the mineral are given and the optical anomalies are fully discussed.—*G. För. Förh.* xvi, *p.* 73, 1894.

Recently L. J. Igelström has described a number of supposed new antimony and arsenic minerals from the Sjögrube Örebro, Sweden. Thus *Lampeostibian*, a ferrons manganous antimonate apparently tetragonal, *Elfstorpite* a manganous arseniate, perhaps orthorhombic, *Shloroarsenian* a possible manganous arseniate, *Rhodoarsenian* occurring in small pink spheroids, for which the following composition is given after deducting some admixed calcite.

As_2O_5	MnO	CaO	MgO	H_2O by diff.
12·17	49·28	21·53	5·37	11·65

This is interpreted to stand for $10RO.As_2O_3 + 10R(OH)_2$ where R=MnCa&Mg. Hardness 4, vitreous luster, pale pink streak. Easily soluble in HCl. *Basilite* a foliated dark metallic bluish looking mineral occurring with hausmannite. In thin foliæ translucent with blood-red color. An analysis on impure material gave

Sb_2O_5	Mn_2O_3	Fe_2O_3	H_2O
13·09	70·01	1·91	15·00

Sjögruvite occurs in thin lamellæ in veins and druses with jacobsite. Translucent blood-red color. Streak yellow. The analysis gave:

As_2O_5	MnO	Fe_2O_3	CaO	PbO	H_2O	
49·46	27·26	11·29	3·61	1·74	6·81	= 100·17

This brings it very near Arseniöpleite previously described by the same author. All of these minerals are however so imperfectly investigated that it is impossible to say whether they will stand as definite new species or not. Some of them have been determined as such only by qualitative analyses carried out upon material of doubtful purity. All crystallographic and nearly all physical examinations are wanting. Such work in mineralogy is to be greatly deplored as tending to promote confusion and disorder.—*Zeit. f. Kryst.*, p. 467, vol. xxii, 1894.

Rittingeaite has been shown by MIERS to be identical with *Xanthokonite.* The former name thus becomes only a synonym. Also that the mineral is really monoclinic, ang. $\beta = 88° 47'$ simulating hexagonal symmetry. In conjunction with this, the analytical work by PRIOR shows that it is a silver sulpharsenite and not a sulpharsenate. Thus it has the same composition as proustite, the molecule $Ag_3As\,S_3$ being dimorphous (*Ibid.* 433).

Frankeite is a new mineral from the mines in the Dept. of Potosi, Bolivia, described by STELZNER. An analysis by WINKLER gave

Pb	Sn	Sb	S	Fe	Zn	Gang
50·57	12·34	10·51	21·04	2·48	1·22	0·71=98·87;

the iron and zinc being deducted as pyrite and sphalerite, the remainder gives the formula $Pb_5Sn_2Sb_2S_{12}$. Traces of germanium were also found. Occurs in radiating fibrous or foliated masses. Cleavage in one direction good. H.=$2\frac{3}{4}$. Sp. Gr.=5·55. Luster metallic, opaque, color blackish gray to black. Under the name of "llicteria" is known as an ore.—(*Jahb. f. Min.* 1893, vol. ii, p. 114). L. V. P.

8. *Manuel de Mineralogie;* par A. DES CLOISEAUX, tome 2d deux. fasc. Paris, 1893. (Dunod.)—The first volume of this work appeared in 1862, the last part of the second volume in 1874. Of the plan and scope of the work it is unnecessary to say anything here, it is familiar to every mineralogist of every nationality, and it is a matter of congratulation that the veteran mineralogist, whose services to science have been so great, has

been able to add this further contribution to his important work. The present part includes the phosphates, arsenates, etc. The author proposes to issue a third volume describing the sulphates and allied species. L. V. P.

III. Astronomy.

1. *Total Eclipses of the Sun;* by Mabel Loomis Todd. Boston, Roberts Brothers. 12mo, 1894, pp. 244.—This is a very pleasantly written volume, designed not for astronomers but for those without technical knowledge who are curious as to the strangely impressive phenomena of total eclipses. It is profusely illustrated, and professional astronomers will, we believe, find the little volume not only interesting but useful, as it has an extensive index and abundant references to original sources.

2. *Publications of the Lick Observatory of the University of California.* Vol. II, Sacramento, 1894. 4°, pp. 255.—This volume contains Mr. Burnham's observations at Mount Hamilton upon double stars made with the 36 inch and the 12 inch refractors of the Lick Observatory between August, 1888, and June, 1892. The six catalogues, Nos. 14–19, of new double stars discovered by Mr. Burnham at Mount Hamilton, and originally contributed to the *Astronomische Nachrichten,* are included in this volume.

3. Prof. M. Updegraff, who has had charge of the Laws Observatory of the University of the State of Missouri at Columbia since July, 1890, has communicated to the Academy of Sciences of St. Louis a description of the building and principal instruments together with the determination of the latitude, longitude, and altitude above sea level of the Observatory. These are:

Mean N. latitude,	$38° 56' 51''\cdot70 \pm 0''\cdot08$
W. longitude,	$6^h 9^m 18^s\cdot334$
Height above sea level,	737·41 feet.

The equatorial telescope is a refractor of 7·45 inches clear aperture, made in Munich, and used by Prof. Winlock at Shelbyville and at Cloverden. It has been provided with a spectroscope by Fauth. The transit instrument has a clear aperture of 2·10 inches.

IV. Botany.

1. *Guide to Sowerby's Models of British Fungi in the Department of Botany, British Museum,* 1893. 8°, pp. 82. Figs. 93.—This attractive pamphlet which is offered to the visitors of the British Museum for the moderate sum of fourpence is intended as a guide to the collection of models of edible and poisonous fungi made by James Sowerby during the publication of his classic work, English Fungi, 1797–1809. The collection was exhibited to the public during Sowerby's life in his own house and after his death it became the property of the British Museum. It con-

sisted of more than two hundred models most of which were made of unbaked pipe-clay and being very fragile they had become somewhat injured with time but they have been skilfully restored by Mr. Worthington G. Smith, so that the collection is one of the finest in existence. Probably the only other collections to be compared with it are the wax models made by Pinson after Bulliard's plates in the Museum of the Jardin des Plantes in Paris and the models made by Barla in the Museum at Nice of which there is also a duplicate series in the Ecole de Pharmacie in Paris. The figures which illustrate the Hymenomycetes are from Stevenson's British Fungi and the remainder were prepared by Mr. Smith, who also wrote the text which includes numerous remarks on edible and poisonous properties of the different species, the result of Mr. Smith's large experience. W. G. F.

2. *A Monograph of Lichens found in Britain: being a Descriptive Catalogue of the Species in the Herbarium of the British Museum;* by the Rev. JAMES M. CROMBIE. Part I. 8°. Pp. 518. Figs. 74. London, 1894.

This excellent monograph, printed by order of the Trustees of the British Museum, although treating specially of British Lichens will prove to be of great value to American lichenologists on account of the illustrations of the fruit of different genera, the clear descriptions and well arranged synonymy. In fact we know of no treatise covering the same ground in which the student of lichens will find so much information as to the generic and specific distinctions presented in a compact and comparatively inexpensive form. The present volume includes the greater part of the gymnocarpic forms, the *Lecideæ*, *Graphidei* and angiocarpic forms being reserved for another volume. The order of genera is essentially that of Nylander's Synopsis, but *Myriangium*, a genus which in our opinion should not be included in lichens in any sense, is placed after the angiocarpous forms. Perhaps the most valuable part of the volume is that relating to *Ephebacei* and *Collemacei*, very perplexing families, the descriptions of whose species have hitherto been scattered in different papers and journals not infrequently inaccessible to the student. We regret, however, that in the description of the gonidia, or gonimia as they are called in these families by lichenologists, the author has retained the cumbersome terminology of lichenological treatises instead of referring them to the alga—forms which, to say the least, they resemble. As an illustration we may take *Ephebei* whose gonidia are described as "gonimia tunicated in nodulose syngonimia." Since they are undistinguishable from the alga-genus *Stigonema*, a genus which must be familiar to lichenologists as well as others, it seems to us that it would be better to describe the gonidia in this case by the word Stigonematoid. The convenience and accuracy of such an adjective seems to us to be quite independent of the question whether a writer accepts or denies the validity of the alga-fungal theory of the nature of lichens. So far as the general descriptions are concerned they are excellent, spore characters, chemical reactions, habitats and localities being given sufficient but not too great prominence, so that the whole appears well proportioned. In several genera, as *Usnea*, forms generally classed in this country as varieties and regarded as such in Nylander's Synopsis are raised to the rank of species. It is to be hoped that the author will be able soon to publish the second volume for, at present, we have no treatise in which the species of *Verrucaria* and their allies are adequately described, not to mention the scattered condition of the literature relating to *Lecideei* and *Graphidei*. W. G. F.

V. Miscellaneous Scientific Intelligence.

1. *The Condition of Kilauea March 20th*, 1892; by F. S. Dodge.—A paper by Mr. Dodge in vol. xlv of this Journal contains an account of the crater of Kilauea at the time of his survey in August, 1892. A recent letter, dated the 26th of March last, states that since that on the 20th, he had found great changes since 1892.

The deep pit of Halemaumau or pit at the southwest end of the crater of Kilauea had become completely filled up by overflows from its lake; and the lake has thereby raised until now its level is but 75 feet below the Volcano House datum; and it is still rising. [The Volcano House is on the northeast border of the crater of Kilauea; and in 1887, the highest part of the margin of Halemaumau was 320 to 330 feet below the Volcano House datum.] The lake has increased in size by the addition of a circular portion—on the S. W. or Kau side—the total area being now about 15 acres, and the newer portion is the scene of the greatest activity. Seven overflows were counted at one time last Tuesday evening. The largest was fully 50 feet in width at the outlet, and extended to the foot of Kau bluff near Uwekahuna, the west side of Kilauea. The rise in the lake has been 447 feet since Aug. 1892, and now a flat cone surrounds the lake, so that instead of a pit with a lake in its bottom area, there is a low broad cone with the lake on its summit, and it is this summit which is only 75 feet below the datum point at the Volcano House.

2. *On the Leicester Earthquake of August* 4, 1893; by Charles Davison. (Read before the Royal Society, London), February 28, 1894. (Abstract.)

On August 4, 1893, at 6.41 P. M., an earthquake of intensity nearly equal to 6 (according to the Rossi-Forel scale) was felt over the whole of Leicestershire and Rutland and in parts of all the adjoining counties. The disturbed area was 58 miles long, 46 miles broad, and contained an area of about 2066 square miles. The direction of the longer axis (about W. 40° N. and E. 40° S.) and the relative position of the isoseismal lines show that the originating fault, if the earthquake were due to fault-slipping, must run in about the direction indicated, passing between Woodhouse Eaves and Markfield, and heading towards the northeast. The anticlinal fault of Charnwood Forest, so far as known, satisfies these conditions, and it is highly probable that the earthquake was caused by a slip of this fault.

The beginning of the sound preceded that of the shock in all parts of the disturbed area ; the end of the sound followed that of the shock in the central district and in the neighborhood of the minor axis, but preceded it near the end of the major axis. Thus the sound apparently outraced the shock in the direction of the major axis, but not in that of the minor axis. These time-relations of the sound and shock can be readily explained if the area over which the fault-slip took place were several miles in length, for the sound in all probability is due to small and rapid vibrations proceeding chiefly from the margins of that area.

The intensity was greatest at and near Woodhouse Eaves, and it is probable that the fault-slip began in the neighborhood of this place, gradually diminishing in amount in either direction, rather rapidly towards the northwest, and much more slowly towards the southeast; the rate at which the slipping advanced being greater than the velocity of the earth-wave. The total length of the fault-slip may have been as much as 12 miles or even more and there can be little doubt that it was continued for some distance under the Triassic rocks on which Leicester is built.

3. *Congrès Geologique International.* Compte Rendu de la 5^{me} Session, Washington, 1891, i–ix, pp. 1–529, figs. 1–39, pls. i–xxi, Washington, 1893.

This Report of the fifth session of the International Congress of Geologists, held in Washington in 1891, prepared by the general Secretary S. F. EMMONS, like most of its predecessors, contains much valuable matter in addition to the Procès-verbeaux of the proceedings of the Congress itself.

Part first gives a brief account of the history of the Congress; part second contains the Procès-verbeaux; part third contains reports of special discussions; A communications, and B discussions on the correlation of rocks; C discussion upon the classification of the Pleistocene deposits; D discussion of the color-scheme for geological maps, and E a brief compte-rendu of the geological excursions. Part 4, more than one-half the volume, contains illustrated explanations of the three main excursions; A, Geology of Washington and vicinity, prepared by W. J. McGee, with the collaboration of G. H. Williams, Willis and Darton; B, Geological Guide Book of the Rocky Mountain Excursion, edited by S. F. Emmons, parts of it being written by Gilbert, G. H. Williams, I. C. White, Orton, Emmons, Grant, Eldridge, Hague, Iddings, Weed, Peale, Cross, Walcott, and McGee, and interesting notes are added by the visiting geologists, T. McK. Hughes, Fritz Frech and H. M. Cadell. The thanks of all geologists are due to Mr. Emmons for so successfully editing this valuable report, and to the Government, through the U. S. Geological Survey, for its excellent publication. H. S. W.

4. *An international Congress of applied Chemistry* is to be held at Brussels, Aug. 6th to 11th. Mon. F. Sachs (rue d'Allemagne, 68), and H. Van Laer (rue de Holland, 15), Brusselles, are the general secretaries of the committee of organization.

The Lower Silurian Lamellabranchiata of Minnesota; by E. O. ULRICH, pp. 475–628, pls. xxxv–xlii. (From vol. iii of the Final Report of the Geological and Natural History Survey of Minnesota.) June 16, 1894.

Études industrielle des Gites Métallifères; par GEORGE MOREAU. pp. 439, fig. 1–39. (Baudry et C^ie^.) Paris, 1894.

On the hereditary transmission of acquired characters: by WM. H. BREWER. (Agricultural Science. Vol. vi, and Vol. vii; a series of nine papers closing with Vol. vii. pp. 433–438.) 1893.

The volcanoes of the Kula basin in Lydia; by HENRY STEPHENS WASHINGTON. pp. 1–67. Pls. i–iv. New York, 1894.

Iron ores of North Carolina, a preliminary Report; by HENRY B. C. NITZE, Assistant Geologist. (Bulletin No. 1, North Carolina Geological Survey, J. A. Holmes, State Geologist.) pp. 1–233, figs. 1–58, pls. I–XX, one map. Raleigh, 1893.

The Relation of Biology to Geological Investigations; by CHAS. A. WHITE. From the Report of the U. S. National Museum for 1892, pp. 245–368 (with plate xiv). Washington, 1894.

Geomorphology of the Southern Appalachians; by C. WILLARD HAYES and MARIUS R. CAMPBELL, from the National Geographic Magazine. Vol. vi, pp. 63–126. Pls. 4–6. Washington, 1894.

Iowa Geological Survey, Vol. II, *Coal Deposits of Iowa*; by CHARLES ROLLIN KEYES. pp. 536. Pls. I–XVIII. Des Moines, 1894.

United States Geological Survey, Bulletins.—The following Bulletins have been recently published:

97. The Mesozoic Echinodermata of the United States, by W. B. Clark. 1893. 8°. 207 pp. 50 pl.

98. Flora of the Outlying Carboniferous Basins of Southwestern Missouri, by David White. 1893. 8°. 139 pp. 5 pl.

99. Record of North American Geology for 1891, by Nelson Horatio Darton. 1892. 8°. 73 pp.

100. Bibliography and Index of the Publications of the U. S. Geological Survey, 1879–1892, by Philip Creveling Warman. 1893. 8°. 495 pp.

101. Insect Fauna of the Rhode Island Coal Field, by Samuel Hubbard Scudder. 1893. 8°. 27 pp. 2 pl.

104. Glaciation of the Yellowstone Valley north of the Park, by W. H. Weed. 1893. 8°. 41 pp. 4 pl.

105. The Laramie and the overlying Livingston Formation in Montana, by Walter Harvey Wood, with Report on Flora, by Frank Hall Knowlton. 1893. 8°. 66 pp. 6 pl.

106. The Colorado Formation and its Invertebrate Fauna, by T. W. Stanton. 1893. 8vo. 288 pp. 45 pl.

107. The Trap Dikes of Lake Champlain Valley and the Eastern Adirondacks, by J. F. Kemp. 1893. 8°. 62 pp. 4 pl.

108. A Geological Reconnoissance in Central Washington, by Israel Cook Russell. 1893. 8°. 108 pp. 12 pl.

12th Annual Report of the United States Geological Survey. 1890–91. By J. W. POWELL, director, Part I Geology, xiii, 675 pp. 53 pl. Part II Irrigation, xviii, 576 pp. 146 pl. Washington, 1891. (Vol. I contains—The Origin and Nature of Soils, by N. S. Shaler; pp. 213–346; The Lafayette formation, by W. J. McGee; pp. 347–524; The North American Continent during Cambrian time, by C. D. Walcott; pp. 523–568; The Eruptive rocks of Electric Peak and Sepulchre Mountain, Yellowstone National Park; by J. P. Iddings; pp. 569–664.)

The following extracts from the 13th Annual Report of the Director of the U. S. Geological Survey have appeared:

The Mechanics of Appalachian structure, by Bailey Willis.

The Rensselaer Grit Plateau in New York, by T. Nelson Dale.

Second Expedition to Mount Saint Elias, by Israel Cook Russell.

The Average Elevation of the United States, by Henry Gannett.

The American Tertiary Aphidæ, by S. H. Scudder.

APPENDIX.

Art. X.—*Footprints of Vertebrates in the Coal Measures of Kansas;* by O. C. Marsh. (With Plates II and III.)

The Museum of Yale University contains a small collection of footprints of much interest, which were found in 1873, in the Middle Coal Measures, near Osage, in southeastern Kansas. This collection is part of a larger series of specimens obtained at the locality by the late Prof. B. F. Mudge, who published a short notice of the discovery, which was subsequently copied in this Journal (vol. vi, p. 228, 1873). The writer examined this entire collection at Manhattan, Kansas, in the autumn of 1873, and secured it for the Yale Museum. The more important specimens were then sent to New Haven, and tracings and notes were taken of the others, which were left to be forwarded later. A careful re-examination of these footprints has been recently made by the writer, and the main results are given in the present article.

The impressions are well preserved in a calcareous shale, which separates readily into thin slabs, each representing a surface of the beach at the time the footprints were made upon it. A few shells in the shale are sufficient to prove that the formation is marine. Trails of annelids, and perhaps of other invertebrates, are seen on some of the surfaces. The footprints of vertebrate animals, however, are of paramount importance, and the large number and variety of these here recorded on a single surface, if they could be rightly interpreted, would form an interesting chapter of land vertebrate life in the Carboniferous, about which so little is at present known.

On Plate II, accompanying the present article, five distinct series of footprints are shown, each one-twelfth natural size. All were found on essentially the same surface, and at one locality. The five different animals they represent were thus contemporaries, and indicate a wealth of air-breathing, land vertebrate life at this period, hitherto unsuspected.

With these impressions were still others, made either by animals nearly allied or by the same animals under different circumstances. These need not be further noticed in this connection, but they serve to emphasize the diversity of life at this point. The typical series are briefly described below.

Nanopus caudatus, gen. et sp. nov.

The first series represented on Plate II, figure 1, indicates the smallest animal that here left a distinct series of footsteps, and the only one in which an imprint made by the tail was preserved. This small quadruped had evidently but three functional toes on the fore feet and four on those behind. The fore feet were considerably smaller than the hind feet. The impressions made by the latter are nearly all separate from the anterior footprints, although at times slightly overlapping them. One fore and one hind footprint of this series are represented, natural size, on Plate III, figure 1.

The nature of the animal indicated by these impressions can at present be a matter of conjecture only, but the probabilities are in favor of its reference to the Amphibians rather than to the true *Reptilia*. As it is evidently distinct from anything hitherto described, the above name is proposed for it.

Limnopus vagus, gen. et sp. nov.

In figure 2, Plate II, a second series of footprints is represented, somewhat larger than those above described, and evidently made by a very different animal. A fore and hind footprint of this series are shown, natural size, in figure 2, Plate III. The front feet had four functional toes, while those behind had five, all well developed. The impressions of the hind feet, as a rule, overlap those of the corresponding fore feet. No indications of a tail can be detected. In length of stride, and in the distance between the footsteps of the right and left sides, the present series is proportionately about the same as those above described, although the animals differed much in size. They were probably both Amphibians, and may have been nearly allied.

Dromopus agilis, gen. et sp. nov.

The third series of footprints shown on Plate II, figure 3, is of special interest, and indicates an animal very distinct from the two already described. On Plate III, figure 3, an outline impression is given, natural size, of one double footmark of this series, made by the fore and hind feet of the left side. This diagram represents the impression of the phalanges sufficiently in detail to indicate their number and general form. A striking feature in the fore and hind feet of this animal was the long, slender digits, terminated by sharp claws. Another point of interest, as recorded in the footprints, is that the animal in walking swung the hind feet outward, and so near the ground that the ends of the longer toes sometimes made trails in the mud, marking accurately the sweep of the foot. This would seem to indicate a comparatively short hind leg, rather than the long, slender one which the footmarks themselves naturally suggest.

The animal that made these interesting footprints was probably a Lacertilian rather than an Amphibian, but there is also a possibility that it was a primitive Dinosaur.

Allopus littoralis, gen. et sp. nov.

Besides the footprints above described, which pertain to animals of comparatively small size, there are several other series in this collection made by very large animals, which were probably all Labyrinthodonts. These tracks were made on the same beach, and at about the same time as the small footprints, but not all under the same circumstances. The largest animal thus represented appears to have walked on one part of the beach that was quite firm, leaving very shallow footprints, and again to have traversed another part, quite near the first, but slightly covered with water, or at all events so soft that deep impressions were made by the feet, while the toes of the hind feet also left deep trails as they swung outward at each step. On Plate II, figures 4 and 4a, these two kinds of footprints are represented. They show the stride of the animal, and, as put together, also denote the width between the footprints of the two sides, so that the series can be compared with the others on the same plate.

These tracks show that the animal had five toes in the fore feet and four behind. The hind feet show a distinct impression of a sole. There is no imprint of a tail, even where the mud appears to have been deep.

Baropus lentus, gen. et sp. nov.

The most abundant of the large footprints are represented by several series, which are remarkably uniform in stride and in width between the right and left rows. One of these series is represented on Plate II, figure 5, and this is typical of the others. The animal that made these footprints evidently had four functional toes in front and the same number behind. On the inner side of each foot, however, there was a projection, which, in the hind feet, was quite prominent and characteristic, but can hardly be interpreted as the imprint of the first digit. Nearly all these footprints show a distinct impression of a sole. This is usually faint in the tracks of the fore feet, but strongly marked in those behind.

It is hardly necessary at this time to attempt a detailed comparison of the footprints above described with those already on record, but the writer hopes to do this later. The present specimens all have well-marked characters, and, being from a single horizon and locality, have a value of their own as throwing light on the land vertebrate life, during the deposition of the true Coal Measures. If, in themselves, they add but little to what is already known, they at least offer encouragement to investigators in an interesting field not yet systematically explored. The publications of Logan, Lyell, King, Lea, Dawson, and others, have already made known discoveries of importance in this country, and others have been recorded in the Old World.

So far as at present known, land vertebrate life began in the Carboniferous age, no footprints or other remains of this kind having been detected below the Subcarboniferous. That such remains will eventually be found in the Devonian, there can be no reasonable doubt, and perhaps even in the Silurian, if the land surfaces then existing can be explored.

Yale University Museum, New Haven, Conn., June 12, 1894.

EXPLANATION OF PLATES.

Plate II.

Figure 1.—Series of footprints of *Nanopus caudatus*, Marsh; showing, also, impression made by the tail.

Figure 2.—Series of footprints of *Limnopus vagus*, Marsh.

Figure 3.—Series of footprints of *Dromopus agilis*, Marsh; showing trails made by the toes.

Figure 4.—Two pairs of footprints of *Allopus littoralis*, Marsh; right side.

Figure 4a.—Footprints of same; showing trails made by the toes; left side.

Figure 5.—Series of footprints of *Baropus lentus*, Marsh.

All the figures are one-twelfth natural size.

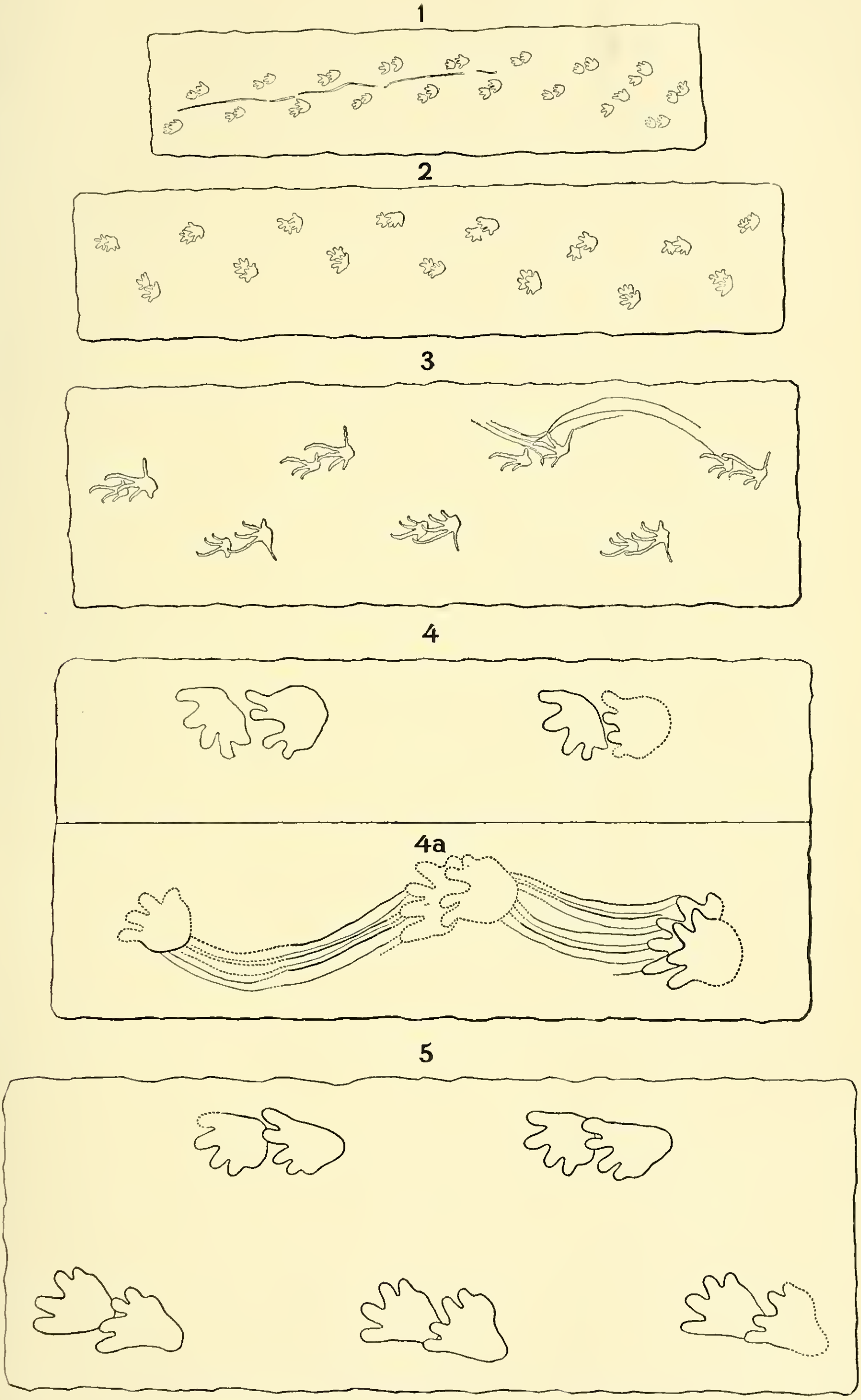
Plate III.

Figure 1.—Outline of left fore and hind footprints of *Nanopus caudatus*.

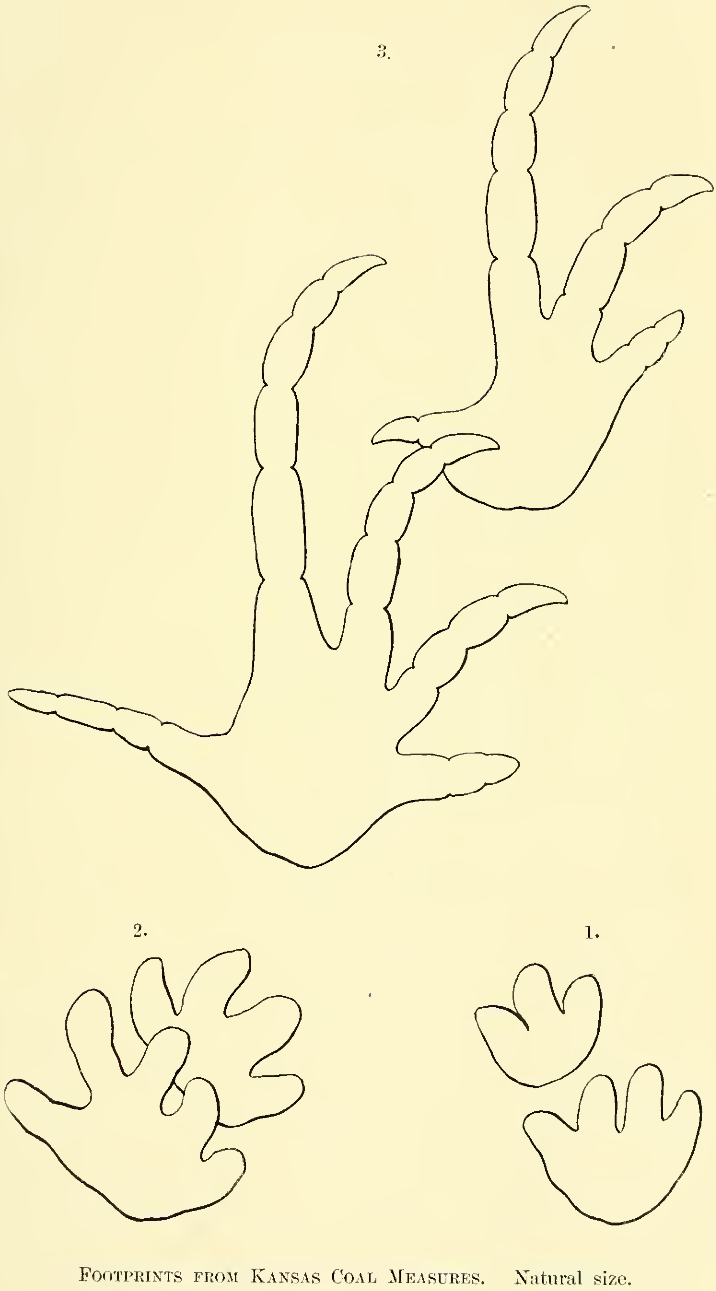
Figure 2.—Outline of left fore and hind footprints of *Limnopus vagus*.

Figure 3.—Diagram of left fore and hind footprints of *Dromopus agilis*.

All the figures are natural size.



FOOTPRINTS FROM KANSAS COAL MEASURES. One-twelfth natural size.



FOOTPRINTS FROM KANSAS COAL MEASURES. Natural size.

ART. XI.—*The Typical* ORNITHOPODA *of the American Jurassic;* by O. C. MARSH. (With Plates IV–VII.)

THE herbivorous Dinosaurs now known from the Jurassic deposits of this country consist mainly of the gigantic *Sauropoda* and the huge *Stegosauria*, both quadrupedal forms. A third group is the bipedal *Ornithopoda*, which contains the genus *Camptosaurus* as well as various smaller and more bird-like types. The first two groups have been investigated by the writer, and the main results published in this Journal. The third group also received considerable attention during the above investigation, but a recent study both of the type specimens and additional material has revealed new points of interest, and some of these are given in the present article.

Camptosaurus, Marsh, 1885.

The large Dinosaur described by the writer as *Camptosaurus dispar*, of which a restoration also has recently been published,* is now so well known that it may be taken as a form typical of the group. It is exceeded in size by *Camptosaurus amplus*, Marsh, but there are at least two smaller species of the genus (*C. medius* and *C. nanus*, noticed below). So far as at present known, these species are found in successive deposits of the same general horizon, the smallest below and the largest above.

Camptosaurus amplus is represented by remains which show that this reptile when alive was about thirty feet in length. The type specimen of *C. dispar* was about twenty feet in length, and ten feet in height. *C. medius* was about fifteen feet long. The smallest species of the genus, *C. nanus*, was not more than six feet in length, and perhaps four feet in height when standing at rest. One of the striking features of this diminutive species is its long sigmoid scapula shown in figure 3, Plate V. This is in strong contrast with the short, straight scapula of *C. dispar*, seen on the same plate, figure 2. The limb bones of all the species of this genus are very hollow.

* This Journal, vol. xlvii, p. 245, March, 1894. See also, vol. xviii, p. 501, December, 1879; and vol. xxix, p. 169, February, 1885

The skull, brain, and teeth, of *C. medius* are shown on Plate IV. The peculiar peg and notch articulation in the sacral vertebræ of this genus, already described, is indicated on Plate VI, figure 2, and a summary of the principal characters of the genus, and of the nearest allied genera, will be found in the text below.

Dryosaurus, gen. nov.

Another genus of Jurassic Dinosaurs, allied to *Camptosaurus*, but differing from it in many important respects, is *Dryosaurus*, the one here established. The type was described by the writer in 1878, under the name *Laosaurus altus*, and a tooth, the pelvis, and a hind leg, were also figured.* Additional material since received shows that this genus is quite distinct from *Laosaurus*, to which it was at first referred, and is intermediate between *Camptosaurus* and that genus, as is shown in a summary of the characters of these genera given later in the present article.

The European representative of *Dryosaurus* is *Hypsilophodon*, Huxley, from the Wealden of England. That genus, however, differs from the nearest allied forms of this country in several well-marked characters. Among these, the presence of teeth in the premaxillary bones and a well-ossified sternum are features not seen in American Jurassic forms. The fifth digit of the manus, moreover, in *Hypsilophodon* is almost at right angles to the others, and not nearly parallel with them as in *Dryosaurus*. It agrees with the latter genus in having the tibia longer than the femur.

The only species of *Dryosaurus* at present known is the type first described, and in future this may be called *Dryosaurus altus*. Several specimens of this Dinosaur are preserved in the Yale Museum, and they show it to have been in life about twelve feet long, and one of the most slender and graceful members of the group. The known remains are all from the Atlantosaurus beds of Colorado and Wyoming.

Laosaurus, Marsh, 1878.

The present genus includes several species of diminutive Dinosaurs, all much smaller than those above described, and possessing many features now seen only in existing birds, especially in those of the ostrich family. The two species of the genus first described by the writer (*Laosaurus celer*, the type, and *L. gracilis*)† show these avian features best of all,

* This Journal, vol. xvi, p. 415, plate ix, November, 1878.
† *Ibid.*, vol. xv, p. 244, March, 1878.

and it would be difficult to tell many of the isolated remains from those of birds. A larger species, which may be called *Laosaurus consors*, is now known by several skeletons nearly complete. The type specimen, here figured in part on Plates V–VII, is the most perfect of all, and this was collected by the writer in 1879. The animal when alive was about eight or ten feet in length. The known remains are from the Atlantosaurus beds of Wyoming.

One of the distinctive features of this genus, which separates it at once from those above described, is the pubis. The prepubis, or anterior branch of this bone, which was very large and broad in *Camptosaurus*, still long and spatulate in *Dryosaurus*, is here reduced to a pointed process not much larger than in some birds. These differences are shown in Plate VII, figures 1, 2, and 3.

Nanosaurus, Marsh, 1877.

The smallest known Dinosaur, representing the type species of the present genus, was described by the writer in 1877, under the name *Nanosaurus agilis*.* The type specimen consists of the greater portion of the skull and skeleton of one individual, with the bones more or less displaced, and all entombed in a slab of very hard quartzite. The whole skeleton was probably thus preserved in place, but, before its discovery, a part of the slab had been split off and lost. The remaining portion shows on the split surface many important parts of the skeleton, and these have been further exposed by cutting away the matrix, so that the main characters of the animal can be determined with considerable certainty.

A study of these remains shows that the reptile they represent was one of the typical *Ornithopoda*, and one of the most bird-like yet discovered. A dentary bone in fair preservation (Plate VI, figure 3) indicates that the animal was herbivorous, and the single row of pointed and compressed teeth, thirteen in number and small in size, forms a more regular and uniform series than in any other member of the group. The ilium, also, shown on the same plate, is characteristic of the *Ornithopoda*, having a slender, pointed process in front, but one much shorter than in any of the larger forms. The posterior end is also of moderate size. All the bones of the limbs and feet are extremely hollow, strongly resembling in this respect those of birds. The femur was shorter than the tibia. The metatarsals are greatly elongated and very slender, and there were probably but three functional toes in the hind foot.

* This Journal, vol. xiv, p. 254, September, 1877.

A second form referred by the writer to this genus, under the name *Nanosaurus rex*, may perhaps belong to the genus *Laosaurus*. The femur is shown on Plate VI, figure 5. The animal thus represented was considerably larger than the present type species, and from a somewhat higher horizon in the Atlantosaurus beds.

The type specimen here described, which pertained to an animal about half as large as a domestic fowl, was found in Colorado. This reptile was a contemporary of the carnivorous *Hallopus*, likewise one of the most diminutive of Dinosaurs, and one of the most remarkable.

The various Dinosaurs thus briefly referred to under their respective genera have many other points of interest that cannot be here discussed, but their resemblance to Birds is worthy of some notice. This is apparent in all of them, but, in the diminutive forms, the similarity becomes more striking. In all the latter, the tibia is longer than the femur, a strong, avian character, and one seen in Dinosaurs only in the small bird-like forms.* In *Nanosaurus*, nearly all, if not all, the bones preserved might have pertained to a bird, and the teeth are no evidence against this idea. In the absence of feathers, an anatomist could hardly state positively whether this was a bird-like reptile or a reptilian bird.

The main characters of the four genera above discussed are as follows :—

Camptosaurus.

Premaxillaries edentulous, with horny beak. Teeth large, irregular, and few in number. A supra-orbital fossa. Cervical vertebræ long and opisthocœlous. Lumbars present. Five free vertebræ in sacrum, with peg and notch articulation. Limb bones hollow. Fore limbs small. Sternum unossified. Five functional digits in manus. Prepubis long and broad; postpubis elongated. Femur longer than tibia. Metatarsals short. Three functional digits in pes; the first rudimentary, and the fifth wanting.

Dryosaurus.

Premaxillaries edentulous, with horny beak. Teeth of moderate size. A supra-orbital fossa. Cervicals long and biconcave. No lumbars. Six coössified vertebræ in sacrum, without peg and notch articulation. Limb bones hollow. Fore limbs very small. Sternum unossified. Five digits in manus. Prepubis long and narrow; postpubis elongate and slender. Posterior limbs very long. Femur shorter than tibia. Metatarsals long and hollow. First digit in pes complete; fifth metatarsal represented by short splint only.

* Besides the genera here mentioned, *Cœlurus*, *Compsognathus*, and *Hallopus* also possess this character.

Laosaurus.

Premaxillaries edentulous. Teeth small and irregular. Cervicals short and flat. Six vertebræ in sacrum; no peg and notch articulation. Sternum unossified. Fore limbs small. Limb and foot bones hollow. Prepubis very short and pointed; postpubis slender. Femur shorter than tibia. Metatarsals elongate. First digit in pes functional; fifth rudimentary.

Nanosaurus.

Teeth compressed and pointed, and in a single uniform row. Cervical and dorsal vertebræ short and biconcave. Sacral vertebræ three (?). Anterior caudals short. Ilium with very short, pointed front, and narrow posterior end. Fore limbs of moderate size. Limb bones and others very hollow. Femur curved and shorter than tibia. Fibula pointed below. Metatarsals very long and slender.

The genera thus defined contain all the known forms of the the typical *Ornithopoda* from the American Jurassic. They are, moreover, the earliest representatives of this group known in this country from osseous remains, as such fossils have not yet been found in the Triassic, where the oldest Dinosaurs occur. Some of the bird-like footprints in the Connecticut river sandstone may indeed have been made by Dinosaurs of this group, but there is no positive evidence on this point. The American Cretaceous forms of the typical *Ornithopoda*, so far as at present known, are all of large size, and highly specialized, and this appears to be true, also, of the Old World species.

In considering the relations of this well-marked group, here called the typical *Ornithopoda*, with the other two nearest allied suborders, the quadrupedal *Stegosauria* and *Ceratopsia*, it becomes evident, as previously shown by the writer, that all three belong in one great group, which may be regarded as an order. Although differing widely from each other in many notable features, they have a few characters in common, which are important enough to bind them together, and perhaps to indicate a common origin. The most significant of the characters shared by all is the predentary bone, which no other vertebrates possess. Another common character of importance, although sometimes nearly obsolete, is a postpubic bone which is present in all Birds, although in some recent forms it is rudimentary. A comparative series showing the relative development of the anterior and posterior branches of the pubis in six genera of American Predentate Dinosaurs is shown in Plate VII.

In recognition of the manifest relations of the three groups, *Ornithopoda* as here restricted, *Stegosauria*, and *Ceratopsia*, sharply defined as suborders, they should be placed together in a single order, which may appropriately be named the PREDENTATA. This order should be regarded as of equal rank with the *Sauropoda*, the *Theropoda*, and perhaps also the *Hallopoda*, as defined by the writer, the whole constituting the subclass known as the *Dinosauria*.

Yale University Museum, New Haven, Conn., June 15, 1894.

EXPLANATION OF PLATES.

PLATE IV.

FIGURE 1.—Skull of *Camptosaurus medius*, Marsh; seen from the left side.

FIGURE 2.—The same skull, with brain-cast in position; seen from above. Both figures are one-fourth natural size.

FIGURE 3.—Tenth upper tooth of *Camptosaurus medius.*

FIGURE 4.—Fifth lower tooth of same species. Both figures are natural size. *a*, outer view; *b*, posterior end view; *c*, inner view.

PLATE V.

FIGURE 1.—Pelvis of *Camptosaurus dispar*, Marsh; seen from the left. One-twelfth natural size.

FIGURE 2.—Left fore leg of same species. One-twelfth natural size.

FIGURE 3.—Left fore leg of *Camptosaurus nanus*, Marsh. One-fourth natural size.

FIGURE 4.—Left hind leg of *Laosaurus consors*, Marsh. One-sixth natural size.

PLATE VI.

FIGURE 1.—Lower tooth of *Laosaurus consors.* Natural size. *a*, outer view; *b*, posterior end view; *c*, inner view.

FIGURE 2.—Posterior sacral vertebræ of *Camptosaurus dispar;* showing peg and notch articulation; top view. One-fourth natural size.

FIGURE 3.—Dentary bone of *Nanosaurus agilis*, Marsh; seen from the left.

FIGURE 4.—Ilium of same individual; left side. Both figures are natural size.

FIGURE 5.—Left femur of *Nanosaurus rex*, Marsh. One-half natural size. *a*, front view; *b*, side view; *c*, back view; *d*, proximal end; *e*, distal end.

PLATE VII.

FIGURE 1.—Left pubis of *Laosaurus consors;* outer view. One-fourth natural size.

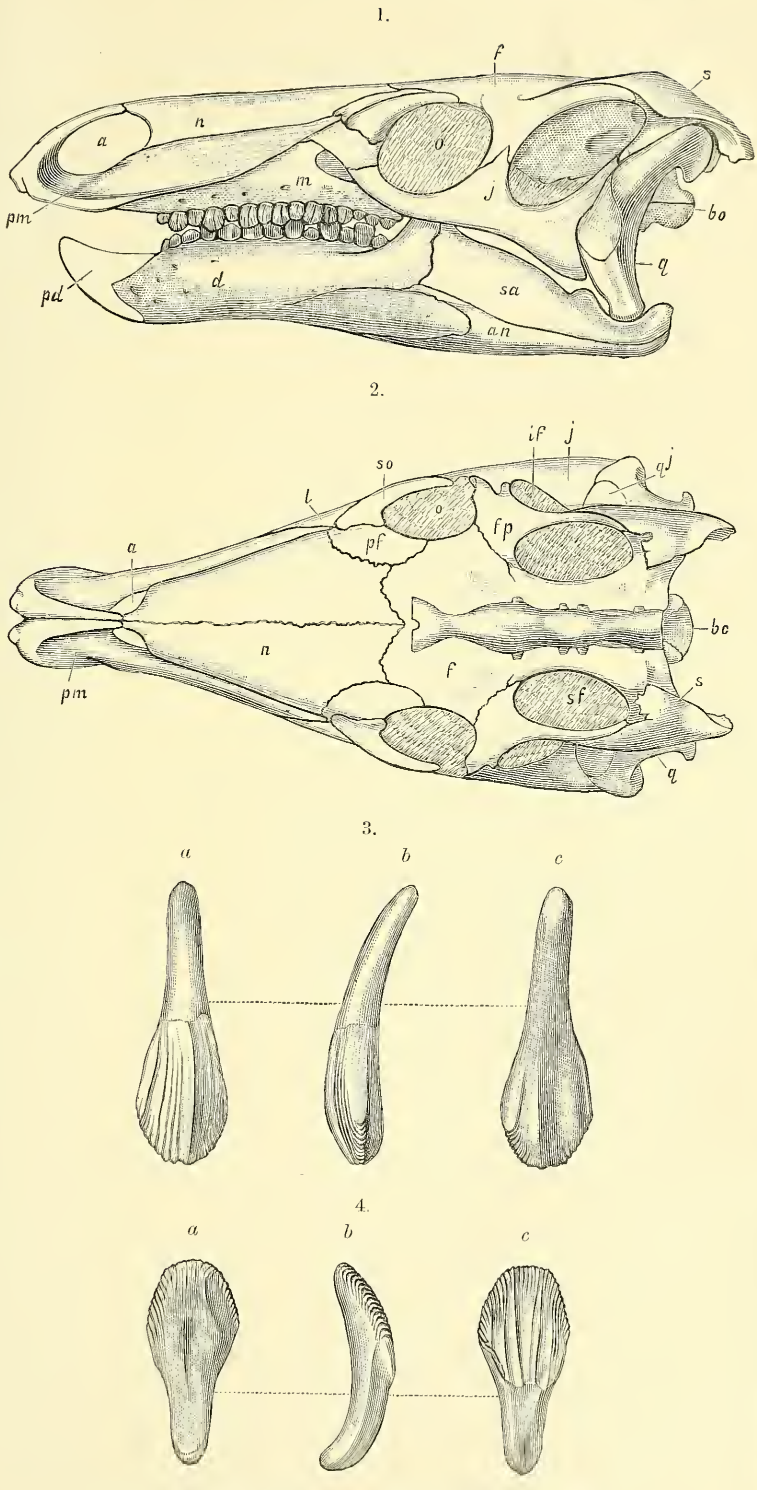
FIGURE 2.—The same bone of *Dryosaurus altus*, Marsh. One-eighth natural size.

FIGURE 3.—The same of *Camptosaurus dispar.* One-twelfth natural size.

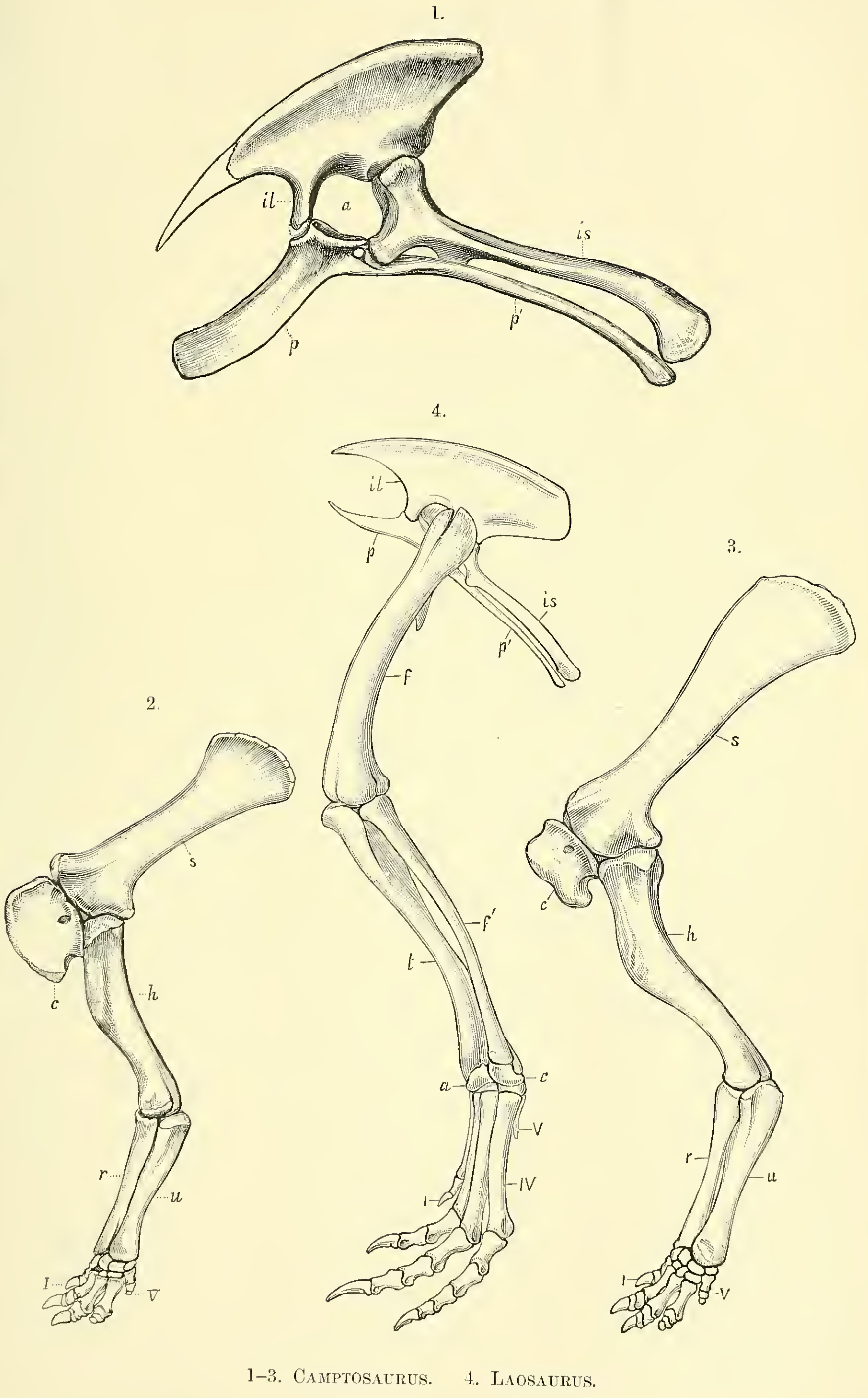
FIGURE 4.—The same of *Triceratops prorsus*, Marsh. One-twentieth natural size.

FIGURE 5.—The same of *Claosaurus annectens*, Marsh. One-sixteenth natural size.

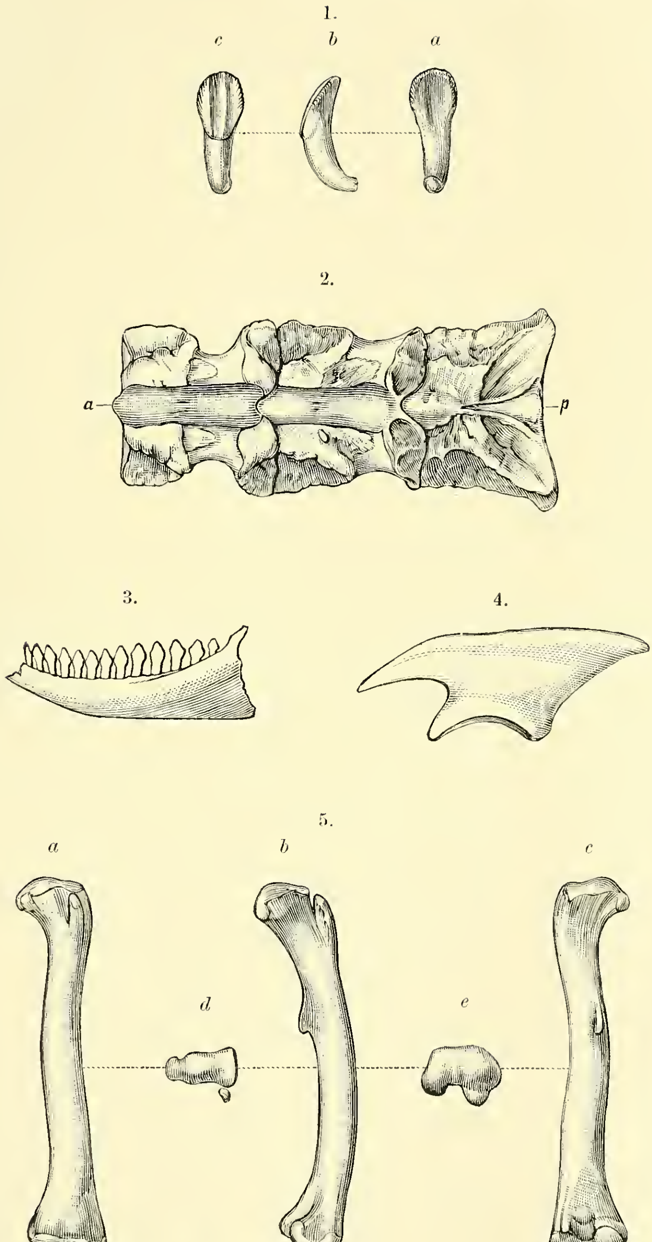
FIGURE 6.—The same of *Stegosaurus ungulatus*, Marsh. One-twelfth natural size. *p*, prepubis; *p'*, postpubis.



Skull and teeth of Camptosaurus medius, Marsh.



1–3. Camptosaurus. 4. Laosaurus.



1. Laosaurus. 2. Camptosaurus. 3–5. Nanosaurus.

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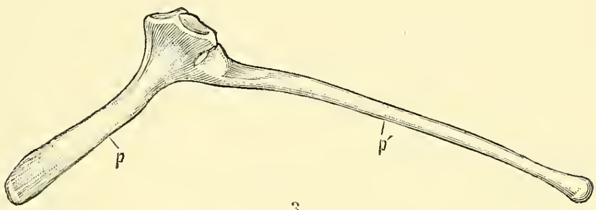

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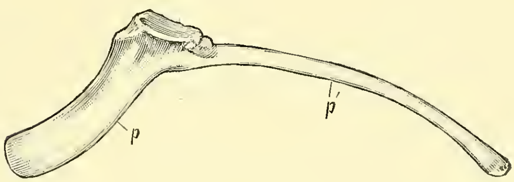

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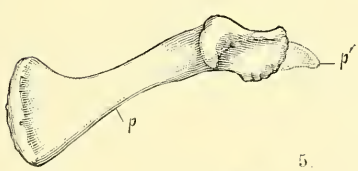

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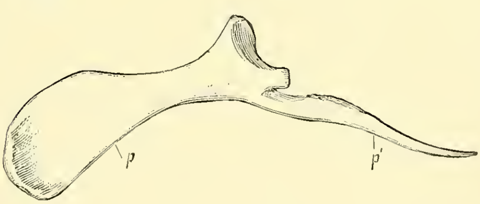

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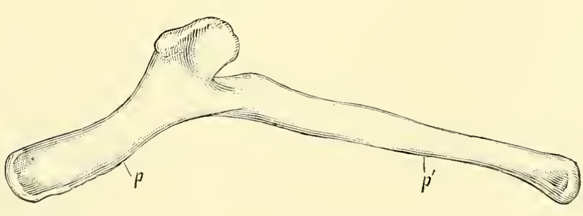


Pubes of Predentate Dinosauria.

ART. XII.—*Eastern Division of the Miohippus Beds, with Notes on some of the Characteristic Fossils*; by O. C. MARSH.

IN 1871, the writer explored the Miocene deposits of Oregon, especially along the valley of the John Day river, and these were again examined with more care in 1873. The strata were found to be nearly a mile in thickness, and deposited in a single lake-basin, which was subsequently named the John Day basin, from the river that now drains it.* The upper portion of these Miocene deposits represented a distinct horizon, and was named by the writer the Miohippus beds, from one of the most characteristic genera discovered in it.† Among other ungulate mammals likewise obtained from these strata were *Diceratherium*, a new genus of the *Rhinoceros* family, and *Thinohyus*, a suilline form allied to the existing peccaries. Subsequent researches brought to light other interesting fossils in this horizon, which has since been supposed to be represented only on the Pacific coast.

The Miocene strata on the eastern slope of the Rocky mountains have long been recognized in two distinct horizons, the lower known as the Titanotherium, or Brontotherium, beds, from the huge mammals which they contain, and above these, the Oreodon beds, of which that genus is characteristic.

Various vertebrate fossils have been obtained from time to time in the eastern Miocene deposits, which were not known to occur in either of the two horizons, but only of late have the uppermost strata been recognized as distinct from the Oreodon beds on which they rest. The horizon thus indicated has been named by Wortman the Protoceras beds, from a most remarkable genus, *Protoceras*, recently found in them, and described by the writer.‡

An examination of material from this horizon, recently made by the writer, brought out the interesting fact, that the genus *Miohippus* is one of its characteristic fossils, and that the type species, *M. annectens*, Marsh, described in 1874 from the Oregon beds, is present. *Diceratherium*, *Thinohyus*, and other genera typical of the western strata, are also found in the eastern, so that it is now demonstrated that the Miohippus horizon has an eastern as well as a western division, a fact of much scientific interest. Doubtless each division will be found to contain certain forms peculiar to itself, even if all are contemporaneous, a question which future discoveries must decide.

* This Journal, vol. ix, p. 52, January, 1875.
† *Ibid.*, vol. xiv, p. 355, November, 1877.
‡ *Ibid.*, vol. xli, p. 81, January, 1891.

The next Tertiary horizon higher up has been regarded by the writer as of Pliocene age, and named the Pliohippus beds, from one of the characteristic equine genera contained in it. This horizon is a very extensive one, and has been identified by the writer at various points along the eastern side of the Rocky mountains, from Canada to the Gulf of Mexico. Essentially the same deposits were likewise found by the writer in 1871 above the Miohippus beds in Oregon. Strata of still later age, named by the writer the Equus beds, occur in the same regions, east and west, often covering the Pliohippus deposits.

Among the fossils of the eastern *Miohippus* beds, the artiodactyle mammals play an important part, and a few of the more interesting of these are noticed in the present article. The *Protoceras* family is of paramount interest, and the specimens in the Yale Museum promise to add considerable to what is now known of this group. The interesting family *Agriochœridæ* also occurs in this horizon.

Another family, the *Anthracotheridæ*, is well represented, and contains some of the largest mammals of the horizon. Two of these, briefly noticed below, are now known only by fragmentary remains, some of which are characteristic. The two figures in the text show respectively a last upper molar of each of these animals. A comparison of these figures indicates that the two animals were quite distinct from each other, although about the same size, and perhaps nearly related.

Octacodon valens, gen. et sp. nov.

The tooth represented natural size in figure 1 below may be regarded as the type of the present genus and species. It is the last upper molar of the right side, and is in fine preservation. The slight wear of the tooth shows that the animal was adult. There are five main cusps in the crown, two on the posterior half, and three on the anterior, the antero-median cusp being the smallest. On the outer margin of the tooth are three prominent buttresses with conical summits, making in all eight prominences on the crown, which feature has suggested the generic name.

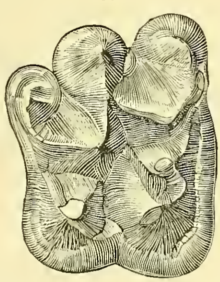
The three conical buttresses on the outer border of this tooth, all strongly developed, will serve to distinguish it from the corresponding molar of *Hyopotamus*, which in several respects it resembles. In that genus, the main cusps are much more elevated. *Heptacodon*, perhaps an allied form, has a similar buttress at the anterior angle, but none at the posterior. An upper incisor found with the present tooth, and doubtless pertaining to the same individual, has a very short, compressed crown, with a strong inner basal ridge, making the inner face deeply concave.

Heptacodon armatus, sp. nov.

Figure 2, below, represents natural size the last right upper molar of another large ungulate mammal, the exact affinities of which cannot now be determined. This tooth is considerably worn, showing that it belonged to an old animal. The remaining molars and part of the premolars in the same series are preserved, and with them a very large canine still in position in the jaw. All are worn, but otherwise in good preservation. The tooth figured has a crown composed of five main cusps, the antero-median being the smallest. The outer buttresses are of moderate size, and there is none at the posterior angle. The enamel of this tooth and of all the series is rugose. The true molars differ greatly in size, the first being quite small, the second intermediate, and the last equal in bulk to the two others.

The last premolar has one outer and one inner cusp. The next tooth in front is larger, and has a triangular crown, and the next is close to it. The canine is very large, dependent, and oval in section. Behind it is a long diastema.

1.



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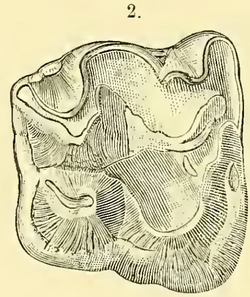

FIGURE 1.—Last upper molar of *Octacodon valens*, Marsh; seen from below.
FIGURE 2.—The same tooth of *Heptacodon armatus*, Marsh; seen from below.
Both figures are natural size.

Protoceras comptus, sp. nov.

A second species of this interesting genus is indicated by a young skull from the same horizon in which the type was found. This specimen, apparently the skull of a female, is in good preservation, and, when compared with the type, differs in several essential points. The maxillary plates are not elevated along the sides of the nasal aperture, and the posterior nares extend forward to between the first true molars. The whole skull is proportionally more elongate, and the facial part especially produced.

The maxillary plates of the palate are deeply cleft in front. The anterior palatine foramina open just in front of the second premolars, and long, shallow grooves extend from them to the front of the palate. The nasals are deeply furrowed behind by grooves leading backward to the supra-orbital foramina. The parietal ridges show a rugosity at the points where the horn-cores would later have appeared. The entire length of the skull is about eight inches, and from the front to the end of the molar series is five inches.

Calops cristatus, gen. et sp. nov.

The present type specimen is a skull in fair preservation, indicating a fully adult animal, which when alive was about half as large as a goat. In its general form and in most of its characters, this skull agrees so closely with the type of *Protoceras* as to suggest at once some affinity between the two. The dentition preserved in the premolar and molar series is essentially the same. The high maxillary plates joining the short, pointed nasals; the deep lachrymal fossa; and the posterior orbit strongly closed behind, all suggest an ally of *Protoceras*, but the parietal ridges are here elevated into distinct crests, and are without horns.

This skull when complete was about six inches in length. The distance from the front of the nasals to the junction of the parietal crests is about four inches and a half. The space occupied by the last three premolars and the true molars is about two and one-half inches.

Thinohyus robustus, sp. nov.

A new species of this genus is indicated by a nearly perfect skull, which shows many features of interest. It indicates an animal much larger than the type from Oregon, and one slightly superior in size to the existing collared peccary. In many respects, it resembles the latter so much, that it may be considered one of its direct ancestors.

The present species has the full complement of teeth, forty-four, but the skull has shortened, so that the first upper premolar has been crowded inside the canine. The teeth are proportionately larger than in *Dicotyles*. The last upper molar is smaller than the first or second. The last premolar has two outer cones, and one inside. The space occupied by the three upper molars is one and three-fourths inches, and the extent of the entire dental series is five inches. The whole skull is about nine inches in length.

Yale University Museum, New Haven, Conn., June 22, 1894.

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SCIENTIFIC INTELLIGENCE.

Chas. D. Walcott.

VOL. XLVIII. AUGUST, 1894.

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[THIRD SERIES.]

ART. XIII.—*On Certain Astronomical Conditions favorable to Glaciation*; by GEO. F. BECKER.

THE influence of local terrestrial conditions on glaciation is manifest to observers, and few geologists will entertain the idea that cosmical conditions alone can have determined the glacial epoch. Yet variations in the elements of the earth's orbit have certainly influenced climate, and they must have influenced it more favorably to glaciation at some periods than at others. The nature and extent of this influence have been much discussed; but it seems to me that further light can be thrown upon the subject by considering in detail the distribution of solar energy with reference to latitude, and the rate at which this energy is received during the two great seasons separated by the equinoxes.

The elements of the earth's orbit undergo slow variations, and three of these variations affect climate. The time at which the earth is in perihelion affects the length of the two great seasons. If perihelion coincides with either equinox, the seasons are of equal length. If perihelion coincides with either solstice, the seasons differ in length as much as they can for a given eccentricity of the orbit. The whole time which intervenes between the occurrence of seasons of equal length and that of seasons of the most diverse length is five or six thousand years, being the time required for the precession of the equinoxes to amount to a right angle. The eccentricity of the earth's orbit determines the possible difference between the seasons, and it slightly affects the mean distance of the earth from the sun, so that at a period of high eccentricity the world receives a little more heat than it does at a period of zero eccentricity.* It is mechanically possible for the eccentricity to become zero,† and it is never a large quantity. The latitude of the tropical circles also fluctuates within somewhat narrow limits, and of course the polar circles fluctuate correspondingly. There appear to be no other changes in the orbit which can affect the accumulation of ice, and all of these have been considered before now.

Dr. James Croll, as is well known, attributed the glacial epoch to the more or less indirect action of the difference in the length of the seasons, some 35 days, which occurs when the eccentricity is high.‡ Sir Robert Ball dwells upon the difference in the amount of heat received in the two seasons by an entire hemisphere, and he regards the low rate at which the winter hemisphere receives sunshine when the winter has its greatest length as an explanation of the ice age. This astronomer computed that the proportion of heat received during warm season (irrespective of its length), is expressed by $\frac{1}{2} + \sin\varepsilon/\pi$, where ε is the latitude of the tropical circles, and at present this fraction is expressed numerically by 0·627. Thus at the period of greatest eccentricity three eighths of the entire heat of the year may be spread over a winter some two hundred days in length.§

Sir Robert quotes a passage from Sir John Herschell from which it appears that this famous astronomer, at least momentarily, assumed that each hemisphere would receive the same amount of heat in each of the two great seasons, so that the difference of climate would depend solely on the length of the season.‖ If Herschell was under this impression, the mistake was a temporary one; for a page or two before the passage in which the erroneous statement is found he says:—"Now the temperature of any part of the earth depends mainly on its exposure to the sun's rays. . . . Whenever then the sun remains more than twelve hours above the horizon of any place, and less beneath, the general temperature of that place will be above the average; when the reverse below. As the earth, then, moves from A to B, the days growing longer, and the nights shorter in the northern hemisphere, the temperature of every part of that hemisphere increases and we pass from spring to summer."

This is of course the usual explanation of the seasons to be found in all astronomies and physical geographies. If it were true that a hemisphere received the same amount of heat in

* See the note appended to this paper on the calculation of sunshine per unit area.

† Cf. J. N. Stockwell, Smiths. Cont. to Knowledge, vol. xviii, 1873.

‡ Climate and Time.

§ Cause of the Ice Age, 1892.

‖ Outlines of Astronomy, § 368 (c) in 9th ed. 1867.

each great season, the winter would always be the long season, and therefore winter would occur in both hemispheres at the same time! It appears from the paragraph following that in which the mistake occurs, that Herschell was thinking particularly of tropical climates. Now at the equator it is literally true that the heat received in summer and in winter is the same, as will be shown in the second part of this paper, and the application which Herschell makes of his equal division is to explain the alleged great intensity of summer heat in the tropical regions of Australia as compared with those of northern Africa.

While at or close to the equator the heat received in each season is the same, at the poles all of the heat is received in summer. Hence while it is true that with the present obliquity only about three-eighths of the entire heat received by a hemisphere is received in winter, this fact helps but little towards an explanation of climate. The distribution of heat between the seasons varies with the latitude, and to form any just idea of the effect of eccentricity on climatic conditions one must know the heat received per unit area in any latitude.

The method of finding the amount of sunshine per unit area between equinoxes is very simple in principle. The great circle bounding the illuminated half of the earth is called the circle of illumination, and is represented by the right hand circle in figure 1. Any parallel of latitude projected onto the

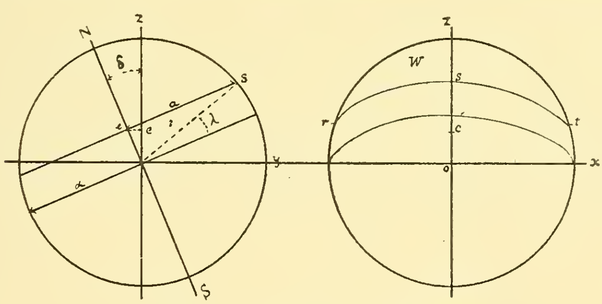


FIGURE 1.—Circle of Illumination.

circle of illumination becomes an ellipse, e. g., the ellipse *r*, *s*, *t*. The heat received between this parallel and the pole while the sun remains in the same position will be proportional to the crescentic area marked W. If one supposes a second parallel very close to the first, say at the unit distance from it, the narrow interval between their projections will be proportional to the heat received upon a zone of the earth's surface. These conditions apply only to an instant of time because the declination of the sun varies from zero at the equinoxes to 23° 27′ at the solstices. The next step is to find the average area on the circle of illumination representing the projection of the narrow zone from equinox to equinox. When this is accomplished, one has only to multiply the result by the time interval and divide by the length of the parallel of latitude to obtain the area on the circle of illumination representing the solar radiation received per unit area of the earth's surface between the autumnal and the vernal equinoxes. The unit in which radiation is measured may be arbitrarily chosen and as arbitrarily changed, provided that it is employed for all latitudes. I have chosen one which is convenient. It and the formulas for computation are explained in a note appended to this paper.

The heat received per unit area between equinoxes is independent of the length of the season being proportional to the change of the earth's longitude in its orbit.* The average rate at which heat is received during one of the great seasons is therefore merely the total heat per unit area divided by the length of the season.

The radiant energy per unit area depends to a slight extent upon the eccentricity of the orbit. If u_0 is the energy per unit area for zero eccentricity, and u the energy for eccentricity e, then

$$u = \frac{u_0}{\sqrt{1-e^2}}.$$

Though the difference is small, it is perfectly easy to take it into consideration, and this I have done.

At the present time the warm season in the northern hemisphere is approximately 186 days 10 hours long† or 1·0208 times half the year. The eccentricity of the orbit is 0·01677, so that if P is the present mean rate at which sunshine is received per unit area in summer in the northern hemisphere and L the length of the summer‡

$$\mathrm{P} = \frac{u_0}{\mathrm{L}\sqrt{1-e^2}} = 0{\cdot}97978\ u_0.$$

So too if p is the present winter rate I find

$$p = 1{\cdot}02138\ u_0.$$

* The heat received on the area when the earth is in a given position is directly as the time and inversely as the square of the distance, r, from the sun. In an instant therefore it is proportional to dt/r^2. By Kepler's first law this is equal to $d\vartheta/h$ where ϑ is longitude and h a constant.

† See Nautical Almanac for 1895.

‡ The coefficients are stated to five figures not because they are of themselves of interest to this degree of accuracy, but because in checking the tabulated values the numbers really used should be known.

The exact value of the greatest possible eccentricity of the earth's orbit is somewhat uncertain. It is dependent upon the masses of the planets, and these are not determined with final accuracy. It is not far from 0·07 and I shall assume that it is 0·0745, the value taken by Sir Robert Ball. The greatest possible difference between the seasons occurs when the long season is $(1 + 4e/\pi)$ times half the year; and if X and x are the mean rates of receipt of sunshine during the long and short seasons respectively for greatest eccentricity and greatest difference between seasons in the hemisphere where the winter is long, I find

$$X = 1·10788\ u_0$$
$$x = 0·91590\ u_0.$$

The values are tabulated below with two other sets of values to be explained presently. The diagrams, figures 2 and 3, show the rates graphically, but before commenting upon the differences between the curves it is desirable to consider how the present distribution of heat-rates is related to climate as known by observation.

No one doubts that temperature is dependent in some manner upon solar radiation, but the phenomena are complicated not only by the transfer of heat from one locality to another through the agency of currents of air and water, but also by the selective absorption of the atmosphere, and it is a question therefore how far the mere receipt of sunshine, or what Humboldt called "the astronomical climate," can be made to explain actual climate. That absorption of radiant energy by the atmosphere affects climate has long been understood. Energy of different wave lengths however is differently absorbed by the same gas, and different gases absorb energy differently; so that the subject is one of great complexity. According to Prof. S. P. Langley,* the temperature of an airless planet, even under a vertical sun, would be little above the freezing point of water; and of course the unilluminated part of such a planet would tend toward the absolute zero. Hence the actual temperature of the earth is determined to a very great extent by selective absorption of the atmosphere. No doubt this has always been the case, and, since the composition of the air must have changed as geological time progressed, it is highly probable that differences in selective absorption have determined, or partly determined the differences in mean tem-

* The Temperature of the Moon. Nat Acad of Sci, vol. iv, part II. 1889, page 193. The conclusion drawn from observations on Mt. Whitney, that an airless planet would fall far short of zero C., is modified in this passage.

perature at different epochs.* The glacial epoch is relatively speaking so recent that the composition of dry air was probably much the same then as now; but even moisture affects absorption of heat rays, greatly increasing it, so that relatively moist air tends to become hotter while dry air tends to sink below the average temperature.

It is notorious that climate is enormously affected by oceanic currents, themselves due to winds of prevalent direction, and it would therefore be in vain to seek any very close relation between temperature and solar radiation in littoral areas. On the other hand, in the interior of the continents, where air currents alone distribute the heat received from the sun, it seems possible that a relation may show itself. Considering the facts presented above it seemed to me that a reasonable trial hypothesis would be this:—The average variation of temperature from a certain mean in purely continental areas during a great season may be nearly proportional to the mean rate at which solar energy is received during that season.

In an ideally continental climate the summers will be hotter and the winters will be colder than in any real climate, since the actual tendency is always toward an equalization of temperature. Hence to test the trial hypothesis it is required to know the lowest latitudes to which mean winter isotherms descend in continental areas, and the highest latitudes which mean summer isotherms reach. In this enquiry the lag of heat effects would have to be taken into consideration, so that the seasons for temperature would not be divided by the equinoxes. I do not know of any isothermal charts suitable for the enquiry in this form. The next best material would be charts for the two extreme months, January and July, for though such charts would give temperatures exceeding the means in intensity, these temperatures would probably be proportional to the means. In other words it is probable that the temperature curve for a representative cold winter is derivable from that of a representative warm winter by projection.

Proceeding on this assumption I collected data from Mr. A. Buchan's January and July charts based on the mean observations for eleven years.† The lowest latitudes to which each isotherm descended in January in Asia and in North America were noted and the highest latitudes to which they ascended in July. They are recorded in the following table.

* It is substantially certain that the sun's own heat has varied. The record of its variation must exist in the rocks, but as a palimpsest. The greater equability of the earlier climates seems to me explicable, at present, only by greater atmospheric absorption.

† Encyc. Brit., 9th ed. Art.: Meteorology.

Deg. F. Isotherm.	Lowest January Latitude. Asia.	N. America.	Highest July Latitude. Asia.	N. America.
—50°	60°	....		
—40	63	....		
—30	59	64		
—20	55	56		
—10	46	52		
0	45	49		
+10	42	47		
20	38	42		
30	36	39		
40	27	34	77	....
50	25	31	72	69
60	21	....	68	66
70	17	....	59	56
80	10	....	48	46
90	....	....	39	43

Some of these temperatures are affected to a greater or less extent by the neighborhood of water as may be seen from the charts. Thus the polar sea must certainly have a cooling effect in Siberia in summer at latitude 77, and 40° must be there somewhat too low a reading for a continental climate in July. Similarly in winter 70° and 80° must be rather higher than the isotherms in winter would be in southern Asia if land continued southward. Again the great elevation of Central Asia and of the Rocky Mountain region must give summer readings lower than would be recorded were these areas at sea-level.

Imperfect as these data are, they seem the best available, and as such they are entered in diagram 2, an arbitrary unit being selected as representing a Fahrenheit degree. Each X represents an Asian observation, and each Y a North American one.

It will be observed that the points representing temperatures lie remarkably close to the curves representing the present rate of receipt of solar energy, and thus seem strongly confirmatory of the trial hypothesis which, it may be well to state, was not framed to fit the temperature observations. A still closer agreement would be obtained by using a somewhat larger unit for temperature. The climate represented by the curves is intentionally shown as somewhat more extreme than the observed climate because such would be the case if the air were immobile. It might be easy to lay too much stress on the close agreement of the curves and temperatures. I desire to draw but one conclusion from it, viz: the mean rate at which sunshine is received per unit area in continental climates is so important an element in determining the seasonal deviation from the mean temperature, that the curves representing mean rate afford a sound basis for comparison between continental climates for different values of the eccentricity of the earth's orbit or for different values of obliquity of the ecliptic, the composition of the atmosphere and the intensity of solar radiation being supposed constant. This conclusion seems to me fully justified by diagram 2, and it will be assumed in what follows.

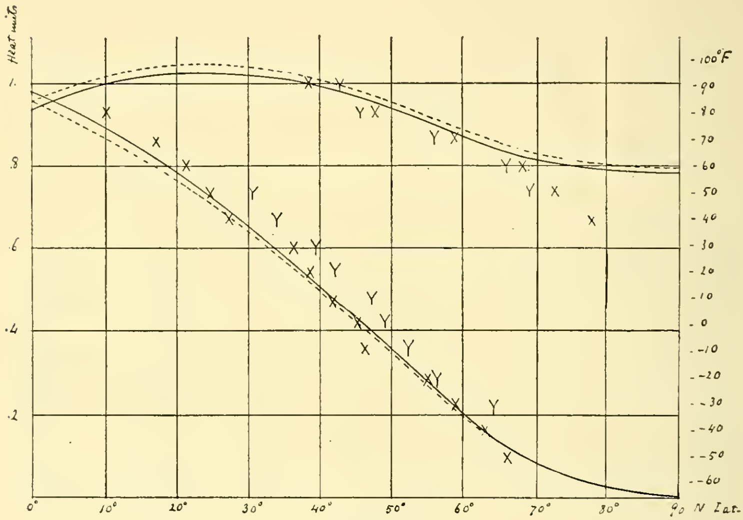


FIGURE 2.

Heat rates for present conditions in each of the great seasons. The rates for zero eccentricity and present obliquity are shown by dotted lines. Points marked X are Asian mean temperatures in January and July. Points marked Y are North American mean temperatures for the same months.

In considering the effect of secular variations of the earth's orbit on the accumulation of ice, certain criteria of climate must be fixed upon. So far as I can see, the conditions prevailing in a glaciated hemisphere should be as follows. The torrid and lower temperate zone, in which evaporation chiefly takes place, should be as warm as is consistent with other conditions; for it must be remembered that the tension of aqueous

Heat-rates for Northern Summer.

Lat.	P	N	X	B
0°	0·9397	0·9592	1·0626	0·9552
10	0·9945	1·0150	1·1245	1·0144
20	1·0216	1·0427	1·1552	1·0457
30	1·0208	1·0419	1·1543	1·0489
40	0·9930	1·0135	1·1229	1·0245
50	0·9411	0·9605	1·0642	0·9762
60	0·8721	0·8901	0·9862	0·9111
A	0·8270	0·8441	0·9352	0·8768
70	0·8115	0·8283	0·9176	0·8587
80	0·7869	0·8032	0·8898	0·8381
90	0·7798	0·7959	0·8818	0·8326

Heat-rates for Northern Winter.

Lat.	*p*	*n*	*x*	*b*
0°	0·9797	0·9592	0·8785	0·9552
10	0·8955	0·8768	0·8030	0·8698
20	0·7869	0·7705	0·7057	0·7610
30	0·6577	0·6439	0·5898	0·6326
40	0·5127	0·5019	0·4597	0·4893
50	0·3583	0·3508	0·3213	0·3384
60	0·2051	0·2009	0·1840	0·1901
A	0·1164	0·1140	0·1044	0·1198
70	0·0821	0·0804	0·0736	0·0764
80	0·0198	0·0194	0·0177	0·0182

P and *p* stand for present obliquity, eccentricity and length of seasons.

N and *n* stand for present obliquity, 23° 27′, and zero eccentricity.

X and *x* stand for present obliquity, eccentricity = 0·0745, and greatest difference of seasons.

B and *b* stand for obliquity = 24°36′ and zero eccentricity.

N, *n*, B and *b* are computed from the formulas developed in the note appended to this paper which P, *p*, X and *x* are derived from N. and *n* as explained in the text. The rates for the southern hemisphere, shown in diagram 3, are identical with those in the northern hemisphere except in the case of greatest eccentricity when they are multiples of those in corresponding northern latitudes.

A represents the latitude of the arctic circle, or 66° 33′ in all cases excepting those of B and *b* for which A = 65° 24′.

vapor increases much more rapidly than temperature* and so also must the rate of evaporation. On the other hand the cold in high latitudes must be great to promote condensation in the form of snow; besides which the temperature gradient should be high or steep because the energy available for wind, and for water currents due to winds, is in direct proportion to the difference of temperature. The great foe to glaciation in summer is rather warm rain than sunshine, for warm rain represents heat transferred from lower latitudes to higher ones. A cer-

* The tension is a function of the temperature, and this function is not linear.

tain amount of sunshine in high latitudes will not seriously diminish the accumulation of névé; for a great part of the winter snowfall has a temperature far below freezing; and in summer, water resulting from superficial melting will freeze again as it percolates through subjacent snow until the entire accumulation of the past winter is raised to the melting point. Such a process is apparently essential to the formation of glacier ice. While a portion of the direct sunshine is harmlessly employed in converting snow to ice, another and very large part will be reflected from the névé fields. Hence it seems to me that the features of a summer climate in a glaciated hemisphere which are most favorable to ice accumulation are cool tropics and a low temperature gradient toward the pole, even if the direct sunshine in very high latitudes must be increased to bring about a dry climate.

It seems proper to begin a comparison between various climates by considering the conditions in opposite hemispheres at any time when the difference of seasons is considerable. Since the total amount of heat received by a hemisphere between equinoxes is wholly independent of the duration of this interval, one hemisphere will then have long cold winters with short hot summers, and the other will have long cool summers and short warm winters. A comparison of curves representing such conditions shows further, that in the genial hemisphere in winter the temperature gradient will be very high and the zone of evaporation very hot, so that the weather will be very wet as well as relatively warm. The summer in the genial hemisphere on the contrary will be cool and not particularly wet. The high winter temperature, and the corresponding brevity of the season in the genial hemisphere would certainly preclude glaciation with the present mean temperature of the globe. Hence in discussing the conditions favorable to glaciation it is needless to consider those in which the winter is shorter than the summer. This is a conclusion upon which, so far as I know, every one is agreed.

A comparison may now be made between the present climates and that which would prevail in both hemispheres were the eccentricity zero, the apparent obliquity of the ecliptic maintaining its present value. The seasons would then be of equal length, and the climate would be intermediate between that of the present time in the two hemispheres. Five or six thousand years ago the seasons were of equal length, and the eccentricity is now and was then so small as to affect the amount of heat received by an insignificant fraction. In fact the earth now receives 1·00014 times as much heat as it would do if the eccentricity were zero. The rates given in the table and the curves shown in figures 2 and 3, enable one to judge sufficiently of the climate of zero eccentricity. The winter in the northern hemisphere would be a little cooler throughout and the temperature gradient a little smaller. Other things being

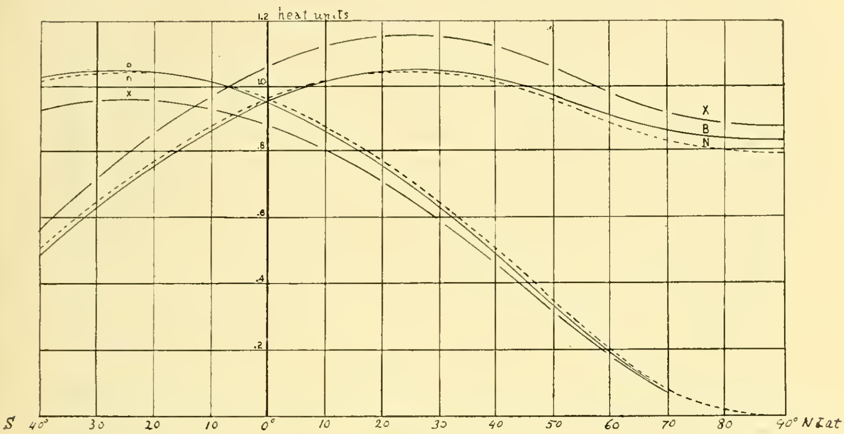


FIGURE 3.

Heat rates for each of the great seasons under various conditions. The curves N and n represent the present obliquity and zero eccentricity. They also appear in figure 2. The curves X, and x show the rates for greatest eccentricity and winter of maximum length in the northern hemisphere The curves B and b display the rates for an obliquity of 24° 36′ with zero eccentricity.

the same, the winter precipitation would be somewhat smaller, but more of it would fall as snow. In summer the July temperature would be two or three degrees F. higher than it now is, and the heat gradient would almost imperceptibly exceed the present. On the whole the normal weather would probably be within the range of present experience or, in other words, the winter would be what is now considered a cold one, and the summer such as is now thought unusually warm in the northern hemisphere; but the seasons would not be so extreme as they would now be in the southern hemisphere were the distribution of continental areas there the same as it is in the northern hemisphere.

Having established a climate of zero eccentricity it may be compared with the extreme climate of highest eccentricity. It appears from diagram 3 and the table that the winter of the eccentric period in the rigorous hemisphere would be intensely cold as compared with that of the period of zero eccentricity, but it is important to observe that the difference would be most marked in the tropics. It is not needful to depend on my formulas or tabulated values of heat rates to assure oneself of the general truth of this result. For an increase in the length of the winter diminishes all heat-rates or temperatures in the same proportion; and since the rates are highest in the tropics, the greatest decrease must also take place in the torrid belt. The indications of the diagram are that the temperature of January in the eccentric period would be greatest at the tropic of Capricorn, and that it would there be no warmer than it now is in July at 45° of north latitude. It follows that the evaporation would be very small and that the snowfall in high northern latitudes would be small. The heat gradient during the eccentric winter is also less steep than it is possible to make it by any other combination of conditions, and therefore the winter of this period in the northern hemisphere would be the calmest, dryest and coldest possible.

The summer of the eccentric period in the hemisphere of rigorous climate will be the hottest possible; nearly 20° F. hotter, it would seem, than that of the present time in temperate latitudes. The evaporation would of course be immense. The heat gradient toward the pole is also considerably greater than it now is, or than it would be at the time of zero eccentricity. Hence the summer would be wet as well as hot. It seems to me, then, that the period of greatest eccentricity would be most unfavorable to glaciation, the snowfall being the smallest, and the summer rainfall the largest which can occur with the present obliquity. It seems much less favorable than the period of zero eccentricity when the winter cold is great enough to preclude much rain in the higher portion of the temperate zone, while the temperature in the tropics is great enough to produce active evaporation. It would be manifestly absurd to suppose equality of seasons sufficient to produce an ice age; but I am forced to the conclusion that, so far as eccentricity is concerned in the matter at all, the smaller the eccentricity the more favorable are the conditions for glaciation.

Thus far only a slight reference has been made to the variation of the obliquity. Its influence on glaciation has been considered by various authors, and Dr. Croll attributes to a greater obliquity a considerable influence on the temperature of the arctic circle. The greatest possible obliquity of the apparent ecliptic is believed to be 24° 36′, and I have adopted this value for computation.* The heat-rates are recorded in the table, and the corresponding curves are shown in figure 3.

At first sight the winter curve of the period of greatest obliquity seems practically undistinguishable from that for the present obliquity, the eccentricities being in both cases zero.

* Stockwell gives as the greatest obliquity 24° 35′ 57″·53 for the values of the masses of the planets which he adopts. Smiths. Cont., vol. xviii, 1873, p. 175.

There is a difference however of considerable importance. In either case the maximum mean rate of receipt of sunshine, or the maximum temperature during the northern winter, is at the Tropic of Capricorn and it is from the maximum that the winds laden with moisture will blow toward either pole.* Now when the obliquity was 1° 9′ greater than it now is, the Tropic of Capricorn was so much further south, and the area to the north of this tropic was about 1,800,000 square miles greater than that north of the corresponding parallel to-day. This area is somewhat greater than the sum of the areas of the Mediterranean Sea and the Gulf of Mexico. The gradient northward in winter was almost exactly what it is to-day, the temperature was lower throughout, though not more than a few degrees; but this was compensated for, more or less completely, by the increased area of evaporation supplying precipitation to high northern latitudes. It would appear therefore that the precipitation may have been as great as it now is, but that a larger part of the precipitation must have been snow.

In summer at high obliquity the zone of evaporation was 1,800,000 square miles less than it now is, and the temperature gradient toward the pole was smaller than any other, smaller even than that of the summer in the genial hemisphere of the period of highest eccentricity. Hence it was perhaps the dryest possible summer. Its temperature was somewhat below that of the present time in the southern hemisphere from the equator to latitude 45°. Beyond this point it was a little higher but, as has been pointed out, dry summer heat in very high latitudes cannot greatly diminish the accumulation of snow.

I began this enquiry without the remotest idea as to what conclusion would be reached. At the end of it I feel compelled to assert that the combination of low eccentricity and high obliquity will promote the accumulation of glacial ice in high latitudes more than any other set of circumstances pertaining to the earth's orbit. It seems to me that the glacial age may be due to these conditions in combination with a favorable disposition of land and water. This theory implies, or rather does not exclude simultaneous glaciation in both hemispheres. It does not imply that the ice age should last only ten or twelve thousand years. If the conditions here suggested are correct, variations in the disposition of land and water may have determined intervals of glaciation, not necessarily the same ones in New England and the basin of the Mississippi; and there may have been considerable time dif-

* It is well known that the July and January winds blow across the equator. This tendency is strongest in July because of the greater land area of the northern hemisphere.

ferences in the inception or the cessation of glaciation in various regions. It is not needful to assume that the glaciation of the Sierra Nevada either began or ended synchronously with the ice age in New England.

The date at which a minimum of eccentricity last coincided with a maximum of obliquity can almost certainly be determined. According to Stockwell the obliquity has been diminishing for the past 8000 years and was within 21 minutes of its maximum value at the beginning of that time. According to Leverrier the eccentricity passed through a minimum 40,000 years ago, the value being then about two-thirds of the present one. So far as I know the obliquity has not been computed beyond 8000. This can of course be done for Stockwell's value of the masses of the planets, or for newer or better ones. All the indications seem to be that within thirty or forty thousand years conditions have occurred and have persisted for a considerable number of thousand years which would favor glaciation on the theory of this paper. It is conceivable that very remote coincidences of high obliquity and low eccentricity might be determined, answering perhaps to glaciation in the Paleozoic; but until some simple law governing the periodicity of secular variations is discovered such a result is not to be looked for; it is at present practicable to formulate the variations only by omitting terms above a certain order and exterpolation beyond a few score thousand years is consequently untrustworthy.

Calculation of Sunshine per unit area.

The following note explains the method of finding the amount of solar energy received per unit area of the earth's surface in any latitude between equinoxes, the ellipticity of the earth being ignored. Mr. L. W. Meech has already solved the very similar problem of finding the heat received per unit area for the entire year, and it is possible to develop from his formulas those applicable to the present purpose; but this would take nearly as much space as a fresh presentation. Mr. Meech's method of dealing with the subject is also quite different from that here presented, which I worked out before making acquaintance with his admirable memoir.*

When the sun's declination is δ, any parallel in latitude λ will be projected onto the circle of illumination as an elliptical arc dividing the circle into two unequal portions. If λ and δ have opposite signs, the smaller of these areas will be a crescent which I shall call W. To find the area W shown in diagram 1, let a be the earth's radius, a and b the semiaxes of

* Smithsonian Contr. to Knowledge, vol. ix, 1857.

the ellipse into which the parallel of λ is projected, x and z the coördinates of the point t at which the ellipse meets the great circle in the projection, c the center of the ellipse, e the center of the small circle which is projected into the ellipse. Then it is easily seen from the diagram that

$$a = \alpha \cos \lambda; \; b = \alpha \cos \lambda \sin \delta; \; c = e \cos \delta = \alpha \sin \lambda \cos \delta;$$

$$z = \frac{\alpha \sin \lambda}{\cos \delta}; \; x = \sqrt{\alpha^2 - z^2} = \frac{\alpha \cos \lambda}{\cos \delta} \sqrt{1 - \frac{\sin^2 \delta}{\cos^2 \lambda}}$$

The area of the circular segment r, z, t is $\alpha^2 \sin^{[-1]} \frac{x}{\alpha} - xz$ and that of the elliptical segment r, s, t is $ab \sin^{[-1]} \frac{x}{a} - xz + xc$. The difference is the area sought or

$$W = \alpha^2 \sin^{[-1]} \frac{x}{\alpha} - ab \sin^{[-1]} \frac{x}{a} - xc$$

The arc whose sine is x/a is the sun's semidiurnal arc. Its value in the cold season may be called for brevity X. In the warm season at the same point its value will be π–X. If ϑ is the earth's longitude in its orbit and if ε is the apparent obliquity of the ecliptic it is easy to see and perfectly well known that

$$\sin \delta = \sin \varepsilon \sin \vartheta$$

and this value is to be substituted in that of W. It is also convenient to employ the abbreviation

$$\Delta(\vartheta) = \sqrt{1 - \frac{\sin^2 \varepsilon}{\cos^2 \lambda} \sin^2 \vartheta},$$

so that the semidiurnal arc is

$$X = \text{arc} \sin \frac{\Delta(\vartheta)}{\sqrt{1 - \sin^2 \varepsilon \sin^2 \vartheta}}.$$

The value of W may now be written

$$W = \alpha^2 \{\sin^{[-1]} (\cos \lambda \sin X) - \cos^2 \lambda \sin \varepsilon \sin \vartheta . X \\ - \sin \lambda \cos \lambda \, \Delta(\vartheta)\},$$

and when λ increases W decreases; so that the rate of increase of W, or the area on the circle of illumination occupied by the projection of a zone of unit width in the cold season, is represented by

$$-\frac{dW}{d\lambda} = \alpha^2 \sin 2\lambda \, \{\cot \lambda \, \Delta(\vartheta) - \sin \varepsilon \sin \vartheta . X\}.$$

Let the amount of sunshine received upon the unit area at the unit distance from the sun in the unit of time be H. Then in an instant of time the amount received upon the zone of unit width at a distance r from the sun would be

$$\frac{-dW}{d\lambda}\cdot\frac{H}{r^2}\,dt.$$

By the principle of the conservation of the moment of momenta, the radius vector of an unperturbed planet sweeps over equal areas in equal times. If h is a constant this, which is one of Kepler's laws, is expressed by $r^2 d\vartheta = h dt$. By substitution in the last expression this gives the following measure of the receipt of solar energy for a small change in the earth's longitude,

$$-\frac{dW}{d\lambda}\frac{H}{h}d\vartheta = \frac{Ha^2\sin 2\lambda}{h}\left\{\cot\lambda\,\Delta(\vartheta) - \sin\varepsilon\sin\vartheta.\,X\right\}d\vartheta \quad (1)$$

and the whole heat received between the autumnal and the vernal equinoxes on a zone of unit width will be proportional to the integral of this quantity from $\vartheta = 0$ to $\vartheta = \pi$, or to twice the integral from zero to $\pi/2$, since the conditions are symmetrical. To find the corresponding value for the summer interval it is only necessary to substitute π–X for X.

To facilitate integration it may be noted that

$$\sin\vartheta\,.\,X\,.\,d\vartheta = \cos\vartheta\,dX - d(X\,.\cos\vartheta)$$

and

$$\frac{dX}{d\vartheta} = -\frac{\sin\varepsilon\cos\vartheta\tan\lambda}{(1-\sin^2\varepsilon\sin^2\vartheta)\Delta(\vartheta)}$$

These values reduce (1) to

$$-\frac{dW}{d\lambda}\frac{H}{h}d\vartheta = \frac{Ha^2}{h}\sin 2\lambda\Big\{\cot\lambda\,\Delta(\vartheta) +$$

$$\tan\lambda\left(\frac{1}{\Delta(\vartheta)} - \frac{\cos^2\varepsilon}{(1-\sin^2\varepsilon\sin^2\vartheta)\Delta(\vartheta)}\right) + \frac{d}{d\vartheta}\Big(X.\cos\vartheta\sin\varepsilon\Big)\Big\}d\vartheta. \quad (2)$$

For values of λ from 0 to $\pi/2-\varepsilon$, or from the equator to the polar circle, this is integrable term by term. If $\sin\varepsilon/\cos\lambda = \varkappa$ and if $E^1(\varkappa)$, $F^1(\varkappa)$, $\Pi^1(\varkappa)$ denote complete elliptic integrals of the three classes for the modulus $\varkappa$; and if Z is the integral of (2), being the solar radiation received between equinoxes on the zone of unit width,

$$Z = \frac{2Ha^2}{h}\sin 2\lambda\left\{\cot\lambda\,E^1(\varkappa) + \tan\lambda[F^1(\varkappa) - \cos^2\varepsilon\,\Pi^1(\varkappa)]\right.$$

$$\left.\pm\frac{\pi}{2}\sin\varepsilon\right\} \quad (3)$$

the plus sign giving the value for summer and the minus sign that for winter.

At the equator, or for $\lambda = 0$, (3) reduces to the term containing $E^1(\varkappa)$. At the polar circle Z ceases to be doubly periodic; for then $\Delta(\vartheta)$ degenerates into $\cos\vartheta$ and $\cos\lambda = \sin\varepsilon$ so that

$$\frac{dX}{d\vartheta} = -\frac{\cos\varepsilon}{1 - \sin^2\varepsilon\sin^2\vartheta}.$$

These relations also reduce (1) to an integrable form and give for this one latitude

$$Z = 2\frac{H\alpha^2}{h}\sin 2\varepsilon\left\{\tan\varepsilon + \cos\varepsilon\, ln\cot\frac{\pi/2-\varepsilon}{2} \pm \frac{\pi}{2}\sin 2\right\}$$

Within the polar circle the limits of integration change, because for a part of the time there is no illumination. Furthermore $\sin\varepsilon/\cos\lambda > 1$, and a transformation is needful to reduce the functions to standard forms. To effect this let

$$\frac{\sin\varepsilon\sin\vartheta}{\cos\lambda} = \sin\varphi, \text{ and } \frac{\cos\lambda}{\sin\varepsilon} = \mu < 1.$$

Then

$$\varkappa = 1/\mu;\ \Delta(\vartheta) = \cos\varphi;\ \cos\vartheta = \sqrt{1-\mu^2\sin^2\varphi} = \Delta(\varphi);$$

$$d\vartheta = \frac{\mu\cos\varphi\, d\varphi}{\Delta(\varphi)}.$$

The superior limit of integration is given by

$$\Delta(\vartheta) = 0 \text{ or } \varphi = \pi/2.$$

By these substitutions (2) becomes*

$$-\frac{dW}{d\lambda}\frac{H}{h}d\vartheta = \frac{H\alpha^2}{h}\sin 2\lambda\left\{\frac{\sin\varepsilon}{\sin\lambda}\Delta(\varphi) + \frac{\cos\varepsilon}{\tan\varepsilon\sin\lambda}\cdot\frac{1}{\Delta(\varphi)}\right.$$

$$\left.-\sin\lambda\frac{\cos\varepsilon}{\tan\varepsilon}\frac{1}{(1-\cos^2\lambda\sin^2\varphi)\Delta(\varphi)} + \frac{d}{d\varphi}(\sin\varepsilon\,\Delta(\varphi).X)\right\}d\varphi,$$

and this when integrated from zero to π is

$$Z = 2\frac{H\alpha^2}{h}\sin 2\lambda\left\{\frac{\sin\varepsilon}{\sin\lambda}E^1(\mu) + \frac{\cos\varepsilon F^1(\mu)}{\tan\varepsilon\sin\lambda} - \frac{\sin\lambda\cos\varepsilon}{\tan\varepsilon}\Pi^1(\mu)\right.$$

$$\left.\pm\frac{\pi}{2}\sin\varepsilon\right\}.$$

Knowing the zonal receipt of solar energy for any and every latitude, the heat per unit area is within reach; for the length of a parallel of latitude is $2\pi a\cos\lambda$, and if u is the sunshine per unit area for the interequinoctial period

* In testing the truth of this formula it is convenient to remember that

$$\frac{\cos^2\phi}{\Delta(\phi)} = \frac{\Delta(\phi) - (1-\mu^2)/\Delta(\phi)}{\mu^2}.$$

$$u = Z / 2\pi\alpha \cos\lambda.$$

At the equator this becomes

$$u = 2\,\frac{H\alpha}{\pi h}\,E^1(\varkappa);$$

$E^1(\varkappa)$ being in this case the quadrant of an ellipse the numerical eccentricity of which is sin ε. The quantity h is a function of the sum of the masses of the sun and earth, say m, the major semiaxis of the earth's orbit, A, and the eccentricity, e, in fact

$$h^2 = Am\,(1 - e^2).$$

Now the major axis of a planet's orbit has until lately been assumed to be absolutely constant. In 1879, Mr. D. Eginitis showed that a surmise of Tisserand's was correct, and that the major axis is subject to a secular inequality of the third order with respect to the masses.* For most purposes, however, this minute change is negligible as well as the increment of mass due to the accumulation of meteoric matter. Hence e may be regarded as the only variable in the value of h. If the obliquity were zero and the eccentricity were zero, so that the orbit would be a circle of radius A, its plane also coinciding with that of the equator, $E^1(\varkappa)$ would reduce to $\pi/2$, and the solar energy received between equinoxes at the equator would be

$$u = \frac{H\alpha}{\sqrt{Am}}.$$

Now the unit in which radiant energy is measured is arbitrary; this last value is a convenient unit and I have adopted it.

For computation it is desirable to reduce the elliptic integral of the third class to integrals of the first and second classes. This is possible by a well known theorem which applied to $\Pi^1(\varkappa)$ and $\Pi^1(\mu)$ gives

$$\Pi^1(\varkappa) = \Pi\left(\varkappa, \sin\varepsilon, \frac{\pi}{2}\right) = F^1(\varkappa) + \frac{\cot\lambda}{\cos\varepsilon}\left\{F^1(\varkappa)\,E\left(\varkappa, \frac{\pi - 2\varepsilon}{2}\right)\right.$$
$$\left. - E^1(\varkappa)\,F\left(\varkappa, \frac{\pi - 2\varepsilon}{2}\right)\right\}$$

E and F denoting integrals of amplitude less than $\pi/2$, and

$$\Pi^1(\mu) = \Pi\left(\mu, \cos\lambda, \frac{\pi}{2}\right) = F^1(\mu) + \frac{\tan\varepsilon}{\sin\lambda}\left\{F^1(\mu)\,E(\mu, \varepsilon)\right.$$
$$\left. - E^1(\mu)\,F(\mu, \varepsilon)\right\}.$$

* Ann. Observ. Paris. Mém. vol. xix, 1889, paper H.

Substitution of these values in $Z/2\pi a \cos\lambda$ gives the following expressions for actual use :—

At the equator the modulus is $\sin\varepsilon$ and for either season alike

$$u = \frac{2\,E^1}{\pi\sqrt{1-e^2}}.$$

From the equator to the polar circle the modulus is $\sin\varepsilon/\cos\lambda$ and the sunshine per unit area between equinoxes is

$$u = 2\frac{\sin\lambda}{\pi\sqrt{1-e^2}}\left\{ E^1\cos\varepsilon\left[\frac{\cot\lambda}{\cos\varepsilon} + F(90^\circ-\lambda)\right]\right.$$

$$\left. - F^1\cos\varepsilon\left[E(90^\circ-\lambda) - \tan\lambda\tan\varepsilon\sin\varepsilon\right] \pm \frac{\pi}{2}\sin\varepsilon\right\}.$$

At the polar circle

$$u = 2\frac{\cos\varepsilon}{\pi\sqrt{1-e^2}}\left\{\tan\varepsilon + \cos\varepsilon\, ln \cot\frac{90^\circ-\varepsilon}{2} \pm \frac{\pi}{2}\sin\varepsilon\right\}$$

From the polar circle to the pole the modulus is $\cos\lambda/\sin\varepsilon$ and

$$u = 2\frac{\sin\lambda}{\pi\sqrt{1-e^2}}\left\{E^1\cos\varepsilon\left[F(\varepsilon) + \frac{\tan\varepsilon}{\sin\lambda}\right] - F^1\cos\varepsilon\left[E(\varepsilon)\right.\right.$$

$$\left.\left. - \frac{\cos\lambda}{\tan\varepsilon\tan\lambda}\right] \pm \frac{\pi}{2}\sin\varepsilon\right\};$$

and at the pole this reduces to

$$u = \frac{1}{\sqrt{1-e^2}}\left\{\sin\varepsilon \pm \sin\varepsilon\right\}$$

These formulas can be computed from known series or by the help of Legendre's tables. For $\varepsilon = 23^\circ\ 27'$ I have computed the values tabulated in both ways with coincident results. For $\varepsilon = 24^\circ\ 36'$ I used the tables and checked by differences with the other series. The radiant energy received during the entire year is of course the sum of the energy received during the two seasons. The quantities thus found and multiplied by a constant coincide with Meech's values to four significant figures. Meech took the apparent obliquity at 23° 28′, and the sine of this angle is 1·0007 the sine of 23° 27′, so that a closer correspondence could not be expected.* I have stated my results to four decimals, though for the purposes of this paper three would have been ample.

It need scarcely be mentioned that the effect of the real ellipticity of the meridian is to reduce the receipt of solar energy towards the the poles by a trifling amount.

Washington, D. C., June, 1894.

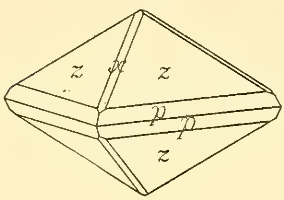
* The obliquity was 23° 27′ 30″ in 1852, or after Meech had begun his investigation. It is now about 23° 27′ 11″.

Art. XIV.—*Mineralogical Notes;* by S. L. Penfield.

1. *Octahedrite from Magnet Cove, Arkansas.*

Up to the present time octahedrite has been found in the United States at only a few places. It is interesting, therefore, to record its occurrence at a new locality, especially as it is one which is noted for the two other forms of titanic oxide, brookite and rutile. While examining the stock of minerals of Dr. A. E. Foote of Philadelphia, Pa., one specimen was found, among a lot of brookites from Magnet Cove, which attracted the writer's attention from its unusual crystalline form. On measuring the crystals they were found to be tetragonal and to have the angles of octahedrite. The habit is shown in fig. 1, the forms being:

1.



p, 111, 1 z, 113, $\frac{1}{3}$ x, 103, $\frac{1}{3}$-i

The reflections of the signal were fairly good and the angles which were measured agree very well with those calculated from the length of the vertical axis as given by Miller,* $\dot{c} = 1{\cdot}7771$.

	Measured.	Calculated.		Measured.	Calculated.
$p \wedge p'$, $111 \wedge \bar{1}11$ =	82° 6′	82° 9′	$z \wedge z'$, $113 \wedge \bar{1}13$ =	53° 54′	54° 1′
$p' \wedge p''$, $\bar{1}11 \wedge \bar{1}\bar{1}1$ =	82 12	"	$z' \wedge z''$, $\bar{1}13 \wedge \bar{1}\bar{1}3$ =	53 49	"
$p \wedge p^{iv}$, $111 \wedge 11\bar{1}$ =	43 22	43 24	$z \wedge z^{iv}$, $113 \wedge 11\bar{3}$ =	100 20	100 5½

The crystals are black and have a fine metallic luster. The largest are about 5^{mm} in axial diameter. They are implanted upon a white saccharoidal albite, showing small, distinct crystals of albite in the cavities. When tested with salt of phosphorus before the blowpipe they gave the reaction for titanium.

Although a careful search was made, only this one specimen was found, which is now in the collection of Prof. Geo. J. Brush. There can be no doubt about its having come from Magnet Cove, as it resembles in its character and association other specimens from there and also shows a few brookite crystals.

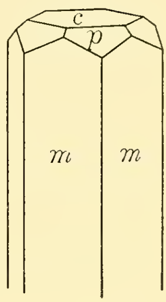
2. *On the Crystallization of Penfieldite.*

In the September number of this Journal, 1892, page 260, my friend, the late Prof. F. A. Genth, described a new min-

* Mineralogy, 1852, p. 229.

eral from Laurion, Greece, of the composition $PbO \, . \, 2PbCl_2$, which he named after the writer. This was one of the last papers published by Prof. Genth and the last new mineral species described by him.

2.



All of the specimens in Prof. Genth's possession were sent to the writer for crystallographic study. As described by him, the crystallization is hexagonal. No indications of hemihedrism were observed. The usual combination is that of prism *m* with basal plane *c*. A few of the crystals showed a pyramid of the second order *p*, $11\bar{2}2$, 1–2, in combination with prism and base, fig. 2. On one small crystal, which gave fair reflections from three of the pyramidal faces, the following measurements of $c \wedge p$ were made, 41° 53′, 41° 52′ and 41° 55′. Taking 41° 53′ as fundamental the axial ratio becomes $a : c =$ 1 : 0·8967.

Some specimens showed the prismatic faces in combination with steep pyramids of the first order. These were in oscillatory combination, giving rise to horizontal striations and often causing the crystals to taper to a point. The reflections from these pyramids were numerous and so uncertain that no definite symbols could be assigned to them.

The cleavage is distinct parallel to the base and sections show in polarized light a normal interference figure. The double refraction is positive and about as strong as that of calcite.

3. *On the cleavage and parting Planes of Oligoclase and Albite.*

In the November number of this Journal, 1888, page 324, the writer described a very clear glassy feldspar from the Hawk mica mine, near Bakersville, Mitchell Co., N. C., which seemed to show abnormal optical properties. It is found as cleavage masses without crystal faces at a considerable depth in the mine. An analysis by Mr. E. S. Sperry showed that it contained the albite and anorthite molecules in the proportion of 3·6 : 1 and was to be classified therefore as oligoclase. The material that was used for the investigation was a single specimen from the collection of Mr. Norman Spang of Etna, Pa. This was without twinning striations and presented a perfect cleavage parallel to the basal, and an imperfect one, supposed to be parallel to the brachy-pinacoid (010). Plates parallel to this second cleavage showed in convergent polarized light an optical axis almost in the center of the field, while basal sections gave with the polarizing microscope extinctions inclined about 38°–40° from the edge formed by the meeting of the two cleavages. These optical relations seemed entirely unlike those of oligoclase and the material was therefore described as abnormal. Offret* has since shown that the Bakersville oligoclase has normal optical properties and, therefore, in order to reconcile these differences and to make a further study of the material a new supply was secured from Mr. Geo. F. Kunz of New York and Mr. W. Vance Brown of Plum Tree, N. C., to whom the author's sincere thanks are due. Among the specimens some pieces presented the normal cleavage, polysynthetic twinning and optical properties of oligoclase. Some, however, that were clear and free from twinning, showed the abnormal properties as previously described, but from the examination of a number of fragments it was soon discovered that the second cleavage is not parallel to (010) and that the feldspar thus presents an unusual and unexpected cleavage or parting instead of abnormal optical properties.

In oligoclase the angle γ, between the $\breve{a}$ and $\bar{b}$ axes is practically 90° and the extinction direction on basal sections is +1° or almost parallel to the $\breve{a}$ axis, hence it follows that the angle of 38°–40° which the cleavage makes with the axis of greatest elasticity in a basal section serves to orient the cleavage with reference to the lateral axes. From the measurements of vom Rath† it has been calculated that the pyramid ($\bar{1}\bar{2}1$) makes angles of 92° 35′ =(001 ∧ $\bar{1}\bar{2}1$) and 87° 25′ with the base, the measurement of the abnormal cleavage being about 88°, and that the trace of the pyramid on the base intersects the edge between (001) and (010), or the direction of the $\breve{a}$ axis at an angle of 38° 1′, about corresponding to the extinction direction. Exact measurements cannot be made for determining the position of this peculiar cleavage, owing to the poor reflection which it gives and the absence of other planes except the basal cleavage, but it is distinctly parallel to a pyramid and the form ($\bar{1}\bar{2}1$) has the position to yield all of the abnormal properties that were observed. This abnormal cleavage is well shown on many of the specimens and whether it is a true cleavage or a parting of secondary origin, produced perhaps by pressure, is uncertain but it is probably the latter. The forms that can be broken out, bounded by the basal and abnormal cleavages and an irregular fracture inclined to the base at an angle about equal to β of the feldspars, look like ordinary cleavage blocks of feldspar, and thus caused the

* Bull. Soc. Min. de France, xiii, p. 648, 1890.

† Pogg. Ann., cxxxviii, p. 464, 1869. Also Dana's Mineralogy, Sixth edition, p. 332.

original error in the orientation. Another surprising and unexpected peculiarity of this feldspar is the difficulty of producing the cleavage parallel to (010). Among the specimens that show the unusual pyramidal parting there is not one that shows the (010) cleavage. Some are broken so that the fracture runs nearly parallel to (010) but they present only the curved surfaces of a conchoidal fracture. When the direction of (010) is known, which can be determined by the extinction, it is difficult to produce the cleavage by striking the blocks in a favorable direction with the peen of a hammer, or by striking on a knife blade or chisel whose edge is placed on the crystal in the direction of the desired cleavage. On specimens which show the usual poly-synthetic twinning striæ on the base the (010) cleavage can always be readily obtained. This has given rise to the query, is the good cleavage on plagioclase parallel to (010) only apparent, and is it not possibly the result of a separation along the plane of twinning? Certainly those feldspars which show well developed poly-synthetic twinning readily yield good cleavage surfaces, while those showing no twinning, which the writer has been able to examine, usually yield the (010) cleavage only with difficulty, so that it might well be designated as rather poor and interrupted.

In experimenting upon the cleavages of albite the following peculiarities were also observed. The specimen examined was a large crystal from Amelia, Va., associated with quartz and muscovite. It presented a combination of twinning according to the Carlsbad and albite laws, similar to fig. 7, page 328 of the sixth edition of Dana's Mineralogy, and measured over 70^{mm} in the direction of the $\breve{a}$ and $\dot{c}$ axes. Two of the twinning individuals were fully 6^{mm} broad, measured at right angles to the twinning plane; they were clear and glassy, and free from cracks and poly-synthetic twin lamellæ. The crystal was firmly united by the pinacoid (010) to the quartz and when fragments were detached by striking with a hammer they were always bounded by the basal cleavage and surfaces parallel to the prism $m(110)$ and the pyramid $o(\bar{1}\bar{1}1)$. These latter surfaces had the appearance of perfect cleavages, and often their presence was revealed by cracks, running wholly or partly across the detached fragments. The following measurements were obtained on the reflecting goniometer, the reflections, especially those from m, being sharp and well defined:

$c \wedge m$, $001 \wedge 110 = 65° 10'$ mean of five independent measurements, varying from $65° 7'$–$65° 12'$.
$c \wedge o$, $001 \wedge \bar{1}\bar{1}1 = 57° 50'$ and $57° 33\frac{1}{2}'$.

The calculated angles taken from Dana's Mineralogy are $c \wedge m = 65° 17'$ and $c \wedge o = 57° 49'$. The parting parallel to *m* was moreover observed at a number of places on the specimen where the latter had been broken. Subsequent attempts to produce surfaces parallel to these same planes by breaking up the detached fragments with a hammer, using the customary devices for obtaining cleavage in definite directions, utterly failed. In other words, the partings parallel to *m* and *o* do not have the properties of true cleavage. They seem to be partings along definite cracks within the crystal or they were produced by the peculiar strain to which the fragments were subjected in breaking away from the attachment of quartz. The partings parallel to (110) and $\bar{1}\bar{1}1$) were readily produced on this material by pressure in the direction of the $\bar{b}$ axis, the blocks of feldspar being held between plates of lead and squeezed in a vice. As shown by Lehmann* a parting parallel to (110) results from the contraction due to sudden cooling, when heated fragments of albite are thrown into water. A similar result was obtained by the writer but no parting parallel to ($\bar{1}\bar{1}1$) was observed.

Tests made by pressing the Bakersville oligoclase, and by contraction from sudden cooling, did not yield flat surfaces that could be referred to definite crystal directions.

In conclusion, therefore, it should be emphasized that the cohesion relations of the plagioclase feldspars may show considerable variation. The basal cleavage is always perfect. That parallel to the brachy-pinacoid (010) is usually distinct, while it is sometimes imperfect and hard to produce and especially when poly-synthetic twin lamellæ are absent. Under certain conditions of pressure or tension, partings may occur parallel to the prism *m*(110) or the pyramid ($\bar{1}\bar{1}1$) which resemble perfect cleavages, while, as in the case of the Bakersville oligoclase the partings may run in other directions resembling imperfect or interrupted cleavages.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, February, 1894.

* Zeitschr. Kryst., xi, p. 612, 1886.

ART. XV.—*Development of the Lungs of Spiders;* by ORVILLE L. SIMMONS. (With Plate VIII.)

ALTHOUGH several persons* had suggested the close affinity of the Arachnids and Limulus, it was not until the appearance of Lankester's paper, "Limulus an Arachnid" ('81[b]) that the view of such a relationship came into prominence. Since that date it has attracted more and more numerous advocates until now the majority of the special students of Arachnids and Xiphosures recognize the close relationships of the two groups. One of the special homologies insisted upon by Lankester was that existing between the lungs of the Arachnids and the gills of Limulus. But to explain the differences between these organs—the one being an internal air-breathing structure, the other an external apparatus for aquatic respiration—several hypotheses have been advanced, all based upon conditions existing in the adult.

At first Lankester evidently shared the common view that tracheæ were homologous structures throughout the Arthropoda, and so he sought for traces of them in Limulus. In his article "On stigmata in the King Crab" ('81[a]) he announced that he had found traces of stigmata. The position of insertion of each thoracico-abdominal muscle is marked by a deep funnel-like depression of the integument, which from the external surface appears as a stigma.

Later, in his paper "Limulus an Arachnid" ('81[b]) he formulates an hypothesis to show how the gills of Limulus and the lungs of Scorpio (taken because more primitive than Spiders) could have been derived from a common ancestor which he describes as being an aquatic form, breathing by book-like gills. To derive Limulus from such a form would involve only a few changes in dimensions and other unimportant points. To obtain the condition occurring in Scorpio, he assumes that the cup-like depressions behind the appendages, as seen in Thelyphonus, became deeper and larger, finally engulfing the whole appendage. The walls then gradually extended over the cavity, leaving only a slit for communication with the exterior. As change of habits went on this slit was closed up and another slit, still within the area formed by the closure of the primitive opening of the cave of invagination, was formed. Air would enter by this slit, where in Limulus and the early Scorpion ancestors there was blood space. Thus a blood space has been changed to an air space. In the same way an air space (that of the investing sac) has

* Strauss-Durckheim (teste Lankester), van Beneden ('70).

been converted into a blood space. The atropy of the muscles which move the gills in Limulus and similar forms was considered very essential to this theory. The difficulties involved in the changes of blood and air spaces were so considerable as to prevent the acceptance of this hypothesis.

Later, Lankester ('85) put forth a new theory. Because of discoveries concerning the muscles (veno pericardiac) of Scorpio, as well as on account of the insuperable difficulties of his previous view, he gave up his old and advanced a new hypothesis. In the latter the common ancestor is assumed to have had six pairs of mesosomatic appendages, of which five were lamelligerous. These latter in Scorpio became smaller and served only for respiratory organs, soon becoming air-breathing. The four hinder pairs took a "trick" of growth, viz: an invagination of the appendages, beginning at their distal ends, so that they grew into the Scorpion's body, turning their outside in, just as a glove may be turned wrongside out, beginning at the ends of the fingers. Thus the appendages would be tucked into the blood sinus instead of growing out normally. The blood sinus would become a venous sac around the appendage. He explains the "trick" of growth by the least resistance theory—the pressure being exerted on the embryo before it leaves the mother.

J. MacLeod ('82 and '84) sets forth an hypothesis by which he develops Scorpions and similar forms from a Limulus-like ancestor. His first proposition is that the abdomen of Limulus be considerably elongated without other change. This would cause the imbrication of the members to cease—each appendage would stand out by itself although closely following each other. Then suppose that the sternal plate increase in size and unite with the ventral surface of the abdomen. Thus the gill-book cavity would be entirely filled up by the sternal plate except in those cavities on the ventral side which contain the gills or lungs, now greatly reduced in size. In this condition the lungs are quadrangular plates, attached by two edges only. Inserted on each plate is a number of lamellæ which are attached by one side only. In this condition when removed from the water, the lamellæ would cling together and be imperfectly in contact with the air. To be of service the lamellæ would have to unite their lateral edges to the plate, leaving only the posterior edge free. Thus MacLeod developed the lamellæ and other structures of the lungs of Arachnida. By a comparison of structures in the adult form, MacLeod came to the conclusion that the tracheæ of Spiders are developed from the lungs.

J. S. Kingsley ('85 and '93) advances a much simpler explanation to account for the transition from a Limulus gill-book to the lung-book of a spider or scorpion. By a sinking in of the whole appendage bearing the gill-leaves and an increase of the inpushings of the integument and a decrease in the outgrowths, the whole matter is explained. This involves a diminution of growth on the anterior side of the appendage and an increase of growth on the posterior side. These conditions would carry the appendage within the body wall where it would be situated as seen in the adult—the spiracle at the posterior end of the lung cavity and the lamellæ projecting toward the posterior end of the body. As Kingsley states, viewed from a histological standpoint, the description of the pulmonary organ of the spider or scorpion applies, almost word for word, to the gill-book of Limulus. He believes that the lungs of spiders are the primitive and the tracheæ the derived structures. The tracheæ of the Hexapoda have no relation to the tracheæ of spiders, having an entirely different origin.

Malcolm Laurie ('90) in his article on "The Embryology of a Scorpion" thinks the lung-books are undoubtedly comparable to the abdominal appendages of Limulus but hesitates to decide which of two propositions he advances is the correct one. He inclines toward the view that the lung-books of Scorpions are invaginated, i. e. the edge of each lamella in the Limulus gill-book corresponds to the interior fold between the lamellæ in the Scorpion lung-book. He imagines that he sees difficulties in explaining his second proposition which states that the whole appendage has sunk without invagination into a cavity in the abdominal surface. By either proposition the air space of the primitive condition would be air space in the derived condition.

On the other hand many comparative anatomists, recognizing the homologies pointed out years ago by Leuckart, as existing between the lungs and tracheæ of spiders and believing that these last were the homologues of the structures known by the same name in the Hexapods, have failed to recognize the cogency of the reasoning of the advocates of the Arachnidan affinities of Limulus. Thus Arnold Lang in his Lehrbuch der vergleichenden Anatomie (II Heft, p. 548, 1890) writes that the respiratory organs of Arachnoidea are tracheæ —tubular and book-leaf tracheæ. His view of the morphological signification of the latter is that they are modified tracheal tufts which, standing close together, have been flattened into hollow plates. He believes that the view of those who would bring the gill-books of Limulus and the lung-books of scorpions and similar types into close relationship, is artificial and unsupported by comparative anatomy and ontogeny.

So, too, Bernard ('92) in "The Apodidæ" says it is easiest to believe that the lung-books of the various forms are only a specially concentrated arrangement of tracheal tubes. He regards the tracheæ, including the lungs of all "Tracheates" as having their origin in dermal glands which have gradually been modified for respiratory purposes. He also states that in considering the relationships of these various forms, the limbs are of so little importance that one might almost be tempted to leave them out of account. In a later paper on "The Chernetidæ" Bernard ('93) repeats in substance his earlier views.

In a word, these authors, regarding the tracheal form of respiration as the primitive—a premise which the observations of Moseley on the tracheæ of Peripatus seemed to render valid—have looked upon the air tubes of the arachnids as the primitive and the lungs as the derivative condition.

The question thus brought into prominence can only be settled by tracing the development of the respiratory organs of the Arachnida. Several authors have touched upon this question. Thus Locy ('86) describes the later stages of *Agelena nævia* as follows: The lungs arise as a pair of extensive invaginations. In sagittal sections they appear as oblong plates of cells with the nuclei in parallel rows. These nuclei are flattened on one side and convex on the other. The cells of two adjoining rows unite by the edges toward which the convex sides of the nuclei project and thus a lamella is formed. Later the nuclei of adjoining cells fuse, forming protoplasmic pillars between which are the blood lacunæ. Around each lamella is a chitinous membrane—the ventral and the dorsal being continuous at the free (posterior) end of the lamella. The cells of the ventral wall become arranged into two distinct layers. A part of the development described takes place after the hatching of the egg.

A. T. Bruce ('86–'87) says that a lung-book of a spider may be regarded as an involuted appendage or appendages. He noticed that the abdominal appendages become less conspicuous and that slight folds appear on their *anterior* faces. He did not observe all the stages and, judging from his text and figures, it is very evident that he was confused in some of his interpretations. K. Kishinouye ('90) states that in the basal part of the first abdominal appendage there is an ectodermic invagination—not deep or large. The wall of this pocket which faces the distal end of the appendage is thicker and its cells become arranged in parallel rows. Two of these rows, adhering to each other, produce a lamella. He confirms Locy's description of the later stages. On the second abdominal appendage is another ectodermic invagination—a deeply invaginated tube which remains in about the same state of development until after hatching. The appendage shortens but is not invaginated. He believes it is very probable that the lungs were derived from the respiratory apparatus of some Limulus-like, aquatic form. He thinks that tracheæ are modified lungs.

Laurie ('90), beginning with his stage K, describes the changes in the abdominal segments of the Scorpion. At this stage the pectinæ and lung-book appendages are about equal in size and structure. In stage L, the pectines have become folded in a direction transverse to their axes. The other appendages are pushed in, forming little cavities (directed forward) on the posterior sides of the appendages. In the stage M the pectines are separated from the body wall at their distal ends. The lung-book inpushings are deeper and the cavities are divided up by lamellæ. In the last stage described (just before hatching) the pectines and lung-books have much the same structure as in the adult.

Morin ('88)* states that the lungs of the dipneumonous spiders arise in form of infoldings at the bases of the two appendages of the second abdominal segment. At the anterior end of the sac on the dorsal side, is an infolding which is the beginning of the lung leaves. The space between two leaves connects directly with the body cavity. Two adjoining leaves unite by the fusing of cells, as described by Locy. He agrees with Locy as to the later stages. Morphologically the lungs of Arachnida show great resemblance to the gills of Limulus and similar forms. He emphasizes the position of the infoldings on the posterior side of the appendage in both cases. The lungs of Spiders are merely sunken gill-books of Limulus. As the appendage sinks the stigma is left as an opening between the posterior wall of the appendage and the body wall. This author agrees with those who believe that tracheæ are modified lungs.

It must not be forgotten that Elias Metschnikoff ('70) described some features of the lungs of the Scorpions but it is not easy to understand either his text or his figures beyond the fact that he states that the lungs develop behind the abdominal limbs.

As will be seen from the foregoing summary, the development of the respiratory organs of the Arachnids has not been followed throughout and the gaps in our knowledge are at just the most critical points. To supply these deficiencies the investigations described below were undertaken.

The work was done in the Biological Laboratory of Tufts College. The eggs used were those of *Agelena nævia* and *Theridium tepidariorum*. The eggs were killed in water

* As summarized by Korschelt and Heider, '92, pp. 604–607. I cannot refer to the original text.

heated to 80° C. and hardened in alcohol, beginning with 50 per cent. The staining was usually *in toto* with alum cochineal. The sections described, unless otherwise specified, are sagittal.

In the first stage studied, corresponding in general to Locy's fig. 6, somite VII is cut off from somite VIII. Somites VIII and IX are still united (fig. 1) and the unsegmented mesoderm extends farther back. The ectoderm is a single layer deep except a portion over somite VII (possibly the anlage of an appendage) and between VIII and IX. The infolding of ectoderm shows the first differentiation of external segmentation.

In the next stage (fig. 2) which is about midway between Locy's figures 6 and 7, the second abdominal somite is differentiated, and to a less extent the line between somite IX and somite X, which has developed, is marked off. The ectoderm has become thickened from somite VII to somite IX. It is to be noticed that the cœlomic pouches are flattened in all except somite VIII.

The succeeding stage (fig. 3) shows the same features carried still farther. The XI somite has appeared. This stage corresponds to Locy's figure 7 or a stage a little earlier. I may note here that I have found at least as many cœlomic pouches as are described by Kishinouye in his "Note on the Cœlomic Cavity of the Spider," 1894.

After the stage just mentioned the appendages begin to be formed; no detailed account need be given of the external appearance of these, as in the main, my observations are but the repetition of those of various authors, from Claparède to Kishinouye. They grow out, one on either side of somites VIII–X, as rounded knobs.

Pulmonary organs.

In figure 4, which represents somites VII and VIII, the early appearance of the appendage is seen. In somite VII the cœlome is already greatly reduced and no trace of an appendage is to be seen. In the next somite (VIII) the appendage is plainly visible. It is marked off from somite VII by a slight groove, while the groove separating it from somite IX is deeper and directed forward, giving the limb a markedly backward direction, a tendency which is even more pronounced in later stages. Its outer wall is formed of several layers of cells while the cœlomic pouch sends into the budding appendage an outgrowth like that described by various authors.

With farther growth the conditions just described become more strongly emphasized; the anterior demarkation of the appendage becomes more and more faint, while behind, the inpushing becomes more and more marked, so that eventually a pit is formed, actually extending into the general body surface, the outer wall of the pit being formed by the appendage whose growth we are tracing. This pit forms the pulmonary sac and the opening of the inpushing persists as the respiratory stigma. At no time do the appendages rise to any considerable distance above the general abdominal surface.

The changes described can be seen by a glance at fig. 5 which, besides the points already mentioned, shows some other features worthy of notice. The cœlome of somite VII still persists. That of VIII has become divided into two portions, one of which remains in the appendage, while the other portion, reduced in size, has been pushed backwards by the ingrowing pulmonary sac. The sac itself is irregular in outline, its inner wall being slightly undulating, while its outer wall, i. e. the morphologically posterior surface of the appendage, has its ectoderm thrown into folds, the anlagen of the leaves of the lung-book. The ectoderm lining the inner wall of this sac is but a single cell in thickness, but that of the appendicular side is thicker, the nuclei being rather irregularly arranged, the pulmonary ingrowths forcing their way between them. In this stage but two lung leaves are outlined, as shown in the figure.

In eggs of the same lot as the last, a stage apparently a little older was found ; and from it the section figured in 6 was drawn. In its general features the changes are slight but there are some details of importance. From the fact that the plane of this section is not the same as that of the last, the appendicular cœlome is not shown, while the cœlomic cavity of the body is here much larger. So, too, the inner wall of the pulmonary cavity is shown to be thicker, a fact probably due to the obliquity of the section. In this stage four gill leaves are shown, the most developed ones being the most distal ones. In these, too, the nuclei are already arranged with their major axes parallel to the plane of the leaves. Proximally the leaves are much shorter and the nuclei are irregularly arranged. These facts place it beyond a doubt that the growing point of the organ is at the base of the appendage, a point of no little importance in comparison with the Xiphosures.

Figure 10 shows the ventral view of the embryo at the stage which figures 5, 6 and 8 represent in sections. This stage is about two or three days before the reversion of the embryo. Changes during this period are very rapid. In 4–5 days after this stage the lungs are almost fully developed and have about the same appearance as in hatched specimens, except in size and number of lamellæ. The embryo hatches in from 7–8 days after the stage figured in 10.

With the reversion of the embryo, the changes rapidly proceed toward the adult condition. In fig. 7 I insert an illustration which serves to connect my account with the papers of Locy, Kishinouye, Laurie and others. Here the gill lamellæ have slightly increased in number while they have become greatly increased in length. In the figure the pulmonary sac is somewhat funnel-shaped owing to a pulling open of the spiracle in some process of manipulation.

From this stage the transition to the conditions described by MacLeod and Locy is but slight and although I have studied the later stages up to and even beyond hatching, my observations are but a confirmation of theirs and so I do not repeat them here. The lungs are well developed and apparently ready to function as respiratory organs at the time of hatching. With the growth of the young spider the principal changes are an increase in the number of lamellæ and a corresponding increase in the size of the pulmonary organ, the new lamellæ being formed at the inner end of the sac.

Tracheæ.

The study of these has been a matter of considerable difficulty and I have been able to follow with certainty only the earlier stages. The tracheæ arise behind the appendage on somite IX, which, in its earlier stages has exactly the same history as appendage VIII. There is the same inpushing behind the limb, which results in its taking a position not pointing outward but towards the median line and backward. In fig. 8 is seen the first differentiation of the tracheæ. The inpushing has given rise to the spiracle as before, but the sac which results does not show so markedly those infoldings of the appendicular wall which occur in the case of the lungs. There is at most but a slight undulation of this surface. At the inner end, however, two ingrowths are seen, the earliest indications of the formation of the tracheal twigs. It is, however, easy to see that these inpushings are to be compared with the infoldings which produce the lamellæ, while the undulations just referred to admit of the interpretation that they are aborted lung leaves.

After the reversion of the embryo the same parts can be recognized (fig. 9). The inpushing has been carried to a greater extent, and sections in other planes show that this ingrowth is tubular in character. The cells lining its walls are elongate and are already taking the character shown in the tracheæ of the adult. At the inner end of the tracheal trunk thus formed, the nuclei are arranged in a radiating or bush-like manner, apparently indicating that here is the place where the trunk is about to divide into the tracheal twigs, but I have not been able to trace any tracheal lumina between these cells. I have not followed the later history of the tracheal system with any detail but think that the foregoing is sufficient to justify my thesis that the tracheæ and the lungs are to be regarded as homologous structures.

Conclusions.

From the preceding it will be seen that:

I. The lungs of the spider arise as infoldings upon the posterior surface of the appendages of the second abdominal somite in the same manner as described by Kingsley ('85 and '93) for the gills of Limulus. They have the same growing point at the base of the appendage and form the lung leaves in exactly the same way that the gill-leaves arise. In other words, the lung-book of the spider (and presumably of all arachnids which possess one) arises at first as an external structure upon the posterior surface of the abdominal appendages. These appendages sink in, without any inversion or other complications, in exactly the manner theoretically deemed probable by Kinsgley, so that there can no longer be any doubt as to the exact homology existing between the lungs of the spider and the first pair of gills in the horse shoe crab.

II. The tracheæ develop from the next pair (third abdominal somite) of limbs. In their earlier stages these appendages show on their posterior surface a folding similar to that on the preceding members. From this it follows that the lung-book condition is the primitive, the tracheæ of the Arachnids being derived from it. And with these facts there is left no ground for those who regard the "Tracheata" as a natural group of the animal kingdom.

Tufts College, Mass., May 25th, 1894.

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EXPLANATION OF THE FIGURES.

Reference Letters.

a^1.–a^{11}. Appendages.
c^7.–c^{11}. Cœlomic cavities.
e. Ectoderm.
m. Mesoderm.
pc. Pulmonary cavity.
pl. Pulmonary leaves.
s. Spiracle.
so. Somatoplure.
sp. Splanchnoplure.
t. Trachea.
y. Yolk.

All figures except fig. 10 arc magnified 125 diameters.

EXPLANATION OF THE PLATE.

Fig. 1.—A sagittal section showing the cœlomic cavities of the VII, VIII and IX somites.

Fig. 2.—A sagittal section through the same region as the preceding at a little later stage. The coelomic pouch of the X somite is seen as well as the inpushings of ectoderm behind somites VII and VIII.

Fig. 3.—A section cut under conditions similar to those of the two preceding sections. The stage is a little later than fig. 2 and shows the cœlomic cavity of somite XI and further inpushings of the ectoderm. In all of the preceding sections the somatopluric wall is the thicker.

Fig. 4.—In this figure the cœlome of somite VII is much reduced in size. The cœlome of VIII is beginning to thrust itself into the appendage, which is marked off by a shallow groove in front and by a deeper inpushing, which has a forward direction, between somites VIII and IX.

Fig. 5.—In this section the inpushing, seen in fig. 4, has gone much farther, dividing the cœlome of somite VIII into two parts. On the inner wall of the appendage are two inpushings which are the beginnings of the lamellæ of the lung book.

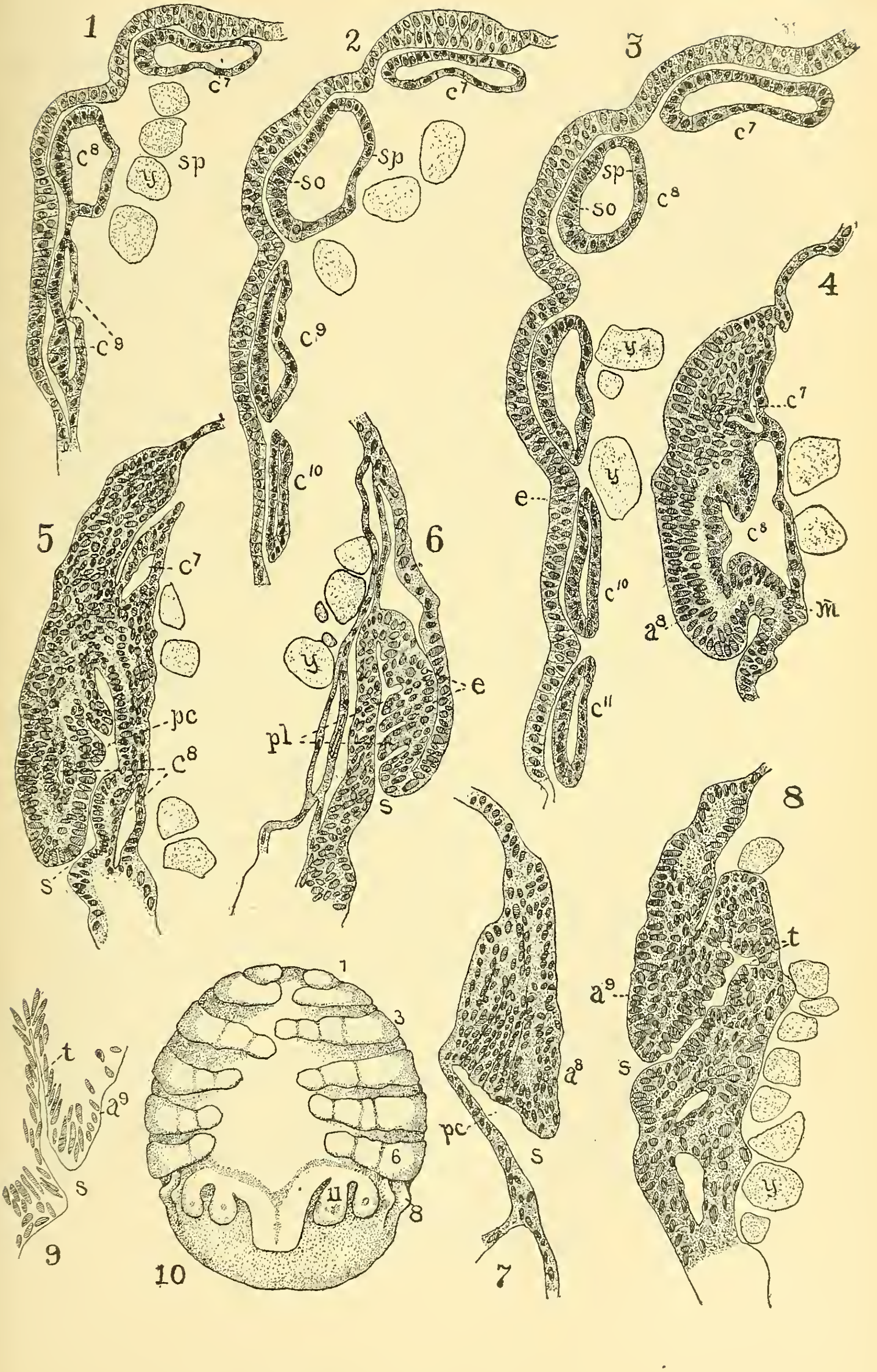
Fig. 6.—A section of the appendage of somite VIII cut at a different angle from the preceding. Here four lamellæ are seen.

Fig. 7.—A sagittal section from a stage just after the reversion of the embryo.

Fig. 8.—A section of the appendage of the IX somite, showing, at the inner end of the inpushing, the beginning of the tracheal tubes.

Fig. 9.—A section of the tracheal region after the reversion of the embryo.

Fig. 10.—This figure is a representation of the ventral surface of an embryo which is about the same age as those from which sections seen in figs. 5, 6 and 8 were cut.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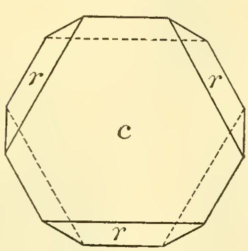
ART. XVI.—*On Alunite, from Red Mountain, Ouray County, Colorado*; by E. B. HURLBURT.

THE alunite which will be described in this communication occurs as an aggregate of minute crystals, resembling kaolin, filling pockets and seams in the ore body of the National Belle Mine at Red Mountain. The ore that is mined is chiefly enargite with some tetrahedrite and pyrite. A small quantity of the mineral was observed by Prof. S. L. Penfield on some enargite specimens among material which had been collected by him while engaged in summer work with the United States Geological Survey, and through the kindness of Mr. W. B. Wilson, superintendent of the mine, an abundant supply was obtained. It was at first supposed to be a well crystallized kaolin, similar to that described by Hills,* Cross and Hillebrand† and Reusch‡ from the same mine, but the shape of the crystals and the optical properties did not correspond to the description of the above named authors. Moreover when heated in a closed tube abundant water was given off along with SO_3 and SO_2 and the mineral was determined to be alunite.

The form of the crystals as seen under the microscope is a combination of rhombohedron and base, shown in vertical projection by the figure. The largest crystals were about 0·13^{mm} in diameter and 0·01^{mm} thick. Professor Penfield succeeded in measuring one of these minute crystals on the reflecting goniometer but the faces were somewhat rounded so that they did not give good reflections, the angle of base on rhombohedron was found to be about 54° while Breithaupt gives for alunite $c \wedge r$, $0001 \wedge 10\bar{1}1 = 55° 20'$. The crystals exhibited normal optical properties and positive double refraction.



To secure suitable material for analysis the mineral was suspended in water and the smaller crystals poured off. The larger ones were then brought into the potassium mercuric iodide solution and further purified, that portion which was taken for analysis, and which constituted the bulk of the material, varied in specific gravity between 2·826 and 2·843,

* This Journal, III. xxvii, p. 472, 1884.
† Bull. Geolog. Survey 20, p. 98, 1885.
‡ Neus Jahrb., 1887, ii, p. 70.

which is considerably higher than that given by other authors for alunite.

The results of the analysis are as follows:

				Theory where K: Na: 4: 7
			Ratio.	
SO_3	38·93	·486	4·00	39·65
Al_2O_3	39·03	·382	3·12	37·93
K_2O	4·26	·042 } ·117	·95	4·21
Na_2O	4·41	·075 }		4·83
H_2O	13·35	·741	6·07	13·38
Insol.	·50			
	100·48			100·00

The ratio of $SO_3 : Al_2O_3 : (K+Na)_2O : H_2O$ is very nearly 4 : 3 : 1 : 6 as required by the commonly accepted formula of alunite $KAl_3S_2O_{11}$, $3H_2O$. The agreement between the theory and analysis is satisfactory. The mineral suffers no loss by heating in an air bath at 300° C. and water is first given off at a temperature near redness. It is therefore to be regarded as water of constitution and the formula should be written $K[Al(OH)_2]_3(SO_4)_2$.

An interesting feature of this analysis is the large percentage of sodium, the ratio of K : Na being about 4 : 7, while alunite has usually been regarded as a potash compound only. Another interesting feature is the insolubility of the mineral in hydrochloric acid. By digesting for two weeks on the water bath 13·30 per cent of the mineral and 3·84 per cent of SO_3 went into solution.

The occurrence of alunite from the Rosita Hills in Colorado has been mentioned by Cross,* who regards its formation as the result of solfataric action on rhyolite. The material described by him consisted of immense rock masses made up essentially of alunite and quartz. He cites an analysis of nearly pure white crystals made by Eakins in which the ratio of K : Na was found to be nearly 4 : 7 corresponding to the material from Red Mountain. The origin of the mineral from this last locality is probably similar to that from the Rosita Hills.

In closing the author desires to express his thanks to Professor Penfield for valuable advice during the progress of this examination.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, 1894.

* This Journal, III, xli, p. 466, 1891.

ART. XVII.—*On the Geographic and Hypsometric Distribution of North American Viviparidæ;** by R. ELLSWORTH CALL, Louisville, Ky. (With Map.)

IN some respects these unattractive mollusks constitute a remarkable assemblage of natural forms. They are not widely separated in point of geological history from the Mississippi valley *Unionidæ* which, with these shells, apparently date back to strata of Laramie age. Specimens referred to this genus have been described from Laramie rocks in Montana, Colorado, Wyoming and British America. It is more than probable that from this region as a center all the recent forms have been derived.

The *Viviparidæ* of North America are all comprised in four genera. Of these the species numbers, as well as individuals, differ widely. The recognized natural genera are *Tulotoma*, with two species; *Lioplax*, with two species; *Vivipara*, with four species; and *Campeloma*, with nine species. There are many synonymic names, chiefly in the Campelomoid section which is the most widely distributed and is by far the most abundant in individuals. Questions of priority in no wise enter into the plan of this paper which has to do solely with questions of geographic distribution and the hypsometric range of the several forms. Yet, to prevent misconception, it will be necessary to indicate the names which we believe, with present information, must be applied to the members of these groups. The remaining names, familiar to students of mollusca, will be regarded as synonyms of one or another form herein listed.

With this restriction, then, it is proposed to recognize in *Tulotoma* the following forms:

Tulotoma magnifica Conrad.
Tulotoma coosæensis Lea.

In *Vivipara* the following forms will stand:

Vivipara intertexta Say.
Vivipara subpurpurea Say.
Vivipara contectoides W. G. Binney.
Vivipara troostiana Lea.

The genus *Lioplax* will comprehend the following forms:

Lioplax cyclostomatiformis Lea.
Lioplax subcarinata Say.

* Read before the Indiana Academy of Sciences, December, 1893.

The largest genus, *Campeloma*, will have the following species and varieties:

Campeloma ponderosum Say.
Campeloma decisum Say.
Campeloma subsolidum Anthony.
Campeloma integrum DeKay.
Campeloma rufum Haldeman.
Campeloma coarctatum Lea.
Campeloma decisum geniculum Conrad.
Campeloma limum Anthony.
Campeloma integrum obesum Lewis.

The specific facts here indicated may not be in accordance with those which are usually held by collectors. But this arrangement is based upon the examination of several thousand specimens from all over the wide range of territory to which they belong. What disposition may be made of several problematical forms will depend upon more complete collections in the southwestern portions of the Union.

The species of *Campeloma* of widest geographic range is *Campeloma decisum* Say. Rather more than two thousand specimens of this form alone have passed in review during the past twenty years until its particular features render it very easy of identification. This form ranges from the Dartmouth Lakes, Nova Scotia, northwestward through portions of Quebec and Ontario to the northern shore of Lake Superior and on to the Saskatchawan river, British America. Throughout all this region it is commonly scarce, being found nowhere in abundance except in the St. Lawrence, near Montreal. From Nova Scotia southwards the species ranges throughout New England to Maryland and Virginia. It does not occur south of the Ohio river in the region west of the Appalachian system. That is to say no forms which may not better be referred to some other member of the group have yet occurred south of that stream. The westernmost range of the form is Michigan and Minnesota. Under the name of *Campeloma decisum* however numerous shells belonging to the related *Campeloma subsolidum* have been submitted to us and very many more are to be noted in the United States National Museum and in other large collections. But typical *decisum* has to be looked for only within the portions of the country above outlined. The variety herein designated as *Campeloma decisum geniculum* Conrad will extend the range far to the south but the characters of the variety appear to be so constant and to have such well defined geographic limits that it is deemed best to separately consider it.

Campeloma decisum is a very abundant shell in Central New York, in the Mohawk river and especially in the Erie Canal wherein are to be found the optimum conditions for development and growth. Indeed, as one passes from Maine westwards to New York the form appears to become increasingly abundant. It finds its maximum in individuals in New York and either ceases entirely in the regions about or gradually is replaced by the other forms mentioned herein.

Conrad's form, the geniculate variety, has been discovered in South Carolina and onwards to middle Alabama. It is a very common, often abundant shell in the larger streams of Georgia and in the smaller ones of the northern portions of that State and Alabama. Extensive collecting over all the regions in northwest Georgia never failed to reveal it in all streams in which mollusks of any sort were found, except, indeed, in the very smallest. In most of the tributaries of the Coosa it appeared and always with its well marked characters. Its range may be regarded as pretty well limited by a line drawn along the Appalachians from the boundary of North Carolina to near Wetumpka, Alabama, thence southeastwards to the Flint river at and below Albany. Thence it passes northwards to middle South Carolina and to the place of starting. Without this area it has not yet been detected. What relation, if any, this peculiar form may sustain to the conditions of its environment as a causal factor in determining its modification one may only guess rather than state. But it is believed that therein will lie the explanation.

The most widely distributed western species of *Campeloma* is the form described by Anthony as *C. subsolidum.* Under the various synonymic names of *C. milesii* Lea and *C. exilis* Anthony the typical shell occurs over a very extensive region, embracing Indiana, Illinois, Iowa, Michigan, Minnesota, Nebraska, Kansas, Missouri, and portions of Arkansas and possibly Kentucky. Specimens which are best referred to this species have been submitted from Arkansas but they pass into the more southern and characteristic *Campeloma coarctatum* Lea. Over southwestern Michigan and in Minnesota this shell is very abundant and quite characteristic. In the lakes of Northern Indiana and Illinois, as well as in those of Minnesota, the shells are lighter both in texture and in color than when found in rivers or creeks. To this circumstance is due the reference of very many specimens of this form, which is quite characteristic, to *Campeloma decisum.* Throughout the Upper Mississippi river this is the only species of *Campeloma.* North of St. Louis it gradually grows more common becoming abundant in that stream along Iowa and Illinois shores. The most northern localities are Ft. Snelling, Minnesota, whence come specimens from the Minnesota river, and the Big Sioux river. To the south of Missouri it is replaced by its congener *Campeloma coarctatum* Lea. It has never occurred in any stream which is not tributary to the Mississippi or which does not belong to the Mississippi drainage. Its center of distribution appears to be the Mississippi river in that portion of its course which lies between Minneapolis and Keokuk.

Numerous examples of a much thinner and lighter colored variety come from ponds and lakes all over the area of distribution of this species. To these collectors commonly give the name of *Campeloma decisum* Say. But the less ventricose whorls, elongated peristome, dark olive color, longer spire and heavier texture will serve to differentiate them from Say's form.

The form described by DeKay as *Campeloma integrum* has a less wide distribution than either of the forms previously mentioned. Rare specimens have been found in western Connecticut and Massachusetts. In New York, particularly in the Erie Canal, it is very abundant and large. Thence it ranges westwards to middle Ohio where it assumes such widely diversified characters that a variety name has been established for it. In southern Michigan and western Indiana this species occurs in considerable abundance but nothing like those in which it is found in the New York localities. It has not been reported south of the Ohio river nor south of Pennsylvania. The specimens which have been reported from west of the Mississippi river belong either to Anthony's species or to the variety mentioned below. The limits of distribution of DeKay's form then will be from western New England to Indiana and Michigan and, so far as we now know, mostly in streams of the Lake drainage.

Campeloma integrum obesum Lewis, belongs only to the region west of the Appalachians and north of the Ohio river. It came originally from Columbus, Ohio, where it abounds. Specimens have been taken in considerable numbers in Kent county, Michigan. In the Rouge river, Grand river and Reed's Lake, in Michigan the species abounds. West of the Mississippi river it has occurred only in one locality, near Iowa City, Iowa, where it exists in very large numbers in a small stream. About Columbus, Ohio, the species appears to be very prolific. Dr. James Lewis, who described this shell, originally based his work on the male shell. Later the female form, with young shells in the ovisacs, fell into his hands ; the great numbers of young coupled with the much more ventricose form of the body whorl caused him to erect a new species which he called *Campeloma fecunda.* The identity of the two is now established beyond question. It may not be uninteresting, in this connection, to say that *Campeloma exilis* Anthony and *Campeloma milesii* Lea are both species which are based upon the male of *Campeloma subsolidum* Anthony; the males of all the known species are very much smaller, in every corresponding dimension, than are the females.

The form described as *Campeloma rufum* Haldeman has a fairly wide range over the northern United States from Taunton, Massachusetts, and Waterbury, Connecticut, to Rum river, in Minnesota. It is common and abundant in New York, Ohio, Michigan, Indiana, and in northeastern Illinois. It has been seen from west of the Mississippi river only in the State of Minnesota, from a locality near Anoka. From streams which flow into the Tennessee river in east Tennessee, notably in the Hiawassee river and Tellico creek, come specimens which are referred to this species. In all the large number of examples which have passed in review the characters are remarkably constant. The highly polished epidermis, pink apical whorls and usually ruddy interior distinguish it readily from its congeners. Examples of other forms, with this name frequently come to us; but they are often examples colored with iron oxide. The epidermis of very young examples is somewhat hirsute while striæ parallel to the sutures occur on all typical examples. The southernmost locality from which examples have come to us is Huntsville, Alabama.

A nearly related form comes from the southern States all the way from South Carolina to Florida and west to Alabama. This is the *Campeloma limum* Anthony. The northernmost locality is the Santee Canal and the southernmost Wekiva river, Florida. From Montevallo, Alabama, and Talledaga creek in the eastern portion of the same State come the westernmost representatives of this very beautiful shell. Its distribution is quite restricted and it may, perhaps prove to be but a highly marked aberrant form of *Campeloma rufum*. At present, however, the facts do not warrant their union.

The largest species of this genus is *Campeloma ponderosum* Say. Originally described from the Ohio it has now been recorded from nearly all its greater tributaries. It is not a form which occurs in small streams and has never been reported from lakes or ponds unless they were in connection with some great river, and in such relation as to receive the overflow. The form ranges from western New York, in streams tributary to the Ohio, to the Mississippi; southwards, along the west slope of the Alleghanies, it extends to the headwaters of the Coosa river, the Oostanaula and Etowah rivers. In the Alabama, which is but the continuation of the Coosa, and in the Tennessee rivers it is very common and very large. At Bridgeport, in the latter stream are found gigantic specimens which are excelled only, in size, by specimens from the Cumberland at and about Nashville. In the greater tributaries of all these streams it occurs but, as in the region north of the Ohio, it does not exist in the smaller streams. West of the Mississippi the species has not yet occurred.

Over all the western States from Arkansas south to Texas and east to central Alabama ranges a form to which Mr. Lea gave the name of *Campeloma coarctatum.* In the White and Saline and St. Francis rivers in Arkansas as far as Caddo Lake and the Rio Brazos in Texas this shell is very abundant. Eastwards it occurs in numerous streams in Mississippi and south Alabama. The northernmost locality in the latter State is at Helena where it is exceedingly numerous in Buck creek. It appears to be most nearly related to *Campeloma subsolidum* being related to it somewhat as *Campeloma limum* is to *Campeloma rufum.* In northern Arkansas it is replaced by the typical western form, *Campeloma subsolidum* Anthony.

The genus *Lioplax* has but two representatives and these occupy not only entirely distinct areas but do not occupy the same drainage systems. The form of widest distribution is *Lioplax subcarinata* Say. The range of this species is from the Ohio river southwards to and including the Tennessee river; westwards to Missouri and central Iowa; northwards the range is limited to Minnesota in which State, at Ft. Snelling, in the Minnesota river, it occurs abundantly. In Illinois and Indiana it occurs somewhat numerously in certain of the larger streams. The only Kentucky habitat is the Licking river so far as present information goes. These localities are all west of the Appalachians. East of that system it has been reported only from New Jersey in which State it was originally found. With this exception it is limited to the north central States.

Its only other congener, *Lioplax cyclostomatiformis* Lea, is readily distinguished by its greater irregularity of outline, its rounded whorls and its characteristic orange colored aperture. It has occurred only in streams of the Gulf drainage. Under its proper name and the synonymic names of *Lioplax spillmanii* Lea and *Lioplax elliottii* Lea it ranges from east Mississippi in the Tombigbee river to Othcalooga creek in Georgia. In the Alabama, Cahaba, Coosa and Flint rivers it is very abundant. Its habit in the Cahaba and Coosa rivers, where we collected it in very large numbers, is very interesting and peculiar. It was found buried in the mud under large, flat rocks, from under a single one of which it was sometimes possible to take 300 or more examples! It occurred rarely in the Black Warrior at Tuscaloosa. Unlike the northern shell many specimens were obtained in certain small creeks but always under conditions similar to those which obtained in the Cahaba.

Tulotoma magnifica Conrad will include all the forms described by Dr. Isaac Lea except the single one hereinafter mentioned. It is confined to a single stream in Alabama and has been obtained in but two or three localities in that river. From Wetumpka, Alabama, to a point just below Claiborne constitutes the extreme range of the genus and its two species. At Wetumpka it was found in wonderful abundance attached to the under surface of flat rocks in the most swiftly flowing portions of the river just above the government works. Its discovery was quite an accident and several days had been spent in its search when a fall revealed its whereabouts.

The second species of the genus *Tulotoma coosænsis* Lea is found only at Wetumpka and in similar situations. The very young and perfect shells are ornamented with minute hairs arranged in regular lines. The whorls are always much more convex than those of the associated form and the aperture is never angulated. All the other names are synonyms of these two; they chiefly apply to Conrad's form.

The widest distribution of the genus *Vivipara* is seen in the form *Vivipara contectoides* W. G. Binney. This occurs all over the Mississippi valley from Iowa to southern Missouri and eastwards to central Ohio. Southwards it extends to Mississippi, Alabama, Georgia and Florida, being abundant in all these States. East of the Appalachians its northernmost range is in South Carolina. But in central New York is a large area over which it has become distributed owing to certain favoring conditions. Dr. James Lewis colonized a number received from Illinois in the Erie Canal and from these have arisen a most wonderful number of descendants. The Erie Canal from Utica to Troy is alive with them; many have escaped into the Mohawk river and have there found a congenial home. Aside from this rapidly disseminating colony, however, no forms occur naturally east of the Appalachians in the northern States. In the southeastern States other forms have been based upon this species and these under the names of *Vivipara waltoni* Tryon and *Vivipara georgiana* Lea have been considered in stating the limits of this form. The southernmost locality west of the Mississippi river is Fourche Creek, Pulaski county, near Little Rock.

Vivipara intertexta Say does not occur outside of the Mississippi valley except in certain portions of Louisiana. It was originally described from near New Orleans whence it ranges northwards to White Bear Lake and Winona, Minnesota. In eastern Iowa and portions of Illinois and western Indiana it is an abundant shell in ponds and bayous being rarely found in the more swiftly flowing rivers.

The most restricted species of the genus is *Vivipara troostiana* Lea described from Tennessee. The original locality was unknown to Lea who described it as having been received from Dr. Troost. I found it abundantly in a small stream at Murfreesboro and think it possible that this was the original locality. It has been found at no other place so far as we know and is still the rarest Viviparid in all our collections.

The form known as *Vivipara subpurpurea* Say is found over all the Mississippi valley from Caddo Lake, Texas, to Ft. Snelling, Minnesota; thence it ranges eastward into western Indiana. In the Mississippi river at Davenport and in the St. Francis river, at Wittsburg, Arkansas, it attains the maximum of numbers. It has somewhat the habit, at Davenport, of *Tulotoma* being very common under large flat rocks in the Moline rapids. In the more southern localities it is, like most of its congeners, a mud-loving form.

The facts connected with the hypsometric or vertical distribution of the *Viviparidæ* are relatively few in number and may be briefly recited. Of the localities from which we have seen specimens or of which we have any authentic record most of them lie between 100 and 700 feet altitude. The species which has greatest vertical range is *Campeloma decisum* which is reported from Hiram, Ohio, at an elevation 1260 feet. Many localities ranging from 500 to 800 feet altitude have been noted; but this one gives the greatest vertical range observed up to the present time. This genus has the greatest geographic range and it is not surprising that it should also furnish examples of extreme hypsometric distribution. From this altitude it extends downwards to sea-level or with 10 feet of it at Stonington, Ct., and several localities in New Jersey.

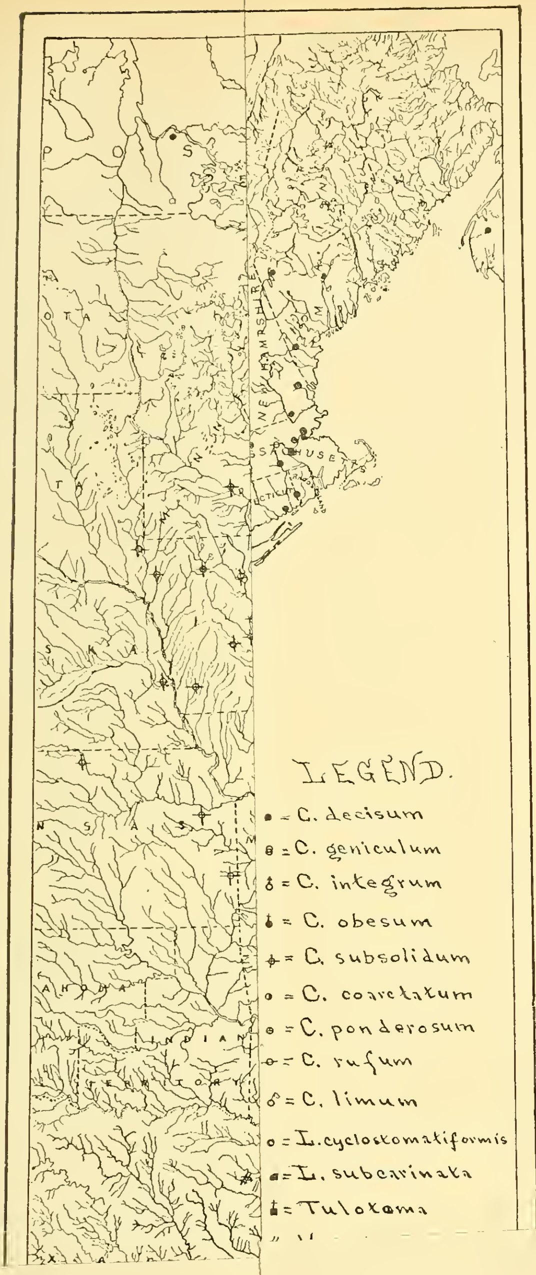
Campeloma subsolidum has the next highest distribution, specimens having been taken from the Des Moines river, Iowa, at Fort Dodge, at an elevation of 1100 feet. *Campeloma coarctatum* ranges to 890 feet, reported from Sedalia, Missouri. It ranges downwards to within 20 feet of sea-level as near the city of Natchez, Mississippi. *Campeloma rufum* has been reported from only one locality which reaches 1000 feet altitude, namely at Akron, Ohio. The same fact is true for *Campeloma ponderosum* which has its greatest vertical range at the same place. *Campeloma integer* has never been taken at an elevation greater than 735 feet, which locality is the St. Joseph river, at South Bend, Indiana. *Campeloma decisum geniculum* has been found at Athens, Georgia, at an elevation of 705 feet. Probably this form will be found to range considerably higher since we have many examples from streams in northern Georgia whose elevations are near that of Athens or even greater but there is no means of determining the exact height.

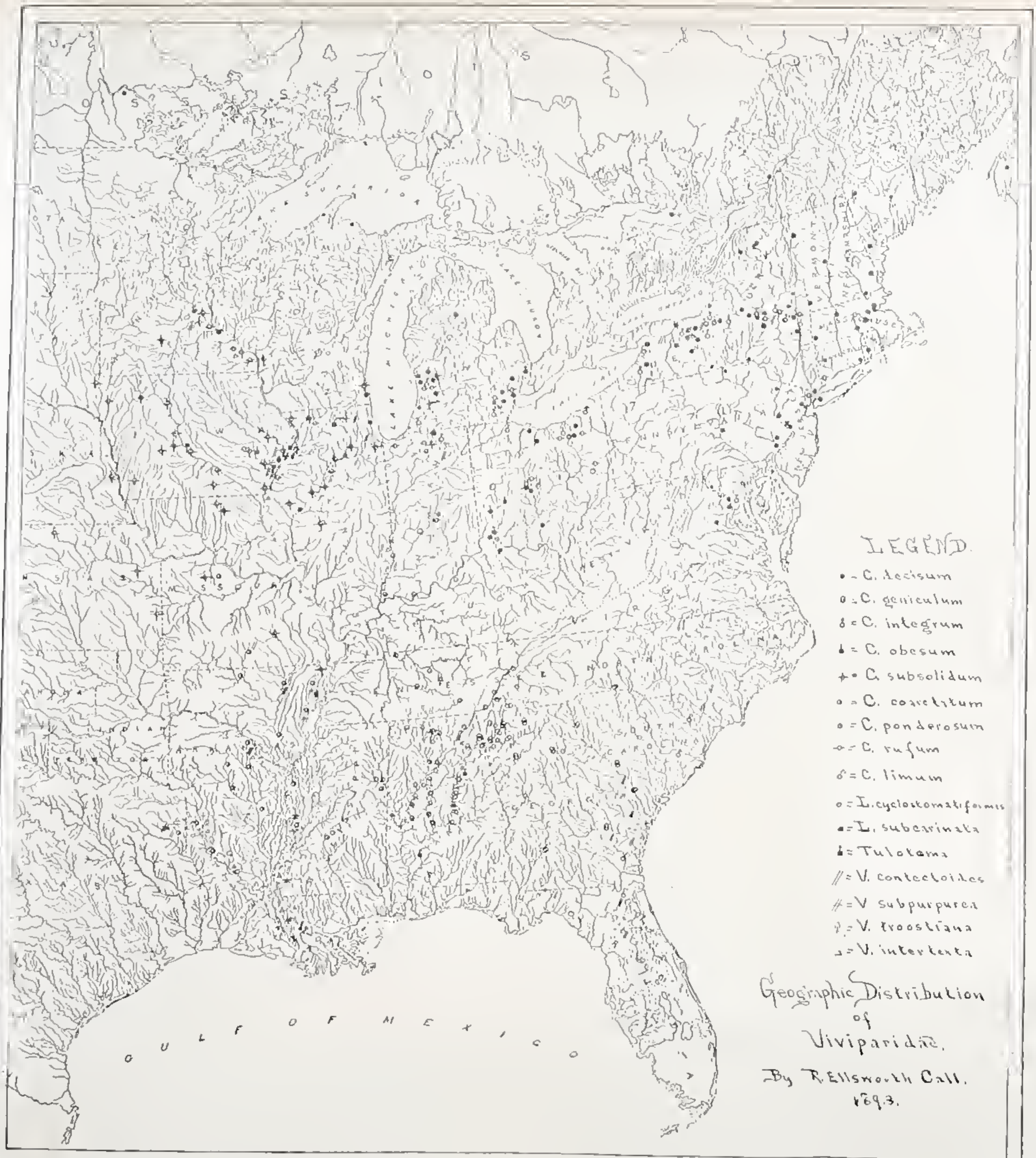
Summing up all the facts gleaned in comparing the elevations of the various localities from which the species of *Campeloma* have been sent to us the general statement may be ventured that the vertical range is constantly below 1300 feet. Furthermore, at the highest limit of range the species appear to be somewhat depauperate and in other ways show the influence of environmental factors of an unfavorable nature. The several species of *Campeloma* find expression in greatest numbers at from 150 feet to 600 feet elevation. Above that limit they are less numerous in individuals. This last range, then, may be safely regarded as the limit of range of optimum stations.

Of the genus *Tulotoma* little need be said. Occurring in only one stream, the Coosa river and its continuation the Alabama, the range of course is determined by its distribution in that stream. Claiborne, the southernmost limit, is about 16 feet elevation; Wetumpka, the northernmost range, is 185 feet elevation. Within these hypsometric limits, therefore, this genus and its two species are confined.

The genus *Vivipara* comes down to within 5 feet of the sea-level in Florida and Louisiana. From this point it ranges vertically to 1150 feet, in a sluggish stream near Eminence, Missouri, tributary to Jack's Fork, in the Ozark mountains, where it abounds. But one species, *Vivipara contectoides*, is found at this extreme elevation. Thence the range is down to 5 feet above sea-level near New Orleans, Louisiana. Like *Campeloma* the genus *Vivipara* has an optimum hypsometric range which falls between 50 and 500 feet. Of the 4 species which we have recognized *Vivipara contectoides* has the greatest vertical distribution. The form known as *Vivipara subpurpurea* comes next with a maximum vertical range of 722 feet, at which elevation it occurs in the Minnesota river, at Fort Snelling, Minnesota. It is practically impossible to make any comparisons between this shell and *Vivipara intertexta* which also has a similar range; the latter form, however, does not come so nearly down to sea-level.

The genus *Lioplax* has an extreme vertical distribution of about 722 feet which is the altitude of Fort Snelling, Minnesota, where it occurs abundantly. At the Jefferson Coal Mines, on the Warrior river, in Jefferson county, Alabama, abundant specimens of the genus, represented by *Lioplax cyclostomatiformis*, have been taken. The altitude of this


LEGEND.
= C. decisum
= C. geniculum
= C. integrum
= C. obesum
= C. subsolidum
= C. coarctatum
= C. ponderosum
= C. rufum
= C. limum
= L. cyclostomatiformis
= L. subcarinata
= Tulotoma
NEW HAMPSHIRE
MASSACHUSETTS
INDIAN TERRITORY



LEGEND.
• = C. decisum
= C. geniculum
= C. integrum
= C. obesum
= C. subsolidum
= C. coarctatum
= C. ponderosum
= C. rufum
= C. limum
= L. cyclostomatiformis
= L. subcarinata
= Tulotoma
// = V. contectoides
= V. subpurpurea
= V. troostiana
= V. intertexta
GULF OF MEXICO
Geographic Distribution of Viviparidae.
By R. Ellsworth Call.
1893.

Chas. D. Walcott.

locality is 507 feet. Wetumpka, Alabama, at 185 feet, and Columbus, Mississippi, at 208 feet, represent the localities which are nearest sea-level. The form found here is the same as that of the Warrior river. The other form of *Lioplax*,—*L. subcarinata*—has a much greater range being found at Fort Snelling, in the Minnesota river, at an elevation of 722 feet, and in the Raritan river, New Jersey where it occurs in a station some 12 feet above tide water.

The accompanying map is designed to present at a glance the chief facts now known in the distribution of these forms. Its drainage features are based upon those of the United States Geological Survey Contour Map. In but a few cases have the mnemonics been employed on the face of the map. Their introduction in greater numbers would have obscured the facts sought to be illustrated in the distribution. Extreme localities for each form herein mentioned have been given and by an inspection of these and mentally connecting them the areas of individual distribution for the several species will be approximately shown.

Louisville, Ky., 18th Dec., 1893.

ART. XVIII.—*Mineralogical Notes;* by S. L. PENFIELD and D. A. KREIDER.

1. *On the Identity of Hydrofranklinite and Chalcophanite.*

THE name hydrofranklinite was given by W. T. Rœpper* to a supposed new hydrous oxide of iron, zinc and manganese, from Sterling Hill, near Ogdensburg, N. J. The mineral is described as crystallizing in small, brilliant, iron black octahedrons, with octahedral cleavage. The original chemical examination was never completed, and it seemed therefore desirable to investigate the mineral, an excellent suite of specimens in the Brush collection, which had been collected by Professor Brush at the locality in 1875, being available. The mineral occurs as a coating of minute crystals, the largest not over 1^{mm} in greatest diameter, deposited upon a manganese ore, which is possibly of the same composition as the crystals but not distinctly crystallized. As it was found to be practically impossible to separate the pure crystals by hand picking, the method suggested by Retgers,† of separating minerals of high specific gravity by means of fused thallium-silver nitrate, was resorted to, but a satisfactory separation could not be effected by this means as much of the gangue was of about the same

* Appendix III, 5th ed. Dana's Min., p. 61. Dana's Min., 6th ed., p. 259.
† Jahrb. f. Min., 1893, I, p. 90.

specific gravity as the crystals. It was noticed, however, in washing the pulverized mineral, that the crystals had a decided tendency to float, owing probably to the smooth surfaces that they possess, combined with the fact that water does not seem to wet them. By covering the powdered mineral with a shallow layer of water in a large beaker, and inclining the latter so that a wave or ripple passes over the powder, the crystals are readily brought to the surface, and by a little manipulation almost a continuous layer of them can be made to float on the water. By repeating this operation a number of times, and making fractional separations, a product was finally obtained which, when examined with a lens, showed only brilliant crystalline particles, and which could readily be made to float wholly upon a limited surface of water. The mineral was then further separated by means of the thallium-silver nitrate fusion and, excluding the heavier and lighter portions, a product of intermediate specific gravity was reserved for the chemical analysis. The specific gravity of this material, taken with the pycnometer, was found to be 4·012. Rœpper gives 4·06–4·09 and Moore 3·907 for chalcophanite.

The mineral when finely pulverized yielded a powder of a dark chocolate-brown color. A qualitative analysis showed the presence of iron, zinc, manganese and water. In the closed tube water is given off at a very low temperature, and on stronger ignition oxygen gas is liberated. The mineral is readily soluble in hydrochloric acid with evolution of chlorine. The results of the analysis are as follows:

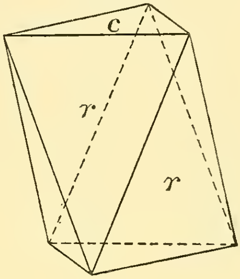
		Ratio.			Theory where Fe : Zn = 8 : 13
FeO	10·00	·139	·364	1·07	9·53
ZnO	18·25	·225			17·52
MnO	48·27	·680		2·00	49·33
O	11·21	·701		2·06	11·11
H_2O	11·85	·658		1·94	12·51
Insoluble	·25				
	99·83				100·00

The ratio of (Fe+Zn)O : MnO : O : H_2O equals nearly 1 : 2 : 2 : 2, indicating that the composition of the mineral can be expressed by the formula RO, $2MnO_2$, $2H_2O$, or RMn_2O_5, $2H_2O$, where R=Fe and Zn in the proportion of about 8 : 13. The above formula is identical with that derived by Moore* for chalcophanite, except that in the material analyzed by him iron was practically wanting and R=Zn and Mn. The agreement between our analysis and the theory is quite satisfactory. The water is a little low, but the material may have suffered a slight alteration as it loses its water very readily, some going

* Amer. Chemist, vi, p. 1, 1875.

off at 100° C. and nearly all of it by heating the fine powder for two hours at 200° C. The water is therefore water of crystallization and the mineral is undoubtedly to be regarded as a hydrated salt of the acid $H_2Mn_2O_5$. The acid in question is analogous to di-silicic acid, H_2SiO_5, a normal salt of which is represented by petatite, $LiAl(SiO_5)_2$. From a more careful examination of the crystals of the mineral it has been found that they are not isometric as stated by Rœpper, but exhibit a combination of rhombohedron and base as shown in figure 1, and yield a perfect basal cleavage. In reality the crystals look much more like octahedrons than would be inferred from the figure, since the faces are vicinal and the rhombohedral planes curve and flatten somewhat as they approach the base. No satisfactory measurements could be made, the angle $c \wedge r$, $0001 \wedge 10\bar{1}1$, varying several degrees, but averaging near that given by Moore for chalcophanite. The crystals described by him were scales and rarely plates, showing the combination of *c* and *r*.

Fig. 1.



We take pleasure in expressing to Prof. B. W. Frazier of South Bethlehem, Pa., our thanks for the loan of a specimen from the collection of Lehigh University which was labeled hydrofranklinite in Professor Rœpper's own handwriting and which was in every respect similar to the material analyzed by us.

2. *On the Separation of Minerals of High Specific Gravity by means of the fused Double Nitrate of Silver and Thallium.*

Mineralogists and petrographers are certainly indebted to Dr. J. W. Retgers for the fortunate discovery* that the nitrates of silver and thallium, when brought together in the molecular proportion of 1 : 1, yield a double salt, which fuses at 75° C. to a clear, mobile liquid, having a specific gravity of about 5 and miscible with water in all proportions at temperatures between its melting point and 100° C. The melting point also diminishes rapidly as water is added, going down to 50° or 60° C., and fusion and solubility pass uninterruptedly into one another. We have thus at our command for the separation of mineral particles a liquid far exceeding in specific gravity any of the previously described heavy solutions, and which has the advantage of being practically colorless, neutral, soluble in water and of being readily recovered from the aqueous solution by simple evaporation on the water bath. As suggested by Retgers, separations may be made in test tubes heated in a

* Loc. cit.

water bath. After a separation is completed and the fusion cooled, the test tube is broken and the solid cake divided, when the heavier and lighter portions may be obtained by dissolving the double salt. There are some disadvantages, however, in working with test tubes, especially as it is always convenient and frequently quite necessary to secure fractional separations or to draw off the heavy material from the bottom for examination, and with a test tube this cannot be accomplished without interrupting the whole experiment and clearing the material. As the ordinary glass stop-cock separating funnels are not well adapted for use with a fused salt at a temperature of near 100° C. an apparatus has been devised, which is illustrated by fig. 2 in one-fourth its natural size. The glass rod is ground into the tube with fine emery and serves as a stop cock. This apparatus slips inside of a test tube, and a rubber band is so adjusted around the top of it that the lower end of the tube comes to within a few millimeters of the bottom of the test tube. The tubes are most conveniently heated in a beaker of hot water and can be held in a vertical position by a simple rack or test-tube stand made of metal. The contents of the tube are conveniently agitated by means of a plunger made from a glass rod bent at one end as in fig. 3. Before drawing off the heavy material from the bottom it is best to place a loosely fitting perforated cork in the end of the separating tube, through which the rod passes and is supported so that the rod can be raised straight up and dropped back into place without fear of breaking the tube. Difficulty sometimes arises at this point from particles getting caught in the stopper, so that after the heavy portion has been drawn off the rod will no longer close the tube. If the particles are small and not too hard they may be ground out by twisting the rod, or if this cannot be done the fusion must be allowed to run out and the apparatus cleaned. But even in this latter case, there is a decided advantage in saving of time over the use of a test tube, as a separation has been accomplished, and the mineral powder and apparatus can soon be made ready for another treatment with a fresh portion of the fused salt. The stop-cocks need to be carefully ground in order to make them perfectly tight, as they are subjected to a considerable pressure from the column of heavy liquid, but a slight leakage is not especially objectionable as the few drops that leak out are caught in the outer test tube.

Fig. 2.

Fig. 3.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, April, 1894.

Art. XIX.—*Carboniferous Fossils in the Norfolk County Basin;* by J. B. Woodworth.

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

In 1880, Messrs. Crosby and Barton published in this Journal* an account of the discovery by them of traces of fossil plants in the rocks of the Norfolk County basin in Massachusetts at a place near the present station of Pondville on the Walpole & Wrentham R. R. It was the opinion of the authors that these plants, together with the physical connection of the rocks of this basin with those about Attleborough, Mass., in the northern part of the Narragansett basin, were evidence of the Carboniferous age of the series of strata studied by them.

Subsequently, the vegetable nature of the fossils was called in question in an unpublished statement by an observer who had visited the locality and had examined the hollow casts described by the original discoverers. In April, 1892, the present writer under the guidance of Mr. Barton, to whom belongs the credit of the discovery, visited the locality, and from a small opening similar to the numerous larger holes which were appealed to in 1880 as evidence of fossil plants, abstracted the solid cast of a longitudinally, coarsely striated stem, probably but not certainly identifiable with a species of sigillaria or calamites. Between the cast of the interior and the matrix of sandstone was a limonitic and cellular layer apparently representing the cortical part of the plant, too poorly preserved for identification. In many of the holes originally described by Messrs. Crosby and Barton, the same ferruginous and cellular layer was seen. These plant remains occur in sandy beds or partings in a simple, quartzose conglomerate, which outcrops in nearly vertical strata along two lines on either side of a synclinal axis.

In greenish slates, lying above the conglomerate bed, were found cylindrical, vermiform casts, of small size, apparently the underground rootlets of plants. In none of these specimens, however, are afforded characters which enable one to discriminate them from plant remains which occur elsewhere in rocks of Devonian age,† the period to which the red beds of this basin were referred by Prof. Edward Hitchcock.

* Extension of the Carboniferous formation in Massachusetts, 3d ser., vol. xx, pp. 416–420.

† See Sir William Dawson, *The Geological History of Plants.*

In the summer of 1892, in the course of a rapid reconnaissance made in the Norfolk County basin, the writer found a second locality of fossils in the railroad cut about one-half mile north of Canton Junction station on the Old Colony R. R., and 15 miles south of Boston, a brief announcement of which was made in the 14th Annual Report of the Director. This section was examined by Mr. W. W. Dodge as early as 1875, and probable fossils were seen by him which he described, in *Notes on the Geology of Eastern Massachusetts*,"* as "dark, cylindrical forms which appear to be branching stems of some kind." I am indebted to Mr. Dodge for the privilege of seeing the specimens in his collection. They are unidentifiable stem-like bodies. Under the microscope in thin section, the dark ring which forms the cross-section of the body proves to be chlorite enclosing an axis of the same constitution as the matrix. The chlorite is evidently a metamorphic product. A similar chloritic coating is found on the impressions of calamites from this locality. Since the evidence from this locality confirms the conclusion reached by the geologists before mentioned as to the Carboniferous age of, at least, a portion of the rocks in this basin, the following account of the Canton Junction section is here given. For a more extended statement of the relation of these beds to those of the Narragansett Basin, the reader is referred to a forthcoming report on the Carboniferous rocks of this district by Prof. N. S. Shaler.

Granitite.—The cut just north of the station at Canton Junction is in the hornblendic granitite which forms the floor of the Carboniferous along the southern border of the Norfolk County basin. Two narrow dikes of diabase cut the granitite, with their contacts following nearly vertical sets of joints.

Carboniferous, gray series.—About 2500 feet north of the granitite exposure is a small outcrop of greenish and grayish slates, originally fine muds with interlaminated sandy layers. The strike is about N. 60° E., and the dip 65° to 70° south; the cleavage dips north about 70°.

The fine, shaly partings between the sandy layers carry flattened plant stems, adhering to the under surface of the bedding. Compressed stems of *Calamites* occur about one inch wide and finely striated. They are ill preserved, but one form suggests *C. cistii* Brgt., which, according to Lesquereux, occurs in the Narragansett basin. *Sigillaria* is also found in the same bed.

Northward, about 135 feet of beds are covered with drift, when there appears the following section, also fossiliferous:

* Proc. Boston Soc. Nat. Hist., vol. xvii, 1875, p. 414.

1. Sandstone	12	feet.
2. Shale (slaty)	10	"
3. Sandstone	6	"
4. Quartzose conglomerate	18	"
5. Sandstone	10	"
6. Shales (slaty)	6	"
7. Sandstone	20	"
8. Shales (slaty)	2	"
9. Sandstone and shale (slaty)	75	"

The measurements are based on pacing, but are sufficiently accurate to exhibit the stratigraphic characters of the section, the dip and strike of which agree closely with that of the first outcrop. Flattened plant stems occur in the shales of bed No. 6 and again in No. 9. The plants are calamites and the stems of ferns, but no fronds of the latter have been found.

Carboniferous, red series.—For about 3800 feet north of the above described section, there are no outcrops along the line of the railroad. At this distance from the gray rocks, is a cut in reddish strata having the typical lithological characters of most of the rocks in the Norfolk County basin and the lower portion of the Carboniferous in Attleborough, Mass. The strata dip steeply to the south or are in places nearly vertical. The section from south to north apparently in descending order is as follows:

1. Fine quartzite conglomerate, with quartz veins	25	feet.
2. Red sandstone and slate	15	"
3. Fine quartzite conglomerate, with quartz veins	20	"
4. Red and gray sandstone	30	"
5. Red sandstone	50	"
6. Fine quartzite conglomerate and sandstone	10	"
7. Red slate	6	"
8. Limestone, a lens, highly cleaved	(1·5)	"
9. Red sandstone and slate	10	"
10. Red slate	15	"
11. Dike, diabase?	(1·5)	"
12. Calcareous white and red slates	2	"
13. Red slates	10	"
14. Calcareous slates	4	"
15. Red slates	30	"
16. Red sandstone, with veins of quartz and calcite	5	"
17. Red slates	20	"
18. Covered beds	100	"
19. Red slates	50	"

These measurements, like those in the preceding sections are based on pacing, the succession being made out on the west side of the railway track. This section was also measured by Mr. Dodge,* who evidently mistook the dip of the cleavage for that of the stratification planes, in making the beds dip 45° N. No fossils have been found in this section, and, except certain small pitted impressions and fine straight furrows seen in demi-relief on the underside of some red beds, no markings were seen on their surfaces. The calcareous portion of the section differs from the calcareous red shales of the Cambrian in Attleborough and Wrentham in the apparent absence of fossils, a characteristic of the limestone bands in the Carboniferous at Attleborough. In part, the carbonate of lime is of vein origin like the lenticular quartz bodies which occur in the same section.

It has been assumed that these red rocks in the eastern portion of the Norfolk County basin are of Carboniferous date. The same presumption has proved only partially true in the southwestern part of the basin between Wrentham and Attleboro, where a section of red calcareous and sandy strata of lower Cambrian age occupies a narrow belt in the midst of the red Carboniferous.† For this reason, and owing to the absence of fossils in what appears to be the lower portion of the section at Canton Junction, it seems unwise at the present stage of our knowledge to hold on mere lithological evidence all of the red beds in this field to be of Carboniferous age.

Northward of the last outcrop about half a mile, gray rocks recur on the east of the railroad with nearly vertical dip.

In addition to the occurrences above mentioned, fossils were also found in the glacial drift at the following localities:

1. In Canton, about one and a half miles south of the border of the basin: *Calamites cistii* (?) in a sandstone pebble.

2. In East Walpole, on the south side of Traphole brook, near the western end of the Neponset swamp, small bowlders carry calamites and plant stems.

In both these instances, the drift of the fossiliferous pebbles was from the north and from a distance not exceeding three miles, the limit of known Carboniferous in that direction.

The occurrence of, at least, three dikes in the Canton junction section is interesting as setting aside the sharp distinction which has been thought to exist between the Norfolk County basin and that of Boston north of the Blue Hills. The scarcity of exposures in the former basin is one of the reasons for the apparent difference in this regard.

Cambridge, Mass., May 28th, 1894.

* Op. cit., p. 413

† N. S. Shaler: On the Geology of the Cambrian district of Bristol County, Mass. Bull. Mus. Comp. Zool., xvi, 1888, pp. 13–41.

ART. XX.—*On the Determination of Ferrous Iron in Silicates;* by J. H. PRATT.

THE determination of ferrous iron in silicates made by dissolving them in a mixture of hydrofluoric and sulphuric acids and titrating with potassium permanganate is one of the well recognized methods of analytical chemistry. The apparatus described by Prof. J. P. Cooke,* by means of which the solution can be made in an atmosphere of steam and carbon dioxide, is well adapted for preventing any oxidation by the air but the necessary appliances are not always at hand. Prof. S. L. Penfield has suggested to the author a simpler means for accomplishing the same purpose, namely to displace the air by carbon dioxide led directly into the crucible by means of a platinum tube, and at his request a series of experiments has been made to determine the accuracy of the method.

The arrangement of the apparatus is similar to that devised by H. Rose† for igniting precipitates in hydrogen. The solution can be accomplished by boiling in a crucible directly over a small flame and after cooling the contents are transferred to a beaker or caserole and titrated. With a 50^{cc} crucible one-third full, the boiling may be continued for ten minutes with safety, but if too much of the water and hydrofluoric acid are evaporated the resulting hot concentrated sulphuric acid will act as an oxidizing agent. The solution may also be made on a water bath, but experiments with black tourmaline which is a very difficult mineral to dissolve, have shown that nearly as much was dissolved by boiling for ten minutes over a flame as by heating quietly for two hours on the water bath.

For testing the method, weighed quantities of ferrous sulphate were used. In the first series of experiments dilute sulphuric acid was taken as a solvent, and the results indicate that the heating may be continued for a considerable time without fear of oxidation.

Time.	Method of heating.	FeO taken.	FeO found.	Error.
30 minutes	water bath	·0786	·0782	·0004 —
3½ hours	water bath	·0711	·0709	·0002 —
30 minutes	water bath	·0785	·0785	·0000
1 hour	water bath	·0978	·0979	·0001 +
15 minutes	water bath	·1012	·1014	·0002 +
10 minutes	flame	·0810	·0808	·0002 —
10 minutes	flame	·0835	·0836	·0001 +

* This Journal, II, xliv, 347.

† Handbuch der Anal. Chem., 1871, p. 77. Also Fresenius' Quantitative Analysis, American edition by O. D. Allen, p. 251.

In the second series, a mixture of hydrofluoric and sulphuric acids was taken, such as would be used in dissolving silicates. The results indicate that when hydrofluoric acid is present and the heating long continued, there is a slight oxidation. It is evident, however, from the results of the last five experiments that very accurate determinations of ferrous iron can be made by this method.

Time.	Method of heating.	FeO taken.	FeO found.	Error.
4 hours	water bath	·1214	·1202	·0012—
3 hours	water bath	·1054	·1047	·0007—
1 hour	water bath	·0866	·0862	·0004—
3 hours	water bath	·0459	·0458	·0001—
7 minutes	flame	·1527	·1525	·0002—
10 minutes	flame	·0445	·0445	·0000
8 minutes	flame	·0345	·0345	·0000
8 minutes	flame	·0421	·0424	·0003+
8 minutes	flame	·0472	·0479	·0007+

Fairly accurate determinations may also be made without the use of carbon dioxide, the contents of the crucible being cooled as quickly as possible after boiling, and titrated as usual. This is the method commonly employed for determining ferrous iron in silicates. To test the extent of the oxidation the following series of experiments was made, using a mixture of hydrofluoric and sulphuric acids as a solvent.

Time.	Method of heating.	FeO taken.	FeO found.	Error.
10 minutes	flame	·0843	·0825	·0018—
10 minutes	flame	·0594	·0578	·0016—
10 minutes	flame	·0739	·0728	·0011—

It is evident from these results that the errors are somewhat greater than in the cases where CO_2 was used.

In experiments with very refractory minerals, where only a portion is dissolved by the acids, the insoluble mineral can be filtered off after titration, and the filtrate evaporated in a platinum dish until all the hydrofluoric acid is expelled. After dissolving the residual sulphates, the iron is reduced by hydrogen sulphide, the excess of the latter removed by boiling and the total iron determined by titration. By these two determinations, the ratio of the ferrous to ferric iron is established, and as the total iron can be determined in a separate portion fused with sodium carbonate, the percentages of ferrous and ferric iron can be readily calculated.

In making these experiments it has been found best to use water that has been previously boiled to expel air and subsequently cooled. As an additional precaution the carbon dioxide was generated from cleavage pieces of calcite which were freed as far as possible from air by boiling in water for some time and transferring them while still wet to the generator. The gas was washed with a dilute solution of sodium carbonate. With very refractory minerals the strongest hydrofluoric acid that is available, mixed with about one-fifth its volume of concentrated sulphuric acid, should be used, in most cases, however, dilute acids are sufficient and much more convenient. Occasionally there is a tendency for the mineral to settle on the bottom of the crucible and cause bumping, but this can usually be prevented by addition of some coils of platinum wire.

In conclusion, the author takes pleasure in expressing to Professor Penfield his thanks for valuable advice and assistance.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, April, 1894.

ART. XXI.—*The Action of Reducing Agents on Iodic Acid;* by CHARLOTTE F. ROBERTS.

[Contributions from the Kent Chemical Laboratory of Yale College—XXXI.]

I. *The Absorption of Nitric Oxide by Iodic Acid.*

THE following investigations were first undertaken with the object of studying the solubility of nitric oxide in iodic acid. Although most chemical authorities agree in the statement that nitric oxide is absorbed by iodic acid with the separation of iodine, there is a certain indefiniteness with regard to the *degree* of solubility, which led me to investigate the subject for myself. Thus, Gmelin-Kraut states that "All the lower oxides of nitrogen decompose iodic acid into iodine and nitric acid, but the decomposition takes place only in presence of a considerable quantity of water," but the *degree of ease* with which the decomposition takes place meets with no comment, and the "considerable quantity of water" seems a somewhat indefinite condition. Kämmerer,* who is the authority referred to for the above facts, and who, some years ago, made a thorough study of iodic acid, says, without referring to any illustrative experiments, "At ordinary temperature, I_2O_5 is reduced only in aqueous solution by nitric oxide, but this gas is without action upon the water-free acid and its solution in concentrated sulphuric acid. At 100° the latter is very slowly, the water-free acid not at all decomposed."

A portion of this latter statement was very easily verified. Some nitric oxide was passed through the dry acid, and other

* Jour. für prak. Chem., lxxxiii, 73.

portions were collected and allowed to stand over sulphuric acid solutions of HIO_3 and I_2O_5, without any appreciable separation of iodine.

In order to test the solubility of the gas in *aqueous* solutions of iodic acid, the nitric oxide was prepared in a generator containing potassium nitrate and ferrous sulphate, the air having been previously driven from the apparatus by means of carbon dioxide. The gas was next passed into a Will and Varrentrapp tube containing potassium iodide, and then into a Geissler bulb containing the iodic acid. The experiment was made several times with iodic acid of various degrees of concentration, and always with the same result. There was no evidence of iodine being set free from the iodic acid, though the liquid showed occasionally a barely perceptible tinge of yellow. There was, however, a smaller amount of nitric oxide collected, by two or three cubic centimeters than should have resulted from the amount of nitrate used, and on two or three occasions, an odor like that of chlorine was observed about the Geissler bulb, when the apparatus was disconnected, which could only be explained on the supposition that gaseous hydrochloric acid was carried over from the generator through the potassium iodide.

A later experiment in which nitric oxide was collected in a tube containing iodic acid and hydrochloric acid so dilute that no reaction took place between the two acids in the cold, showed that under these circumstances the nitric oxide was absorbed without any separation of iodine and that the liquid became yellow and gave odor like that of chlorine, so that the above seemed a plausible explanation of the disappearance of some nitric oxide in the Geissler bulb without a simultaneous liberation of iodine.

Two or three experiments were then made with the apparatus as before but with the addition of a new absorption tube containing silver nitrate to prevent the hydrochloric acid from going over into the iodic acid. Still there was no evidence of iodine being set free. It seemed apparent then, that the nitric oxide was not sufficiently soluble in iodic acid so that it could be absorbed by simply passing it rapidly through the solution.

To determine whether the gas was soluble upon long contact with the iodic acid or not, different portions were collected in U tubes closed at one end and filled with solutions of iodic acid of different degrees of concentration. The gas had been collected and allowed to stand over potassium iodide and sodium hydroxide for from twenty-four to forty-eight hours before being transferred to the U tube, in order to remove completely any other oxide of nitrogen which might be present. Solutions of iodic acid were used in the different U tubes varying from a saturated solution containing about 50 grams to 25 cubic centimeters to a rather dilute solution containing not more than 5 grams to 25 cubic centimeters. There was no apparent absorption as the gas passed up through the liquid, but after the nitric oxide had been standing over the iodic acid for a few moments, iodine appeared on the surface of the liquid. This deposit gradually increased in amount and the liquid rose in the tube, reaching its maximum in 24 hours or less, depending on the amount of gas used.

The result of my experiments, then, has been to show that nitric oxide is absorbed by solutions of iodic acid of any degree of strength, but the reaction takes place slowly even when the gas is confined over the acid, and not at all when passed rapidly through the solution.

II. *The Action of Reducing Agents on Iodic Acid in presence of Hydrochloric Acid.*

It has already been stated that when the nitric oxide was collected over iodic acid mixed with dilute hydrochloric acid, the gas was absorbed, but there was no liberation of iodine, and in some cases an odor like that of chlorine was observed when the tube was opened. A similar phenomenon was noticed with several other reducing agents. It is well known that iodic acid with *strong* hydrochloric acid, or *heated* with dilute hydrochloric acid, forms iodine chloride and may set free chlorine, but in these experiments the dilute acids were used in the cold, and there was no change apparent until the reducing agent was added. Besides the nitric oxide, other substances which had a similar effect were potassium iodide, sodium thiosulphate, arsenious oxide, ferrous sulphate, stannous chloride, and potassium sulphocyanide. If the reducing agent was added in a very concentrated form, iodine was sometimes evolved, and in many cases traces of iodine would first form where the reagent touched the liquid, but would disappear on shaking, and a light yellow liquid would result with an odor like that of chlorine.

The first explanation of this phenomenon that suggested itself was that the iodic acid was not immediately completely deoxidized by the reducing agent but was first transformed to a lower oxide of iodine* which was more active and therefore more easily acted upon by hydrochloric acid than the iodic acid itself, and that the chlorine thus set free united wholly or partially with the iodine formed by the first reduction. It was with the object of studying the reduction of iodic acid in the presence of hydrochloric acid that some experiments were

* Gmelin-Kraut, Anorganische Chemie, I, 2, 290–292.

undertaken with potassium iodide, iodic acid, and dilute hydrochloric acid. Potassium iodide was chosen as the reducing agent on account of the simplicity of its oxidation products. Approximately $\frac{N}{10}$ solutions of iodic acid and potassium iodide were used and dilute hydrochloric acid of specific gravity 1·05. The latter acid was so dilute that it could be added in apparently indefinite quantities to the iodic acid without producing any perceptible odor or change of color.

With 10^{cc} of iodic acid and half that volume of hydrochloric acid, if the potassium iodide was added gradually from a burette, the addition of 4 or 5 cubic centimeters gave a clear, light yellow liquid in which no free iodine could be proved either by starch or chloroform. As the amount of potassium iodide increases, the liquid gradually becomes orange until finally particles of iodine are precipitated out and accumulate until they reach the quantitative yield represented by the common equation:

$$5KI + HIO_3 + 5HCl = 3H_2O + 5KCl + 3I_2$$

These phenomena seem to indicate that the reaction takes place in two steps, giving first the iodine chloride, and then the decomposition of this by means of more potassium iodide setting free iodine. Even after solid particles of iodine appear in the liquid, starch paste is not colored blue, showing the well-known disturbing action of the chloride of iodine. That the intermediate product is essentially the *monochloride* of iodine instead of the *trichloride* may be inferred from the superior stability of the former in dilute solutions containing hydrochloric acid, since most authorities agree that the trichloride is completely broken up in dilute solutions into the monochloride, iodic acid and hydrochloric acid. If any trichloride were first formed and underwent this decomposition, the final form of the reaction would be the same as if the monochloride were the sole product. This inference was further confirmed by later results and by the following experiment.

The clear yellow liquid obtained by putting together 10 cubic centimeters of iodic acid, half that volume of hydrochloric acid, and 4 cubic centimeters of potassium iodide was agitated with benzene which is said to dissolve iodine trichloride with a dark cherry-red color.* The result was a barely perceptible pinkish tinge to the benzene, which left no appreciable residue on evaporation. After separating the benzene and adding ether, the color was quickly taken from the aqueous solution, and the ether became yellow and, on evaporation, left a considerable quantity of a volatile reddish-brown liquid. This

* Ladenburg, Handwörterbuch, v, 359.

experiment showed plainly that the essential product was iodine monochloride.

In three different ways I have tried to estimate the proportions in which iodic acid and potassium iodide unite in presence of an excess of the former and hydrochloric acid. The direct method of letting potassium iodide of known strength slowly into a mixture of the two acids and determining the first appearance of free iodine is difficult on account of the action of the iodine chloride on the blue iodide of starch which one would naturally use as an indicator. I have succeeded, however, in getting an approximate result, by taking out a drop of the liquid from time to time and testing on starch paper. With 5 cubic centimeters of iodic acid, 9·5 cubic centimeters of potassium iodide were added before there was any effect on the starch paper. This would indicate molecular proportions of iodic acid to potassium iodide as 1 : 1·9.

In the second method, 20 cubic centimeters of iodic acid, 10 of hydrochloric acid, and 4 of potassium iodide were put together, the resulting iodine chloride was extracted with ether and separated with a separating funnel. The aqueous solution containing free hydrochloric acid was then treated with an excess of potassium iodide and the amount of iodine set free determined, after neutralization, by alkaline arsenious acid. From this the iodic acid remaining in the solution after the extraction of the iodine chloride could be readily estimated, and the difference between this and the amount taken gave the amount used in the reaction. Three trials of this experiment gave the following results for the molecular proportions in which the iodic acid and potassium iodide unite in presence of hydrochloric acid while the iodic acid is in excess:

HIO_3 : KI	
1 : 2·06	Average = 1 : 1·98
1 : 1·99	
1 : 1·9	

The third method consisted in putting together the reagents in the same proportions as above and then decomposing the iodine chloride with acid potassium carbonate and estimating the iodine set free by alkaline arsenious acid. According to Gay-Lussac, the reaction between iodine chloride and an alkali is represented thus:

$$6KOH + 5ICl = 5KCl + KIO_3 + 3H_2O + 2I_2$$

The iodine shown by the arsenious acid is then only $\frac{4}{5}$ of that in the iodine chloride. Making this correction and knowing the amount of iodine in the potassium iodide used, it becomes an easy matter to determine the iodic acid which has contributed to the formation of the iodine chloride.

The following results were obtained:

$$\left.\begin{array}{rcl} HIO_3 & : & KI \\ 1 & : & 1{\cdot}92 \\ 1 & : & 2{\cdot}02 \end{array}\right\} \text{Average} = 1 : 1{\cdot}97$$

The three methods, then, agree fairly well in indicating two molecules of potassium iodide to one of iodic acid, a reaction which would be expressed by the following equation:

$$HIO_3 + 2KI + 5HCl = 3H_2O + 2KCl + 3ICl$$

The formation of iodine monochloride has thus been proved by three methods, two of which would be sufficient to establish the reaction. The first two methods are independent of the reaction between iodine monochloride and carbonated alkalies, while the third depends directly upon that reaction. Assuming the correctness of Gay-Lussac's equation, this third method may be taken simply as an additional way of proving what has been already sufficiently established in two different ways. On the other hand, considering the formation of iodine chloride sufficiently established by the two other methods, the last set of experiments may be used to discriminate between Gay-Lussac's and Grüneberg's reaction. The latter* states, without describing his work in detail, that he has found by many carefully repeated experiments that the action of alkaline carbonates on iodine monochloride gives potassium chloride and potassium chlorate, and *all* of the iodine is set free. My results, however, show the correctness of Gay-Lussac's equation, since it is only on the assumption that *four-fifths* of the iodine is set free that my third method of work gives results corresponding with those obtained in two other ways. Moreover, some iodine chloride was prepared by putting together potassium iodide, and an excess of iodic and hydrochloric acids, and extracting with ether, specially purified by standing over sodium bisulphite and distilling from sodium hydroxide. Portions of this ethereal solution were drawn off from a burette and treated with potassium iodide, and the iodine estimated by sodium thiosulphate. Similar portions were then treated with hydrogen potassium carbonate, and the iodine estimated by arsenious acid. Grüneberg's reaction would demand that one-half as much iodine should be set free in the latter case as in the former, instead of which only four-fifths of that amount was found, which is in direct agreement with Gay-Lussac's equation.

* Jour. für prakt. Chemie, lx, 172.

III. *Action of Iodine on Iodic acid in presence of Hydrochloric acid.*

Some light is thrown upon the reaction just established by the behavior of free iodine in a mixture of iodic and hydrochloric acids.

Although a solution of iodine in iodic acid turns starch blue, and also one of iodine in hydrochloric acid, if the solutions be mixed, the starch immediately loses its color, but regains it on the addition of alkaline carbonate. Also, if a colorless mixture of iodic and hydrochloric acids be taken, and aqueous iodine added gradually from a burette, the first effect of the addition is to make a colorless liquid in which the presence of iodine can be proved only upon addition of an alkaline carbonate. Further addition of the iodine gives a yellow liquid whose properties and reactions seem identical with that obtained by putting together iodic and hydrochloric acids and potassium iodide. This same liquid may be produced by allowing iodine to dissolve slowly in the cold in a mixture of dilute hydrochloric and iodic acids.

Apparently, then, the action of reducing agents is to set free iodine from the iodic acid, and this dissolves in a mixture of iodic and hydrochloric acids to form iodine chloride. Two experiments were made to determine the proportions in which the iodine and iodic acid unite in this reaction. Solid iodine, in carefully weighed quantity, was allowed to dissolve in a mixture of the acids, then the acid was neutralized with alkaline carbonate, and the iodine set free estimated by means of arsenious acid. The molecular proportions of iodic acid to iodine as found were as follows:

HIO_3	:	I
1	:	4·02
1	:	4·07

The same proportions were obtained by direct titration of iodic acid against a solution of iodine in hydrochloric acid of known strength. The operation was performed in a flask, a definite quantity of iodic acid being first introduced and then the solution of iodine added from a burette until, upon shaking the flask, the presence of free iodine was indicated by the characteristic color given to chloroform.

The molecular proportions found were:

HIO_3	:	I
1	:	4·02
1	:	4·06

These results, it will be seen, are in complete accordance with those obtained by the former method and indicate the following reaction:

$$HIO_3 + 2I_2 + 5HCl = 3H_2O + 5ICl$$

The equation obtained above for the reaction between iodic acid, potassium iodide, and hydrochloric acid, viz:

$$HIO_3 + 2KI + 5HCl = 3H_2O + 2KCl + 3ICl,$$

can be derived directly by a combination of the ordinary equation, in which iodine is set free,

$$[5KI + HIO_3 + 5HCl = 3H_2O + 5KCl + 3I_2]2,$$

with the equation just established,

$$[HIO_3 + 2I_2 + 5HCl = 3H_2O + 5ICl]3,$$

in which the iodine reacts upon iodic acid. This fact supports the assumption that the effect of a reducing agent upon an excess of iodic acid in presence of hydrochloric acid is to set free iodine which then dissolves in a mixture of the two acids to form iodine monochloride.

Iodine has apparently no effect upon either acid taken singly, and there is nothing in these experiments to show whether the action of the iodine on the iodic acid in the mixture of the two acids is in the first instance of an oxidizing or reducing nature. It may be that the iodic acid is first reduced to a lower oxide, as has been previously suggested, or that it is oxidized to periodic acid. The first condition is expressed in equations I, and the latter in equations II, from which it is seen that either assumption agrees with the equations just established.

$$\text{I.}\ \left\{\begin{array}{l} 2HIO_3 + I_2 + 2HCl = I_4O_4 + 2H_2O + 2ICl \\ I_2O_4 + 3I_2 + 8HCl = 4H_2O + 8ICl \\ \text{Combined: } 2HIO_3 + 4I_2 + 10HCl = 10ICl + 6H_2O \end{array}\right\}$$

$$\text{II.}\ \left\{\begin{array}{l} 2HIO_3 + 2H_2O + 2I_2 = 4HI + H_2O + I_2O_7 \\ I_2O_7 + 4HI + 10HCl = 7H_2O + 6ICl + 2Cl_2 \\ \quad 2Cl_2 + 2I_2 = 4ICl \\ \text{Combined: } 2HIO_3 + 4I_2 + 10HCl = 10ICl + 6H_2O \end{array}\right\}$$

In any case it is evident that the mixture of iodine and iodic acid, both ordinarily oxidizing agents, is able to effect the decomposition of hydrochloric acid with the formation of iodine monochloride.

ART. XXII.—*The Stratigraphic Position of the Thomson* Slates;* by J. E. SPURR.†

Location and Extent of the Series.

THE Thomson slates (St. Louis slates, Cloquet slates) are schistose or slaty rocks which occupy an extensive area in Eastern Minnesota. They afford continuous exposures along the St. Louis River, not far from Duluth, near Thomson, Carlton and Cloquet. Here they were first noted and described. They are in this region well cleaved, but possess evident and little-altered sedimentary characters. Further west they are found along and beyond the Mississippi River, in the vicinity of Little Falls. Here they have become schistose; they are often micaceous, staurolitic, hornblendic, or garnetiferous. Frequent outcrops have been found, demonstrating the continuity of the series between the St. Louis and the Mississippi. In a north and south line, the belt has already been shown, by the explorations of C. W. Hall, Merriam, Upham, and others, to extend, roughly speaking, from near the lower part of Mille Lacs to near the northern boundaries of Aitkin and Carlton counties. The writer has been able to trace these rocks as far north as T. 51–19, where an exposure is found which will be referred to later. This prolongs the known extent toward the north by 10 or 15 miles. The dimensions of the belt are thus about 100 miles east and west by 50 north and south, making an area of not far from 5000 square miles.

For the lithological variations from the simple cleaved slates, found within this area, we may quote from Irving:‡

"They include, among the slates, fine-grained graywacke-slates, clay-slates, sericitic quartz-slates, true quartzites, mica-slates (often hornblendic), staurolitic mica-slates (often garnetiferous), and hornblende schists; and among the eruptives, diabases, gabbros, and diorites, the latter presumably altered forms of diabase or gabbro."

Relations of the Thomson Series to the surrounding Rocks.

On three sides, south, east, and west, the general boundaries of the Thomson rocks are known. To the south and west lie

*To this series the name *St. Louis* has been applied by Irving, Sweet, Van Hise, and others. Inasmuch as this name, however, is already well established for a formation of quite different age, it has been thought best, in accordance with a suggestion of Professor H. S. Williams, to designate the Minnesota series in some other way. The term *Thomson*, therefore, which has already been used by Professor N. H. Winchell, has been adopted.

† Published by permission of the State Geologist of Minnesota.

‡ Fifth Annual Report U. S. Geol. Survey, p. 197.

areas of granite which have been referred to the Laurentian; and various post-Animikie (post-Huronian) sediments, as far up as the Cretaceous. To the east lie the Keweenawan rocks, chiefly igneous. To the north, however, the Thompson series is hid beneath a great thickness of drift which occupies a broad belt of country through which run the St. Louis and Mississippi rivers. Between the southern border of this drift mantle and the nearest known outcrops on the north (those of the Animikie of the Mesabi Range) the distance is about 40 miles.

Sketch of previous Correlations.

The Thomson rocks have been correlated, up to the present time, with the Animikie (the Upper Huronian). It is the object of this paper to suggest that there are no firm grounds for this correlation, and that they be referred rather to the Keewatin* (Lower Huronian). It will be advisable to inquire first into the reasons for which they have hitherto been assigned their place.

Irving† and Sweet‡ assigned these rocks to the Huronian in 1880. The reasons were mainly lithological. The Thomson (St. Louis) rocks presented the characters of an undoubted and little metamorphosed clastic series, especially in that part which alone was definitely known, i. e. the outcrops along the St. Louis River about Thomson. At that time there were recognized but three general horizons to which this series could be referred,—the Keweenawan, the Huronian, and the Laurentian. The Thomson (St. Louis) rocks were seen to underlie the Keweenawan, and to be cut by dikes of supposed Keweenawan age; and no rock of recognizable clastic characters could be referred to the Laurentian.

In the third annual report of the United States Geological Survey,§ Irving first hinted at the correlation of the "St. Louis slates" with the Animikie of northeastern Minnesota, as observed at that time around Gunflint Lake and Thunder Bay. He pointed out the general lithological resemblance between the two series, and noted the difference in that the "St. Louis slates" are cleaved. In the same report, however,‖ he suggested the correlation of the uncleaved Animikie slates with

* The terms Animikie and Keewatin are to be understood here in the sense in which they are employed by the Minnesota Survey; they are provincial designations, both of formations and of divisions of geological time, which correspond in general to the more comprehensive terms (Upper and Lower Huronian) used by the United States Survey.

† Geology of Wisconsin, III, p. 18.

‡ Op. cit., p. 339.

§ Copper-Bearing Rocks of Lake Superior, p. 162.

‖ Op. cit., p. 170.

the folded schists lying further north, and his descriptions and accompanying diagram clearly show that he included among these schists the larger part, if not the whole, of what we now know as Keewatin (Lower Huronian). In the fifth annual report* he first *confidently* assigned to the Thomson (St. Louis) series a place equivalent to that of the Animikie. A few pages later on,† however, he states that he hesitates to accept the idea of "a general unconformity between the flat-lying Animikie and an older series, including the gneiss and folded schists,"‡ but considers that, as suggested in the third annual report, there is a transition between the two, and that the schists are but the folded northward continuation of the Animikie. In the seventh annual report,§ he again refers to the St. Louis slates as Animikie; and here first hints as to what horizon of the Huronian they were believed by him to belong, i. e. the same as that of the upper slates of the Animikie series as represented upon the Mesabi Range.

If the writer understands correctly what has been done, the results may be briefly summed up as follows:

Irving, Sweet, N. H. Winchell,‖ and Hunt¶ assigned the Thomson (St. Louis) series to the Huronian, because of their undoubted detrital nature. No attempt was made at first to give them a definite horizon in this formation. Afterwards, however, Irving was led to conclude, from an examination of the Animikie rocks around Thunder Bay and Gunflint Lake and westward, that the upper slate member of the Animikie series of the Mesabi Range was the same as the slates along the St. Louis.

Subsequent writers have adopted this correlation, but no new arguments of value have been offered, either pro or con. Van Hise** has mentioned, as a circumstance tending to show their Upper Huronian (Animikie) age, the occurrence of ferruginous beds "in the northward extension of the St. Louis slates." No ores, however, have been found in the St. Louis slates; and if by the quoted phrase the ores of the Mesabi Range were meant, the occurrence of iron in the Animikie can have no bearing upon the correlation between the Ani-

* Archæan Formations of the Northwestern States, p. 196.

† Op. cit., p. 206.

‡ That is, an unconformity at the base of the Animikie; the Huronian unconformity as now understood. Irving recognized perfectly well an unconformity between the Huronian in general and the Laurentian, or fundamental complex of granites and gneisses.

§ Classification of Cambrian Formations, p. 422.

‖ Tenth Ann. Rep. Minnesota Geol. and Nat. Hist. Survey, p. 95; Eleventh Ann. Rep., pp. 169 and 170.

¶ Trans. Roy. Soc. Canada, vol. i, Sec. iv, 1883, p. 250.

** Tenth Ann. Rep. U. S. Geol. Survey, p. 461; Bulletin U. S. Geol. Survey, No. 86. Correlation papers, Archæan and Algonkian, p. 186.

mikie and the St. Louis series. The correlation, therefore, has rested entirely upon very broad lithological resemblances.

During the summer of 1893, the writer made an examination of the Western Mesabi region and south to the St. Louis slates, and came to suspect that there were no valid reasons for correlating the St. Louis series with the flat-lying Animikie of the Mesabi district. On the other hand, the evidence seemed rather in favor of correlation with the underlying schistose and slaty rocks, referred to the Keewatin in the same district.*

The Animikie Slates upon the Western Mesabi.

The slates which constitute the uppermost recognized member of the Animikie upon the Western Mesabi are usually soft, black, and carbonaceous; they dip gently southward to southeastward, and disappear beneath the heavy covering of drift. These rocks have been almost unaffected by altering dynamic forces since their deposition. There is no sharp crumpling, no cleavage or strongly-marked jointing; and very few fissure or gash-veins.

The Keewatin of the Western Mesabi.

The slates, with the lower members of the Animikie (the iron-bearing member and the quartzite), are in abrupt unconformity with the underlying rocks. Ordinarily, the underlying rock appears to be the granite of the Giant's Range, which has been supposed to be Laurentian; but in places a narrow belt of schists appears between the granite and the Animikie, and in T. 58–17 probable faulting has brought up a triangular area of schists 6 or 8 miles in its north and south extent. The appearance of this area and the attendant phenomena establishes two important facts: first, that the rocks on which the Animikie here rests are mainly schistose and slaty, instead of gneissic and granitic; and second, that the granite is intrusive into these cleaved rocks, and therefore cannot be regarded as Laurentian. The schists have been generally recognized as Keewatin.

The triangular upthrust area, which the writer has called the Virginia area,† has one side against the granite belt. Near the contact it is made up of mainly holocrystalline mica and horn-

* Professor N. H. Winchell was at one time in the field with the writer; and came to substantially the same conclusions. It should be stated, moreover, that Professor Winchell had for some time previous been skeptical as to the Animikie age of the Thomson series, and had even mapped a small part of the area as Keewatin, in a preliminary unpublished map exhibited at the World's Fair in 1893.

† Bulletin No. 10, Minn. Geol. and Nat. Hist. Survey, p. 17.

blende schists; but on going away from the granite area these are seen to have resulted from the metamorphic influence of the granite, for the rock soon changes into the common "green schist." This is a rock of which the original characters can be suspected, but ordinarily not readily determined. It is characterized by the development of sericite and kindred minerals along the schistosity planes. This green schist type occupies the central part of the area. In the southern part, however, near the apex of the triangle, the evidence of metamorphism decreases rapidly, and the rocks become mainly easily recognizable as detrital. Here are found what appear to be only slightly altered siliceous and clay-slates, and graywackes. In hand-specimen these Keewatin detritals often can hardly be distinguished from specimens of the overlying Animikie slates.

The Keewatin rocks possess a strongly-marked regional cleavage or schistosity, not far from vertical in hade, and nearly constant in trend,—averaging about N. 70° E. This is also nearly the direction of both the northern and southern contacts of the granite belt; and, in a general way, of the predominant rock-structure of a large part of the gneissic and schistose terranes lying further north, in northeastern Minnesota and Canada.* In short, it indicates the direction of movement of a regional disturbance which has affected a great area. This structure is still more pronounced in some of the country north of the Mesabi Range, and here granitic invasions and accompanying metamorphic action have also been more common; so that it seems that the seat of greatest disturbance lay north, rather than south of the Mesabi. This disturbance took place prior to Animikie time, for the Animikie rocks are unaffected by it.

The Animikie slates which overlie the Keewatin to the south, in T. 57–17, disappear beneath the drift within a few miles and are thence not traceable southward. On the east, their southward continuation is also hid by the overlying Keweenawan rocks, and on the west by the Cretaceous.

Physical characters of the Thomson Slates at Cloquet.

On passing south across the swamp-covered area, the first rocks which appear above the thinning mantle of drift are those of the Thomson series. The physical characters of the rock, as it appears typically on the St Louis River at Cloquet, near the place where it was first recognized, may be briefly described.

* Consult A. C. Lawson, Report on Geology of the Lake of the Woods Region, p. 21 et seq., Annual Report of the Geol and Nat. Hist. Survey of Canada, 1885.

The rock is in most places of evident sedimentary origin. It varies from a fine-grained slate, black, gray, or dark-green in color, to a siliceous slate or graywacke. Often small pebbles of detrital material, especially of quartz, may be found. The sedimentary structure is usually indicated by no parallel parting, but by the alternation of coarser and finer layers. An observation of these alternations shows that there is no constant dip and strike, but that the rocks have been much folded and crumpled. There are, however, persistent and continuous systems of cleavage. There are two principal sets of cleavage planes, one running from N. 80° E. to E. and W., and the second cutting the first at an angle of about 45°. The first cleavage is best developed, and gives the appearance of stratification to the formation. Where it is most strongly marked, there results a very perfect division of the rock into thin sheets; where both are well developed, the rock is cut up into fine rhombohedral blocks. In some of the coarser rocks, such as the graywacke, the structure is rather schistose than slaty. It is to be noted that neither of the cleavages corresponds to the bedding, or has any constant relation to it.

In places, where the rocks are cut by basic dikes, a third cleavage has been induced, extending for a few yards on either side of the dike, and running strictly parallel to its walls. This third cleavage cuts the other two, and near the dike almost obliterates them. The predominant cleavage or schistose structure, which runs a little north of east, has been very commonly described as stratification by previous writers. The minor parting, however, has been very generally recognized as a cleavage. Throughout the rock there are numerous irregular veins, chiefly of quartz.

This series was traced by the writer as far north as T. 51–19, near the St. Louis River. Here several specimens were taken from an outcrop (about N.W. $\frac{1}{4}$ S.W. $\frac{1}{4}$, Sec. 27). One phase is a dark green siliceous slate or quartzite; another is a fine-grained slate; a third is a silvery sericitic schist or slate. In the two last-named rocks what appears to be the original stratification may generally be distinguished; and in the specimens taken this structure runs nearly at right angles with the cleavage. It is not so plain, however, as ten miles further south. There was found at this place only one cleavage or schistosity (for in different zones it appeared as each) in the rock. This corresponded in general with the main cleavage at Cloquet, with a steep hade, and a trend between N. 60° E. and N. 80° E.

Grounds for Correlation.

We may now suggest grounds for correlating the Thomson series with the Keewatin of the Mesabi Range rather than with the Animikie of that district.

1. *Lithological.*—Since the basis on which the Thomson slates have been correlated with the Animikie was purely lithological, we will first present the same argument for correlation with the Keewatin; and it appears that the grounds for the latter are much stronger.

The slates as seen about Cloquet resemble very closely the slates of the southern part of the Virginia area. Almost every phase of the Cloquet rocks can be duplicated in this Keewatin district. They differ only in that the St. Louis rocks are traversed by a minor transverse cleavage. But the resemblance of the northern part of the known St. Louis rocks, those in T. 51–19, described above, to those of the Virginia area is complete. Here not only the little altered detrital phases are duplicated, but to a certain extent some of the less altered schistose rocks, such as the sericitic slate already described. Moreover, all the specimens have the peculiar greenish tint which is usual in the Keewatin rocks (the "green schists") and is a distinctive mark as compared with the dead black of the unaltered carbonaceous Animikie slates.

In the region further west, especially in the vicinity of the Mississippi River, the Thomson series becomes in part crystalline, having changed into sericitic, micaceous, hornblendic, staurolitic, or garnetiferous schists. These phases, which occupy a considerable portion of the series, correspond exactly to the "green schists" and crystalline schists of the Keewatin in the Mesabi district.

2. *Dynamical.*—One of the greatest differences between the least altered Keewatin rock of the Virginia area and the Animikie slates in the vicinity is the presence of the steeply dipping regional cleavage, which has an average trend of about N. 70° E. This, as has already been noted, marks a distinctively pre-Animikie disturbance. In the Cloquet rocks there is a strongly developed cleavage, nearly constant, running a little north of east (averaging perhaps N. 85° E.) and so having approximately the same trend as that of the Mesabi district. In T. 51–19, ten miles further north, the same strong cleavage, with nearly the same direction, was found, and the transverse cleavage which is seen at Cloquet was not observed. From here to the first rock exposures, upon the Mesabi Range, the distance is about 40 miles; and here, as before observed, there is no sign of disturbance in the Animikie rocks, but the Keewatin exhibits the same cleavage, as well as the same lithological peculiarities.

It may be allowed to suspect, then, that the cleavage of the Thomson series was developed at the same time and by the same forces as that of the Mesabi Range and as the corresponding structures which are found further north, in Minnesota and Canada. If this be the case, the Thomson series must be put below the unconformity exhibited upon the Mesabi, and provisionally correlated with the Keewatin. The secondary cleavage shown in the Thomson slates, as at Cloquet, may for the present be supposed to be more local, and to have had its cause near by,—perhaps connected with the advent of some of the larger masses of igneous Keweenawan rock, as we have noted that the rare third cleavage accompanied the introduction of the narrow dikes.

We must also take into account the considerable folding which the Thomson series has undergone, as distinguished from the undisturbed condition of the Animikie. In this respect also it resembles more the Keewatin. The occurrence in the Thomson slates of many veins of quartz and the generally indurated appearance of the rocks accords with the appearance of Mesabi Keewatin, and suggests that the beds have been deeply buried.

The Animikie-Keweenawan Unconformity.

If it shall be finally considered that this suggested correlation is correct, we shall appear to have in this region Keewatin strata directly overlaid by the Keweenawan rocks which are exposed in great quantities a little further east. If we believe in the original extension of the Animikie sediments over the whole Lake Superior basin, it will follow from this correlation that the erosion interval between the Animikie and the Keweenawan was very great.

Minneapolis, May 3, 1894.

Art. XXIII.—*The Generation of Chlorine for Laboratory Purposes;* by F. A. Gooch and D. Albert Kreider.

[Contributions from the Kent Chemical Laboratory of Yale College—XXXIII.]

That chlorine may be generated in a state of greater or less purity, variable with the conditions of evolution, by the action of hydrochloric acid upon potassium chlorate has been shown by Pebal* and Schacherl,† but the application of this fact to the practical generation of chlorine for the purposes of the

* Ann. der Chem., clxxvii, 1. † Ibid., clxxxii, 197.

laboratory has not to our knowledge been proposed. The desirability of an automatic generator from which an abundant flow of chlorine gas may be drawn at will or shut off without danger or inconvenience has led us to a study of the conditions most favorable to the safe evolution of chlorine by the action of the chlorate.

Pebal* showed that the gas evolved at ordinary temperatures from a mixture of potassium chlorate and sodium chloride acted upon by sulphuric acid diluted with twice its volume of water consists of chlorine and chlorine dioxide in nearly equal proportions. Schacherl† found that when potassium chlorate was acted upon by hydrochloric acid diluted with twice its own volume of water the yield of chlorine was about 46 per cent or 57 per cent of the mixed gases according as the chlorate was granular or in fine powder; that hydrochloric acid of half-strength yielded a gas containing nearly 60 per cent of chlorine, and that the proportion of chlorine rose nearly to 68 per cent when the gas was passed through concentrated hydrochloric acid and then washed with water; that the chlorate when acted upon by the strongest hydrochloric acid cooled to 0° C. and then warmed only enough to start the action yielded a gas carrying 87 per cent of chlorine; and that when a solution of potassium chlorate was permitted to flow into hot strong hydrochloric acid the free chlorine constituted nearly 75 per cent of the mixture. So it appears that the highest yield of chlorine resulted when the solution of the chlorate entered gradually the hot strong acid—a condition not easily attained in an automatic generator.

The fact that chlorine dioxide is so easily decomposed by heat into chlorine and oxygen naturally suggests the possibility of increasing the proportion of chlorine evolved in the first instance by working at the highest temperatures practically attainable under the conditions. In order, however, to secure a temperature approaching the boiling point of water it is necessary to reduce somewhat the strength of the hydrochloric acid acting (in order to avoid the evolution of hydrochloric acid gas and the consequent interference with the regular automatic action of the generator), thus sacrificing the advantage naturally attending the use of acid of the highest degree of concentration. Upon experiment we find that acid of half-strength (sp. gr. 1·10) can be made to yield a very satisfactory proportion of chlorine. We have employed in our work potassium chlorate fused (best in platinum) and cast in sticks or broken into coarse lumps. A small Kipp's apparatus, holding about a half-liter of liquid in the two lower chambers, makes a convenient generator, and the requisite temperature

* Loc. cit.

† Loc. cit.

may be secured by wrapping the two lower chambers with flexible metallic tubing through which steam is driven, or, with equal convenience, by simply standing the whole apparatus in heated water. When the simple precaution is taken to heat the acid to 60° or 70° C. before allowing it to come slowly into contact with the fused chlorate no difficulty whatever is met with in the practical automatic working of the generator; but if cold acid is permitted to act upon the chlorate it becomes charged more or less with the chlorine dioxide and a subsequent rise of temperature may cause dissociation of the explosive gas with sufficient suddenness to expel the liquid from the generator with considerable violence. The gas evolved directly from the generator is never pure chlorine. To determine the relative proportions of chlorine and chlorine dioxide (the sole products of the action according to Pebal) the gas as it issued from the generator was passed through two pipettes fitted with glass stopcocks and joined to one another. After allowing a reasonable time for the complete expulsion of air from the pipettes the stopcocks were closed, and the pipettes were disconnected from one another and from the generator. The gas contained in one of the pipettes was slowly forced by means of carbon dioxide through a solution of potassium iodide; that in the second pipette was driven slowly by means of carbon dioxide through a hard glass tube filled with asbestos and heated to redness by a Bunsen burner, and then passed through a solution of potassium iodide. The iodine set free in each case was determined in the acidified solution by standard sodium thiosulphate, and the difference in the amounts of iodine found was attributed to the action of the oxygen of the chlorine dioxide. It was assumed that the gas filling the pipettes ranged in line was homogeneously distributed, and this assumption is probably nearly enough true for the purpose of this discussion. The temperature of the acid in the generator was determined by inserting a thermometer in the lowest chamber of the generator, so that the indication for the point of action is only approximate.

In two experiments made with acid of half strength and at indicated temperatures of 80° and 81° the chlorine in the gas amounted to 81·6 per cent and 84 per cent respectively of the mixture. A comparison experiment made with the strongest acid heated to 50°—the highest temperature attainable without evolution of the hydrochloric acid gas—the yield of chlorine was 77·3 per cent. It is evident that the acid of half strength acting at 80° is productive of a more favorable yield than the strongest acid at 50°.

Temperatures very much higher than those employed can hardly be secured continually under the conditions of work, and yet it is plain that a considerable amount of the oxide still accompanied the chlorine. We made the attempt, therefore, to accomplish the destruction of the oxide by passing the mixed gases as they issued from the generator through a small wash-bottle containing a hot saturated solution of manganous chloride in strong hydrochloric acid, making use of a device previously employed in this laboratory for the decomposition of nitric acid and chloric acid.* The results of several experiments conducted in this manner are recorded in the accompanying statement. The gas after leaving the manganous chloride passed through a small wash-bottle filled with water, was dried by calcium chloride, and collected in the pipettes arranged in train, and analyzed by the method previously described.

Strength of hydrochloric acid.	Temperature of acid.	Temperature of the solution of $MnCl_2$.	Bubbles of gas passing the wash-bottle per second.	Per cent of chlorine.
Sp. gr. 1·1	83°	90°	5–6	87·5
" "	83	90	4–6	89·5
" "	70–80°	90	1–2	96·4
" "	87·5	90	3	98·6
" "	83	90	3	96·9

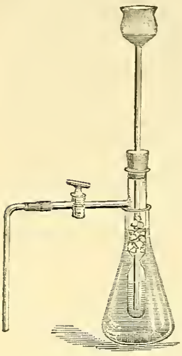
It is evident from these figures that the efficiency of the manganous chloride is considerable and naturally most manifest when the current of gas is slow. Indeed, during the passage of gas through the manganous salt small bubbles of chlorine are evolved from the entire surface of the liquid. The washed gas is pure enough for most laboratory purposes, but if chlorine perfectly free from chlorine oxide is desired it may be obtained by passing the washed gas through a hard glass tube filled with asbestos and heated by a Bunsen flame.

In the exceptional cases in which the ignition tube is used it is well to keep in mind the fact that in starting the generator the acid should not be thrown in too great quantity upon the chlorate at first lest an unusually large proportion of the dioxide be liberated, which may cause a slight explosion in the ignition tube. Should such be the case, however, the liquid in the wash-bottle will prevent the extension of the explosion to the gas in the generator proper, and the insertion of the wash-bottle should never be omitted when the ignition tube is to be put to use. So long as it is kept hot we have never found the apparatus other than perfectly manageable, safe, and automatic in action.

Inasmuch as a single gram of potassium chlorate produces approximately a half-liter of chlorine, and a cubic centimeter

* This Journal, xliv, 117; xlvi, 231.

more than a liter, it is obvious that a very compact generator may be capable of delivering a considerable supply of the gas, and we have found the diminutive apparatus shown in the accompanying figure an exceedingly convenient addition to the furnishings of the laboratory table when chlorine is needed frequently and in small amounts. This little generator is easily made of a side-neck test tube, funnel tube, stopper, glass stopcock, and flask. The upper chamber of the test tube, which is constricted near the middle, holds easily ten grams of the fused chlorate, and when the outer flask is filled with hot water the automatic action is satisfactory for a considerable length of time. A little wash-bottle containing a hot saturated solution of manganous chloride in strong hydrochloric acid is a desirable addition when a purer gas is needed



than that delivered directly from the generator, and the attachment of the ignition tube makes it possible to secure the chlorine entirely free from chlorine oxide, though carrying, of course, some free oxygen.

SCIENTIFIC INTELLIGENCE.

I. Geology and Mineralogy.

1. *Geologic Atlas of the United States, Livingston Folio, Montana* (folio No. 1), *U. S. Geol. Surv.*, J. W. Powell, Director. Washington, 1894, Ex. 2° 2 pp. text, 4 maps 1 pl.—Those who are interested in the progress of the work performed by the Geological Survey will be pleased to see this folio. Some small preliminary and experimental editions of similar sheets have been previously published, but this is the first folio issued in complete form and for the public. It marks in a certain way the beginning of the final results for which the Survey was organized. There are few, save those who have watched the progress of the organization from its inception, who realize the vast amount of careful and laborious work necessary to produce the present folio.

The area chosen for illustration upon the first sheet of the geologic and topographic atlas, has been well selected to display the high order of scientific work the survey is doing. It lies between 110° and 111° west and 45° and 46° north; and Livingston, situated on the Northern Pacific R. R. and the Yellowstone River, and within these boundaries, has given its name to the folio. The area therefore, lies immediately north of the Yellowstone National Park. The southeastern portion comprises an elevated block of mountains called the Snowies, chiefly of Archæan formation but cut by intrusions of igneous rocks and covered in part by enomerous extensions of lavas and tuffs. Around the western and northern slopes of this great mass winds the Yellowstone river in an open valley. The Paleozoic formations lie tilted up against its flanks, while the Mesozoic are partly upturned and partly occupy in more horizontal position the open valley of the Yellowstone. The western edge is defined by the slopes of the Gallatin Range, chiefly composed of igneous extrusive masses, and the Bridger Range of Archæan and Paleozoic upturned rocks. To the north the line passes through the southern flanks of the Crazy Mt. massive, Cretaceous ? strata injected with igneous masses of which only the singularly vast and intricate system of radiating dikes shows on the map.

Thus there is great variety both in topographic form and in the range of geological formations, affording an excellent opportunity for the display of the varied resources of the survey in geological work and map-making.

The folio contains first two pages of text explanatory of the geography, topography and geology both scientific and economic. Then follows a topographic map with the elevations given by contours and on a scale of four miles to the inch. These maps produced by the survey, often in conjunction with the States, have become tolerably familiar to the public of late years. When the amount of time and money available for their production is taken into consideration they are wonderfully accurate, while the mechanical execution is extremely perfect and beautiful. The triangulation and topography of the Livingston sheet are by Messrs. Renshawe, Douglas, Tweedy and Leffingwell, under the supervision of Mr. Gannett, chief topographer and Mr. Thompson, chief geographer in charge.

The geological maps in colors that follow are three in number, the first giving the areal geology on the topographic base, the second devoted to economic geology is similar but with the coal-bearing strata strongly accentuated, while the third on a flat base gives only the main geologic areas and is cut by sections giving the geological structure in detail.

These are followed by a plate giving the columnar section of the sedimentary formations accompanied by full notes and details.

The geological portion of the work has been under the charge of Arnold Hague, the geology in the field having been done by Messrs. J. P. Iddings and W. H. Weed. The names of these specialists are sufficient to indicate the clear and excellent manner in which the survey has been carried out, and the maps themselves give the best evidence of the careful and painstaking work that has been put upon them both in the field and in the office.

The pleasing tones and patterns and the artistic combinations of colors of these maps deserve a separate word of commendation. In this they are in striking contrast to the generality of geological maps, such for instance as the new geological atlas of Germany, issued at Gotha under the supervision of Prof. Lepsius, whose glaring colors and sharp contrasts offend the eye. In only one point does it appear that the Livingston map could have been improved. In the areal geology sheet the tone of the color selected for Archæan is too dark, making it difficult to see the contour lines and to study the geology in connection with the relief form. The same may be said of the areas of basic andesitic breccia. On the other hand the tone of the same color employed for the corresponding areas on the economic sheet is all that could be desired, in this respect.

The use of yellow instead of the conventional tones of red to designate the igneous rocks will appear novel to many, but it must be admitted that it adds to the artistic beauty of the map and defines the areas with great clearness. L. V. P.

2. *Relation of double refraction to Soda in Hornblende;* by Alfred C. Lane. (Communicated).—I find that the following law fits not only my own observations on hornblende, but also such few indications as I can find in the literature,—

$$n = 90/17\ (0{\cdot}012 - b)$$

where n is the amount of soda contained, and b the refraction of the orthopinacoidal (100) section; b to be considered negative, as is natural, whenever the refraction for the vertical axis is less than for the lateral. That this double refraction should be dependent on the amount of soda is rendered less surprising by the fact that with the increase of soda there is generally also a progressive absorption of the red end of the spectrum in the same section.

If the amphiboles contained but two molecules, one containing soda and the other not, a law of the above form must theoretically be true as a first approximation,* but I am rather surprised that it seems to apply so widely as it does in so complex a group. It is to be remembered, however, that for any two molecules having the same axial plane there will be a couple of sections at right angles to the axial plane which will have the same double refraction in each molecule, and therefore will not vary in double refraction in isomorphous mixtures of the two. It is probably true therefore that for the commoner and more important non-sodiferous molecules the orthopinacoidal double refractions are nearly the same. This is not true, however, for the brown Bohemian hornblende described by Levy and Lacroix, and this is the only case that I know of where the law can be said definitely to fail. But observations are few, and the main object of this communication is to call the attention of fellow-workers to the subject, and urge upon all those who make hornblende analyses to observe this double refraction. Or, if they will exchange material with the writer he will be very much obliged.

* Pockels, Neues Jahrbuch, 1893, Beilage Band viii, p. 135.

3. *A new locality for Silurian Limestone in Northern Michigan;* by A. E. Seaman. (Communicated).—In view of the fact that much has been written about Limestone Mountain, west of Baraga, and as it has been stated, that it is the only outcrop of Silurian limestone in Michigan west of Keweenaw Bay, I think the knowledge of a new locality will be of interest to the readers of your magazine.

Early last winter Mr. Abner Sherman of Houghton, brought to my office at the Mining School, a specimen of limestone which, he said, was taken from an outcrop near the center of Section 7, T. 51, R. 34. Having some doubt as to the limestone being in place, I decided to visit the location in order to verify the observations of Mr. Sherman. June 4th I started for the locality, in company with Drs. Hubbard and Lane, of the Geological Survey, and Mr. L. A. Wright, of the Mining School.

The limestone was found to occupy a synclinal basin, the greater part of which lies south of the center of the aforesaid section. The major axis of the fold lies about north 30° east, and the dip varies from 3° to 28°, the steeper dip being northwesterly. The strata exposed will approximate a hundred feet in thickness, and form bluffs, which in places, rise precipitously to the height of sixty-five feet. These bluffs form a higher and a lower terrace, which can be traced for about five hundred paces. The Lake Superior sandstone was seen to dip in conformity with the limestone, the two rocks being separated by only a few feet of talus.

The fossils collected are characteristic of the Lower Silurian (Trenton). Besides brachiopods, lamellibranchs, gasteropods, corals, crinoids, bryozoa, etc., I found the pygidium of one trilobite.

Advantage of the occasion was taken to visit Limestone Mt. on sections 13, 14, 23 and 24, T. 51, R. 35. Here near the bottom of the limestone series, fossils were collected which correspond with those above mentioned from section 7. Higher up in the series were found characteristic Upper Silurian fossils, probably Niagara. Our observations thus verify those of Mr. W. L. Honnold,* who three years ago, collected Niagara fossils from this location. The finding of limestone outcrops on section 7, makes it quite probable that careful search will reveal others capping high synclinal hills in the sandstone area.

Michigan Mining School, Houghton, Mich., June 18, 1894.

4. *Etude sur la détermination des Feldspaths dans les plaques minces;* by A. Michel Lévy (Baudry), Paris, 1894, 8°, 70 pp. 8 pl. in col.—The appearance of this work is another token of the excellence of the methods of research with which petrography is being supplied.

We are already indebted to the author for many valuable researches on the relations between the optical and crystallographic properties of the feldspar group with special reference to their use

* This Journal, xlii, p. 170, 171, 1891.

in microscopical petrography. In the present case, the author has in addition extended the recent works of Federov and Becke, added new methods of his own and produced a volume which will be gratefully received by working petrologists. It is now possible on a single section of a microlitic soda lime feldspar to determine within close boundaries not only its chemical composition but its orientation as well. It is thus to be hoped that the indefinite word plagioclase will henceforth be used in much restricted manner.

The volume is embellished by eight beautiful plates in color showing in stereographic projection all the relations between the optical properties of the soda lime feldspars and their crystal form, thus adding greatly to its value. L. V. P.

Obituary.

George Huntington Williams died at Utica, N. Y., on the 12th of July, at the age of 38. He was born at Utica, and graduated from the Utica Free Academy, entered Amherst College in 1874 and took his first degree with the class of 1878. While in college he caught his enthusiasm for geology from his Professor, B. K. Emerson, and spent a year in graduate studies at Amherst. He then went to Berlin, where he perfected his knowledge of German, and to Heidelberg where he was a devoted pupil of Rosenbusch and took the Ph.D. degree in 1882. In the following year he became a fellow in Johns Hopkins University where he was appointed Professor of Inorganic Geology in 1885, which position he still held at the time of his death.

Petrography and Crystallography were the special departments of geology which he cultivated, and his text-book on Crystallography is a lucid exposition of the methods of research in this line. At the time of his death he was at work on a treatise on the Microscopic Structure of American Crystalline rocks. He was one of the best authorities on these subjects in America, and served as one of the judges of award in the department of Mineralogy at the Columbian Exposition. His untiring devotion last summer at Chicago to the duties thus put upon him, it is feared may have laid the foundation of the disease which overcame his otherwise vigorous constitution. Professor Williams was an attractive teacher and had a peculiarly pleasing manner in both private conversation and public address, and the animated and clear descriptions he gave of even the most technical subjects went far to interest his hearers in any topic he chose to speak upon. His broad education, attractive personal qualities and thorough acquaintance with the facts of his science gave him a prominent place among his fellows, and although still a young man he was rapidly rising to honor and fame. His loss will be keenly felt by all who knew him.

APPENDIX.

Art. XXIV.—*Miocene Artiodactyles from the Eastern Miohippus Beds;* by O. C. Marsh.

In recent numbers of this Journal, the writer has described various ungulate mammals from the upper Miocene of South Dakota and adjoining regions.* These were artiodactyles mainly, and of them the larger forms were related more or less closely to the genus *Anthracotherium*, established by Cuvier in 1822. These forms prove, on further study, to be more numerous and important in the horizon where *Protoceras* was found, or in the eastern Miohippus beds, than was at first suspected, and some additional specimens are described briefly and figured in the present article.

Heptacodon gibbiceps, sp. nov.

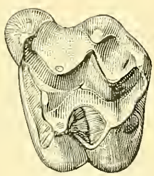
The type specimen of the present species is a skull in good preservation, except the posterior part, which is lost. The portion preserved fortunately affords a number of characters sufficient to separate the genus from allied forms of the same horizon, which will be discussed later.

The facial portion of this skull is strongly rounded above, especially in the frontal region, and this has suggested the specific name. The orbits are large, and not closed behind, although limited posteriorly by strong processes above and below. There is no antorbital depression, and the lachrymal foramen is inside the orbit. The nasals are elongate, narrow in front, and widely expanded behind where they join the frontals. They touch the lachrymals, thus separating the maxillaries from the frontals.

* This Journal, vol. xlvii, p. 409, May, 1894; and vol. xlviii, p. 91, July, 1894. See also, vol. xli, p. 81, January, 1891; vol. xlvi, p. 407, plate vii, November, 1893; and vol. xxxix, p. 524, June, 1890.

There were in all forty-four teeth. Three incisors were present on each side above, and there is a diastema behind the last one. The upper canine was large, and directed well forward and outward. There is no diastema behind the canine, and the four premolars form with the true molars a continuous series. The first and second premolars are secant, the third is subtriangular in outline, while the fourth has its crown composed of one external cusp and one internal cone. The upper molars conform strictly to the pattern of the type specimen on which the genus was based. A figure of this tooth and one of the corresponding molar of the present specimen are given below, natural size, in cuts 1 and 2.

1.



2.

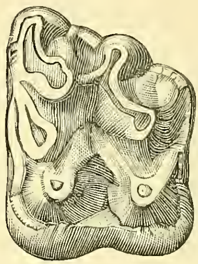


FIGURE 1.—Last upper molar of *Heptacodon curtus*, Marsh; left side; seen from below.
FIGURE 2.—The same tooth of *Heptacodon gibbiceps*, Marsh.
Both figures are natural size.

The posterior nares open opposite the middle of the last upper molars. The anterior palatine foramina appear to be confluent, forming together a heart-shaped aperture, which may in part be due to injury.

This type specimen indicates an animal about the size of a wild boar.

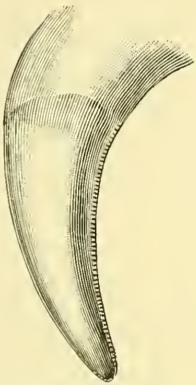
Elomeryx armatus, gen. nov.

The specimen described in the last number of this Journal as *Heptacodon armatus* proves on examination to belong to a distinct genus, which may be called *Elomeryx*. Of this genus, two species are now known. Some of the main characters are as follows :—

The skull is elongate, with the facial part quite narrow. The frontal region between the orbits is flat or even concave. The orbits are very small, and not closed behind. There is no lachrymal fossa. The anterior narial opening is large, and the snout broad.

There are the usual forty-four teeth. The upper incisors diverge, and have short, compressed crowns. The upper canine is very large and dependent. It is oval in outline near its base, but compressed below, with a serrated posterior edge; a feature not before observed in ungulate mammals.

3.



4.

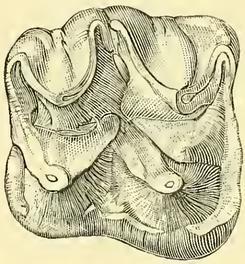


FIGURE 3.—Left upper canine of *Elomeryx armatus*, Marsh; outer view.
FIGURE 4.—Last upper molar of same species; right side; seen from below.
Both figures are natural size.

There is a long diastema behind the canine. The premolars and molars form a close series. An upper canine and last molar of the type species are shown above, natural size, in figures 3 and 4, and the upper molars of a new smaller species, in figure 5 below.

5.

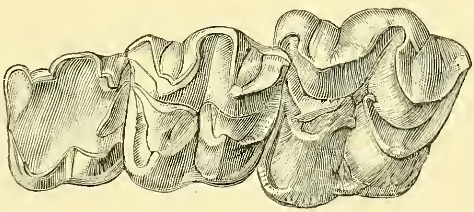


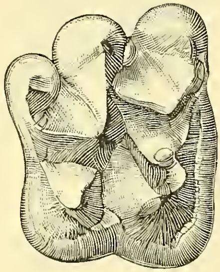
FIGURE 5.—Upper molars of *Elomeryx mitis*, Marsh; left side; seen from below. Natural size.

The posterior nares are placed well behind the molar series, much as in existing swine. There is a postglenoid process, and a long paroccipital. The type species has a small auditorial bulla, and the other, a larger one. The zygomatic arch is slender, and curved well outward. The temporal fossæ are large, and separated above by a narrow sagittal crest. The brain was well developed. The type specimen of *E. armatus* indicates an animal about the size of a large deer.

Octacodon valens.

In addition to the two genera above described, there is a third, closely allied to them apparently, which is now known from various remains found in the same horizon. These remains may for the present be provisionally placed in the genus *Octacodon*, a typical upper molar of which is shown below, figure 6. One character seen in the teeth of this genus is the short crowns of the premolars and molars and the low cusps and cones of which they are composed. This feature will at once distinguish the teeth from those known as *Hyopotamus*,* found in the same region. In the latter forms, the elevations of the crowns are especially prominent and pointed, as shown in the molar represented in figure 7.

6.



7.

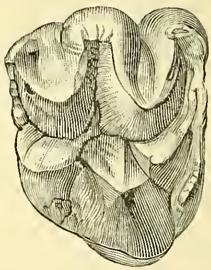


FIGURE 6.—Last right upper molar of *Octacodon valens*, Marsh; seen from below.
FIGURE 7.—The same tooth of *Ancodus* (*Hyopotamus*) *deflectus*, Marsh.
Both figures are natural size.

The position of the first premolar is another character of importance. In *Heptacodon* and *Elomeryx*, this tooth is situated close to the second premolar, but in the specimens here referred to the present genus, it is separated from both the canine and the second premolar by a well-marked diastema. None of these genera have the dependent process on the lower jaw which is characteristic of *Anthracotherium*. The nearer relations of these various allied forms will be discussed by the writer in a later communication.

Yale University Museum, New Haven, Conn., July 19, 1894.

* The generic name *Ancodus*, Pomel, has priority over *Hyopotamus*, Owen, and the latter must be regarded as a synonym. The name of the family therefore should be *Ancodontidæ*.

GEO. L. ENGLISH & CO.'S ANNOUNCEMENTS.

OUR NEW CATALOGUE, 16th EDITION, JUNE, 1894, 124 pp., 86 cuts; in paper, 25 cents; cloth, 50 cents; *No Free Copies.* The PRICE LISTS, comprising the first 44 pp. are issued as a separate pamphlet, which will be sent free to customers, or to others for 4 cents. The "CLASSIFIED LIST OF MINERAL SPECIES," embracing pp. 45–105, gives the crystallographic form, hardness, specific gravity, and chemical composition both in words and symbols of all mineral species and elaborates their varieties. The "INDEX" contains over 3,200 names, gives the new and old Dana numbers and designates whether the name is that of a species or a variety or is a synonym. THE LIST OF SPECIES *and the* INDEX *contain exclusively scientific matter, there not being a word of advertising in them.* No brief book of reference on mineralogy so valuable as this has ever before been issued. *Sample pages free.*

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SCIENTIFIC INTELLIGENCE.

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[THIRD SERIES.]

Art. XXV.—*The effect of Glaciation and of the Glacial Period on the present Fauna of North America;* by Samuel H. Scudder.

The time has perhaps arrived when at least a beginning may be made in an investigation which shall show with some degree of exactitude just what amount of influence the Glacial Period has exerted upon the present distribution of animal life in North America. Within a few years, and with a degree of precision sufficient for our purpose, geologists have mapped the areas which were once completely buried beneath the northern ice-sheet, and which were then absolutely devoid of animal life. With the slow southward advance of the ice, animals were crowded southward; with its recession they advanced again northward to reoccupy the desolated region, until now it has long been repopulated, either with the direct descendants of its former inhabitants or with such limitations to the integrity of the fauna as this interruption of local life may have caused. Precisely what modifications may have resulted, what probable resemblance the present fauna bears to that which preceded it before the interruption of its occupancy of the whole area, is the problem before us, though we shall only attempt a first step toward its solution.

In considering this question it occurred to me that some light might be thrown upon the matter if one were to tabulate separately the animals of the eastern half of the continent now found (1) upon the area once covered by the ice-sheet and (2) upon the driftless area, using the mapped limits of the terminal moraine to separate the two regions; to discover how many genera and species were common to both, and how many peculiar to each, of the two areas; and finally, to compare these results with those reached by a similar study of the existing fauna of somewhat equivalent areas upon the Pacific coast where, it is claimed, no continental ice-sheet covered the face of the country. Here one would have to choose somewhat arbitrarily a delimitation between the two areas, north and south, which should tolerably correspond climatically with that of the terminal moraine of eastern America. Accordingly, before beginning any tabulation, I selected the following areas for comparison: East of the Rocky Mountains, the "barren ground" of the high north, the immediate vicinity of the Rocky Mts. and the extreme south of Florida and Texas were left out of consideration, and the two areas were separated by the line of the great terminal moraine as mapped by Chamberlin. West of the Sierra Nevadas, the two areas were separated by the northern border of California, and the southern district was limited southwardly by the omission of the region south of Los Angeles; while the northern district was made to include the northern part of Washington and the southern portion of British Columbia, though drift covered, so as to embrace in the lists the numerous collections made on Vancouver Island and the adjoining main land.

Of course it is well understood that the fauna of eastern is far better known than that of western America; but this is no real obstacle, since the comparison is to be made in either section between the northern and the southern districts of that section only, and there no great inequality exists; the special point of enquiry is as to the relative faunal weight of the north, if the expression may be allowed, in the east, where the ground required complete reoccupancy, and in the west, where occupancy had not been interrupted.

This would furnish a gauge, as it were, of the effect of the Glacial Period upon the present faunal distribution of life. For if it should be found that the relative proportion of endemic northern genera and species was distinctly less in the east than in the west, and the relative number of genera and species common to north and south also less; then surely such relative poverty might properly be taken as a gauge of the insufficiency of the time that has elapsed since the glacial period for the fauna to have recovered its ancient territory. If, on the other hand, no sign of such poverty can be discovered, then we may fairly assume that the east has fully recovered from the shock of the Glacial Period, and that, excepting in minor points which special investigation would point out, the present distribution of life is much what it would have been had there been no Glacial Period. I may venture to add that before beginning this enquiry I had no idea what the result of my tabulation would prove.

In the following discussion of the question, I shall limit myself to the use of insects, and indeed of a single order of insects, as subjects for illustration: not only because some limitation must be made in this place with so large a subject before us, but also, and principally, because insects may rightly be regarded as better tests than any other group of animals or than any group of plants, in nice questions of distribution either in space or time. This is not generally acknowledged, but a single pertinent illustration will suffice.

It is well known that as we pass upward in the Tertiary period there is a growing resemblance of the animals and plants of its different subdivisions to those living at the present time; a resemblance both in general and in particular, an increasing percentage of forms regarded as identical or nearly identical with existing types being found as one passes from the Eocene to the present time. Furthermore the plants and (leaving the mammals out of account) the known animals of the Quaternary are, with extremely rare exceptions, identified altogether with those now living. Nearly all the mammals are extinct. Now, although the main broad features of insect life appear to have been much the same in the early Tertiary as now, not only has not a single Tertiary insect been shown to be living at the present day, whether in Europe or America, but a considerable proportion of Quaternary insects have also been described as extinct. It is true that a few, a dozen or two, Tertiary insects have been listed as belonging to existing forms, but in each such case the determination has been made by one not conversant with insects, or else with no statement of the basis or terms of comparison.

As to the Quaternary insects, I find in Europe 80 Coleoptera which have been studied with more or less care; of these 13 are treated as extinct and 67 identified more or less confidently with existing European forms. This number however, it should be insisted upon, is made up very largely of remains from peat bogs, which are relatively very recent. In our own country, 48 species of pleistocene Coleoptera have been described,* of which only a single one is regarded as probably identical with an existing form, three are specifically indeterminate and 44 are extinct, though in some cases intimately allied to forms now living. I add a list of these.

* Including five species from Hadley, Mass., described in an unpublished memoir.

List of described American Quaternary Coleoptera.

Name.	Locality.	Allied to	From	Resemblance.
Scolytidæ				
Hylastes squalidens	Scarboro, Ont.			
Tenebrionidæ				
Tenebrio calculensis	Greene's Cr., Ont.	T. molitor Linn.	Eur., N. Amer.	general
Chrysomelidæ				
Saxinis regularis	Hadley, Mass.	S. saucia LeC.	Pac. coast to Color.	general
Donacia stiria	Scarboro, Ont.	D. porosicollis Lac.	Lake Sup., N. Engl.	general
pompatica	" "	D. pubicollis Saffr.	Illinois	close
elongatula	Hadley, Mass.	D. lignitum Sord.	Ital. Quaternary	close
Scarabæidæ				
Aphodius præcursor	Port Kennedy, Pa.	A. ruricola Melsh.	Anticosti to La.	close
Phanæus antiquus	" "	A. pluto Har.	Ariz, Mex.	close
Chœridium ebeninum	" "			
Elateridæ				
Corymbites æthiops?	Hadley, Mass.	(Recent)		
Fornax ledensis	Greene's Cr., Ont.	F. calceatus Say	Canada; Mass.	close
Byrrhidæ				
Byrrhus ottawaensis	" "	B. geminatus LeC.	Lake Sup., N. H.	very close
Staphylinidæ				
Arpedium stillicidii	Scarboro', Ont.	A. cribratum Fauv.	Michigan	general
Geodromicus stiricidii	" "	G. nigrita Müll.	North. U. S.; Can.	distant
Bledius glaciatus	" "	B. brevidens LeC.	New York	close
Oxyporus stiriacus	" "			
Lathrobium interglaciale	" "	L. grande LeC.	Lake Sup. to N. Car.	general
Hydrophilidæ				
Hydrochus amictus	Cleveland, O.	H. subcupreus Rand.	Lake Sup., southw.	general
Helophorus rigescens	" "	H. tuberculatus Gyll.	North. U.S.; Scandin	general
Dytiscidæ				
Dytiscidæ sp.	Hadley, Mass.	Matus bicarinatus Say	Canada to Fla.	possible
Carabidæ				
Chlænius punctulatus	Port Kennedy, Pa.	C. laticollis Say.	N. Y. to Fla.; Ariz.	close
Cymindis aurora	" "	C. americana Dej.	New York	close
extorpescens	Hadley, Mass.	C. elegans LeC.	Mass.; Fla.	general
Platynus casus	Scarboro', Ont.	P. rubripes Zimm.	Mid. St. to Kansas	general
hindei	" "	" "	"	general
halli	" "	P. crenistriatus LeC.	Western U. S.	general
dissipatus	" "	"	"	distant
desuetus	" "	"	"	close
harttii	" "			
dilapidatus	" "	P. maculicollis Dej.	Oreg.; Calif.; Ariz.	general
Dicælus alutaceus	Port Kennedy, Pa.	D. dilatatus Say.	U. S. E.of Gr. Plains	close
sp.	" "	D. elongatus Bon.	"	general
Pterostichus abrogatus	Scarboro', Ont.	P. herculaneus Mann.	Pac coast; Brit. Am.	close
dormitaus	Cleveland, Ohio.	P. lætulus LeC.	California	very close
destitutus	Scarboro, Ont.	P. sayi Brullé	Atl. and west. St.	close
fractus	" "	"	"	distant
destructus	" "	P. patruelis Dej.	Mid. St.; N. York	very close
gelidus	" "	P. hudsonicus LeC.	Hudson Bay	close
lævigatus	Port Kennedy, Pa.			
sp.	" "			
Patrobus gelatus	Scarboro', Ont.	P. septentrionis Dej.	N. Eur.; Arc. Amer.	very close
Bembidium glaciatum	" "	B. longulum LeC.	Lake Sup.; N. York	close
fragmentum	Cleveland, Ohio.	B. constrictum Lec.	New England	close
Loricera glacialis	Scarboro', Ont.	L. cærulescens Linn.	Bor. Am. & Eur.; Sib.	general
lutosa	" "			
Elaphrus irregularis	" "	E. viridis Horn	California	close
Cychrus wheatleyi	Port Kennedy, Pa.	C. viduus Dej.	Pennsylvania	general
minor	" "	C. andrewsii Harr.	Centr. Atl. states	general

It should be noted that this series, in contradistinction from the European, does not include any forms from the peat, regarding which nothing has yet been published. I may however add that I have studied a very large collection of peat insects from Massachusetts and have so far separated over 60 species of Coleoptera, of which 27 are identified with existing forms, 10 are probably the same as species now living, and only one, a Hydrocanthus, is certainly different from anything yet known. The study of the remainder has not been concluded.

In our own country, then, the coleopterous fauna of the peat is practically identical with that now living; while that of deposits further removed from the present, but laid down *since* the beginning of the Glacial Period, is practically entirely extinct. When the early Quaternary Coleoptera of Europe have been attentively studied, I believe that the same conclusion is likely to be drawn from them. It thus appears that in this country the Coleoptera are at least as sensitive standards of climatic or faunal changes as are the Mammalia, which have hitherto been regarded as the only group of animals any considerable portion of which have become extinct in quaternary times; and that they are more sensitive tests than other groups of animals or than plants.

Having for these reasons selected insects as the best subjects for investigation, I have further restricted myself to Coleoptera, as the order which has been longest studied, is best known, and is most numerous in described species, the greater part of which have had the benefit of monographic revision. The main difficulty, that the catalogues give no indication of the geographical distribution of the different species, has been completely removed by the signal kindness of my friend Mr. Samuel Henshaw, who has liberally allowed me the freedom of his manuscript catalogue, in which he has placed against each species every published indication of special locality or general range, besides those furnished by his own knowledge.

The following table gives in detail for each family of Coleoptera the result of my examination of Mr. Henshaw's catalogue, and includes over 7500 species. For brevity, I have designated the drift-covered area of the east as D; the driftless area of the same as E; the northern portion of the Pacific region as N; and the southern as S. The first figure in each column indicates the number of genera, the second of species. The sign >, as in S>N, indicates that the numbers in that column are the number of genera found in S and not occurring in N, and the number of species in those same genera occurring in S. The sign +, as in S+N, means the number of genera common to both S and N and the number of species of those genera occurring in one or the other or in both (which is usually fully twice the number of species common to both). Although beside my immediate purpose I have added the middle set of three columns for the sake of comparison.

Table of the regional distribution of North American Coleoptera.

Families.	S>N	S+N	N>S	N>D	N+D	D>N	D>E	D+E	E>D
Cicindelidæ	2:2	2:23		1:2	1:32	1:1		2:73	1:1
Carabidæ	24:39	22:172	5:6	3:4	26:382	47:132	12:15	64:679	33:69
Amphizoidæ		1:3		1:3	1:3				
Haliplidæ	2:2	2:2			2:9			2:13	
Dytiscidæ	8:12	10:51	2:2		12:129	13:24	2:3	23:171	3:3
Gyrinidæ	2:2	1:5			1:18	2:5	1:1	2:6	
Hydrophilidæ	6:7	4:28			4:33	10:32	3:4	12:84	5:5
Leptinidæ					2:2	2:2	2:2	2:2	
Silphidæ	1:1	10:22	4:4	6:9	10:60	6:13		13:62	4:4
Scydmænidæ	1:1	1:4			1:15	5:6	3:4	3:29	1:1
Pselaphidæ	3:3	2:10	1:1	1:1	15:104	14:35	1:1	14:103	11:14
Staphylinidæ	24:54	21:142	9:9	9:9	22:311	55:138	13:20	61:519	33:51
Trichopterygidæ		3:17		1:1	2:14	3:6		5:29	5:6
Sphæriidæ	1:1	1:1							
Scaphidiidæ	1:1	1:1			4:9	4:9	1:1	3:14	2:3
Phalacridæ	1:2	1:1	1:1		2:8	1:5		3:24	6:11
Corylophidæ	2:2		1:1		1:1	5:9	3:4	3:10	
Coccinellidæ	2:2	9:37	1:1	1:1	9:66	11:20	2:2	18:109	2:3
Endomychidæ	2:4	1:3			1:3	6:6		7:9	3:8
Erotylidæ	1:2	1:1			1:11	6:16		7:42	
Colydiidæ	4:4	5:11	1:1	4:5	2:3	8:9		10:20	10:14
Rhyssodidæ	1:2		1:1		1:2	1:1		2:2	
Cucujiidæ	3:8	3:4	1:1	2:2	2:5	6:18		8:35	6:8
Cryptophagidæ	2:3					7:9	1:1	6:14	2:2
Mycetophagidæ	1:1	2:4			2:8	4:7		6:20	
Dermestidæ	5:10	3:8			3:11	6:10		9:27	3:3
Histeridæ	4:5	3:21			3:58	8:16		12:128	7:8
Nitidulidæ	3:4	4:9	2:2	2:2	4:20	14:30		18:60	6:6
Latridiidæ	4:15					4:22	2:2	3:37	2:2
Trogositidæ	2:2	3:7	1:2		3:16	4:8	1:1	6:24	2:2
Derodontidæ					1:1	1:1		1:1	
Byrrhidæ	2:7	1:3	2:2	1:2	2:5	4:12	4:12	2:12	1:1
Georyssidæ	1:1					1:1		1:1	
Parnidæ	2:2	1:4			1:9	5:10		6:24	2:2
Heteroceridæ		1:2			1:9			1:13	
Dascyllidæ	6:6	1:2	2:2	1:1	2:8	9:13	3:3	8:24	2:2
Rhipiceridæ	1:1					3:5		3:5	
Elateridæ	14:18	17:100	3:4	1:1	19:200	29:53	5:8	42:269	14:20
Throscidæ	1:1	1:5			1:6	1:2		2:11	
Buprestidæ	6:14	6:37	1:1	1:1	6:61	12:41	2:2	16:146	9:14
Lampyridæ	8:14	8:36		1:1	7:66	18:43	2:2	23:13	10:11
Malachidæ	5:9	5:35		3:4	1:8	5:9	1:1	6:35	5:8
Cleridæ	4:5	4:12			4:17	11:20	2:4	13:53	3:4
Ptinidæ	15:23	4:9	1:1		4:13	22:36	2:3	24:77	12:18
Cupesidæ			1:1	1:1		1:2		1:2	
Lymexylidæ						3:3	3:3		
Cioidæ	1:1					3:6		3:11	
Sphindidæ	1:1					3:3	3:3		
Lucanidæ		3:8		1:1	2:6	3:6		5:10	
Scarabæidæ	14:22	8:46	2:3	1:1	9:80	31:80	3:3	37:247	16:24

[TABLE continued.]

Families.	S>N	S+N	N>S	N>D	N+D	D>N	D>E	D+E	E>D
Spondylidæ		1:1			1:1	1:1	1:1	1:2	1:1
Cerambycidæ	27:32	22:90	12:14	8:8	23:170	55:95	8:11	67:258	51:74
Chrysomelidæ	20:30	21:75	8:12	3:4	25:144	40:95	6:8	60:431	22:34
Bruchidæ	2:9					1:7		1:32	3:4
Tenebrionidæ	26:37	12:54	4:4	9:15	8:33	22:30	5:5	28:97	34:72
Aegialitidæ	1:1	1:1							
Cistelidæ	2:3					7:22		7:33	2:6
Othniidæ		1:1						1:2	1:2
Lagriidæ								1:1	1:3
Melandryidæ	1:1	3:6	2:2	2:2	5:11	23:33	7:8	19:37	3:3
Pythidæ	5:5		1:1	1:1	1:1	5:5		2:3	1:2
Oedemeridæ	3:3	2:6	1:1		3:9	3:3	1:1	5:12	2:3
Cephaloidæ			1:1		1:3	1:2			
Mordellidæ	2:4	1:3			1:4	2:14		4:100	3:4
Anthicidæ	3:16	1:6	1:1	1:1	1:6	6:35	1:1	6:69	4:7
Pyrochroidæ			1:1		1:3	3:3	1:1	3:7	
Meloidæ	7:11	4:33		1:4	4:25	5:8		8:69	7:20
Rhipiphoridæ	2:3					3:11		3:19	
Stylopidæ						2:2	1:1	1:1	
Rhinomaceridæ	1:1	1:3			1:2			1:2	
Rhynchitidæ	1:1	1:5			1:3	3:7		4:14	
Attelabidæ					1:3	1:3		1:4	
Byrsopidæ								1:1	
Otiorhynchidæ	12:16	6:11	3:4	9:12		11:15	3:4	8:13	23:33
Curculionidæ	17:22	16:77	10:11	5:5	19:138	52:80	14:19	56:411	28:44
Brenthidæ								1:2	1:1
Calandridæ	6:7	2:7			3:19	5:7		7:36	13:17
Scolytidæ	1:1	9:34	2:2		10:58	12:22	2:2	22:99	4:5
Anthribidæ	2:2		1:1		1:1	9:11	2:2	8:18	7:10
Totals	334:521	281:1300	88:101	81:104	307:2355	690:1446	129:169	844:5072	432:673

Translating these totals into percentages we shall reach the following figures:

Districts.	S>N	S+N	N>S	N>D	N+D	D>N	D>E	D+E	E>D
Percentages	48:27	40:68	12:5	8:3	28:60	63:37	9:3	60:86	31:11

Or, if we place the percentages of the west and the east in parallel columns, we shall have the following:

	West	East
North	12 : 5	9 : 3
In common	40 : 68	60 : 86
South	48 : 27	31 : 11

Here it will be seen that in the northern percentage of both genera and species, the East lags a little behind the West, but it is only a very little, and it is much more than made up by the considerably larger percentage in the East of the genera common to North and South.

I have also tabulated the species reported as found common to the northern and southern districts on each side of the continent and find that about 16 per cent of all the western species are common to the two districts, while about 35 per cent of all the eastern are common to the drift-covered and driftless areas. I append a table of these numbers. One difference between this table and the previous one is that here the common species form the base, while in the previous one the common genera form the base; hence a genus represented in the two districts, but only by *distinct* species, does not appear in this table, but only in the previous one. Seven families in which there are no species recorded as found in two regions are omitted from the list.

Table of the species common to pairs of regions.

Families.	S+N	N+D	D+E	Families.	S+N	N+D	D+E
Cicindelidæ	2:5		2:22	Throscidæ			2:5
Carabidæ	20:46	14:25	62:245	Buprestidæ	5:10	4:6	16:62
Amphizoidæ	1:1			Lampyridæ	5:6	3:3	22:65
Haliplidæ			2:6	Malachidæ	3:3		5:12
Dytiscidæ	8:12	4:7	22:67	Cleridæ	2:3	2:2	12:18
Gyrinidæ		1:2	2:10	Ptinidæ	3:3		23:28
Hydrophilidæ	4:6	2:2	11:37	Cupesidæ			1:2
Silphidæ	13:17	7:12	15:43	Cioidæ			3:3
Scydmænidæ	1:1		2:7	Lucanidæ	3:3		5:8
Pselaphidæ	1:1		14:36	Scarabæidæ	6:9	2:3	36:106
Staphylinidæ	15:29	13:27	57:189	Spondylidæ	1:1	1:1	1:1
Trichopterygidæ	1:1		3:5	Cerambycidæ	17:20	12:13	66:155
Scaphidiidæ			3:7	Chrysomelidæ	15:19	12:14	59:164
Phalacridæ	1:1		2:5	Bruchidæ			1:7
Corylophidæ		1:1	3:5	Tenebrionidæ	10:14	1:1	28:45
Coccinellidæ	8:10	6:7	17:45	Cistelidæ			7:11
Endomychidæ	1:1		7:8	Lagriidæ			1:1
Erotylidæ			7:20	Melandryidæ	1:1	2:2	19:26
Colydiidæ	3:3	1:1	10:11	Pythidæ		1:1	1:1
Rhyssodidæ			2:2	Oedemeridæ			4:5
Cucujidæ	3:3		8:19	Mordellidæ	1:1		4:31
Cryptophagidæ			6:6	Anthicidæ			5:24
Mycetophagidæ	1:1	1:1	6:12	Pyrochroidæ		1:1	2:2
Dermestidæ	3:5	3:3	8:16	Meloidæ	3:4		7:15
Histeridæ	2:5	1:1	11:51	Rhipiphoridæ			1:5
Nitidulidæ	4:4	4:4	18:33	Stylopidæ			1:1
Latridiidæ			3:6	Rhinomaceridæ			1:1
Trogositidæ	3:3	1:1	6:16	Rhynchitidæ	1:1	1:1	4:8
Derodontinæ			1:1	Attelabidæ			1:5
Byrrhidæ	1:2		1:1	Byrsopidæ			1:1
Georyssidæ			1:1	Otiorhynchidæ	5:5		6:6
Parnidæ			6:13	Curculionidæ	10:16	7:7	47:117
Heteroceridæ	1:1	1:1		Brenthidæ			1:1
Dascyllidæ		1:1	7:12	Calandridæ	1:1	1:1	6:16
Rhipiceridæ			3:5	Scolytidæ	7:10	6:6	21:39
Elateridæ	9:14	10:15	41:119	Anthribidæ		1:1	6:7
				Totals	205:302	128:174	794:2083

These figures indicate, it seems to me, that on the whole the fauna of the East has nearly or quite recovered from its enforced removal from the northern States and Canada at the time of the Glacial Period, and that whatever influence the past existence of a Glacial Period may now exert upon the distribution of animal life in North America should be sought only in minor features, such as the remnants of boreal faunas lingering in favorable spots amid temperate surroundings, and the similar features induced by the latitudinal trend of our great mountain chains.

ART. XXVI. — *The Constitution of the Zeolites;* by F. W. CLARKE.

THE obvious relationship of many zeolites to the feldspars has long been recognized as a probable key to their constitution; and yet, so far as I am aware, no systematic theory of the connection between the two groups has been put forward. Partial work, indeed, has been done; as by Streng in his study of chabazite, and by Fresenius in his interpretation of phillipsite and harmotome; but a general explanation of the zeolites all together is still wanting. Much evidence, however, has accumulated with reference to the problem; such as that derived from the practical dehydration of the minerals, their modes of decomposition when fused, their synthetic formation, their changes under the influence of reagents, and so on; and the purpose of any exhaustive discussion of their nature should be to bring all these lines of testimony, all these varied data, into convergence. No system of constitutional formulæ can be valid unless it fulfils these conditions. It is possible, of course, to seek for too great a generality, and so to force an apparent harmony where real relations do not exist. To avoid this danger, it seems necessary to admit at once that all zeolites are not of feldspathic origin; some few are compounds of quite a different type; but most of the members of the group are easily represented by one general set of expressions, which apply to the feldspars as well.

The theory of the zeolites which is developed in the present paper, is a direct outgrowth and sequence of the views which I have published of late years concerning the micas, the chlorites, and various other minerals, and it is based upon the same principles. The complex or apparently complex aluminous silicates are regarded as generally being substitution derivatives of simple normal salts, such as $Al_4(SiO_4)_3$, $Al_4(Si_3O_8)_3$, etc.; a conception which brings to light many important relations, and which seems to be fully justifiable from all points of view. The acid radicals SiO_4 and Si_3O_8 are also regarded as mutually replaceable, the one by the other; a belief which may now be looked upon as fairly well established by the evidence of the feldspar and scapolite groups, as studied by Tschermak, and of the mica group as interpreted by myself. These two fundamental conceptions are the foundation stones upon which I have tried to build.

In a paper upon the chemical structure of the natural silicates,* the substitution theory above outlined was applied to the feldspars, although the formulæ were not written out in full. Albite, the soda compound, $AlNaSi_3O_8$, was regarded as a first substitution derivative of the unknown salt $Al_4(Si_3O_8)_3$, and anorthite as the corresponding orthosilicate containing lime. In each case the simplest possible formula is tripled, giving the subjoined expressions representing the two feldspathic salts:

$$
\begin{array}{l}
\quad\diagup Si_3O_8 \equiv Na_3 \\
Al - Si_3O_8 \equiv Al \\
\quad\diagdown Si_3O_8 \equiv Al
\end{array}
\qquad\qquad
\begin{array}{l}
\quad\diagup SiO_4 \equiv Al \\
Al - SiO_4 \equiv Al \\
\quad\diagdown SiO_4 = Ca \\
\qquad\quad | \\
\qquad\;\; Ca \\
\qquad\quad | \\
\quad\diagup SiO_4 = Ca \\
Al - SiO_4 \equiv Al \\
\quad\diagdown SiO_4 \equiv Al
\end{array}
$$

From these formulæ the formulæ of many zeolites are easily derived; providing we assume that the soda salt may be replaced by its equivalent ortho-compound, and the calcium salt by the corresponding trisilicate. The sodium ortho salt would be isomeric with nepheline; but the calcium compound containing Si_3O_8 is purely hypothetical. Upon this basis, if we temporarily regard all water in the zeolites as water of crystallization, and represent the groups SiO_4 and Si_3O_8 by the general symbol X, the greater number of the minerals under consideration fall easily into two groups, having the following generalized formulæ:

$$1.\ \begin{cases} Al_6X_6R'_6,\ \text{n. aq.}, + \\ Al_3X_3R'_3,\ \text{n. aq.} \end{cases}$$

$$2.\ \begin{cases} Al_4X_6R'_{12},\ \text{n. aq.}, + \\ Al_2X_3R'_6,\ \text{n. aq.} \end{cases}$$

For the first group, with varying amounts of water, we have thomsonite, gismondite, edingtonite, phillipsite, harmotome, chabazite, levynite, gmelinite, hydronephelite, and offretite.

* U. S. Geological Survey, Bulletin No. 60, 1887–88.

In the second group we find foresite, laumontite, heulandite, epistilbite, brewsterite, scolecite, stilbite, faujasite, and natrolite. The two groups remain in this form, however, only so long as we ignore water, for when we begin to regard the latter as partly constitutional, several members of the first series must be transferred to the second. This point will be made clear farther on. The species above named may be individually considered as follows:

Thomsonite.—$Al_6(SiO_4)_6Ca_3 . 7H_2O$. This is equivalent to anorthite plus water, and according to Doelter thomsonite yields anorthite upon fusion. Commonly a part of the lime is replaced by soda, either one or two atoms being so replaceable. Sometimes, as in "mesole," there is an excess of silica, which is accounted for by small admixtures of trisilicate molecules, or Si_3O_8 groups. The dehydration experiments of Damour, Hersch, etc., indicate that $\frac{4}{7}$ of the water must be regarded as constitutional. This may be represented as bringing about a replacement of Al by $-Al=(OH)_2+H_2$. Hence the final formula should be written

$$Al_4(SiO_4)_6Ca_3(AlH_2O_2)_2H_4 . 3H_2O.$$

Gismondite.—Uncertain, but probably $Al_6(SiO_4)_6Ca . 12H_2O$, with part of the lime replaced by potash, and perhaps in some cases Si_3O_8 replacing SiO_4. It is stated that $\frac{1}{3}$ of the water goes off at 100°, if the remaining eight molecules are constitutional, four aluminum atoms would be replaced by $4(AlH_2O_2)+H_8$, giving the formula

$$Al_2(SiO_4)_6Ca_3(AlH_2O_2)_4H_8 . 4H_2O.$$

Edingtonite.—Probably $Al_6X_6Ba_3 . 12H_2O$, with X about $\frac{3}{4}SiO_4$ and $\frac{1}{4}Si_3O_8$. Barium partly replaceable by other bases. Mode of hydration undetermined. According to Lemberg edingtonite, or a compound like it, is artificially derivable from natrolite. Although edingtonite has the same total number of water molecules as gismondite, its crystallization is totally different; so that the ratio of crystalline to constitutional water is probably not the same for the two species.

Phillipsite.—$Al_6X_6CaR'_4 . 15H_2O$. R′ may be either Na or K, and the ratio between SiO_4 and Si_3O_8 is quite variable. Little, if any of the water can be regarded as constitutional.

Harmotome.—$Al_6X_6Ba_3 . 15H_2O$. Ratio of Si_3O_8 and SiO_4 commonly 1 : 1. A little Ba replaced ordinarily by H_2 or alkalies. Recognized generally as closely analogous to phillipsite.

Levynite.—$Al_6X_6Ca_3 . 15H_2O$. $SiO_4 : Si_3O_8 :: 3 : 2$. Slight replacements of lime by alkalies. About $\frac{1}{3}$ of the water appears to be constitutional, judging from Damour's experiments.

Chabazite.—Ranges from $Al_6X_6Ca_3 . 18H_2O$, to $Al_3X_3Na_3 . 9H_2O$. with $SiO_4 : Si_3O_8 :: 1 : 1$, giving apparently metasilicate ratios. On fusion, according to Doelter, gives silica and anorthite. In the lime salt four molecules of water and in the soda salt two molecules are to be considered as constitutional; giving the ultimate formulæ

$$Al_4X_6Ca_3H_4(AlH_2O_2)_2 . 14H_2O,$$
$$Al_2X_3Na_3H_2(AlH_2O_2) . 7H_2O$$

Gmelinite.—$Al_3X_3Na_3 . 9H_2O$, or like the non-calcic chabazite; but with $SiO_4 : Si_3O_8 :: 1 : 2$. Two molecules of water are probably constitutional.

Hydronephelite.—$Al_3(SiO_4)_3Na_2H . 3H_2O$. Clearly a derivative of nepheline.

Offretite.—The analysis by Gonnard agrees sharply with the formula—

$$2Al_3(Si_3O_8)_3K_3 . 8H_2O + Al_3(SiO_4)_3CaH . 8H_2O.$$

So much for the first group of zeolites, which is characterized by the perfectly uniform ratio of $Al : X = 6 : 6$ or $3 : 3$, accordingly as bivalent or univalent bases predominate among the remaining metallic components. The second group is similarly defined by the ratio $Al : X = 4 : 6$ or $2 : 3$; the water being the chief variable. In detail, the members of this group are as follows:

Foresite.—$Al_4(SiO_4)_6CaH_{10} . H_2O$.

Scolecite.—$Al_4(SiO_4)_6Ca_2H_8 . 2H_2O$. According to Doelter, yields anorthite on fusion. Converted into natrolite by the prolonged action of soda solutions, according to Lemberg. Loses about $\frac{1}{3}$ of its water at 300°, regaining the same in moist air.

Laumontite. — $Al_4X_6Ca_2H_8 . 4H_2O$. $SiO_4 : Si_3O_8 = 5 : 1$. Yields anorthite and a pyroxenic mineral on fusion. Loses about $\frac{1}{2}$ its water at 300°.

Heulandite.—$Al_4X_6Ca_2H_8 . 6H_2O$, with $SiO_4 : Si_3O_8 = 1 : 1$. According to Doelter, yields a "lime augite" on fusion, with silica. This observation may best agree with the metasilicate formula $Al_2Ca(SiO_3)_6H_4 . 3H_2O$, both formulæ being empirically identical, and both in accord with the behavior of heulandite upon dehydration.

Brewsterite.—Like heulandite, but with barium and strontium replacing lime.

Epistilbite.—Isomeric with heulandite, but with the water apparently more firmly combined. Perhaps a part of the Al is replaced by $AlH_2O_2 + H_2$.

Stilbite.—$Al_4X_6Ca_2H_8 . 8H_2O$, with $SiO_4 : Si_3O_8 = 1 : 1$. On fusion, behaves like heulandite, but sometimes yields anorthite. The variations in composition are probably due to variations in the ratio between the ortho- and trisilicate groups.

Faujasite. — $Al_4X_6Na_2CaH_8 . 15H_2O$. $SiO_4 : Si_3O_8 = 2:1$. Faujasite may also be represented as a salt of the acid $H_6Si_2O_7$, with the formula $Al_4(Si_2O_7)_5CaNa_2H_{14} . 12H_2O$. As the mineral does not gelatinize when decomposed by hydrochloric acid, it may not belong with the orthosilicates.

Natrolite.—$Al_2(SiO_4)_3Na_2H_4$. Doubtful as regards the character of its water. Yields nepheline on fusion, the latter mineral being $Al_3(SiO_4)_3Na_3$, with occasional replacements of SiO_4 by a very little Si_3O_8.

A careful scrutiny of the foregoing formulæ will show that, so far as our present data go, they fulfill all the conditions laid down at the beginning of this article. They agree with the published analyses, and account fully for their variations, and in type they correspond to the two feldspathic molecules of which the configurations have been given. They differ chiefly with respect to hydration, and these differences are now intelligible. Furthermore, several of the species yield anorthite when fused, which connects the formulæ given with the types assumed, and also with the probable genesis of zeolites from feldspars. Their deficiencies correspond to deficiencies in evidence, and they suggest the lines of investigation by which they may be finally established or discarded. If the formulæ do no more than to perform the last named function, they have a value which entitles them to consideration. Neglecting the distinction between crystalline and constitutional water, and omitting for sake of brevity the few barium-strontium salts, the normal zeolites, if I may call them so, can be tabulated as follows:

First Group.

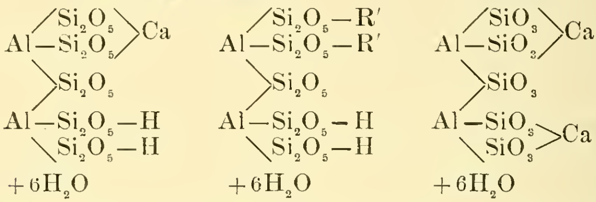
Thomsonite	$Al_6(SiO_4)_6(CaNa_2)_3 . 7H_2O$
Gismondite.....	$Al_6(SiO_4)_6(CaK_2)_3 . 12H_2O$
Phillipsite.......	$Al_6X_6CaR'_4 . 15H_2O$.
Levynite	$Al_6X_6Ca_3 . 15H_2O$
Chabazite. A...	$Al_6X_6Ca_3 . 18H_2O$
" B...	$Al_3X_3Na_3 . 9H_2O$
Gmelinite	$Al_3X_3Na_3 . 9H_2O$
Hydronephelite .	$Al_3(SiO_4)_3Na_2H . 3H_2O$
Offretite	$Al_3X_3R'_3 . 8H_2O$

Second Group.

Foresite	$Al_4(SiO_4)_6CaH_{10} . H_2O$
Scolecite	$Al_4(SiO_4)_6Ca_2H_8 . 2H_2O$
Laumontite	$Al_4X_6Ca_2H_8 . 4H_2O$
Heulandite	$Al_4X_6Ca_2H_8 . 6H_2O$
Epistilbite	$Al_4X_6Ca_2H_8 . 6H_2O$
Stilbite	$Al_4X_6Ca_2H_8 . 8H_2O$
Faujasite	$Al_4X_6Na_2CaH_8 . 15H_2O$
Natrolite.......	$Al_2(SiO_4)_3Na_2H_4$

There still remain several zeolites to be considered, together with some allied minerals, which seem to be compounds of a different type from those represented in the preceding table. Two of these zeolites, ptilolite and mordenite, I have already discussed in a former paper;* and another, the more recently discovered laubanite, appears to be related to them. In ptilolite and mordenite we have salts of the bibasic acid, $H_2Si_2O_5$, while laubanite is a metasilicate of precisely similar type. The two first named minerals shade into each other as mixtures of certain fundamental salts, while laubanite is distinct. The formulæ are as follows:

Ptilolite and Mordenite. Laubanite.



The relationship is so evident that it needs no farther explanation. Laubanite can be so written as to throw it into the normal series; but this constitution is certainly preferable.

Analcite, another zeolite, may be written $H_4Na_2Al_2X_3$, with $\frac{1}{6}$ of $X = Si_3O_8$. This would bring the mineral into the second group of normal zeolites, and into close relationship with natrolite. Analcite, however, is isometric, like the anhydrous leucite; and Lemberg has shown that by the prolonged action of alkaline solutions, analcite and leucite are mutually convertible the one into the other. Hence, the two species should be regarded as closely akin, and of similar type, and their simplest formulæ are as follows:

Leucite. Analcite.

Both minerals, however, occur altered into feldspars; and it is an open question whether their formulæ should not be polymers of those given above, in order that the alterability may become interpretable. The same question arises with spodumene, a compound of similar formula, which splits up easily into albite and eucryptite. These points I shall consider elsewhere.

Three other minerals, which are sometimes classed as zeolites, but which contain no aluminum, are okenite, gyrolite, and apophyllite. These species are undoubtedly related; for

* This Journal, August, 1892.

apophyllite may be generated artificially from okenite, and gyrolite occurs in nature both as the parent and as a derivative of apophyllite. At New Almaden, apophyllite is the secondary mineral; while in Nova Scotia gyrolite appears to be formed by its alteration. All three species, considered as analogous in structure, are most simply represented as salts of the acid $H_6Si_2O_7$, and on this supposition they receive the following formulæ:

Okenite.	Gyrolite.	Apophyllite.
$Ca \langle Si_2O_7 . H_5$	$Ca \langle Si_2O_7 . CaH_3$	$Ca \langle Si_2O_7 . H_4(CaOH)$
$\rangle Si_2O_7 . CaH_2$	$\rangle Si_2O_7 . H_4$	$\rangle Si_2O_7 . H_4$
$Ca \langle Si_2O_7 . H_5$	$Ca \langle Si_2O_7 . CaH_3$	$Ca \langle Si_2O_7 . H_4(CaOH)$

In apophyllite, the univalent $-Ca-OH$ is partly replaced by potassium, and the hydroxyl is often substituted by fluorine. The somewhat uncertain plombierite may also be represented as a member of the same group, having the formula $Ca_2(Si_2O_7)_3 Ca_3H_8 . 9H_2O$.

Since the object of this paper is merely to give a preliminary statement of the conclusions which I have reached, I have not thought it necessary to load down its pages with references to literature or with discussions of analyses. A large mass of data has been examined, and it is my intention to elaborate the subject to a considerable extent within the near future. When that is done the evidence will be presented with sufficient fulness.

U. S. Geol. Survey, Washington, June 20, 1894.

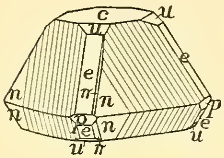
Art. XXVII.—*On Hemimorphic Wulfenite Crystals from New Mexico;* by Charles A. Ingersoll.

The crystals that will be described in this communication were found by Mr. William E. Hidden* at the Turquoise mines in the Jarilla Mountains, Doña Ana County, New Mexico, and were sent to Professor S. L. Penfield in the fall of 1892. They were implanted upon a brown siliceous gangue and were described by Mr. Hidden as occurring in seams in trachyte, associated with quartz, pyrite, chalcopyrite, malachite, gypsum, jarosite and kaolin. They were said to be of quite rare occurrence, only a very few having thus far been found, and are of especial interest on account of their peculiar hemimorphic and pyramidally hemihedral development.

* This Journal, III, xlvi, p. 401, 1893.

These crystals were small, measuring from one to two millimeters in diameter, white in color, subtransparent, and of a decided adamantine luster. Before attempting to measure any of them a careful blowpipe examination was made, and the mineral was found to be Wulfenite. Three crystals were selected as best representing the different habits of the mineral, and one of these (fig. 1) was chosen for crystallographic measurement. This was quite perfect, prominently hemi-

1.



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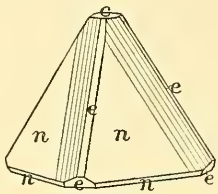

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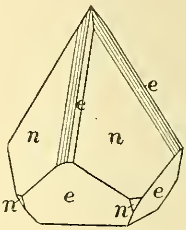


morphic in development, and more highly modified than any of the others. Its faces yielded remarkably distinct reflections of the goniometer signal, thus furnishing very accurate measurements of the interfacial angles. The forms that were observed, together with their hemimorphic occurrence, are as follows:

c,	001,	0	above and below.	*e*,	101,	1-*i*	above and below.
n,	111,	1	" " "	*p*,	$20\bar{1}$,	2-*i*	below only.
u,	102,	½-*i*	" " "	*π*,	313,	$\frac{1\text{-}3}{2}$	above and below.

Of the above forms *p* and *π* were here observed for the first time; moreover, they were found only on a single crystal (fig. 1).

The hemimorphic character of the mineral is shown in the occurrence of the *p* face, only in the lower portion of the crystal, as well as in the relative development of the other faces. The form *π* is present in the upper portion as a very narrow face, while below it is quite well developed. On all the crystals the lower *c* face is the larger, while the upper one is sometimes wanting (fig. 3). The development of the forms *n* and *e* on some of the crystals is very remarkable (figs. 2 and 3). A hemimorphic habit, similar to fig. 3, has already been observed by Breithaupt* on crystals from Berggieshübel in Saxony, which are described by him as being beautifully white, with adamantine luster.

* Handbuch der Mineralogie, II, p. 272, 1841.

The pyramidal hemihedrism is shown by a series of striations, resulting from an oscillatory combination of *n* with one of the adjacent *e* faces. This is found on all the crystals to the right of *n* only. Moreover, the form π is found only to the right of *e*. This development of hemihedrism in the pyramidal forms of Wulfenite is particularly interesting, since it has, hitherto, been observed chiefly in the prismatic zone.

The calculated angles in the following table were obtained from the fundamental measurement of Dauber,* $n \wedge n$, $111 \wedge \bar{1}\bar{1}1 = 131° 42'$, from which the length of the vertical axis, $c = 1{\cdot}5771$, is obtained.

	Measured.		Calculated.	
$n \wedge n$, $111 \wedge 1\bar{1}1$	80°	25′	80°	22′
$e \wedge e$, $101 \wedge \bar{1}01$	115	16	115	15
$e \wedge n$, $101 \wedge 111$	40	12	40	11
$u \wedge u$, $102 \wedge \bar{1}02$	76	20	76	31
$e \wedge u$, $101 \wedge 102$	19	20	19	22
$p \wedge p$, $20\bar{1} \wedge \bar{2}0\bar{1}$	144	31	144	50
$e \wedge p$, $10\bar{1} \wedge 20\bar{1}$	14	42	14	47
$e \wedge \pi$, $10\bar{1} \wedge 31\bar{3}$	15	42	15	43
$n \wedge \pi$, $11\bar{1} \wedge 31\bar{3}$	24	30	24	28
$\pi \wedge \pi$, $313 \wedge \bar{3}\bar{1}3$	117	56	117	56
$\pi \wedge \pi$, $313 \wedge 31\bar{3}$	62	8	62	4

In the above table the measured angles have been taken as the mean of four readings. No accurate measurements could be made on *c*, owing to its vicinal development. The occurrence of the new forms *p* and π is proved not only from the above measurements but from their positions in the correct zones.

It is probable that the isomorphous minerals, scheelite, powellite and stolzite are also hemimorphic; but as yet no forms have been observed which indicate this.

In conclusion the author wishes to express his thanks to Professor Penfield for assistance rendered during the course of this investigation.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, April, 1894.

* Pogg. Ann., cvii, p. 267, 1859.

Art. XXVIII.—*Notes on the Tertiary and later History of the Island of Cuba;* by Robert T. Hill.*

This paper is an abstract of a more extensive manuscript report made to Prof. Alexander Agassiz and is based upon a reconnoissance of most of the Island of Cuba, with the exception of the mountainous region of the Sierra Maestra the geology of which has been partially presented by Kimball in this Journal,† and studied contemporaneously with the writer's observations by Prof. Clarence King. My reconnoissance was accompanied by critical studies of certain typical localities at Havana, Matanzas, Villa Clara, Gibara, Baracoa and the vicinity of Cape Mayci.

The stratigraphy, age, and general relations of the rocks of Cuba have been set forth by De Castro,‡ and Salterain§ together with a good geologic map.

It is not necessary in this paper to dwell upon the details already presented. The geological structure of the Island consists of four stratigraphic units, to wit: (1) The Pre-Tertiary, Metamorphic and Igneous Foundation; (2) The Pre-Tertiary sedimentaries, mostly of Cretaceons age; (3) The Tertiary limestones; and, (4) The modern elevated coral reefs.

1. The Metamorphic and Igneous Foundation. The contemporary investigations of Prof. King in the Sierra Maestra will no doubt throw more light upon these formations than I can give.

These older rocks consist of diorites, serpentines, schists and granites as reported by Kimball from Santiago; of serpentines, green stone, porphyry and basic igneous rocks, fragments of which are brought down by the rivers of the north side of the east end of the Island; of serpentine and metamorphic rocks, with little quartz, as seen underneath the limestone in the vicinity of Villa Clara; and of serpentine, old volcanic material and tuffs, as seen back of Havana. They are exposed by erosion at various points throughout the island, but, with the exception of the Santiago region, seldom if ever, form the rocks of the immediate coast. They now underlie nearly every

* By permission of Prof. Alexander Agassiz through whose generosity the observations set forth in this paper were made possible.

† Geological Relations and Genesis of the Specular Iron Ores of Santiago de Cuba. This Journal, Dec., 1884.

‡ Pruebas Paleontologicas de que la Isla de Cuba ha Estado Unida al Continente Americano y breve idea de su Constitucion Geologica, por Don Manuel Fernandez de Castro. Discurso pronunciado en el cuarto Congreso internacional de Americanistas celebrado en Madrid en Setiembre de 1881.

§ Apuntes para una Description Fisico-geologica de las Jurisdieciones de la Habana y Guanabacoa, etc. por D. Pedro Salterain y Legarra, etc., Madrid, 1890.

part of the island at no great depth, and are exposed near both coasts in many cuts beneath the limestones. From their composition and occurrence there can be little doubt that they once formed an ancient land area almost as large as the present island which became almost or completely submerged during early Tertiary time. Wherever I have seen these rocks, at Villa Clara, Havana and near Baracoa, they have once been covered by the Tertiary limestones, but I cannot speak with certainty concerning the province of Santiago de Cuba, where, according to Kimball,* traces of limestone are preserved as high as 2,300 feet on the south side. On the north side, opposite Santiago, they are certainly overlapped far interiorward by the limestones.

Igneous rocks are rarely intrusive through the Tertiary limestone, no late igneous rocks having been seen by me except one small dike which intrudes into the folded Tertiary limestone near the water-works back of Havana. The presence of eruptives† and of sediments older than Tertiary, reported by DeCastro‡ and seen by me at a few points, and the unconformities testify that in pre-Tertiary time the old metamorphic floor protruded above the level of the sea as a land area, forming a nucleal region around and upon which the later formations were accumulated.

The pre-Tertiary sedimentaries.—Resting upon this metamorphic and igneous foundation at various places, there is a formation of stratified, non-fossiliferous sedimentary clays. These are older than the Tertiary limestone, but apparently immediately preceded them in origin. They have not great thickness and are without determinable fossils wherever I have observed them. In the Havana section a few feet only are exposed beneath the old limestone in contact with the underlying tuffs. They are here green in color and somewhat unctuous.

In traveling overland eastward toward Villa Clara, the limestones extend to beyond Colon; but between that place and San Pedro they are eroded through down to the underlying clay formation which extends from there continuously eastward to Villa Clara, being best exposed in the railway cut at Esperanza. Here the railway has cut across a low anticline of clays which show well-defined stratification and alternate strata of softer and harder beds. These clays are folded and slightly faulted in places.

*This Journal, Dec., 1884.

† The word eruptive is herein used in the restricted sense of igneous material which has protruded to the surface.

‡ Op. cit.

I could find no fossil remains except one poorly preserved plant impression, a monocotyledon, which, with the general character of the material gave the impression that these clays were deposited when the conditions of sedimentation were far different from those of the present. I cannot say positively that the Esperanza clays are identical with the clays at Havana, but they both occupy the same relative position between the limestones and the metamorphic formation, and are both exposed by the erosion of the overlying limestone. De Castro refers the clays of Esperanza to the Cretaceous period; upon what ground except stratigraphic position, I cannot say. He reports other Mesozoic sedimentaries at both ends of the Island together with Ammonites and Radiolites which would clearly indicate the occurrence of Cretaceous deposits in Cuba, but I had not time to study these.

The White Limestone Formations.—In strong contrast with the Esperanza clays and the older metamorphic floor are the Tertiary and later limestones which cover them, and which are the predominant geologic feature of Cuba.

The study and classification of the limestone group is difficult owing to the folding, induration, erosion, the thick covering, in places, of soil and vegetation, the universal alteration they have undergone through solution and internal changes, and the general concealment by tufaceous incrustations of well defined stratification planes and partings. They are clearly divisible into two general groups—the older and the newer. The latter consist mostly of unfolded rocks of undoubted coral-reef origin, and occur on the lower levels adjacent to the coast, while the former, if of coral-reef origin, have lost all characteristic proof of such origin, are undulated and folded and constitute the uplands and high coastal scarps against and around which the later coral rock was deposited.

The Older Limestones.—The more ancient limestones and accompanying beds constitute all the limestones of the Island seen by me above an altitude of 100 feet. They are very diverse in texture and composition. Where good exposures are obtainable they usually exhibit well defined stratification and separation planes, never seen in the undoubted reef rock, sometimes alternating with more marly or very slightly arenaceous layers. While it is in general cellular, a cubic foot of it in any locality exhibits great irregularity in hardness and compactness. There are spots so hard and crystalline that it is difficult to break them with a hammer; other portions are firmly crystalline and banded; while again there are soft, pulverulent layers. All of this difference in structure is of secondary origin, the result of alteration. In some places the cellular cavities are many feet deep, often extensively cavernous, while the remaining thin partitions are indurated into sharp edges of coarsely crystalline marble—a surface induration which I have also often noticed in the chalky Cretaceous limestones of Texas.

On the resisting summit points the rock is hardened and worn into Karrenfelder, while the steeper bluffs are thickly coated with tufaceous deposits. Great caverns abound in these rocks in many parts of the island. So completely has the work of solution and interstitial change gone on that the original nature of the rock is nowhere well preserved. It nowhere exhibits the enormous proportions or abundance of coral remains so apparent in the reef rock, but on the other hand there is an abundance of casts and moulds of molluscan shells, and I seriously doubt if it was originally a reef rock, as has been alleged.

I do not think the occasional traces of coral proves reef rock origin, for all corals are not reef building and the molluscan remains are far more abundant than those of corals. Neither can they be called chalks, although very foraminiferous in places, for they are too coarsely crystalline, and lack that fineness and uniformity of texture seen in the chalky limestones which I have had considerable experience in studying. In places at their basal contact they are certainly detrital, showing at the reservoir south of Havana, where they are in contact with the older series of clays and serpentines, a distinct conglomeritic structure, largely composed of shell fragments and beach wash. Near Villa Clara they contain very small fragments of igneous material derived from the older rocks which they buried. The limestones also contain alternations of other material which is clearly not of reef rock origin, such as the great beds of fine, siliceous and argillaceous material as noted at Matanzas and seen from thence east to Baracoa, forming thick strata of yellow material, containing, at least at Baracoa, Miocene mollusca. These slightly arenaceous yellow beds outcrop at Nuevitas, Gibara and many other places along the coast, and are included between thicker strata of limestone, and I think they are underlain by several hundred feet of the latter material, and belong above the limestone capping Junki and the Yumuri bluffs. These yellow beds underlie the Seboruco reef at Baracoa, and are capped by a thick stratum of old limestone back of the city; the harbor is largely formed by their undermining; they are also well developed beneath the old reef points of Mata Bay.

A peculiar rock material in the old limestone series at Baracoa and not seen elsewhere is a hill of almost vertically stratified siliceous material, which at first sight resembles gray chalk, but has the light specific gravity of some of the diatomaceous earths. Under the microscope this material is found to be largely composed of siliceous remains of minute Radiolarians. It is distinctly stratified, and contains occasional thin layers of a gray blue clay, and some secondary flint, in the form of nodules. It has clearly undergone great disturbance, as shown by the vertical arrangement of its beds, and apparently lies below the yellow beds, which are Miocene. The reservoir for the village water works is located upon the single hill where it outcrops on the southwest side of the harbor. The beds are over 500 feet in thickness; and I think they overlie the oldest of the limestones, but could not ascertain this with certainty. Neither this material nor the yellow beds which together constitute at least 500 feet of the Tertiary series, can be classified as of coral-reef origin.

In many places the Tertiary beds are distinctly stratified, as seen in the Castillo Principe plateau west of Havana, where they contain alternations of stratified argillaceous layers. Likewise at Matanzas, the older limestones exhibit every character of *sedimentary* deposition with molluscan remains, rather than of coral reef growth. At Baracoa, Nuevitas and elsewhere on the west coast the limestones are not only stratified, but they alternate with Miocene argillaceous and arenaceous beds of a yellow material, containing great numbers of molluscan fossils. In fact, I do not believe that any of the Tertiary limestones are of reef rock origin, but they are mostly organic and chemically derived marine sediments mixed with the calcareous debris of the life of the ocean's slopes, and rarely with an almost imperceptible proportion of the finer detrital sediments of the local land.

While these limestones and alternating beds have a great areal extent it would be a mistake to assign to them a proportionate thickness; accurate measurements will not make their thickness anywhere greater than 1000 feet. I estimated from the dips in the Rio Armendaris section that it was there from 800 to 1000 feet; the incomplete section in the cañon of the Yumuri of Matanzas reveals 800 feet; the cañon of the Yumuri of Baracoa shows 600 feet; the summit of Junki displays less than 1000 feet; while the section from 14 kilometers south of Havana to Batabano is not over 1000 feet. In fact, these limestones may be said to constitute a comparatively thin veneering over the old metamorphic floor.

The old limestone formations occur from end to end of the island and extend in many places completely across it down to the water level. Their continuity is interrupted only by erosion in spots along the central region. Only the low coast adjacent to the sea level is covered by later deposits. De Castro's geologic map of Cuba has, in an excellent manner, shown the general disposition of the old limestones. In places as between Mata and Yumuri they form the north wall of the coast. They cap the highest eminences of the island seen by me, overlooking all other rocks, being alone overreached in altitude by the Sierra Maestra. Their close proximity to the north coast and their abrupt protuberance above the newer formations has an important bearing on the history of the island as a whole. So extensive is this old limestone formation and so abruptly does it rise above the coast, that if all the coastal formations were stripped away or if the island should subside for 100 feet its superficial extent would hardly be perceptibly diminished, or its outline materially altered.

The greater part of these limestones examined by me are, as stated by Salterain and De Castro, of Eocene, Miocene, and Pliocene age. In the Armendaris section near Havana, they include both Eocene and Miocene as has been asserted by De Castro and others, and as shown by my collections. At Baracoa the upper layers are Miocene. De Castro, La Sagra and others have recognized the Tertiary age of these limestones and their distinctness from the modern reef rock.

The Post-Tertiary Folding.—The chief feature which separates the older limestone into a distinct system from the modern reef rock is the stratigraphic unconformity between them, and the fact that the former have undergone great folding and disturbance prior to the deposition of the latter, which are always sub horizontal. In no locality have I seen the newer reef rock folded or seriously pitched, but the older limestone is frequently tilted at an angle of 45° or even vertically as at Baracoa, and sometimes folded into anticlines as back of Havana; it presents every degree of folding and disturbance in the numerous railway cuts between Havana and Matanzas, at Villa Clara, Yumuri and elsewhere. In fact it is seldom if ever sub-horizontal on the north coast, and the later deposits are entirely unconformable with it. The general lay of the old limestone is that of a low anticlinal whose axis corresponds with that of the island, accompanied by folds more greatly developed along the north coast. This folding clearly took place at or soon after the close of Tertiary time, and prior to the deposition of the Post-Tertiary formations and elevations to be described, and indicates one of the most important epochs in the geological history of Cuba, representing as it does an orogenic disturbance not observed in continental North American history. There is evidence at Havana that there was some eruptive action at this epoch, dykes having been seen there which protruded through the Tertiary.

The Seboruco or Elevated Coral Reefs.—In strong contrast with the older or Tertiary limestones is the modern group of limestones of undoubted coral reef origin which border the coast in most places, or form small coral islets adjacent thereto, locally known as Seboruco.*

The elevated reef rock can always be recognized by the perfection and abundance of well preserved remains of reef making corals which form the greater proportion of the mass and by the absence of lamination or bedding planes. The formation averages about thirty feet in thickness, and usually extends inland only a short distance, often only a few yards, as on the northwest point of Moro Point, or not over an eighth of a mile as at Baracoa.

The Seboruco is a topographic as well as a stratigraphic feature, for its surface which was that of the old submerged reef represents a bench gently sloping to the sea; it has neither been covered by later deposits nor greatly denuded. It usually forms at the surf line a cliff about fifteen feet in height, against which the surf beats with great force, wearing deep indentations. The spray breaking over the summit produces the surface induration which is visible wherever rain or other moisture falls upon the hot limestones. This induration at Baracoa, for instance, has converted the reef rock in spots into a coarse saccharoidal marble, and aided in the segregation of small bodies of iron ore directly from it.

It is impossible here to describe all the localities where the Seboruco was observed. Sometimes, as along the Havana coast, it occupies a narrow strip extending from the point of one harbor to another. Again as on Moro peninsula opposite Havana it occurs only as a small patch in a small indentation in the old headland composed of folded Miocene rocks.

At Tanamo, and other places on the north coast the Seboruco not only forms the border of the mainland, but constitutes many islets bordering the same, with great areal extent. Generally these are low, standing only a few feet above the water.

There is a vast elongated archipelago of these elevated reefs bordering the coast all the way from a point east of Matanzas to Nuevitas. In the harbor at Nuevitas there are three islands known as Los Ballenatos which have great resemblance to the keys of the Bahamas, presenting a bold, rounded escarpment at the north point, and composed of yellow friable material,

* M. Ramon De La Sagra has defined this formation as follows: "L'autre formation de calcaire moderne, qui a recu dans le pays le nom de *seboruco*, se trouve le long de la côte, dans plusieurs endroits de l'ile; elle est tellement recente, que son agglomeration continue meme aujourd'hui, et c'est a elle que l'on doit les cayes les recifs et tous les bas-fonds de coraux. Les partes superieures s'elevent parfois a partir d'une profondeur de vingt a trente brasses. Toutes les inegalites de cette roche sont recouvertes d'une couche calcaire agglomerée avec des restes d'animaux, de coquilles, de coraux et de madrepores." Histoire Physique, etc. de l'Ile de Cuba, Tome I, p. 110.

which may have been either coral sand, or the yellow Miocene clays. It was impossible to get ashore or to examine them, although it was the only locality seen by me where there was a suspicion of an eolian formation. The greatest areal development of the flat Seboruco was found along the outlet to this harbor. It is found from Cape San Antonio to Cape Mayci on the north side of the island, and on the south side at many places especially at Guanabaco and Santiago, as described by Kimball.

Nowhere have I seen the elevated reef rock folded or otherwise disturbed except by the gently sloping coastward inclined elevation it has undergone. The interior margin I have never observed at a height of over forty or fifty feet. In general there is only one massive layer of this old reef rock exposed, but at Matanzas there is undoubted evidence of two older underlying reefs, the inner edges of which have been elevated with the modern reef so that they do not form distinct terraces. It may be that the almost continuous elevated reef around Cuba represents more than one of these layers. Whether one, or several alternations of reefs, the Seboruco as a whole certainly represents a recent and uniform elevation of the whole periphery of the island, at a very recent period of geologic time, but sufficiently long ago to permit of considerable alteration and erosion.

Cienegas.—Flat marshy alluvial deposits occur in many places, on the south coast. At Batabanos, opposite Havana, the coast for a mile or more inland is composed of ancient alluvial material apparently similar to a calcareous mud now depositing and forming the bottom of the adjacent sea for a mile out from land. These cienegas and cienega deposits are reported to have considerable extent at various places. The elevated portion is synchronous with the Seboruco elevation on the north coast.

A striking peculiarity, both of the older structures and the coast deposits of Cuba, is the scarcity—almost total absence—of arenaceous or sandy deposits. Nowhere is fine quartz sand found, such as accumulates around the northern border of the Gulf of Mexico, and the presence of pieces of quartz gravel in even the delta deposits is rare. This is owing to two reasons. (1) The formations of the Island—both the older metamorphic foundation and the limestones contain very little free quartz, and, (2) The littoral sands or sediments of the peripheral drainage of the Gulf are not transported as far south as Cuba, as already pointed out by Prof. Alexander Agassiz. Even the building sand of Havana and elsewhere is calcareous beach debris.

II.

Geologic History recorded by the Topography.

Having reviewed the fundamental rock structure upon which the sculpture of the land is dependent, we can now consider the general topography and its evolution. It is neither necessary nor possible to give a detailed description of the minute geography of Cuba, except so much as relates to the genesis of the island. Its shape and outlines have been described by various writers, notably Humboldt, Sagra and Reclus, and I shall only touch upon those details or generalities which will help elucidate its geologic history.

The Santiago coast is exceedingly mountainous, and is supposed in some way to be genetically connected with the mountain systems of the other Antilles. Concerning the composition, age, and topography of the mountain ranges we know but little except what has been told by other writers, to the effect that they approximately extend in an east-and-west direction, and tower far above the levels of the remaining portion of the island and occupy a very narrow strip close to the ocean's margin. Extending away to the north and west from this nucleal elevation is the main body of Cuba which is primarily a great limestone plateau deeply eroded and leveled, without any sharply defined central axis of higher elevation except the diverging headwater drainage flowing into the opposing seas. The highest elevations do not occur in a continuous ridge but are irregularly dispersed as if they were produced by the degradation of an elevated plateau resulting in the alternation of plains and irregular chains of hills, the latter often being nearer the margin than the center, and seldom over 2,000 feet in altitude.

The eminences called mountains seen by me, with the exception of the Sierra Maestra and kindred ranges of the Santiago coast, are mostly either (1) the direct remnants of the old limestone covering carved out by circumscribing erosion, or (2) inequalities in the ancient metamorphic floor from which the limestone has been denuded. The mountains of the former kind can be placed in two general classes according to their altitude and degree of erosion. First are the high limestone peaks, mesas, and ridges with a present altitude of from 1,000 to 2,000 feet. The Sierra Junki of Baracoa, the Pan de Matanzas, and the Tetas de Managua, are examples of isolated peaks, standing close to the north shore of the Island. Each of these is surrounded by deep cut drainage valleys and is many miles away from any masses of land of similar altitude. Their summits are made of the subhorizontal strata of old limestone, while the base of at least one, the Sierra Junki, consists of the older metamorphic rocks. The Sierra San Juan and the high ridges of the central portion of the island are remnants of the same old level, and differ from the more isolated summits in having been less eroded. These have no regularity of arrangement or trend, but are found in irregular patches throughout the island. Their slopes are entirely the product of solution and erosion.

The Spanish language to which our geographic nomenclature is already so much indebted, has provided an appropriate name for another class of mountains. These are the Cuchillas, or "knives" so called because of the numerous sharp salients marking their slopes, and caused by the deep incision of an old plain or general level of which they are the fast fading remnant. These are the sharply serrated hills, forming the sharp background to the coasts, especially at the east end of the island. Their summits never exceed 600 feet in altitude, and are clearly the remnants of a general plain of that altitude. The Cuchillas are generally composed of the old limestone which dips at many angles and degrees, but sometimes they consist of a complexity of limestones, yellow beds, Radiolarian beds, and the old metamorphic floor. At Yumuri and around Cape Mayci, they consist of a more massive and unbroken wall of the old limestone; but as we go westward they become more eroded, as illustrated by the high line of hills along the coast and the background against which the little harbors are cut out as far west as Nuevitas. Still westward the contour recedes slightly inland. On the south of Santiago coast the same level of the Cuchillas summits are preserved in diorite and syenite.

In addition to the limestone mountains of erosion described, there are many low hills in the central part of the island adjacent to Villa Clara and Puerto Principe which are clearly structural remnants of the older metamorphic floor from which the folded limestones have been eroded, the latter often being preserved on top of the higher elevations or sharply inclined around their edges. The series of sharply rounded hills between Havana and Matanzas is also the result of the wearing away of the limestone-covering down to a floor of tuffs and serpentines, which, owing to its softer nature is more deeply and sharply sculptured than the limestone regions proper.

Although the close of the Tertiary was marked by much folding, recognizable mountains conforming to the structural folds were not seen by me.

Terraces and Benches.—The most striking feature in the topography of Cuba is the well defined terraces and benches which mark its coasts in many places. These are often so distinct, especially at the east end of the island that their continuity is traceable for many miles, as they rise abruptly from the water's level one above the other in a series of cliffs. On the west end of the island they are not so distinctly visible from any single point of view, for the flat benches are much wider, but they are nevertheless traceable. In other places denudation has destroyed them.

Besides these benches and terraces whose integrity is distinctly preserved, remnants of older and more denuded plains can be traced. For convenience they may be classified as follows:

1. The Seboruco or elevated reef plain. 2. Elevated Beach and Cliff lines and the Havana terraces.	1. Later terraces.
3. The Cuchilla plain. 4. The Junki plain.	2. Older terraces.

1. *The Seboruco or Elevated Reef plain.*—This forms the lowest bench immediately adjacent to the entire north coast and along the Santiago front and is topographically and geologically the elevated coral reef. Synchronous with the formation of this beach the elevated *playa* deposits in the harbors and the elevated *cienega* or mud deposit on the south side of the Island at Batabanos were made.

2. *The Beach and Cliff Terraces.*—On the east end of the island the abrupt north coast is marked by three distinct and abrupt cliffs and terraces cut out of the steep slope of the old 600 foot Cuchilla plain or which forms the upland. The three terraces as seen in this region are so clear and distinct that they are readily visible at one view and their continuity is clearly traceable for miles. They are best displayed along the coast adjacent to the mouth of the Yumuri of the east. Here the river empties directly into the sea through a precipitous cañon affording a fine cross section of the terraces. The coastal scarp consists of three narrow sub-level benches each surmounted by a vertical cliff. Bench No. 1 is the first sub-level strip above the sea, constituting the present beach. This in general represents the level of the elevated reef which nearly everywhere forms the low lying coastal plain and breaks off at the sea in a surf wall some ten feet in height. Its interior margin against the base of the first great cliff is 40 feet high, and it nowhere exceeds 100 yards in width.

This lowest, Terrace No. 1, which usually consists of elevated reef rock is composed of alluvial gravel immediately off the cut of the river, and a quarter of a mile away to the eastward it is elevated reef rock. Several smaller beaches make up this lowest terrace, the uppermost of which is the specially well defined alluvial gravel plain.

This lowest beach abuts against a vertical cliff (No. 2) about 120 feet high (170 feet above the sea) worn out of the old white limestone. Its sides are vertical in most places and inaccessible. This cliff is in turn surmounted by another beach (No. 2) which likewise was formerly an old beach level, from which has disappeared any remnant of the old deposition that may have once existed. This bench is about a hundred feet in width and abuts against a second vertical cliff, the summit of which is nearly as high as that of the first one, or about 350 feet above the sea. The level bench (No. 3) mounting this cliff is similar in appearance to No. 2.

This last bench in turn abuts against the third and uppermost escarpment of the highland, which terminates, at a height of from 500 to 600 feet, in the irregular upland plain forming the fourth level above the sea. This is the general upland as it appears from the sea, and represents the old land from which was carved the group of sea cliffs above described.

All these cliffs and benches, and the cut of the river, are carved out of the old Tertiary limestone, which here forms an unbroken mass. No trace of terraced structure occurs within the vertical walls of the river cañon, showing clearly that the stream has cut its way downward across a rapidly rising land.

The country surmounting this highest escarpment forms a comparatively unbroken plateau overlooking the sea, at the eastern end of the island, but going westward, the increasing drainage cuts it more and more into numerous serrated hills known as the Cuchillas or "Knives," whose summits, with a general culmination of from 500 to 600 feet, are clearly remnants of the Yumuri Plateau. These coastal Cuchillas are a very conspicuous feature from Nuevitas eastward.

4. *The Junki or Higher plain.*—A single glance at the peculiar isolated mountain known as the Junki or Anvil situated six miles west of Baracoa is sufficient to show that its sublevel summit is the remnant of an ancient and higher plain than that represented in the Cuchillas. This is a magnificent butte whose summit is put upon the Pilot chart and estimated by Crosby to be 1800 feet high. The summit is an ovoid mesa, looking apparently level from below, but really having deeply carved drainage ways and an ancient topography indicative of long exposure. The upper portion is composed of a mass of the older Tertiary limestones, not coral reef rock as alleged by Crosby, 1000 feet in thickness, the perimeter of which is an almost inaccessible cliff. This rests upon the old Pre-Tertiary metamorphic nucleus. From this summit one can look down upon the Cuchillas, the Yumuri terraces, the elevated reefs and the wide expanse of the ocean ; and inland towards a country showing remnants of its own level, over-

reached by still higher mountains of the Sierra Maestra to the southward. On every side the drainage has cut deep below this peculiar mountain, carving the lowlying country into an intaglio of serrated hills.

No one can view this or other similar summits without being impressed with the story they tell of the great erosion which has taken place around them, as well as the fact that the difference in elevation between its plateau and that of the lower lying Cuchilla plain represents a vast hiatus in the history of the island's elevation—a long period during which land stripping and degradation ensued, reducing the surrounding areas to the old Cuchilla erosion level.

The levels represented in the three terraces of the Yumuri of the east have remarkable identity with the levels of the west end of the island, as at Havana and Matanzas, where my detailed studies were made. The only difference is that the latter are wider than the former, owing to the lower and more gently sloping country out of which they were cut. The correspondence in altitude is such that no one can doubt that they represent synchronous and identical regional movements and pauses, and that they were once continuous throughout the length of the north coasts of the island and around Cape Mayci to the Santiago coast.*

The Cuchilla, peneplain of the east, presents a resemblance to the higher summits back of Matanzas constituting the upland divide of the west end of the island in the latitude of Havana.

The oldest and highest limestone summits, about 1500 to 2000 feet in height, as typified in Junki, the Sierra del Moa, the Pan de Matanzas, the table land of Mariel, and the Managua paps of the west half of the island which follow near the north coast, the highest limestone of Santiago and other places, represent the remnant of the oldest and highest limestone levels which have been so dissected and planed down that, their extent can only be estimated. These elevations collectively may represent a higher land than existed before the Cuchilla plains were developed. Whether the high summits of the Sierra Maestra adjacent to the Santiago coast preserve traces of still older and more ancient levels is an interesting problem for the future. The interpretation of these levels cannot be finally given, without more extensive study, but the obvious history is as follows:

(1) In a period near the close of the Tertiary to be ascertained, previous to the emergence of the present elevated reef and the erosion of the Cuchilla plain, there was a great upward movement of the island to the height of at least 2000 feet,

* The levels of the Santiago region are described by Kimball in this Journal of Dec., 1884.

which as yet has revealed no history of its details, furthermore than this, that from the absence of later deposits and the character of its ancient and much sculptured topography we may fairly infer that it has not since subsided beneath the sea, but has remained mostly dry land and that its area and outline were very nearly as great as those of the island to-day. This includes those portions of the island above the dissected Cuchilla plains. (2) The Cuchillas, or 600 foot level, represent a plain which was produced by base levelling in the epoch following this oldest period of elevation and represents the time interval between it and the later movement recorded in the first or lower group. The country was planed down by erosion to near sea level; it indicates a long interval between the old Junki and the renewed modern elevation recorded in the Yumuri cliffs cut around them. (3) The Tripartite group of modern cliffs, and the base levels below and cut out of the Cuchilla escarpment, are the product of a renewed and modern upward movement which elevated the old Cuchilla base level to a plateau, and subjected it to the erosion which has since cut it into its present rugged outlines. The Yumuri cliffs were carved from it where it formed a sharp coast scarp, and the Havana and Matanzas benches represent synchronous levels with the latter in the west end of the island where the Cuchilla plain was of less extent. This modern group of elevations was intermittent as is shown by its alternate cliffs and terraces. The modern Seboruco represents the latest and newest regional uplift.

The elevated benches and terraces which border the coast of Cuba with the single exception of the Seboruco or modern coast reef, are not ancient coral reefs either topographically or lithologically, as has been asserted; on the other hand they are beach and erosion plains, produced during a rapid elevation of the island in Post-Tertiary time and carved from various formations principally the older limestones, regardless of structural arrangement and composition. Even if the old limestones are coral-made these old terraces can in nowise be interpreted topographically as elevated reefs, for none of the original reef topography is preserved. On the other hand I can give numerous instances where the same levels are carved out of varying component material which was much folded or disturbed prior to their erosion.

The series of terraces around Cape Mayci and Yumuri are carved out of a massive matrix of old limestone of undulating structure. The terraces at Matanzas are cut out of a series of beds of widely divergent lithologic composition, and all dip at angles from ten to twenty-five degrees. The Moro and Principe Plateau at Havana is a planation surface upon a floor of folded limestone, in which a distinct anticlinal structure can be traced. The terrace upon which the Military Hospital at Baracoa is situated is carved across the almost vertically inclined edges of the older Miocene limestones. The summit of Junki instead of being coral reef is a greatly degraded peneplane. The Seboruco alone of all the levels is topographically an elevated reef and this, as before stated, does not rise anywhere over 50 feet above the sea.

Lack of Evidence of Subsidence.—The writer was unable to discover positive evidences of subsidence after the beginning of Tertiary time, or accompanying these elevations, although it would be rational to think that the movements must have been oscillatory. I failed to find any traces in the upland areas of recent deposits which would indicate any extensive submergence. The soils are everywhere residual, and nowhere did I observe any that could be attributed to transported material or overplacement of marine sediment, and particular care was taken to look for such evidence. Castro reports extensive upland alluvial deposits in the region of Puerto Principe, but gives no evidence whereby we may determine whether they were produced by upland lacustral deposition or submergence of the land to sea level. Nowhere do the rivers show any revival or other evidence of such subsidence, but all have continuous downward cutting sections.

Whether there has been recent subsidence immediately preceding the deposition of the elevated coral reef or Seboruco, whereby the circular harbors were produced as Crosby alleges, is also a point which I cannot accept, though difficult to determine. He advances in support of his position the structure of the circular harbors and the great thickness of the older limestones which he believed to be ancient reef rock. I have endeavored to show that there is no evidence to support the theory that the older elevated limestones were coral reefs in origin, and hence it is not necessary to here discuss this testimony further.

Concerning the mouths of the rivers themselves, their alluvial deposits and the evidence of their valleys may be interpreted to mean elevation more positively than Mr. Crosby interprets them to mean subsidence, nor can I understand why he calls them "half drowned." There is a singular absence of fiord-like valleys or indentations or of ancient estuarine deposits around the coast of Cuba, such as ordinarily indicate subsidence. In fact the rivers in nearly all cases, like the Yumuri of the east, run directly to sea level through almost vertical chasms cut directly across the line of terraces, and are void of any terraces within their cañons, showing unmistakably that they have cut down to sea level across the terraces.

That some of these rivers do at present reach tide level a short distance from the beach is true, but so short is this distance that vessels can always obtain fresh water from them by sending light boats up them less than a mile from where they enter the seas or harbors. I do not think that this slight indentation of tide level up these rivers is indicative of "drowning" or an ancient subsidence; on the contrary, it merely means that the rivers and surf are doing their normal work of degrading the land. If there were really drowned rivers they would be navigable some distance inland, but in case of the three largest streams, the Armendaris of Havana and the two Yumuris of Matanzas and Baracoa I found it impossible to go inland over a mile in the shallowest row boat, being soon retarded by rapids.

On the other hand some of these streams are now forming delta deposits in places outside their mouths, which is more indicative of present elevation than of subsidence. Furthermore, the Yumuri of the east formed similar deltas before the elevation of the coast reef. At any rate, if there had been any serious epochs of subsidence, they would be recorded in great fiord-like valleys or low passages across the central axis of the Island, such as do not exist, and to which the oval harbors may not be compared, for their origin is entirely due to the pre-existing fringe reefs.

On the other hand, it might be alleged that all the ancient topography of subsidence is still beneath the ocean level, and that the angular edges of Cuba are indicative of the fact that the present outline merely represents an ancient summit which is re-emerging. The submarine topography, however, is not within the province of this paper, but I agree with Prof. Agassiz that its irregularities were indicated long before the present history treated, in this paper. The three alternations of gravel and reef in the Matanzas section may also have indicated slight alternations of subsidence and elevation.

It is now possible with the aid of the stratigraphic and paleontologic data previously given to make a few conclusions concerning the Cenozoic history of Cuba. It has been shown by the stratigraphy that the topographic levels are not old reef levels but with the exception of the modern reef, have all been carved out of the previously folded and disturbed Tertiary limestones, and hence the present bench topography of Cuba originated subsequently to this period of Post-Tertiary wrinkling and represents a different kind of movement which was regional or epeirogenic. Since the old folding or orogenic movements occupied at least a small portion of Post-Tertiary time, we may reasonably conclude that the periods of uniform uplifting recorded in the old levels must have taken place at least since the beginning of the Pleistocene. In other words they are comparatively modern in geologic time—some of them absolutely recent.

It is not maintained in this paper that these epochs of regional elevation were continuous and uninterrupted, or unaccompanied by pauses or even alternating epochs of subsidence, but the general progress of the island has been periodically upward and if there were epochs of subsidence they are difficult to distinguish and were of short duration and insignificant in comparison with the great uplifting movement that has generally progressed.

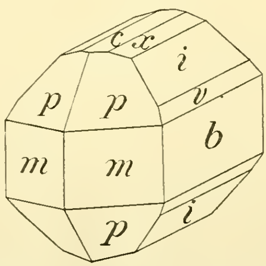
Art. XXIX.—*Mineralogical Notes on Cerussite, Calamine and Zircon*; by J. H. Pratt.

1. *Cerussite.* — The mineral occurs at the Judge Mine, Black Hawk, Meagher Co., Montana, and was collected, through the kindness of Mr. Davis, foreman of the mine, by Mr. L. V. Pirsson, during the summer of 1893 while engaged in field work on the U. S. Geological Survey.

It is associated with several ores of lead resulting from the decomposition of galena, the main constituent of the ore body. The mineral is found in pockets in the form of rough masses, at times as large as one's fist, showing an occasional broad crystal face. These fragments are remarkably clear and free from foreign inclusions. Attached to these are small bright crystals, both simple and twinned. Their faces are generally smooth, giving very good reflections of the signal when measured on the reflecting goniometer.

Specimens of the simple crystals which are represented by fig. 1, were found so attached to the rest of the mineral that

1.



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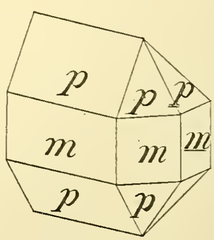


the faces on both ends of the lateral axes were developed and could be measured. The forms observed on them are:

b (010, *i*-$\breve{i}$)	*x* (012, $\frac{1}{2}$-$\breve{i}$)	*v* (031, 3-$\breve{i}$)
c (001, *O*)	*i* (021, 2-$\breve{i}$)	*p* (111, 1)
m (110, *I*)		

The greater part of the crystals observed however were twinned; the twinning following the common method in which the twinning plane is the unit prism *m*, *I*, 110. These crystals are represented by fig. 2. As shown in the figure, the crystals are extended in the direction of the twinning plane and are so attached against the smooth surfaces of larger crystal faces that the twinned pinacoids at the other end are wholly wanting, the crystals being cut square off at this point as in the figure. They resemble strongly the untwinned ones.

The following table shows the identification of the forms by calculated and measured angles. For obtaining the calculated angles the elements of Koksharov* have been used in which,

$$\breve{a} : \bar{b} : \grave{c} = 0{\cdot}609968 : 1 : 0{\cdot}723002.$$

	Calculated.	Measured.
$m \wedge m$, $110 \wedge 1\bar{1}0$	62° 45′ 50″	62° 45′, 62° 45′, 62° 45½′
$m \wedge p$, $110 \wedge 111$	35 46	35 46, 35 45, 35 46½
$p \wedge p$, $111 \wedge 1\bar{1}1$	49 59 30	49 58, 49 57½
$c \wedge x$, $001 \wedge 012$	19 52 30	19 49, 19 51
$c \wedge i$, $001 \wedge 021$	55 20	55 19, 55 19
$c \wedge v$, $001 \wedge 031$	65 15	65 9, 65 11
$m \wedge m$, $110 \wedge 110$ (twin)	54 28 30	54 28, 54 29, 54 26
$m \wedge p$, $110 \wedge 111$ "	43 36 30	43 39½

2. *Calamine.*—So far as the author has been able to dis cover no calamine from any American locality has been described with respect to crystal habit and it has been thought that a brief description of crystals from some of the occurrences, with figures, would be of interest and not without value.

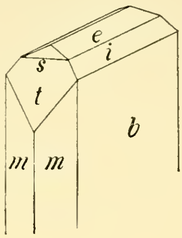
Specimens of this mineral from the majority of American localities rarely show distinct isolated crystals, but rather, masses of them agglomerated together upon the brachy pinacoid, into rounded forms similar to prehnite and these pass into indistinct botryoidal and even earthy amorphons crusts.

In the fine suite of specimens in the Brush collection were found some from Sterling Hill, New Jersey, and from the Harriet and Maid of Erin Mine, Clear Creek Co., Colorado, which contained separate distinct crystals suitable for measurement on the reflecting goniometer. They all show the same habit being thin tabular on *b*(010) and also extended so greatly in the direction of the vertical axis as to form long slender, delicate, needle-like forms.

* As given in Dana's Mineralogy, sixth edition, 1892, page 286.

The crystals from the first mentioned locality are terminated by brachy- and macro-domes as represented in fig. 3. No doubly terminated ones were observed, all being attached upon the pyramidal or antilogous end. The prism faces are more or less striated but not so greatly but that sufficiently accurate measurements could be obtained to identify them. The domes

3.



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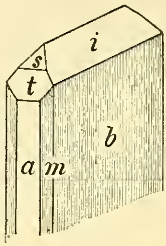


were bright and smooth and gave very good reflections of the signal. The faces observed on these crystals are as follows:

b (010, *i*-ĭ)	*s* (101, 1-ī)	*e* (011, 1-ĭ)
m (110, *I*)	*t* (301, 3-ī)	*i* (031, 3-ĭ)

The crystals from Clear Creek Co., Colorado, as shown by specimens in the Brush collection occur in cavities in hematite. They are similar to those from Sterling Hill but have in addition the macro-pinacoid *a* (100, *i*-ī), while *e* (011, 1-ĭ) is wanting. These crystals which are represented by fig. 4 are so greatly striated that no measurements could be made in the prism zone.

The following table gives the calculated and measured angles. For obtaining the calculated ones the elements of Schrauf* have been used in which

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}78340 : 1 : 0{\cdot}47782.$$

	Calculated.	Measured,
a ∧ *s*, 100 ∧ 101	58° 37′	58° 40′, 58° 40′
a ∧ *t*, 100 ∧ 301	28 39 30″	28 38 30″, 28° 35′
b ∧ *i*, 010 ∧ 031	34 54	34 51
i ∧ *i*, 031 ∧ 0$\bar{3}$1	110 12	110 11 30
e ∧ *e*, 011 ∧ 0$\bar{1}$1	51 5	51 11
m ∧ *m*, 110 ∧ 1$\bar{1}$0	76 9	76 36

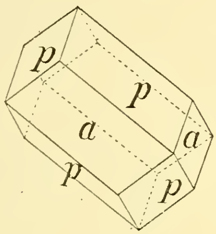
Zircon.—In a recent paper Prof. F. D. Adams† has described the occurrence of a large area of nephelite syenite from the townships of Dungannon and Faraday, Ontario, and

* Dana's Mineralogy, sixth edition, page 546.
† This Journal, vol. xliii, p. 10, 1894.

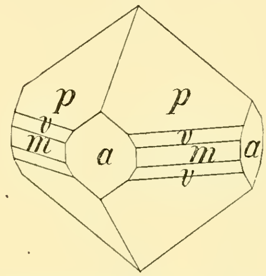
mentions zircon as one of the rock constituents. Some specimens of these zircon crystals have been sent to this laboratory recently by Prof. Adams for crystallographic investigation and as they present several points of interest a brief description of them is given here.

The crystals occur imbedded in the usual manner in the rock, from which they can readily be separated in a nearly perfect condition. They show two quite different habits, one, represented in fig. 5 in which by the development of two opposite pairs of the pyramidal faces together with a pair of the prisms of the second order, the crystal becomes columnar

5.



6.



in this direction and mimics a hexagonal prism of the second order terminated by rhombohedral faces. The only forms observed on these are:

a, *i-i*, (100); and *p*, 1, (111).

In the second habit the pyramidal faces are strongly developed, while the prism faces are short or lacking altogether. These crystals represented by fig. 6, show the following forms.

a, *i-i*, (100); *m*, I, (110); *v*, 2, (221); *p*, 1, (111).

The crystals are well suited for measurement and give fair reflections of the signal on the goniometer. In the following table of calculated and measured angles, the elements of Kupffer* were used to obtain the calculated angles, where,

Axis $c' = 0{\cdot}640373$.

		Calculated.	Measured.
$m \wedge p$,	$110 \wedge 111$	47° 50′	47° 42′ 30″
$m \wedge v$,	$110 \wedge 221$	28 54	28 52
$a \wedge p$,	$100 \wedge 111$	61 40	61 38
$p \wedge p'$,	$111 \wedge \bar{1}11$	56 40 26″	56 38
$p \wedge p''$,	$111 \wedge \bar{1}\bar{1}1$	84 20	84 16

In conclusion the author desires to express his thanks to Mr. L. V. Pirsson for valuable aid during the progress of the work.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, June, 1894.

* Dana's Mineralogy, sixth edition, p. 482.

ART. XXX.—*The Reduction of Arsenic Acid by the Action of Hydrochloric Acid and Potassium Bromide*; by F. A. GOOCH and I. K. PHELPS.

[Contributions from the Kent Chemical Laboratory of Yale College—XXXIV.]

IT was shown in a a former paper from this laboratory* that arsenic acid may be easily reduced by the simultaneous action of hydrochloric acid and potassium iodide, and more recently † this reaction has been successfully applied to the rapid detection of arsenic in presence of antimony and tin, and of antimony and tin associated with arsenic. This paper is the account of work in the course of which it became evident that the action of hydrobromic acid upon arsenic acid is so similar to that of hydriodic acid that potassium bromide may with propriety, and even with advantage, be substituted for the iodide in the process of reduction.

The apparatus which we have used in this work is similar to that employed previously, and is essentially a Mohr's distillation apparatus—consisting of a small flask, of from 25^{cm^3} to 50^{cm^3} capacity, fitted by means of a pure rubber stopper to a pipette which was bent, drawn out at the lower end, and dipped into a test-tube supported and cooled in an Erlenmeyer flask nearly filled with water. The arsenic was introduced into the flask in the form of the pure crystallized dihydrogen potassium arseniate which was dissolved with 3^{grm} of potassium bromide in 5^{cm^3} of water, and 5^{cm^3} of hydrochloric acid of full strength (sp. gr. 1·20) were added. The end of the pipette tube was dipped into 5^{cm^3} of hydrochloric acid of half strength contained in this test tube used as a receiver, and the distillation was carried on until the liquid in the flask had almost entirely passed to the receiver. The residue was treated with 10^{cm^3} of the strongest hydrochloric acid, and the distillation was repeated with the modification that this time the condensation was effected by passing the volatile material into 10^{cm^3} of water, so that the liquid in the receiver at the end of this operation should have the acidity of hydrochloric acid of half strength. This process of treating the residue with the strongest hydrochloric acid and distilling was continued until arsenic ceased to be discoverable in this distillate. At the beginning of the distillation bromine is liberated and collects in this distillate; but later, as the arsenious chloride volatilizes and condenses again, the color of the bromine in the distillate vanishes with

* Gooch and Danner, this Journal, xliv, 308.
† Gooch and Hodge, this Journal, xlvii, 382.

the simultaneous reconversion of the arsenic to the higher form of oxidation. In such a solution, especially if it is not very hot, hydrogen sulphide precipitates the arsenic only slowly, but the addition of a little stannous chloride dissolved in hydrochloric acid of half-strength to the hot solution reduces the arsenic to the lower form of oxidation and prepares the way for the immediate precipitation of arsenious sulphide by hydrogen sulphide. Antimonic acid is likewise reduced under the conditions of the distillation; but, as Koehler has shown,* neither small amounts of antimony and tin, which if present originally may pass partially to the distillate, nor the tin added to effect the reduction of the arsenic finally, will be precipitated by hydrogen sulphide under the existing conditions of temperature and acidity.

The results of experiment are recorded in the accompanying table.

	Arsenic taken as H_3AsO_4 grm.	Antimony taken as H_3SbO_4 grm.	Tin taken as $SnCl_4$ grm.	Precipitation by H_2S in successive distillates after treatment with $SnCl_2$	Precipitation by H_2S in the residue dissolved in water.
(1)	----	----	----	I None	None
(2)	----	----	----	I–X None	Faint coloration
(3)	0·0001	----	----	I Found; II None	None
(4)	0·0010	----	----	I Found; II None	None
(5)	0·0100	----	----	I–II Found; III None	None
(6)	0·1000	----	----	I–III Found; IV None	Faint coloration
(7)	0·4000	----	----	I–VI Found; VII None	Orange precipitation†
(8)	1·0000	----	----	I–X Found; XI None	Orange precipitation†
(9)	----	0·4000	----	I None	Large
(10)	0·0001	0·4000	----	I–II Found; III None	Large
(11)	0·0001	0·0001	----	I Found; II None	Distinct color
(12)	0·0010	0·0001	----	I Found; II None	Distinct color
(13)	0·0100	0·0001	----	I–II Found; III None	Distinct orange
(14)	----	----	0·4000	I None	Large
(15)	0·0001	----	0·4000	I–II Found; III None	Large
(16)	0·0001	----	0·0001	I Found; II None	Distinct color

* Zeit. für Anal. Chem., xxix, 192.

† Subsequently identified as antimony sulphide by depositing the metal on platinum.

Whenever antimony was introduced intentionally it was taken in the form of antimonic acid produced by oxidizing by bromine in alkaline solution tartar emetic purified by boiling with hydrochloric acid until the distillate contained no trace of arsenic. The stannic chloride employed was similarly purified by boiling in strong hydrochloric acid.

It will be seen that no indication was given by hydrogen sulphide either in the distillate or residue when the hydrochloric acid (10^{cm^3}) and the potassium bromide (3^{grm}) were treated in blank. When the bromide was treated in blank ten times successively no indication was obtained in any individual distillate, but the residue showed a trace of color which was apparently intensified by the action of hydrogen sulphide. This effect was slight and probably due to the prolonged action of the acid upon the rubber. It is not sufficient to interfere with the detection of $0{\cdot}0001^{grm}$ of antimony—as subsequent experiments showed.

A single distillation, requiring but three or four minutes, proved to be sufficient for the complete volatilization of $0{\cdot}0010^{grm}$ of arsenic, two distillations were enough to remove $0{\cdot}01^{grm}$, and three $0{\cdot}1^{grm}$ of arsenic. In handling larger amounts of arsenic, $0{\cdot}4^{grm}$ or $1{\cdot}^{grm}$, it became evident that the presumably pure arseniate actually contained a trace of antimony, and the efficiency of the bromide treatment in effecting the detection of a little antimony in presence of a large amount of arsenic is clearly shown. It is plain that while the presence of large amounts of antimony and tin tend to diminish the rapidity of volatilization of the arsenic, the detection of $0{\cdot}0001^{grm}$ of arsenic is always sure, and that antimony and tin if originally present in appreciable amount will always be discoverable in the residue.

In a comparison of the results of these experiments with those recorded in the former paper describing the reduction by means of potassium iodide, it appears that in general fewer distillations are needed to effect the transfer of the arsenic to the distillate when the bromide is employed—a condition of affairs which is doubtless due to the fact that in the former treatment an insoluble and somewhat refractory precipitate of arsenious iodide is formed when large amounts of arsenic are present, while the bromide causes no precipitation of the arsenic, and interferes in no way with the distillation of the reduced product.

ART. XXXI.—*On the Occurrence of Leadhillite in Missouri and its Chemical Composition;* by L. V. PIRSSON and H. L. WELLS.

LEADHILLITE, the hydrated sulphato-carbonate of lead, is a rare mineral, occurring in but a few places in Europe and having been reported from but three localities in this country.*

It is therefore a matter of interest to announce a new occurrence in America, and as the exact chemical composition of the mineral has been uncertain and the material is well suited for mineralogical and especially for chemical investigation, these have been undertaken with the results given in the present article.

Our attention was first called to this occurrence by Messrs. English and Co., of New York City, who sent us some specimens for identification and we take great pleasure in expressing our thanks to these gentlemen for the very liberal manner in which they have placed an abundant supply of fine material at our disposal for this investigation.

The mineral occurs near Granby, Missouri, and has been probably formed by the action of water, carrying carbonic acid and oxygen in solution, on galena.

The specimens which we have studied consist of masses and crusts often apparently pseudomorphous after the original lead ore and consisting mainly of massive cerussite, mingled possibly with other lead salts. The leadhillite occurs implanted upon this in well defined crystals or in aggregated groups studding the interior of cavernous portions of the amorphous crusts.

The isolated crystals are often quite perfect, in rather slender, apparently hexagonal prisms attaining a length of 50^{mm} and terminated at either end by the basal plane. More commonly, however, they occur in rather thick hexagonal tables, at times 1^{cm} in breadth, numbers of which are grouped together in parallel position or consisting of repeated twins. When these occur lining cavities only the front half of the crystals are often developed, and as they extend to right or left or rise one above the other, all in parallel position, they represent in miniature precisely the appearance shown by columnar cliffs of basalt whose broken off hexagonal columns rise step-like above each other.

In these cavities they are often associated with slender, striated, glittering prisms of cerussite, occurring at times in fine twins, the twinning plane being the prism r (130).

* Newberry Dist.; Spartanburg Dist., No. Car. by Shepard and from the Schultz gold mine in Arizona, by Penfield, cf. Dana's Min. 6th ed., p. 922, 1892.

In color the leadhillite varies from colorless in the smaller crystals which are often beautifully clear and limpid, to an exquisite clear sea-green in the larger translucent individuals.

From their freshness, high luster, delicate tints, size and good crystallization these specimens are by far the most striking ones of this mineral that have come under our observation.

Crystallography.—From a crystallographic standpoint the mineral from this new locality is very simply developed, the majority of the crystals appearing like simple hexagonal prisms terminated by the base and consisting of the forms *c*, *o*, (001); *m*, *I*, (110) and *a*, $i\text{-}\bar{\imath}$ (100). Often the positive hemidome *e*, $2\text{-}\bar{\imath}$, $(\bar{2}01)$ is present and the crystals have the habit shown in fig. 1. More rarely the negative hemidome *u*, $-2\text{-}\bar{\imath}$ (201), and the ortho-pyramids *q*, $1\text{-}\bar{4}$, $(\bar{4}14)$ and μ, $\frac{1}{2}\text{-}\bar{4}(\bar{4}18)$ occur and these are shown in fig. 2, which represents the most

Fig. 1.

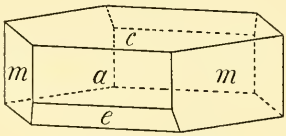
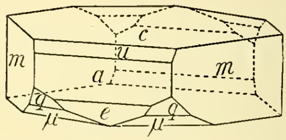


Fig. 2.



complex form observed. These have been identified by the following angles measured on the reflecting goniometer. For the calculated angles the elements derived from the measurements of Laspeyres* have been used in which

$$\acute{a} : \bar{b} : \acute{c} : : 1{\cdot}74764 : : 1 : 2{\cdot}21545, \text{ ang. } \beta = 89^\circ\ 47'\ 38''.$$

	Calc.	Meas.
$c \wedge a$ $(001 \wedge 100)$	89° 47′ 38″	89° 38′, 89° 37′ = ang. β.
$m \wedge m$ $(110 \wedge 1\bar{1}0)$	120 27	120 22
$c \wedge m$ $(001 \wedge 110)$	89 54	89 39
$c \wedge e$ $(001 \wedge \bar{2}01)$	68 39	68 54 69 04
$c \wedge u$ $(001 \wedge 201)$	68 18	68 27
$c \wedge q$ $(001 \wedge \bar{4}14)$	54 16	54 14
$c \wedge \mu$ $(001 \wedge \bar{4}18)$	34 09	34 37

The above measurements represent the best obtained; as a general rule the reflections of the signal are poor in spite of the brilliancy of the luster, owing to the fact that the crystals are usually much striated by lines parallel to the trace of the basal plane and are moreover often slightly curved or twisted. The measurement of $c \wedge a$ $(001 \wedge 100)$ = ang. β was one of the best and obtained on a small crystal which gave good reflections and was free from distortion; it is somewhat less than

* Zeit. f. Kryst., i, p. 199, 1877.

that given by Laspeyres and approaches the angle measured by Artini* on the Sardinian mineral, ang. $\beta = 89° 31' 55''$. The plane μ, $\frac{1}{2}$-$\bar{1}$, ($\bar{1}$18) first mentioned by Artini, is easily identified in the present occurrence by its lying in the zone $\bar{1}10 \wedge 001$ and by the measurement on the base. It may be mentioned here that all the faces shown in fig. 2 have been greatly exaggerated except the pinacoids and prisms, in order to exhibit them better.

One of the most marked peculiarities of leadhillite is its close approach to hexagonal symmetry in certain of its forms. Thus we have,

$a \wedge m$	$100 \wedge 110$	$= 60° 13' 30''$
$c \wedge u$	$001 \wedge 201$	$= 68\ \ 18$
$c \wedge e$	$001 \wedge \bar{2}01$	$= 68\ \ 39$
$c \wedge x$	$001 \wedge 111$	$= 68\ \ 31$
$c \wedge r$	$001 \wedge \bar{1}11$	$= 68\ \ 42$

A combination of these planes evidently could not be distinguished by the eye alone from a hexagonal prism terminated by a hexagonal pyramid. The crystals from Missouri often appear strongly rhombohedral from the fact that they have the habit shown in fig. 1, and are repeatedly twinned on the unit prism. Where the edge between the base and a face in the prism zone is replaced by a single plane as in fig. 1, and the reflections are poor it is often impossible to locate this plane and orient the crystals.

The examination of a cleavage plate in convergent polarized light gives the trace of the axial plane, however, and enables one to decide at once between the pyramids and hemidomes given in the above table, but since the inclination of the angle β is so slight it is still impossible to tell whether they are in the obtuse or acute angle. In the present case the orientation adopted is that given by the agreement between the best measurements and the calculated angles and as these are very close it is regarded as undoubtedly correct.

Twinning.—As previously mentioned twinning on the unit prism is very common. Cleavage plates in polarized light are also seen to contain lamellæ twinned in this way.

Cleavages by reflected light rarely present a perfectly plane surface, but are covered with slight re-entrant and salient angles in all directions, which reflect, on the goniometer, numerous scattered images of the signal.

If the mineral was orthorhombic it is evident that the bases of the intergrown twinned, individuals would all lie in one plane, but as it is really monoclinic these small, apparently vicinal angles are due to the slight inclination of $a\,(100) \wedge c\,(001)$.

* Giorn. Min., i, 1, 1890.

They are not sufficiently large, however, to prevent a simultaneous production of cleavage over the twinned individuals as a whole.

In some cases it appears as if the composition face in twinning was the base (001). Certain cleavage plates examined in convergent light display two axial images superimposed upon each other, the lines joining the focal points of the lemniscate figures being at angles of 60°. Such a method of twinning is like that of the micas and chlorites which indeed leadhillite with its pronounced basal cleavage and simulation of hexagonal symmetry resembles.

To this may be due as suggested by Groth* the optical character of the doubtful mineral susannite which was determined to be uniaxial by Bertrand† on material from Matlock and which we have confirmed by examination of a cleavage plate from a single specimen from Leadhills in the Brush collection.

Physical properties.—The *cleavage* parallel to the base is very perfect and easily produced. The *luster* of the natural basal plane is pearly, while that of cleavage plates is sometimes pearly and sometimes adamantine like that of the faces in the prismatic zone. The luster of the ortho-pyramids is often dull or lacking, resulting from innumerable microscopic pittings. The *hardness* is nearly 3. The *specific gravity* is 6·54, which agrees almost exactly with Hintze's‡ determination, 6·547, for the Sardinian mineral. Our determination was made on a chemical balance at 25° C. with a pure solid fragment weighing over 2 grm. The precaution was taken to remove air before weighing in water, by placing the fragment under water in a vacuum. To use boiling water at 100° for this purpose is inadmissible, because when the mineral is heated in water to this temperature, it becomes filled with a multitude of cracks and afterwards falls to powder upon the application of a slight pressure.

Optical properties.—Cleavage plates being clear and colorless furnish excellent material for optical investigation. The axial plane is, as in all known occurrences, parallel to *a* (100) and the acute bisectrix practically perpendicular to *c* (001). The optical character is negative. The angle of the optic axes is small and the dispersion sensibly large, $\rho < \upsilon$. This was confirmed by measurement of a plate with the large Fuess axial angle apparatus at 25° C. with these results.

$$2\,E_{Tl} = 20°\ 27'$$
$$2\,E_{Na} \doteq 20\ \ 08$$
$$2\,E_{Li} = 18\ \ 52$$

* Tabel. Uebesicht. Min., 1889, p. 62.
† Compt. Rend., lxxxvi, p. 348, 1876.
‡ Pogg. Ann., clii, p. 256.

This agrees pretty closely with the observations of Descloizeaux* and of the other investigators mentioned in this article. Bertrand† gives 2 Ey=72° for the mineral from Matlock, and as it exhibited other optical anomalies mentioned by him the occurrence appears to need confirmation by chemical analysis.

As usual the optic angle diminishes rapidly with increase of temperature. Plates placed on the heating attachment for the microscopic of Fuess became uniaxial when the thermometer registered about 100°C.; the plates themselves, being exposed to the air, were at a somewhat lower temperature. During the process the turning lamellæ disappear as noted by Hintze‡ and Mugge§ and the plate becomes uniform in polarization. In the course of a day or so the uniaxial character disappears and the normal one is resumed. This change seems to be due to molecular rearrangement as the mineral does not suffer any chemical change, as shown by the careful experiments of Hintze.‖

Etching figures.—The monosymmetric character of leadhillite is well shown by the form and disposition of the etching figures produced on the basal surface of cleavage plates by very dilute nitric acid.

After the action of the acid has continued a few moments and the surface has been rinsed and cleaned with water, it is found to be covered with delicate markings. With high powers of the microscope these are resolved into shallow pits whose outline on the surface is the projection of a nearly equilateral spherical triangle.

One side of the triangle is tangential at its middle point to the trace of the orthopinacoid (100) on the base (001) while the opposite angle is bisected by the symmetry plane. The sides of these depressions curve towards each other as they descend and either end in a dihedral angle or in a small plane which truncates it.

Thus the character of the figures produced by etching is precisely similar to that of the micas described and figured by Baumhauer¶ and shows the monoclinic symmetry in the same way.

When the action of the acid is more rapid, the etchings run into one another and in this way the twinned character of cleavage plates, the arrangement of the twinned bands and different individuals is quite clearly brought out.

Chemical composition.—Although leadhillite has been frequently analyzed, its chemical composition has remained some-

* Propr. Opt., 2, 38 N. R. 72, 1867. † Loc. cit.
‡ Pogg Ann, clii, p. 259, 1874. § Jahr. f. Min., i, pp. 63, 204, 1884.
‖ Pogg. Ann., clii, p. 256.
¶ Zeit. für Kryst., vol. iii, p. 113, fig. 12, 1879.

what doubtful. The earlier investigators, including such eminent chemists as Berzlius and Stromeyer, failed to take into account the small amount of water in the mineral, so that its composition was incorrectly supposed to be represented by the formula, $PbSO_4 . 3PbCO_3$.

Laspeyres, in 1872, described "maxite" as a new mineral, which, while resembling leadhillite in other respects, was hydrous. The question of the identity of maxite and leadhillite was for some time the subject of a considerable amount of controversy,* but it was satisfactorily shown by Hintze† that leadhillite was also hydrous and that there was therefore no ground for considering maxite as a separate species, and this was finally admitted by Laspeyres.‡

The formula given to maxite by Laspeyres was, $18PbO . 9CO_2 . 5SO_3 . 5H_2O$. Hintze's formula for leadhillite as well as maxite was, $7PbO . 4CO_2 . 2SO_3 . 2H_2O$. A simpler and more rational formula has been recently suggested by Groth,§ $4PbO . 2CO_2 . SO_2 . H_2O$. The calculated compositions and the molecular ratios for the three formulas are as follows:

	Laspeyres. $18PbO . 9CO_2 . 5SO_3 . 5H_2O$.	Hintze. $7PbO . 4CO_2 . 2SO_3 . 2H_2O$.	Groth. $4PbO . 2CO_2 . SO_3 . H_2O$.
H_2O	1·84	1·86	1·69
SO_3	8·16	8·27	7·53
CO_2	8·08	9·11	8·29
PbO	81·92	80·76	82·49

	PbO	: CO_2	: SO_3	: H_2O.
Laspeyres,	$3\frac{3}{5}$	$1\frac{4}{5}$	1	1
Hintze,	$3\frac{1}{2}$	2	1	1
Groth,	4	2	1	1

A comparison of the above shows that the differences are not large, and it is evident that slightly impure material or small analytical errors would account for the variations from Groth's simple formula. It is to be noticed also that the determinations of SO_3, made in leadhillite before it was known to be hydrous, agree much more closely with Groth's formula than with the other two. A list of these as cited by Hintze is as follows:

	SO_3
Berzelius	7·58
Stromeyer	7·21
Thomson	7·24
Irving	7·66
Bertrand	7·14

* Laspeyres, Jb. Min., 1872, 407, 508; 1873, 292; J. pr. Ch., N. F., v. 470; vii, 127; xiii, 370; Bertrand, Bull. Soc. Chim., xix, 17; C. R. lxxxvi, 348; Hintze, Pogg. Ann., clii, 256.

† Loc. cit.

‡ Zeitschr. Kryst., 1877, 193.

§ Tabell. Uebersicht. Min., 1889, p. 62.

It will be shown beyond that Groth's formula is the correct one, and it is evident that the earlier analysts would have arrived at it if they had detected and determined the water.

Chemical Analysis.—Some of the methods that have been previously used for the analysis of leadhillite have been rather severely criticized, and the operation has been characterized as attended with difficulties. It seems necessary, therefore, to give the process used in the present investigation with some detail.

The carefully selected material was pulverized, and about 2^{g} of the substance, without any artificial drying, was weighed in a platinum boat. The boat was placed in a dry piece of combustion tubing, to one end of which the ordinary apparatus for weighing water and carbonic acid was attached. A slow stream of pure, dry air was passed through the tube and apparatus, and the substance was heated to low redness until the water and carbonic acid were driven off and absorbed in the weighed apparatus. The sum of the weights of the water and carbonic acid varied but 0·07 per cent from the loss in weight of the substance. The water in the calcium chloride tube was neutral to litmus paper, thus showing that no SO_3 had been driven off. In fact a much higher temperature than that used will not decompose lead sulphate if reducing gases are absent.*

The ignited substance was transferred to a platinum crucible and fused with three or four parts of sodium and potassium carbonates to which a trace of potassium nitrate was added. The mass was treated with 2 or 300^{cc} of hot water to which a little ammonium carbonate was finally added. After cooling, the residue was filtered off and washed. Preliminary experiments had shown that the filtrate from this contained scarcely a trace of lead, and it was therefore used for the determination of sulphuric acid, as barium sulphate, in the usual way.

The insoluble residue, consisting of lead oxide with some carbonate, was dissolved in dilute nitric acid. The solution was complete except that a trace of lead peroxide remained which was dissolved in a little hydrochloric acid. The solution containing all the lead was evaporated with sulphuric acid, and after taking up the residue with water, the lead sulphate was collected in a Gooch crucible, ignited to low redness with careful protection from the action of reducing gases and weighed. Nothing could be found in the filtrate from the lead sulphate except extremely minute traces, probably of lead and iron.

* Fresenius states that lead sulphate does not lose weight at the most intense redness. (Quant. Anal., Analyt. Expt. No. 52.)

The material used for the analysis was from a single large crystal and it appeared to be perfectly pure. It had a pale green color and moderately thick pieces were transparent. The results of the analysis are as follows:

	Found.	Ratio.	Calculated for $4PbO . 2CO_2 . SO_3 . H_2O$.
SO_3	7·33	1	7·53
CO_2	8·14	2·02	8·29
PbO	82·44	4·04	82.49
H_2O	1·68	1·02	1·69
	99·59		100·00

These results show that the mineral has the formula $PbSO_4 . 2PbCO_3 . Pb(OH)_2$ and corresponds to the composition suggested by Groth, thus adding one more to the many cases in which his remarkable acuteness has deduced a simplified and correct formula from the more complicated results of previous investigations.

Sheffield Scientific School. New Haven, Conn., June, 1894.

Art. XXXII.—*Thermo-Electric Heights of Antimony and Bismuth Alloys*; by C. C. Hutchins.

The writer, being much interested in the preparation and use of thermo-couples of very small mass, undertook the following experiments with a view to finding the best combination of elements for the purpose.

Much study has been devoted to the subject already, chiefly however for the production of thermopiles designed to replace ordinary batteries. The extremely brittle alloys or sulphides used in these exclude them from the list of available elements when the elements are to be made very thin and are to have several soldered joints.

We have numerous determinations of the electromotive force of thermo-couples by Matthiessen and others, but it is impossible to repeat their experiments, owing to the want of method in the preparation of the couples, and the effects of impurities in the metals used by them.

The effect of physical state of the metal upon its thermo-electric height is clearly seen in Jenkins' table, compiled from Matthiesen's experiments. Here the thermo-electric height of antimony pressed wire is 280 C. G. S. units; but for the same metal with the equator of a crystal 2640. We are not assured however that the wire and crystal were from the same sample of metal.

The effect of impurities can be seen in the table for bismuth and tin given below, where it is seen that the presence of a third of one per cent of tin is sufficient to reverse the direction of the electromotive force of bismuth. Plainly then, if we expect to arrive at anything more than the general order of magnitude of the quantities involved, the greatest care must be taken to procure materials in a state of purity, and from these materials the elements must be prepared in a uniform manner.

Apparatus.

A copper bar, $1{\cdot}5^{cm}$ square, 4^{cm} long, was shaped at one end to a truncated wedge, and at the other inserted in a crossbar of wood. A copper block was held upon either face of the wedge by a light spring. Under these blocks, and pressed by them against the faces of the wedge, pass the bars of the thermo-couple, the bars meeting 1^{cm} beyond the end of the wedge, where they are soldered. The insulation between the bars, the copper blocks and the wedge was effected by a thin film of hard varnish only. It is thought that by the above means the conduction of heat to the other junctions is prevented, and at the same time the insulation was found to be complete. The thermo-junction was connected with a sensitive galvanometer and a thousand ohms additional resistance. It is assumed that the galvanometer deflections produced by the junctions through this circuit are proportional to the electromotive forces of the junctions.

The deflections were produced as follows. Two beakers of water were provided, one at the temperature of the room, the other at a higher temperature. The water in each was at such a level that when the crossbar above spoken of rested upon the rim of the beakers the junction would project a little below the surface of the water. Then the water in each having been stirred and its temperature read off, the junction was shifted quickly from one beaker to the other, and, after the swing of the galvanometer needle, back again. The deflection produced by each couple under experiment was compared in each case with the deflection by a couple of fine iron and copper wires adopted as a standard. The electromotive force of the standard junction was obtained by comparisons with a standard Daniels cell, and found to be 1412 C. G. S. units at a temperature of 30° mean.

Materials and preparation.

The bismuth was prepared by Joseph Torrey of the Harvard chemical laboratory. Mr. Torrey has made the preparation of pure bismuth a special study with a view to the re-determination of its atomic weight. It is freed from lead only with great difficulty, and it is worthy of note that the samples used do not show the lines of that impurity in the spark spectrum.

The antimony employed was a portion of that prepared by Professor Cook for his research upon its atomic weights. The lead, which was made one element in all the junctions, was prepared by electrolysis from the pure acetate.

The metals are cast in thin laminæ as follows. Two pieces of plate glass are smoked slightly, or are very finely ground and rubbed with plumbago. The metal being melted upon charcoal or under fused sodium chloride, a little pool is poured upon one plate and the other is applied to it as quickly as possible. In this way a leaf of very small thickness is obtained, which can be cut into narrow strips with a straight-edge and a thin graver.

Results.

The following table gives in column *a* the composition of the alloy forming one element of the junction, the other element being pure lead; in *t* the mean temperature of the hot and cold junctions; in *t′* the difference of temperature; in *d* the galvanometer deflection per degree difference of temperature: in *h* the thermo-electric height relative to lead. The signs in column *h* are in accordance with the convention that for the Peltier effect a current running down generates heat.

a		*t*	*t′*	*d*	*h*
Bi	Sb				
50	50	32·0	18·5	1·960	— 1845
60	40	31·0	25·1	3·127	2944
70	30	31·4	24·2	4·230	3982
80	20	31·0	22·7	5·710	5374
90	10	32·0	21·5	6·576	6179
95	5	31·2	24·5	7·205	6782
97·5	2·5	30·3	22·5	7·220	6796
98·75	1·25	29·6	24·6	5·558	5232
Commercial Bi		30·6	25·2	4·323	4069
Pure Bi		33·0	26·0	6·869	6466

a		*t*	*t′*	*d*		*h*
Bi	Sn					
50	50	28·9	25·7	0·929	+	875
60	40	32·1	21·2	1·333		1255
70	30	32·0	20·0	2·139		2014
80	20	29·9	25·2	3·109		2926
90	10	31·5	23·1	4·790		4509
95	5	31·5	23·1	4·850		4562
97·5	2·5	30·3	26·7	4·400		4134
98·75	1·25	30·0	26·1	3·556		3348
99·25	0·75	30·6	25·1	1·376		1296
99·62	0·37	30·0	23·0	0·044		41
Sn	Sb					
0	100	33·0	26·0	3·462	+	3267
5	95	29·6	25·7	0·845		793
10	90	30·0	29·5	0·824		777
20	80	28·4	27·7	1·496		1408
30	70	28·0	28·0	1·296		1220
40	60	28·1	28·2	1·330		1254
50	50	31·1	23·3	0·652		614
70	30	31·7	22·4	0·229		216
80	20	30·9	19·8	0·113		107
Commercial Sb		30·0	30·4	2·678		2520
Cd	Bi					
0·25	99·75	28·8	26·7	3·260	+	3801
0·50	99·50	29·9	30·7	3·460		4057
1·00	99·00	31·7	20·5	2·750		3207
1·25	98·75	29·2	27·5	2·710		3160
2·50	97·50	31·9	18·8	2·260		2642
5·00	95·00	28·7	23·4	1·740		2000
10·0	90·00	30·4	23·8	1·202		1401
20·0	80·00	31·9	19·8	0·424		495
100·	0·00	29·5	21·1	0·296		345

An inspection of the table shows that the best combination for a thermo-junction from these alloys is,—for one element bismuth with from two to five per cent antimony; and for the other bismuth with from five to ten per cent tin. Both of these alloys are easily cast into very thin leaves by the method above described, and can then be worked with a fine file as thin as 0·03^{mm} and are sufficiently tough to stand ordinary treatment.

According to Boys the Elliot Bros. instrument makers, use in their thermopiles alloys of bismuth thirty-two parts, antimony one part, and bismuth twelve parts, tin one part.

A junction of two very thin bars of bismuth with two per cent antimony, and bismuth with ten per cent tin (which on the whole seem to be the best combination) exhibited the following properties:

Mean temp. of junctions	7°·3	17°·0	22°·0	31°·5	36°·7
E. M. F. per degree	11150	11670	12050	12410	12630

Plotting these points we find them to lie nearly upon a straight line, from the slope of which we get, for ordinary temperature, the electromotive force of this junction:—$10700+41t$. C. G. S. units.

Bismuth and Selenium.

Melted 0·5^{gm} selenium and 15^{gm} bismuth at first formed a pasty mass which became fluid only above a red heat. It was easily cast into leaves; extremely brittle and soldered with difficulty. The combination was evidently a mixture rather than a true alloy, for when allowed to cool slowly most of the selenium separated. Several of these mixtures were tested but were found to exhibit but feeble electromotive force,—less than half that of the iron-copper junction.

Bowdoin College, May, 1894.

Art. XXXIII.—*On the Magnitude of the Solar System;* being the address delivered before the American Association for the Advancement of Science at its Brooklyn meeting, August 16, 1894, by the retiring president, Wm. Harkness.

Nature may be studied in two widely different ways. On the one hand we may employ a powerful microscope which will render visible the minutest forms and limit our field of view to an infinitessimal fraction of an inch situated within a foot of our own noses; or on the other hand, we may occupy some commanding position and from thence, aided perhaps by a telescope, we may obtain a comprehensive view of an extensive region. The first method is that of the specialist, the second is that of the philosopher, but both are necessary for an adequate understanding of nature. The one has brought us knowledge wherewith to defend ourselves against bacteria and microbes which are among the most deadly enemies of mankind, and the other has made us acquainted with the great laws of matter and force upon which rests the whole fabric of science. All nature is one, but for convenience of classification we have divided our knowledge into a number of sciences which we usually regard as quite distinct from each other. Along certain lines, or more properly, in certain regions, these sciences necessarily abut on each other, and just there lies the weakness of the specialist. He is like a wayfarer who always finds obstacles in crossing the boundaries between two countries, while to the traveler who gazes over them from a commanding eminence the case is quite different. If the boundary is an ocean shore there is no mistaking it; if a broad river or a chain of mountains it is still distinct; but if only a line of posts traced over hill and dale, then it becomes lost in the natural features of the landscape, and the essential unity of the whole region is apparent. In that case the border land is wholly a human conception of which nature takes no cognizance, and so it is with the scientific border land to which I propose to invite your attention this evening.

To the popular mind there are no two sciences further apart than astronomy and geology. The one treats of the structure and mineral constitution of our earth, the causes of its physical features and its history, while the other treats of the celestial bodies, their magnitudes, motions, distances, periods of revolution, eclipses, order, and of the causes of their various phenomena. And yet many, perhaps I may even say most of the apparent motions of the heavenly bodies are merely reflections of the motions of the earth, and in studying them we are really studying it. Furthermore, precession, nutation and the phenomena of the tides depend largely upon the internal structure of the earth, and there astronomy and geology merge into each other. Nevertheless the methods of the two sciences are widely different, most astronomical problems being discussed quantitatively by means of rigid mathematical formulæ, while in the vast majority of cases the geological ones are discussed only qualitatively, each author contenting himself with a mere statement of what he thinks. With precise data the methods of astronomy lead to very exact results, for mathematics is a mill which grinds exceeding fine; but after all, what comes out of a mill depends wholly upon what is put into it, and if the data are uncertain, as is the case in most cosmological problems, there is little to choose between the mathematics of the astronomer and the guesses of the geologist.

If we examine the addresses delivered by former presidents of this Association, and of the sister—perhaps it would be nearer the truth to say the parent Association on the other side of the Atlantic, we shall find that they have generally dealt either with the recent advances in some broad field of science, or else with the development of some special subject. This evening I propose to adopt the latter course, and I shall invite your attention to the present condition of our knowledge respecting the magnitude of the solar system, but in so doing it will be necessary to introduce some considerations derived from laboratory experiments upon the luminiferous ether, others derived from experiments upon ponderable matter, and still others relating both to the surface phenomena and to the internal structure of the earth, and thus we shall deal largely with the border land where astronomy, physics and geology merge into each other.

The relative distances of the various bodies which compose the solar system can be determined to a considerable degree of approximation with very crude instruments as soon as the true plan of the system becomes known, and that plan was taught by Pythagoras more than five hundred years before Christ. It must have been known to the Egyptians and Chaldeans still earlier, if Pythagoras really acquired his knowledge of astronomy from them as is affirmed by some of the ancient writers, but on that point there is no certainty. In public Pythagoras seemingly accepted the current belief of his time, which made the earth the center of the universe, but to his own chosen disciples he communicated the true doctrine that the sun occupies the center of the solar system, and that the earth is only one of the planets revolving around it. Like all the world's greatest sages, he seems to have taught only orally. A century elapsed before his doctrines were reduced to writing by Philolaus of Crotona, and it was still later before they were taught in public for the first time by Hicetas, or as he is sometimes called Nicetas, of Syracuse. Then the familiar cry of impiety was raised, and the Pythagorean system was eventually suppressed by that now called the Ptolemaic which held the field until it was overthrown by Copernicus almost two thousand years later. Pliny tells us that Pythagoras believed the distances to the sun and moon to be respectively 252,000 and 12,600 stadia, or taking the stadium at 625 feet, 29,837 and 1492 English miles; but there is no record of the method by which these numbers were ascertained.

After the relative distances of the various planets are known, it only remains to determine the scale of the system, for which purpose the distance between any two planets suffices. We know little about the early history of the subject, but it is clear that the primitive astronomers must have found the quantities to be measured too small for detection with their instruments, and even in modern times the problem has proved to be an extremely difficult one. Aristarcus of Samos who flourished about 270 B. C. seems to have been the first to attack it in a scientific manner. Stated in modern language, his reasoning was that when the moon is exactly half full, the earth and sun as seen from its center must make a right angle with each other, and by measuring the angle between the sun and moon, as seen from the earth at that instant, all the angles of the triangle joining the earth, sun and moon would become known, and thus the ratio of the distance of the sun to the distance of the moon would be determined. Although perfectly correct in theory, the difficulty of deciding visually upon the exact instant when the moon is half full is so great that it cannot be accurately done even with the most powerful telescopes. Of course Aristarcus had no telescope, and he does not explain how he effected the observation, but his conclusion was that at the instant in question the distance between the centers of the sun and moon, as seen from the earth, is less than a right angle by $\frac{1}{30}$ part of the same. We should now express this by saying that the angle is 87 degrees, but Aristarcus knew nothing of trigonometry, and in order to solve his triangle, he had recourse to an ingenious, but long and cumbersome geometrical process which has come down to us, and affords conclusive proof of the condition of Greek mathematics at that time. His conclusion was that the sun is nineteen times further from the earth than the moon, and if we combine that result with the modern value of the moon's parallax, viz: 3422·38 seconds, we obtain for the solar parallax 180 seconds, which is more than twenty times too great.

The only other method of determining the solar parallax known to the ancients was that devised by Hipparchus about 150 B. C. It was based on measuring the rate of decrease of the diameter of the earth's shadow cone by noting the duration of lunar eclipses, and as the result deduced from it happened to be nearly the same as that found by Aristarcus, substantially his value of the parallax remained in vogue for nearly two thousand years, and the discovery of the telescope was required to reveal its erroneous character. Doubtless this persistency was due to the extreme minuteness of the true parallax, which we now know is far too small to have been visible upon the ancient instruments, and thus the supposed measures of it were really nothing but measures of their inaccuracy.

The telescope was first pointed to the heavens by Galileo in 1609, but it needed a micrometer to convert it into an accurate measuring instrument, and that did not come into being until 1639 when it was invented by Wm. Gascoigne. After his death in 1644, his original instrument passed to Richard Townley who attached it to a fourteen foot telescope at his residence in Townley, Lancashire, England, where it was used by Flamsteed in observing the diurnal parallax of Mars during its opposition in 1672. A description of Gascoigne's micrometer was published in the Philosophical Transactions in 1667, and a little before that a similar instrument had been invented by Auzout in France, but observatories were fewer then than now, and so far as I know J. D. Cassini was the only person beside Flamsteed who attempted to determine the solar parallax from that opposition of Mars. Foreseeing the importance of the opportunity, he had Richer dispatched to Cayenne some months previously, and when the opposition came he effected two determinations of the parallax; one being by the diurnal method, from his own observations in Paris, and the other by the meridian method, from observations in France by himself, Römer and Picard, combined with those of Richer at Cayenne. This was the transition from the ancient instruments with open sights to telescopes armed with micrometers, and the result must have been little short of stunning to the seventeenth century astronomers, for it caused the hoary and gigantic parallax of about 180 seconds to shrink incontinently to ten seconds, and thus expanded their conception of the solar system to something like its true dimensions. More than fifty years previously Kepler had argued from his ideas of the celestial harmonies that the solar parallax could not exceed 60 seconds, and a little later Horrocks had shown on more scientific grounds that it was probably as small as 14 seconds, but the final death blow to the ancient values ranging as high as two or three minutes came from these observations of Mars by Flamsteed, Cassini and Richer.

Of course the results obtained in 1672 produced a keen desire on the part of astronomers for further evidence respecting the true value of the parallax, and as Mars comes into a favorable position for such investigations only at intervals of about sixteen years, they had recourse to observations of Mercury and Venus. In 1677 Halley observed the diurnal parallax of Mercury, and also a transit of that planet across the sun's disk, at St. Helena, and in 1681 J. D. Cassini and Picard observed Venus when she was on the same parallel with the sun, but although the observations of Venus gave better results than those of Mercury, neither of them was conclusive, and we now know that such methods are inaccurate even with the powerful instruments of the present day. Nevertheless Halley's attempt by means of the transit of Mercury ultimately bore fruit in the shape of his celebrated paper of 1716, wherein he showed the peculiar advantages of transits of Venus for determining the solar parallax. The idea of utilizing such transits for this purpose seems to have been vaguely conceived by James Gregory, or perhaps even by Horrocks, but Halley was the first to work it out completely, and long after his death his paper was mainly instrumental in inducing the governments of Europe to undertake the observations of the transits of Venus in 1761 and 1769, from which our first accurate knowledge of the sun's distance was obtained.

Those who are not familiar with practical astronomy may wonder why the solar parallax can be got from Mars and Venus, but not from Mercury, or the sun itself. The explanation depends on two facts. Firstly, the nearest approach of these bodies to the earth is for Mars 33,874,000 miles, for Venus 23.654,000 miles, for Mercury 47,935,000 miles and for the sun 91,239,000 miles. Consequently, for us Mars and Venus have very much larger parallaxes than Mercury or the sun, and of course the larger the parallax the easier it is to measure. Secondly, even the largest of these parallaxes must be determined within far less than one-tenth of a second of the truth, and while that degree of accuracy is possible in measureing short arcs, it is quite unattainable in long ones. Hence one of the most essential conditions for the successful measurement of parallaxes is that we shall be able to compare the place of the near body with that of a more distant one situated in the same region of the sky. In the case of Mars that can always be done by making use of a neighboring star, but when Venus is near the earth she is also so close to the sun that stars are not available, and consequently her parallax can be satisfactorily measured only when her position can be accurately referred to that of the sun, or in other words, only during her transits across the sun's disk. But even when the two bodies to be compared are sufficiently near each other, we are still embarrassed by the fact that it is more difficult to measure the distance between the limb of a planet and a star or the limb of the sun than it is to measure the distance between two stars, and since the discovery of so many asteroids, that circumstance has led to their use for determinations of the solar parallax. Some of these bodies approach within 75,230,000 miles of the earth's orbit, and as they look precisely like stars, the increased accuracy of pointing on them fully makes up for their greater distance, as compared with Mars or Venus.

After the Copernican system of the world and the Newtonian theory of gravitation were accepted it soon became evident that trigonometrical measurements of the solar parallax might be supplemented by determinations based on the theory of gravitation, and the first attempts in that direction were made by Machin in 1729 and T. Mayer in 1753. The measurement of the velocity of light between points on the earth's surface, first effected by Fizeau in 1849, opened up still other possibilities, and thus for determining the solar parallax we now have at our command no less than three entirely distinct classes of methods which are known respectively as the trigonometrical, the gravitational and the photo-tachymetrical. We have already given a summary sketch of the trigonometrical methods, as applied by the ancient astronomers to the dichotomy and shadow cone of the moon, and by the moderns, to Venus, Mars and the asteroids, and we shall next glance briefly at the gravitational and photo-tachymetrical methods.

The gravitational results which enter directly or indirectly into the solar parallax are six in number, to wit: first, the relation of the moon's mass to the tides; second, the relation of the moon's mass and parallax to the force of gravity at the earth's surface; third, the relation of the solar parallax to the masses of the earth and moon; fourth, the relation of the solar and lunar parallaxes to the moon's mass and parallactic inequality; fifth, the relation of the solar and lunar parallaxes to the moon's mass and the earth's lunar inequality; sixth, the relation of the constants of nutation and precession to the moon's parallax.

Respecting the first of these relations it is to be remarked that the tide-producing forces are the attraction of the sun and moon upon the waters of the ocean, and from the ratio of these attractions the moon's mass can readily be determined. But unfortunately the ratio of the solar tides to the lunar tides is affected both by the depth of the sea and by the character of the channels through which the water flows, and for that reason the observed ratio of these tides requires multiplication by a correcting factor in order to convert it into the ratio of the forces. The matter is further complicated by this correcting factor varying from port to port, and in order to get satisfactory results long series of observations are necessary. The labor of deriving the moon's mass in this way was formerly so great that for more than half a century La Place's determination from the tides at Brest remained unique, but the recent application of harmonic analysis to the data supplied by self-registering tide gauges is likely to yield abundant results in the near future.

Our second gravitational relation, viz: that connecting the moon's mass and parallax with the force of gravity at the earth's surface, affords an indirect method of determining the moon's parallax with very great accuracy if the computation is carefully made, and with a fair approximation to the truth even when the data are exceedingly crude. To illustrate this, let us see what could be done with a railroad transit such as is commonly used by surveyors, a steel tape, and a fairly good watch. Neglecting small corrections due to the flattening of the earth, the centrifugal force at its surface, the eccentricity of its orbit, and the mass of the moon; the law of gravitation shows that if we multiply together the length of the seconds pendulum, the square of the radius of the earth, and the square of the length of the sidereal month, divide the product by four, and take the cube root of the quotient, the result will be the distance from the earth to the moon. To find the length of the seconds pendulum we would rate the watch by means of the railroad transit, and then making a pendulum out of a spherical leaden bullet suspended by a fine thread, we would adjust the length of the thread until the pendulum made exactly 300 vibrations in five minutes by the watch. Then, supposing the experiment to be made here, or in New York City, we would find that the distance from the point of suspension of the thread to the center of the bullet was about $39\frac{1}{8}$ inches, and dividing that by the number of inches in a mile, viz: 63,360, we would have for the length of the seconds pendulum one sixteen hundred and twentieth of a mile. The next step would be to ascertain the radius of the earth, and the quickest way of doing so would probably be, first to determine the latitude of some point in New York City by means of the railroad transit, next to run a traverse survey along the old Post Road from New York to Albany, and finally to determine the latitude of some point in Albany. The traverse survey should surely be correct to one part in three hundred, and as the distance between the two cities is about two degrees, the difference of latitude might be determined to about the same percentage of accuracy. In that way we would find the length of two degrees of latitude to be about 138 miles, whence the earth's radius would be 3953 miles. It would then only remain to observe the time occupied by the moon in making a sidereal revolution around the earth, or in other words the time which she occupies in moving from any given star back to the same star again. By noting that to within one-quarter of her own diameter we would soon find that the time of a revolution is about 27·32 days, and multiplying that by the number of seconds in a day, viz: 86,400, we would have for the length of the sidereal month 2,360,000 seconds. With these data the computation would stand as follows; the radius of the earth, 3953 miles, multiplied by the length of a sidereal month, 2,360,000 seconds, and the product squared, gives 87,060,000,000,000,000,000. Multiplying that by one-fourth of the length of the seconds pendulum, viz: 1/6480 of a mile, and extracting the cube root of the product, we would get 237,700 miles for the distance from the earth to the moon, which is only about 850 miles less than the truth, and is certainly a remarkable result considering the crudeness of the instruments by which it might be obtained. Nevertheless, when all the conditions are rigorously taken into account these data are to be regarded as determining the relation between the moon's mass and parallax rather than the parallax itself.

Our third gravitational relation, to wit: that existing between the solar parallax, the solar attractive force and the masses of the earth and moon, is analogous to the relation existing between the moon's mass and parallax and the force of gravity at the earth's surface, but it can not be applied in exactly the same way on account of our inability to swing a pendulum on the sun. We are therefore compelled to adopt some other method of determining the sun's attractive force, and the most available is that which consists in observing the perturbative action of the earth and moon upon our nearest planetary neighbors, Venus and Mars. From this action the law of gravitation enables us to determine the ratio of the sun's mass to the combined masses of the earth and moon, and then the relation in question furnishes a means of comparing the masses so found with trigonometrical determinations of the solar parallax. Thus it appears that notwithstanding necessary differences in the methods of procedure, the analogy between the second and third gravitational relations holds not only with respect to their theoretical basis, but also in their practical application, the one being used to determine the relation between the mass of the moon and its distance from the earth, and the other to determine the relation between the combined masses of the earth and moon and their distance from the sun.

Our fourth gravitational relation deals with the connection between the solar parallax, the lunar parallax, the moon's mass and the moon's parallactic inequality. The important quantities are here the solar parallax and the moon's parallactic inequality, and although the derivation of the complete expression for the connection between them is a little complicated, there is no difficulty in getting a general notion of the forces involved. As the moon moves around the earth she is alternately without and within the earth's orbit. When she is without, the sun's attraction on her acts with that of the earth; when she is within, the two attractions act in opposite directions. Thus in effect the centripetal force holding the moon to the earth is alternately increased and diminished, with the result of elongating the moon's orbit towards the sun and compressing it on the opposite side. As the variation of the centripetal force is not great, the change of form of the orbit is small, nevertheless the summation of the minute alterations thereby produced in the moon's orbital velocity suffices to put her sometimes ahead, and sometimes behind her mean place to an extent which oscillates from a maximum to a minimum as the earth passes from perihelion to aphelion, and averages about 125 seconds of arc. This perturbation of the moon is known as the parallactic inequality because it depends on the earth's distance from the sun, and can therefore be expressed in terms of the solar parallax. Conversely, the solar parallax can be deduced from the observed value of the parallactic inequality, but unfortunately there are great practical difficulties in making the requisite observations with a sufficient degree of accuracy. Notwithstanding the ever recurring talk about the advantages to be obtained by observing a small well defined crater instead of the moon's limb, astronomers have hitherto found it impracticable to use anything but the limb, and the disadvantage of doing so as compared with observing a star is still further increased by the circumstance that in general only one limb can be seen at a time, the other being shrouded in darkness. If both limbs could always be observed we should then have a uniform system of data for determining the place of the center, but under existing circumstances we are compelled to make our observations half upon one limb and half upon the other, and thus they involve all the systematic errors which may arise from the conditions under which these limbs are observed, and all the uncertainty which attaches to irradiation, personal equation, and our defective knowledge of the moon's semi-diameter.

Our fifth gravitational relation is that which exists between the solar parallax, the lunar parallax, the moon's mass and the earth's lunar inequality. Strictly speaking the moon does not revolve around the earth's center, but both bodies revolve around the common center of gravity of the two. In consequence of that an irregularity arises in the earth's orbital velocity around the sun, the common center of gravity moving in accordance with the laws of elliptic motion, while the earth, on account of its revolution around that center, undergoes an alternate acceleration and retardation which has for its period a lunar month, and is called the lunar inequality of the earth's motion. We perceive this inequality as an oscillation superposed on the elliptic motion of the sun, and its semi-amplitude is a measure of the angle subtended at the sun by the interval between the center of the earth and the common center of gravity of the earth and moon. Just as an astronomer on the moon might use the radius of her orbit around the earth as a base for measuring her distance from the sun, so we may use this interval for the same purpose. We find its length in miles from the equatorial semi-diameter of the earth, the moon's parallax and the moon's mass, and thus we have all the data for determining the solar parallax from the inequality in question. In view of the great difficulty which has been experienced in measuring the solar parallax itself, it may be asked why we should attempt to deal with the parallactic inequality which is about twenty-six per cent smaller? The answer is, because the latter is derived from differences of the sun's right ascension which are furnished by the principal observatories in vast numbers, and should give very accurate results on account of their being made by methods which insure freedom from constant errors. Nevertheless, the sun is not so well adapted for precise observation as the stars, and Dr. Gill has recently found that heliometer measurements upon asteroids which approach very near to the earth yield values of the parallactic inequality superior to those obtained from right ascensions of the sun.

Our sixth gravitational relation is that which exists between the moon's parallax and the constants of precession and nutation. Every particle of the earth is attracted both by the sun and by the moon, but in consequence of the polar flattening the resultant of these attractions passes a little to one side of the earth's center of gravity. Thus a couple is set up, which, by its action upon the rotating earth, causes the axis thereof to describe a surface which may be called a fluted cone, with its apex at the earth's center. A top spinning with its axis inclined describes a similar cone, except that the flutings are absent and the apex is at the point upon which the spinning occurs. For convenience of computation we resolve this action into two components, and we name that which produces the cone the luni-solar precession, and that which produces the flutings the nutation. In this phenomenon the part played by the sun is comparatively small, and by eliminating it we obtain a relation between the luni-solar precession, the nutation and the moon's parallax which can be used to verify and correct the observed values of these quantities.

In the preceding paragraph we have seen that the relation between the quantities there considered depends largely upon the flattening of the earth, and thus we are led to inquire how and with what degree of accuracy that is determined. There are five methods, viz: one geodetic, one gravitational, and three astronomical. The geodetic method depends upon measurements of the length of a degree on various parts of the earth's surface, and with the data hitherto accumulated it has proved quite unsatisfactory. The gravitational method consists in determining the length of the seconds pendulum over as great a range of latitude as possible, and deducing therefrom the ratio of the earth's polar and equatorial semi-diameters by means of Clairaut's theorem. The pendulum experiments show that the earth's crust is less dense on mountain plateaux than at the sea coast, and thus for the first time we are brought into contact with geological considerations. The first astronomical method consists in observing the moon's parallax from various points on the earth's surface, and as these parallaxes are nothing else than the angular semi-diameter of the earth at the respective points as seen from the moon, they afford a direct measure of the flattening. The second and third astronomical methods are based upon certain perturbations of the moon which depend upon the figure of the earth, and should give extremely accurate results, but unfortunately very great difficulties oppose themselves to the exact measurement of the perturbations. There is also an astronomico-geological method which can not yet be regarded as conclusive on account of our lack of knowledge respecting the law of density which prevails in the interior of the earth. It is based upon the fact that a certain function of the earth's moments of inertia can be determined from the observed values of the coefficients of precession and nutation, and could also be determined from the figure and dimensions of the earth if we knew the exact distribution of matter in its interior. Our present knowledge on that subject is limited to a superficial layer not more than ten miles thick, but it is usual to assume that the deeper matter is distributed according to La Grange's law, and then by writing the function in question in a form which leaves the flattening indeterminate, and equating the expression so found to the value given by the precession and nutation, we readily obtain the flattening. As yet these six methods do not give consistent results, and so long as serious discrepancies remain between them there can be no security that we have arrived at the truth.

It should be remarked that in order to compute the function of the earth's moments of inertia which we have just been considering, we require not only the figure and dimensions of the earth and the law of distribution of density in its interior, but also its mean and surface densities. The experiments for determining the mean density have consisted in comparing the earth's attraction with the attraction either of a mountain, or of a known thickness of the earth's crust, or of a known mass of metal. In the case of mountains the comparisons have been made with plumb lines and pendulums; in the case of known layers of the earth's crust they have been made by swinging pendulums at the surface and down in mines; and in the case of known masses of metal they have been made with torsion balances, fine chemical balances and pendulums. The surface density results from a study of the materials composing the earth's crust, but notwithstanding the apparant simplicity of that process, it is doubtful if we have yet attained as accurate a result as in the case of the mean density.

Before quitting this part of our subject, it is important to point out that the luni-solar precession can not be directly observed, but must be derived from the general precession. The former of these quantities depends only upon the action of the sun and moon, while the latter is affected in addition by the action of the planets, and to ascertain what that is we must determine their masses. The methods of doing so fall into two great classes according as the planets dealt with have or have not satellites. The most favorable case is that in which one or more satellites are present, because the mass of the primary follows immediately from their distances and revolution times, but even then there is a difficulty in the way of obtaining very exact results. By extending the observations over sufficiently long periods the revolution times can be ascertained with any desired degree of accuracy, but all measurements of the distance of a satellite from its primary are affected by personal equation, which we can not be sure of completely eliminating, and thus a considerable margin of uncertainty is brought into the masses. In the cases of Mercury and Venus, which have no satellites, and to a certain extent in the case of the earth also, the only available way of ascertaining the masses is from the perturbations produced by the action of the various planets on each other. These perturbations are of two kinds, periodic and secular. When sufficient data have been accumulated for the exact determination of the secular perturbations, they will give the best results, but as yet it remains advantageous to employ the periodic perturbations also.

Passing now to the photo-tachymetrical methods, we have first to glance briefly at the mechanical appliances by which the tremendous velocity of light has been successfully measured They are of the simplest possible character, and are based either upon a toothed wheel, or upon a revolving mirror.

The toothed wheel method was first used by Fizeau in 1849. To understand its operation, imagine a gun barrel with a toothed wheel revolving at right angles to its muzzle in such a way that the barrel is alternately closed and opened as the teeth and the spaces between them pass before it. Then, with the wheel in rapid motion, at the instant when a space is opposite the muzzle let a ball be fired. It will pass out freely, and after traversing a certain distance let it strike an elastic cushion and be reflected back upon its own path. When it reaches the wheel, if it hits a space it will return into the gun barrel, but if it hits a tooth it will be stopped. Examining the matter a little more closely, we see that as the ball requires a certain time to go and return, if during that time the wheel moves through an odd multiple of the angle between a space and a tooth the ball will be stopped, while if it moves through an even multiple of that angle the ball will return into the barrel. Now imagine the gun barrel, the ball and the elastic cushion to be replaced respectively by a telescope, a light wave and a mirror. Then if the wheel moved at such a speed that the returning light wave struck against the tooth following the space through which it issued, to an eye looking into the telescope all would be darkness. If the wheel moved a little faster and the returning light wave passed through the space succeeding that through which it issued, the eye at the telescope would perceive a flash of light; and if the speed were continuously increased a continual succession of eclipses and illuminations would follow each other according as the returning light was stopped against a tooth or passed through a space further and further behind that through which it issued. Under these conditions the time occupied by the light in traversing the space from the wheel to the mirror and back again would evidently be the same as the time required by the wheel to revolve through the angle between the space through which the light issued and that through which it returned, and thus the velocity of light would become known from the distance between the telescope and the mirror together with the speed of the wheel. Of course the longer the distance traversed, and the greater the velocity of the wheel, the more accurate would be the result.

The revolving mirror method was first used by Foucault in 1862. Conceive the toothed wheel of Fizeau's apparatus to be replaced by a mirror attached to a vertical axis, and capable of being put into rapid rotation. Then it will be possible so to arrange the apparatus that light issuing from the telescope shall strike the movable mirror and be reflected to the distant mirror, whence it will be returned to the movable mirror again and being thrown back into the telescope will appear as a star in the center of the field of view. That adjustment being made, if the mirror were caused to revolve at a speed of some hundred turns per second it would move through an appreciable angle while the light was passing from it to the distant mirror and back again, and in accordance with the laws of reflection, the star in the field of the telescope would move from the center by twice the angle through which the mirror had turned. Thus the deviation of the star from the center of the field would measure the angle through which the mirror turned during the time occupied by light in passing twice over the interval between the fixed and revolving mirrors, and from the magnitude of that angle together with the known speed of the mirror, the velocity of the light could be calculated.

In applying either of these methods the resulting velocity is that of light when traversing the earth's atmosphere, but what we want is its velocity in space which we suppose to be destitute of ponderable material, and in order to obtain that the velocity in the atmosphere must be multiplied by the refractive index of air. The corrected velocity so obtained can then be used to find the solar parallax, either from the time required by light to traverse the semi-diameter of the earth's orbit, or from the ratio of the velocity of light to the orbital velocity of the earth.

Any periodic correction which occurs in computing the place of a heavenly body, or the time of a celestial phenomenon, is called by astronomers, an equation, and as the time required by light to traverse the semi-diameter of the earth's orbit first presented itself in the guise of a correction to the computed times of the eclipses of Jupiter's satellites, it has received the name of the light equation. The earth's orbit being interior to that of Jupiter, and both having the sun for their center, it is evident that the distance between the two planets must vary from the sum to the difference of the radii of their respective orbits, and the time required by light to travel from one planet to the other must vary proportionately. Consequently, if the observed times of the eclipses of Jupiter's satellites are compared with the times computed upon the assumption that the two planets are always separated by their mean distance it will be found that the eclipses occur too early when the earth is at less than its mean distance from Jupiter, and too late when it is further off, and from large numbers of such observations the value of the light equation has been deduced.

The combination of the motion of light through our atmosphere with the orbital motion of the earth gives rise to the annual aberration, all the phases of which are computed from its maximum value, commonly called the constant of aberration. There is also a diurnal aberration due to the rotation of the earth on its axis, but that is quite small and does not concern us this evening. When aberration was discovered the corpuscular theory of light was in vogue, and it offered a charmingly simple explanation of the whole phenomenon. The hypothetical light corpuscles impinging upon the earth were thought to behave precisely like the drops in a shower of rain, and you all know that their apparent direction is affected by any motion on the part of the observer. In a calm day when the drops are falling perpendicularly, a man standing still holds his umbrella directly over his head, but as soon as he begins to move forward he inclines his umbrella in the same direction, and the more rapidly he moves the greater must be its inclination in order to meet the descending shower. Similarly, the apparent direction of an oncoming light corpuscle would be affected by the orbital motion of the earth, so that in effect it would always be the resultant arising from combining the motion of the light with a motion equal and opposite to that of the earth. But since the falsity of the corpuscular theory has been proved that explanation is no longer tenable, and as yet we have not been able to replace it with anything equally satisfactory based on the now universally accepted undulatory theory. In accordance with the latter theory we must conceive the earth as plowing its way through the ether, and the point which has hitherto baffled us is whether or not in so doing it produces any disturbance of the ether which affects the aberration. In our present ignorance on that point we can only say that the aberration constant is certainly very nearly equal to the ratio of the earth's orbital velocity to the velocity of light, but we can not affirm that it is rigorously so.

The luminiferous ether was invented to account for the phenomena of light, and for two hundred years it was not suspected to have any other function. The emission theory postulated only the corpuscles which constitute light itself, but the undulatory theory fills all space with an imponderable substance possessing properties even more remarkable than those of ordinary matter, and to some of the acutest intellects the magnitude of this idea has proved an almost insuperable objection against the whole theory. So late as 1862 Sir David Brewster, who had gained a world-wide reputation by his optical researches, expressed himself as staggered by the notion of filling all space with some substance merely to enable a little twinkling star to send its light to us; but not long after Clerk Maxwell removed that difficulty by a discovery coextensive with the undulatory theory itself. Since 1845, when Faraday first performed his celebrated experiment of magnetising a ray of light, the idea that electricity is a phenomenon of the ether had been steadily growing, until at last Maxwell perceived that if such were the fact the rate of propagation of an electromagnetic wave must be the same as the velocity of light. At that time no one knew how to generate such waves, but Maxwell's theory showed him that their velocity must be equal to the number of electric units of quantity in the electromagnetic unit, and careful experiments soon proved that that is the velocity of light. Thus it was put almost beyond the possibility of doubt that the ether gives rise to the phenomena of electricity and magnetism as well as to those of light, and perhaps it may even be concerned in the production of gravitation itself. What could be apparently more remote than these electric quantities and the solar parallax? And yet we have here a relation between them, but we make no use of it because as yet the same relation can be far more accurately determined from experiments upon the velocity of light.

Now let us recall the quantities and methods of observation which we have found to be involved either directly or indirectly with the solar parallax. They are, the solar parallax, obtained from transits of Venus, oppositions of Mars and oppositions of certain asteriods; the lunar parallax, found both directly, and from measurements of the force of gravity at the earth's surface; the constants of precession, nutation and aberration, obtained from observations of the stars; the parallactic inequality of the moon; the lunar inequality of the earth, usually obtained from observations of the sun, but recently found from heliometer observations of certain asteriods: the mass of the earth, found from the solar parallax, and also from the periodic and secular perturbations of Venus and Mars; the mass of the moon, found from the lunar inequality of the earth, and also from the ratio of the solar and lunar components of the ocean tides; the masses of all the planets, obtained from observations of their satellites whenever possible, and when no satellites exist, then from observations of their mutual perturbations both periodic and secular; the velocity of light, obtained from experiments with revolving mirrors and toothed wheels, together with laboratory determinations of the index of refraction of atmospheric air; the light equation, obtained from observations of the eclipses of Jupiter's satellites; the figure of the earth, obtained from geodetic triangulations, measurements of the length of the seconds pendulum in various latitudes, and observations of certain perturbations of the moon; the mean density of the earth, obtained from measurements of the attractions of mountains, from pendulum experiments in mines, and from experiments on the attraction of known masses of matter made either with torsion balances or with the most delicate chemical balances; the surface density of the earth, obtained from geological examinations of the surface strata; and lastly, the law of distribution of density in the interior of the earth, which in the present state of geological knowledge we can do little more than guess at.

Here then we have a large group of astronomical, geodetic, geological and physical quantities which must all be considered in finding the solar parallax, and which are all so entangled with each other that no one of them can be varied without affecting all the rest. It is therefore impossible to make an accurate determination of any one of them apart from the remainder of the group, and thus we are driven to the conclusion that they must all be determined simultaneously. Such has not been the practice of astronomers in the past, but it is the method to which they must inevitably resort in the future. A cursory glance at an analogous problem occurring in geodesy may be instructive. When a country is covered with a net of triangles it is always found that the observed angles are subject to a certain amount of error, and a century ago it was the habit to correct the angles in each triangle without much regard to the effect upon adjacent triangles. Consequently the adjustment of the errors was imperfect, and in computing the interval between any two distant points the result would vary somewhat with the triangles used in the computation—that is, if one computation was made through a chain of triangles running around on the right hand side, another through a chain of triangles running straight between the two points, and a third through a chain of triangles running around on the left hand side, the results were usually all different. At that time things were less highly specialized than now, and all geodetic operations were yet in the hands of first-rate astronomers who soon devised processes for overcoming the difficulty. They imagined every observed angle to be subject to a small correction, and as these corrections were all entangled with each other through the geometrical conditions of the net, by a most ingenious application of the method of least squares they determined them all simultaneously in such a way as to satisfy the whole of the geometrical conditions. Thus the best possible adjustment was obtained, and no matter what triangles were used in passing from one point to another, the result was always the same. That method is now applied to every important triangulation, and its omission would be regarded as proof of incompetency on the part of those in charge of the work.

Now let us compare the conditions existing respectively in a triangulation net and in the group of quantities for the determination of the solar parallax. In the net every angle is subject to a small correction, and the whole system of corrections must be so determined as to make the sum of their weighted squares a minimum, and at the same time satisfy all the geometrical conditions of the net. Like the triangles, the quantities composing the group from which the solar parallax must be determined are all subject to error, and therefore we must regard each of them as requiring a small correction, and all these corrections must be so determined as to make the sum of their weighted squares a minimum, and at the same time satisfy every one of the equations expressing the relations between the various components of the group.

Thus it appears that the method required for adjusting the solar parallax and its related constants is in all respects the same as that which has so long been used for adjusting systems of triangulation, and as the latter method was invented by astronomers, it is natural to inquire why they have not applied it to the fundamental problem of their own science? The reasons are various, but they may all be classed under two heads. First, an inveterate habit of over-estimating the accuracy of our own work as compared with that of others; and second, the unfortunate effect of too much specialization.

The prevailing opinion certainly is that great advances have recently been made in astronomy, and so they have in the fields of spectral analysis and in the measurement of minute quantities of radiant heat; but the solution of the vast majority of astronomical problems depends upon the exact measurement of angles, and in that little or no progress has been made. Bradley with his zenith sector a hundred and fifty years ago, and Bessel and Struve with their circles and transit instruments seventy years ago, made observations not sensibly inferior to those of the present day, and indeed it would have been surprising if they had not done so. The essentials for accurately determining star places are a skilled observer, a clock and a transit circle, the latter consisting of a telescope, a divided circle and four micrometer microscopes. Surely no one will claim that we have to-day any more skillful observers than were Bessel, Bradley and Struve, and the only way in which we have improved upon the telescopes made by Dollond one hundred and thirty years ago, is by increasing their aperture and relatively diminishing their focal distance. The most famous dividing engine now in existence was made by the elder Repsold seventy-five years ago; but as the errors of divided circles and their micrometer microscopes are always carefully determined, the accuracy of the measured angles is quite independent of any small improvement in the accuracy of the divisions or of the micrometer screws. Only in the matter of clocks has there been some advance, and even that is not very great. On the whole, the star places of to-day are a little better than those of seventy-five years ago, but even yet there is great room for improvement. One of the commonest applications of these star places is to the determination of latitude, but it is very doubtful if there is any point on the face of the earth whose latitude is known certainly within one-tenth of a second.

Looking at the question from another point of view, it is notorious that the contact observations of the transits of Venus in 1761 and 1769 were so discordant that from the same observations Encke and E. J. Stone got respectively for the solar parallax 8·59 seconds and 8·91 seconds. In 1870 no one thought it possible that there could be any such difficulty with the contact observations of the then approaching transits of 1874 and 1882, but now we have found from sad experience that our vaunted modern instruments gave very little better results for the last pair of transits than our predecessors obtained with much cruder appliances in 1761 and 1769.

The theory of probability and uniform experience alike show that the limit of accuracy attainable with any instrument is soon reached; and yet we all know the fascination which continually lures us on in our efforts to get better results out of the familiar telescopes and circles which have constituted the standard equipment of observatories for nearly a century. Possibly these instruments may be capable of indicating somewhat smaller quantities than we have hitherto succeeded in measuring with them, but their limit cannot be far off because they already show the disturbing effects of slight inequalities of temperature and other uncontrollable causes. So far as these effects are accidental they eliminate themselves from every long series of observations, but there always remains a residuum of constant error, perhaps quite unsuspected, which gives us no end of trouble. Encke's value of the solar parallax affords a fine illustration of this. From the transits of Venus in 1761 and 1769 he found 8·58 seconds in 1824, which he subsequently corrected to 8·57 seconds, and for thirty years that value was universally accepted. The first objection to it came from Hansen in 1854, a second followed from Le Verrier in 1858, both based upon facts connected with the lunar theory, and eventually it became evident that Encke's parallax was about one-quarter of a second too small. Now please observe that Encke's value was obtained trigonometrically, and its inaccuracy was never suspected until it was revealed by gravitational methods which were themselves in error about one-tenth of a second and required subsequent correction in other ways. Here then was a lesson to astronomers who are all more or less specialists, but it merely enforced the perfectly well known principle that the constant errors of any one method are accidental errors with respect to all other methods, and therefore the readiest way of eliminating them is by combining the results from as many different methods as possible. However, the abler the specialist the more certain he is to be blind to all methods but his own, and astronomers have profited so little by the Encke-Hansen-Le Verrier incident of thirty-five years ago that to-day they are mostly divided into two great parties, one of whom holds that the parallax can be best determined from a combination of the constant of aberration with the velocity of light, and the other believes only in the results of heliometer measurements upon asteriods. By all means continue the heliometer measurements, and do everything possible to clear up the mystery which now surrounds the constant of aberration, but why ignore the work of predecessors who were quite as able as ourselves? If it were desired to determine some one angle of a triangulation net with special exactness, what would be thought of a man who attempted to do so by repeated measurements of the angle in question while he persistently neglected to adjust the net? And yet, until recently astronomers have been doing precisely that kind of thing with the solar parallax. I do not think there is any exaggeration in saying that the trustworthy observations now on record for the determination of the numerous quantities which are functions of the parallax could not be duplicated by the most industrious astronomer working continuously for a thousand years. How then can we suppose that the result properly deducible from them can be materially affected by anything that any of us can do in a life time, unless we are fortunate enough to invent methods of measurement vastly superior to any hitherto imagined? Probably the existing observations for the determination of most of these quantities are as exact as any that can ever be made with our present instruments, and if they were freed from constant errors they would certainly give results very near the truth. To that end we have only to form a system of simultaneous equations between all the observed quantities, and then deduce the most probable values of these quantities by the method of least squares. Perhaps some of you may think that the value so obtained for the solar parallax would depend largely upon the relative weights assigned to the various quantities, but such is not the case. With almost any possible system of weights the solar parallax will come out very nearly 8·809″ ±0·0057″, whence we have for the mean distance between the earth and sun 92,797,000 miles, with a probable error of only 59,700 miles; and for the diameter of the solar system, measured to its outermost member, the planet Neptune, 5,578,400,000 miles.

Art. XXXIV.—*On the Nitrogen Content of California Bitumen*; by S. F. Peckham.

[Read at the Congress of Chemists held at San Francisco, Cal., in association with the Midwinter Fair, June 9th, 1894.]

In 1865, when artificial excavations in the Cañons of the Sulphur Mountain in Ventura County, California, brought to the surface bitumens that were free from the action of oxidizing agents, it was soon observed that when those bitumens were exposed in small pools for a short time they became infested with maggots. This phenomenon was observed by a number of persons. In one instance that came under my own observation, the amount of petroleum that filled a small cavity in the rocks might have been two quarts. It was so filled with maggots that they crawled over each other precisely as they would in a pool of blood. It was evident that this petroleum contained the elements of food, and the presence of nitrogen was inferred as an essential constituent of this variety of bitumen.

It was several years after this observation was made before I had an opportunity to prove by analysis the actual presence and amount of nitrogen. I used the ordinary sodalime process. The amount indicated was so large that I was led to suspect that possibly some source of error lay against this process, when used for the analysis of this material. I duplicated my results on the petroleum alone. I also found no difficulty in duplicating results with one of the vegetable alkaloids, which one I do not now remember. I also obtained the proper percentage when operating upon a mixture of petroleum and alkaloid. I concluded that my results upon the petroleum alone were correct. I found that the oils from the tunnels in Wheeler's Cañon on the south side of the Sulphur Mountain yielded an average composition of:

Hydrogen	11·819	per cent.
Carbon	86·934	"
Nitrogen	1·1095	"
Total	99·8625	"

The oil of the Pico Spring contained of nitrogen 1·0165 per cent and that from the Cañada Laga spring contained of nitrogen 1·0855 per cent. Maltha from the Ojai Ranche contained of nitrogen 0·5645 per cent.* These localities lie in the line of strike of the oil-bearing formation of Ventura Co., which crosses the Santa Clara Valley in a generally east and west direction and extends parallel with the range of the Sulphur mountain. The Pico spring is in the range that forms the southern boundary of the the Santa Clara Valley. Several miles to the west and across the valley is the east end of the Sulphur mountain in which is Wheeler's Cañon. Farther west is the Cañada Laga, and in the west end of the range is the spring which furnished the maltha from the Ojai Ranche. About two years later a second determination of the nitrogen was made in the sample from Wheeler's Cañon. The amount obtained was less than one per cent but I have lost the notes of the analytical work. The two springs above named were the only springs of bitumen in Southern California that yielded a green petroleum from natural sources. I have shown in my reports to the Geological Survey of California that the oil of these springs as well as that from the tunnels in Wheeler's Cañon, which are still yielding oil, issues from strata protected

* Reports Geol. Survey Cal., Geology, II, Appendix, pp. 84, 89. Reports 10th Census U. S., vol. x, Petroleum, p. 185.

from infiltration of rain-water and accompanying oxygen, by overlying formations.

The manner in which this nitrogen is combined was not then made a subject of research. It was however my conviction at that time, based largely upon observations made upon the spot, and judged in connection with these results of analysis, that the nitrogen must in some manner be held in combination by bonds that are easily broken, and that in the re-arrangement that followed, the nitrogen content either became free, or entered more stable forms of combination, after the manner in which the process of fermentation converts complex nitrogenous compounds into simpler forms. Here this matter rested for many years.

In April, 1892, in the laboratory of the University of Michigan I distilled some of the same samples of Wheeler's Cañon petroleum in which I had determined the nitrogen more than twenty years before. The distillation was conducted at a temperature approaching the red heat and furnished products of destructive distillation. While observing the effects of various reagents upon the distillates, which I was handling in very small quantities, I noticed the very peculiar and persistent odor of pyridin. The appearance of this substance under the conditions present did not surprise me. I considered it to be a product of the destructive distillation of the petroleum at a temperature approaching the red heat.*

After I returned to California last October and made the acquaintance of Dr. Frederick Salathè, he one day showed me a small vial containing a black oil, that was in appearance Dippel's oil. He said that he had obtained the oil by washing a distillate of California petroleum with dilute sulphuric acid, and further that all of the crude oils found in the neighborhood of Santa Paula yielded basic oils to dilute sulphuric acid. Dr. Salathè seemed to be impressed with the importance of his discovery as demonstrating beyond any question the animal origin of the bitumens; a proposition to which I gave instant assent.

The importance of this discovery immediately impressed me from the technological side, and I urged the doctor to ascertain what results would follow the removal of the basic oils from the various commercial products found in the refinery.

In the laboratory I soon treated both crude oils and their distillates, and found that the basic oils in their natural condition were combined with an exceedingly viscous feebly acid tar. When the crude oils are treated with dilute acid, this acid radical forms a hydrate which produces with the other constitu-

* This Journal, vol. xlvii, p. 30, Jan. 1894.

ents of the petroleum an emulsion, from which the aqueous acid solution of the basic oils is separated with much difficulty. With many of the distillates, and particularly those of highest specific gravity, the acid radical or its hydrate does not dissolve in the oil, and the acid solution of the bases, the acid hydrate, and the oil not acted on by the dilute acid, form three distinct layers in the containing vessel. In consequence of this difference in specific gravity and solubility, the solution of the basic oils and the tar may be easily separated from the oils that originally held the salt of the basic oils in solution.

After ascertaining these facts in the laboratory, I suggested to Dr. Salathè, who then had charge of the refinery of the Union Oil Co., that the presence of these compound ethers in the California petroleums was no doubt the cause of the difficulty which had been experienced in refining them.

Steps were immediately taken to test the correctness of this judgment with the most gratifying results; but it is only very recently and under my own direction that the complete removal of both the basic and acid radicals of these ethers has been carried out on the large scale, in such a manner as fully to demonstrate the great importance of this discovery to the technology of this class of bitumens.

No complete analysis of any of the hydrocarbons that make up California petroleum has yet been made to my knowledge; but it has been assumed on other grounds that they belong to the benzole and not to the paraffine or olefine series. The basic oils also are allied to the benzoles. They form with the dilute acid solutions that may be used to wash them from the oils in which they may be dissolved, a reddish brown liquid. From this liquid they may be precipitated as cream colored flakes, which are hydrates of the basic radicals. If filtered off the precipitate soon changes color on the filter to a dark brown and on drying becomes nearly black. The acid tars also appear as hydrates. The acid hydrates are dark green, brown or black semi-solids, possessing extraordinary viscosity. The basic hydrates when deprived of their water yield brown or cherry-red oils which are very transparent and brilliant and which with the acid hydrates are much heavier than water. The entire series of basic radicals has not yet been isolated with certainty as to the higher members. It appears probable that the series commences with pyridin and embraces a large number of pyridins and chinolins, rising to compounds so dense that when left as a residue resembling coke, from distillation at a temperature near the red heat, they are still soluble in hydrochloric acid from which they may again be precipitated as hydrates in cream-colored flakes.

The discovery of these substances has led to very important changes in the technology of the bitumens in which they occur. Both the acid and basic radicals of the compound ethers are very easily removed from the distillates. The remaining oils are more easily susceptible to ordinary treatment with concentrated acids and alkalies, producing oils in every respect superior for their respective uses to those containing the basic radicals and tars, which it has been found the concentrated acid will only partially remove. The burning oils possess superior illuminating power and the lubricating oils are improved in color and are of greatly increased viscosity for corresponding degrees of specific gravity.

This discovery has also opened up a new source of supply to technology for the pyridin and chinolin bases and probably other allied substances not yet known to science. It is probable that not only pyridin and chinolin are present but that also a large number, if not all, of the methylated compounds of these bases are associated with them. The quality of the basic oils from this source is very superior, they being easily freed from the combination in which they exist in the native bitumens and their distillates.

This discovery is also of equal interest when made the subject of purely scientific speculation. The presence of these basic oils establishes beyond any question the animal origin of the bitumens in which they are found. I have tested all of the varieties of bitumen, from the most fluid petroleums to solid asphaltum, found in the region south of the line which forms the northern boundary of San Louis Obispo, Kern and San Bernardino Counties, and have invariably observed the reaction which indicates their presence. These varieties of bitumen include the petroleums found in the vicinity of Santa Paula, malthas from the same neighborhood, from near Los Angeles, from Carpinteria and from Asphalto on the north side of the Coast Ranges west of Bakersfield. I have not treated any of the oil from the vicinity of the Pico Spring directly for basic oils, but the large amount of nitrogen found on analysis of this oil in 1868, indicates the presence of these compounds. The determination of the percentage amounts of basic oils present in crude bitumens presents some difficulties not yet overcome.

A number of facts observed indicate that all those forms of bitumen that have been least exposed to the action of atmospheric oxygen, contain the largest proportion of basic oils. Analysis shows less nitrogen in the malthas and still less in the asphaltums, than in the petroleums. It appears that the compound ethers or *esters* which exist in the native petroleums are decomposed with substitution of oxygen for nitrogen. This substitution I have made artificially. The result is the precipitation of the acid radical as a hydrate within the oil, in which it dissolves, producing a viscous tar. When this decomposition has proceeded so far that water in appreciable quantity becomes a constituent of the compound, the bitumen is no longer petroleum but maltha. This water of hydration separates only when the maltha is heated to a comparatively high temperature. It will never separate by difference of specific gravity at comparatively low temperatures; but requires a temperature at which the hydrate is decomposed into a dense oil very much less viscous than the hydrate on the one hand and water on the other.

As the change proceeds the bitumen becomes solid asphaltum, and a new compound, that is found in maltha only in small quantity if at all, appears. This is Boussingault's *asphaltane*,* which was assumed by him to be an oxidized product in which oxygen was substituted for hydrogen. Recent experiments not yet completed indicate that asphaltene is not a simple substance, but that it may be resolved by suitable solvents into a compound containing oxygen and a compound that represents the original hydrocarbon, minus a portion of its hydrogen, by virtue of which it is no longer soluble in those fluids that dissolve the hydrocarbon in its original form.

The work that I have been able to accomplish since I first became aware of the existence of these substances in January last, as constituents of California bitumens, has been mainly technical. As related to purely scientific considerations it may be compared to the action of a skirmish line, which by drawing the fire of a vast army has revealed its presence. I am confident that the solution of problems of great importance to all of the varied technical applications of bitumen awaits the careful investigation of the nitrogen content of the immense accumulations of bitumen in all its forms found in California.

Perhaps it may be demonstrated, that the permanent asphaltic constructions of antiquity were made of asphalts of animal origin, consisting of hydrocarbons of the benzole series instead of those of vegetable origin, consisting of terpenes.

University of Michigan, Ann Arbor, Michigan, June 4th, 1894.

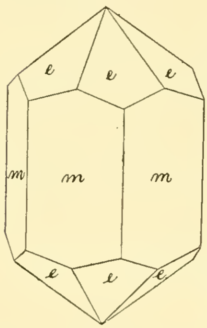
* Annales de Chemie et de Physique (2), lxiv, 141; Journal of the Franklin Institute, xxiv, 138; New Edinburg Philosophical Journal, xxii, 97.

Art. XXXV.—*Note on Artificial Crystals of Zinc Oxide;* by Heinrich Ries.

The occurrence of artificial crystals of zinc oxide in the reverberatory furnaces used in the manufacture of zinc white is not uncommon, but the crystals are usually rounded and their faces give poor reflections.

A number of good crystals have been described by foreign mineralogists,* but the only notice of those occurring in American furnaces is by G. A. Koenig,† who notes some crystals of artificial zinc oxide from the furnaces at La Salle, Ill. The needle-like character of the crystals, and their apparent hexagonal habit is commented on, but no measurements were made of them.

The writer recently received two lots of these crystals, one from Mr. D. A. van Ingen of the New Jersey Zinc and Iron Co., in Newark, N. J., and the other from Mr. G. F. Kunz who collected them at the works of the Passaic Zinc Co., in Jersey City, N. J. The crystals from Newark showed combinations of pyramid and prism, but the faces gave too poor reflections to permit identification. Among the lot from Jersey City were several crystals whose faces gave fairly satisfactory measurements. The following combinations were observed:



A first order prism and first order pyramid $\frac{2}{5}$; a first order prism and first order pyramid $\frac{1}{2}$; a first order prism *m*, and second order pyramid *e*, $\frac{1}{2}$–2. This last crystal was doubly terminated and holohedral. Second order pyramids are not common, and the writer has not seen the face *e* previously noted.

Both the natural and artificial zinc oxide are said to be hemimorphic in habit,‡ but none of the specimens examined could be said to have this habit. One crystal showed a tapering prism, low pyramid, and base. The crystals were colorless, transparent and without basal

* Koch: Beitr. z. Kenntniss Kryst. Hüttenprod.; Göttingen, 1822. Des Cloiseaux: Ann. d. Mines, 1842 (4), vol. i, p. 488. Lévy, Ann. Mines, iv, p. 516, 1843. G. v. Rath: Pogg. Ann. 1864, vol. 122, p. 406 and 1871, vol. 144, p. 580. A. Firket: Ann. Soc. Geol. Belg. 1885, 12th Bull., p. 191. G. Greim: Ber. d. Oberhess. Ges. f. Nat. u. Heilk., 1886, vol. xxiv, p. 51. K. Busz: Zeitschr. f. Kryst. u. Min. 1888–1889, vol. xv. J. T. Cundall: Min. Mag., vol. ix, no. 41, 1890. A. Hutchinson: Ibid., vol. ix, p. 5, 1890.

† Proc. Phila. Acad. Sci., 1873, p. 12.

‡ Dana, System of Mineralogy, 1892, p. 208.

cleavage. They were all of small size, those mentioned being respectively ·5×3, 1×2·5 and ·5×1·5 mm.

The pyramid $\frac{2}{5}$ was observed by Rinne, Greim and Cundall, and the pyramid $\frac{1}{2}$ by Lévy, Greim, Cundall and Hutchinson.*

The following are the angles measured and calculated ; the former did not vary more than 20′ in each case.

	Angle measured.	Angle calculated.
$I \wedge \frac{2}{5}$	54° 27′	53° 9′ 50″†
$I \wedge \frac{1}{2}$	43 47	42 5
$\frac{1}{2}$-2 $\wedge$ $\frac{1}{2}$-2	38 12	36 42

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SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Law and Theory in Chemistry ;* a Companion book for Students. By Douglas Carnegie, M.A. 12mo, pp. viii, 222. London, 1894 (Longmans, Green & Co.).—This little book contains the substance of a summer school course of eight lectures delivered before an audience of school teachers of elementary chemistry at Colorado College, Colorado Springs. As its title indicates it is not intended as a text-book, but is offered as a *resumé* of the more important fundamental principles of chemistry which are less fully considered in ordinary manuals. The subjects treated are Alchemy, the Phlogistic Theory, Chemical Classification, the Atomic Theory, the Classification of Compounds, Isomerism and Molecular Architecture, and Chemical Equilibrium. These chapters are clearly and accurately written and the book will be a valuable aid to the earnest student. It is to be regretted that it is not provided with an index. G. F. B.

II. Astronomy.

1. *A Treatise on Astronomical Spectroscopy :* being a Translation of "Die Spectralanalyse der Gestirne," by Professor Dr. J. Scheiner, Assistant at the Royal Astrophysical Observatory at Potsdam. Translated, revised and enlarged, with the coöperation of the author, by Edwin Brant Frost, M.A., Assistant Prof. of Astronomy in Dartmouth College. 8°, pp. xiii, 482. Figs. 81 ; Pl. 2. Ginn & Co., Boston and London, 1894.—The novelty

* Previously cited.

† These values are based on Rinne's calculations. See Dana, Syst. of Min., 1892, p. 208.

and importance of recent spectroscopic work in Astrophysics ensured for the able and comprehensive survey of the subject, by so competent a writer as Dr. Scheiner, an immediate and cordial reception in astronomical circles, and gave it at once a recognized position as a standard treatise. The very rapid development of this branch of science since 1890, when this work was issued, has resulted in the accumulation of a great number of interesting discoveries, and thrown new light upon many important problems. This fact, as well as the desirability of making the work accessible to a wider circle of students and readers, afforded excellent reasons for a revision.

Professor Frost's translation follows the original text, in the main, very closely, especially in those portions where there has been comparatively little occasion for change. Additions have been liberally made, however, where necessary, and in some instances the newer material is of such a character as to supersede the older results and require a substantial recasting of the topics. Thus, in the chapter upon the motion of the stars in the line of sight, the remarkable application of photographic methods made by Vogel in 1892, giving values with a degree of precision hitherto unapproached, has necessitated the omission of the long list of star velocities determined at Greenwich, and the substitution therefor of Vogel's list of fifty-one stars made by the new method, while the excellent determinations made by other observers in a few cases have not been overlooked. Among other additions may be mentioned Rowland's determination of solar lines, his catalogue of standard lines, and his table of elements occurring in the sun; Young's table of chromospheric lines, corrected and extended by his recent observations; the extension of this catalogue into the ultra-violet region by Hale and Deslandres, and Hale's work upon the spectra of sun-spots and faculæ; recent discoveries of Huggins, Vogel, Keeler, and Campbell in respect to spectra of the nebulæ; Keeler's determinations of the motion of nebulæ in the line of sight; Langley's remarkable work upon the ultra-red region of the solar spectrum, and Abney's table of wave-lengths of solar lines in the ultra-red. Very great changes have been made also in the part relating to the spectra of stars of the different types, the amount of new matter added being very considerable, and well representing the work in this department to the date of publication. A very judicious change is the adoption of Rowland's scale of wave-lengths, unquestionably the most accurate now extant, and, in connection with his photographic charts, the most convenient for practical use.

The volume, as thus expanded, has but few pages more than the original work, owing not only to the slightly larger and more compactly printed page employed, but also, as explained by the author, to the fact that the English saves in space nearly one page for every ten of the German in translation. Professor Frost has executed his task very skillfully, and has shown excellent judgment in the selection and co-ördination of the new material. The style is clear and flowing, and remarkably free from the stiffness and awkwardness so difficult of avoidance in a translation.

A. W. W.

Chas. D. Walcott,

APPENDIX.

Art. XXXVI.—*Description of Tertiary Artiodactyles;* by O. C. Marsh.

The main object of the present paper is to figure, and to describe more fully, several interesting ungulate mammals, which have been previously named and noticed by the writer. A number of others, mostly allied forms, are here described for the first time. The specimens discussed are chiefly from the western part of the country. Some of them from the Miocene, however, are apparently identical with those found on the Atlantic coast, and thus for the first time it is possible to make out a definite horizon in the Tertiary, extending nearly across the continent.

Eocene Bunodont Artiodactyles.

The Artiodactyles known from the Eocene of this country are few in number, and nearly all small generalized forms. The oldest hitherto found appear to have suilline affinities, but the others cannot be placed with any certainty in any of the existing groups. The first Artiodactyles, so far as now known, are preserved in the lower Eocene, in the horizon named by the writer the "Coryphodon beds," and these are all primitive forms. In the middle Eocene, especially in the "Dinoceras beds," the remains of these mammals are more abundant, and some of them permit accurate determination. In the upper Eocene, in the Diplacodon horizon, more specialized forms occur, and for the first time resemblance to several modern types can be recognized.

Eohyus distans, sp. nov.

The present genus was proposed by the writer in 1877, in an address before the American Association for the Advancement of Science.* In reviewing the extinct ungulates of this country, the following statement was then made in regard to the present group:—

* Introduction and Succession of Vertebrate Life in America, this Journal, vol. xiv, p. 362, 1877.

"The Artiodactyles, or even-toed Ungulates, are the most abundant of the larger mammals now living; and the group dates back at least to the lowest Eocene. Of the two well marked divisions of this order, the Bunodonts and the Selenodonts, as happily defined by Kowalevsky, the former is the older type, which must have separated from the Perissodactyle line after the latter had become differentiated from the primitive Ungulate. In the Coryphodon beds of New Mexico, occurs the oldest Artiodactyle yet found, but it is at present known only from fragmentary specimens. These remains are clearly Suilline in character, and belong to the genus *Eohyus*. In the beds above, and possibly even in the same horizon, the genus *Helohyus* is not uncommon, and several species are known."

The type specimen of the genus *Eohyus* is represented below, natural size, in figure 1. Various other remains have been found, which might be referred to this species, but they give but little definite information as to its affinities, since it is not certain that the reference is correct. The type specimen is a last upper molar, and the characters of its crown are well shown in the figure. Another upper molar shows the same essential features. Judging from these specimens alone, the animal would appear to have been a suilline, or at all events, a bunodont Artiodactyle. Future discoveries must determine its exact position. With the specimens described next below, the present remains represent a distinct family, which may be called the *Eohyidæ*.

Eohyus robustus, sp. nov.

A larger species, which may be referred provisionally to the genus *Eohyus*, is represented by portions of a pair of lower jaws with imperfect teeth, and fragments of other specimens. The teeth are tubercular, and agree sufficiently well with the type of the genus to be regarded as belonging to an allied species. The lower jaws are very short and robust, with a strong symphysis. There were apparently four lower premolars and three molars, forming a continuous series, measuring about three inches in length. The depth of the jaw below the first true molar was one inch. The remains representing this species are from the lower Eocene of New Mexico.

Various remains of animals with a dentition resembling that of suillines have been described by Cope under the generic name *Periptychus*, which is preoccupied. These remains are from the so-called Puerco deposits, or lower Wahsatch of New Mexico, a horizon lower than that in which the type of *Eohyus* was discovered.

Parahyus aberrans, sp. nov.

In figure 2 below, a last upper molar tooth is represented natural size, which may be referred to the present genus, described in 1876.* There can be little doubt that the type species, as well as the present tooth, belonged to suilline mammals, although they indicate animals much larger than would be expected from so low a horizon. Moreover the type had but three lower premolars, and thus was more specialized than most of the ungulates from the same horizon.

The present specimen resembles somewhat the last upper molar of *Homacodon*, but shows distinct indications of a third posterior cone on its inner margin. This specimen was found in the Coryphodon beds of Wyoming, near the locality where the type of *Parahyus vagus* was discovered. It represents an animal about half as large as the type of the genus.

1. 2. 3. 4.

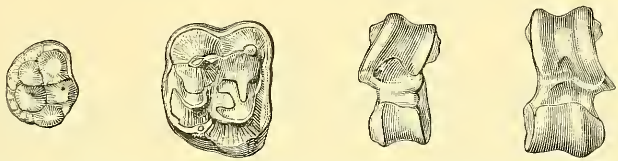


FIGURE 1.—Last upper molar of *Eohyus distans*, Marsh; seen from below.
FIGURE 2.—The same tooth of *Parahyus aberrans*, Marsh; seen from below.
FIGURE 3.—Astragalus of *Homacodon priscus*, Marsh; front view. All three figures are natural size.
FIGURE 4.—Astragalus of *Homacodon pucillus*, Marsh; front view. Twice natural size.

Homacodon priscus, sp. nov.

Among the undoubted Artiodactyles of the lower Eocene are two species which cannot at present be separated from the genus *Homacodon*. The astragalus of one of these is represented above in figure 3, and a second smaller species, *H. pucillus*, in figure 4. The other known remains of these two species are not distinctive, but indicate true Artiodactyles of the bunodont type, and are interesting mainly from proving the existence of such forms in the lower Eocene. They occur in the Coryphodon beds of Wyoming and New Mexico.

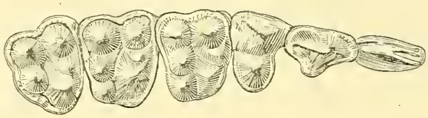
Teeth resembling those of *Helohyus* are likewise found in this horizon, but it is not certain that they pertain to true Artiodactyles. Some have been referred to the Perissodactyles. Others may belong to the *Mesodactyla*.

*This Journal, vol. xii, p. 402, November, 1876.

Homacodon vagans, 1872.

In the Dinoceras beds of the Bridger basin, in Wyoming, which may be regarded as middle Eocene, various remains of Artiodactyles have been found, but none with the selenodont dentition. All yet discovered still belong to the bunodont division of *Artiodactyla*, and most of these are small in size. The first genus discovered and described was *Homacodon*, and the type specimen is the most perfect of the group yet found.* In figures 5 and 6 below, the upper and lower molar teeth of this specimen are represented, and in figures 7 and 8, the distal end of the tibia and the astragalus of the same individual are also shown, all twice natural size.

5.



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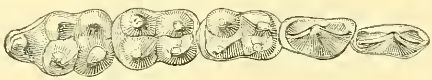

FIGURE 5.—Upper molar series of *Homacodon vagans*, Marsh; (type) seen from below.
FIGURE 6.—Lower series of same individual; seen from above.
Both figures are twice natural size.

The present genus has apparently the complete dentition, forty-four teeth, although the type specimen does not reveal the exact number of incisors. The canines are large. The anterior premolars, above and below, are secant. The last upper premolar has a single outer cusp and one inner cone. The upper molars have each two conical external cusps. There is a small median anterior cusp, also, on each. The first molar has three posterior cusps, all well developed. The second molar has the inner posterior cusp small, and in the third molar, this is wanting, or only represented by the basal ridge from which the others were derived.

The skull of the type specimen of the present species has a brain case of fair size, and a sharp sagittal crest. The orbits are not closed behind. The cervical vertebræ are short, and have their ends oblique, indicating a curved neck. The dorsals are of moderate length, with the centra broad, and their ends flat. The posterior trunk vertebræ are all keeled below.

* This Journal, vol. iv, p. 126, August, 1872.

There appear to have been five digits in the manus, and the same number in the pes, although probably only four were functional. The animal was about the size of a small rabbit.

The present genus with the one next described represent a distinct family, which may be called the *Homacodontidæ.*

After the establishment of the genus *Homacodon*, by the writer, in 1872, Cope proposed the name *Pantolestes* for a small animal from essentially the same horizon. The type was a lower jaw, with the teeth too imperfect for exact determination, but the animal was referred to the Lemuroids.* This reference was subsequently strengthened by Cope, who placed this specimen in the genus *Notharctus* of Leidy, with *Pantolestes* as a synonym.† Afterwards he revived the name *Pantolestes*, and placed under it remains of Artiodactyles, some evidently pertaining to the genus *Homacodon*, and later still he included other species, but none of them apparently distinct from that genus.

7. 8. 9. 10.

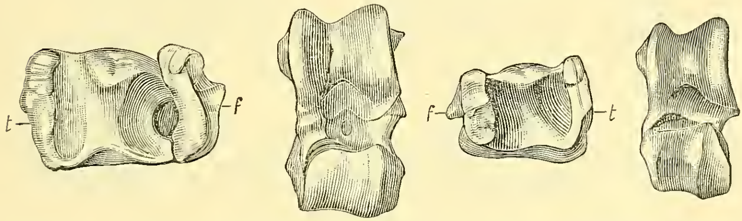

FIGURE 7.—Tibia of *Homacodon vagans ;* (type) distal end. *t*, tibia ; *f*, fibula.
FIGURE 8.—Astragalus of same individual ; front view.
FIGURE 9.—Tibia of *Nanomeryx caudatus*, Marsh ; distal end.
FIGURE 10.—Astragalus of same species ; front view.

All the figures are twice natural size.

Nanomeryx caudatus, gen. et sp. nov.

This genus appears to be nearly related to *Homacodon*, with which it agrees in several respects, but may be distinguished from it by the fact that the fibula is reduced, and coössified distally with the tibia. The lower jaws are more slender and compressed than in *Homacodon*, and there is a short diastema between the canine and first lower premolar. The bones of the skeleton, even the vertebræ, are very hollow.

* Proc. Amer. Philos. Soc., vol. xii, p. 467, for 1872.
† Sixth Ann. Rep. U. S. Geol. Surv. Terr., p. 549, 1873.

The humerus is perforated above the lower condyle, and the inner condylar margin is without the process characteristic of *Homacodon*. The radius and ulna are separate, but the latter bone is quite slender. The fibula is incomplete. The lower part has coalesced entirely with the tibia, but the suture remains distinct, except in very old individuals. In figures 9 and 10, the distal end of the tibia and the astragalus of this species are represented twice natural size.

The present species is only about half as large as *Homacodon vagans*, and is thus one of the smallest Eocene Artiodactyles known. The first specimens discovered were found by the writer in 1870, near Fort Bridger, Wyoming. The type specimen here described is from the same region. All are from the Dinoceras beds of the middle Eocene.

Helohyus plicodon, 1872.*

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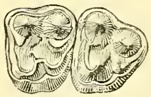

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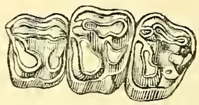

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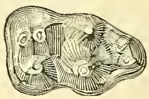

FIGURE 11.—Last upper molar of *Helohyus plicodon*, Marsh; (type) seen from below.
FIGURE 12.—Second and third upper molars of same species.
FIGURE 13.—Three worn upper molars of same.
FIGURE 14.—Lower teeth of same.
FIGURE 15.—Last lower molar of *Helohyus* (*Thinotherium*) *validus*, Marsh; top view.
FIGURE 16.—The same tooth of *Helohyus* (*Elotherium*) *lentus*, Marsh.

All the figures are natural size.

The genus *Helohyus*, as at present known, includes several species of suilline mammals, all much larger than those of *Homacodon*, and most of them, at least, from a higher horizon of the middle Eocene. The type specimen of the present species, which is also the type of the genus, includes the last upper molar represented natural size, in figure 11 above. This is in fine preservation, and shows clearly the characteristic features of the crown. Other remains found with the type, and still others from the same locality or horizon, give more characters of the genus, although no single skeleton is known

* This Journal, vol. iv, p. 207, September, 1872.

as complete as that of *Homacodon*. Figure 12 above shows the second and third upper molars of the present species; figure 13, three upper molars of an old animal; and figure 14, the lower teeth, all natural size. The astragalus is well shown in figure 17. The upper molars resemble those of *Homacodon*, but differ in having but two posterior cones.

17.

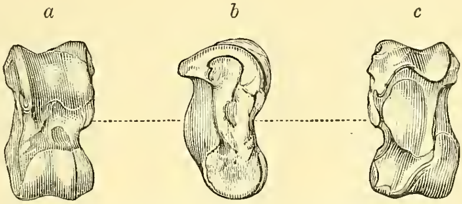

FIGURE 17.—Astragalus of *Helohyus plicodon*. Natural size. *a*, front view; *b*, side view; *c*, back view.

Two other species which probably should be referred to the present genus are *Thinotherium validum* and *Elotherium lentum*, described by the writer from specimens found in the same region as the type of *Helohyus*. The last lower molar of each is shown in figures 15 and 16. It is quite possible that another allied species was described by the writer under the name *Stenacodon rarus*, but at present the exact relationship between these forms cannot be determined. All are from the middle Eocene of Wyoming.

EOCENE SELENODONT ARTIODACTYLES.

In the autumn of 1870, the writer explored a new Tertiary lake-basin, which he had discovered south of the Uinta mountains, in Utah. This exploration was carried on with great hardship and much danger from hostile Indians, but proved conclusively that this lake-basin was of late Eocene age, and it was subsequently named by the writer, the Uinta basin. The first results of this exploration were published in an article "On the Geology of the Eastern Uinta Mountains,"* a paper that appears to have been overlooked by several recent writers on the subject. This Eocene lake-basin was quite distinct from the older Bridger basin, north of the Uinta mountains, which the writer also first explored in 1870. These researches further resulted in securing many new vertebrate fossils from each basin. The two were later distinguished by the writer, by names taken from the largest and most characteristic animals found in them. The strata of the Uinta basin were thus named the "Diplacodon beds," and those of the northern lake deposits, the "Dinoceras beds."

* This Journal, vol. i, p. 191, March, 1871.

Eomeryx pumilus, Marsh.

Among the interesting fossils found by the writer in the Uinta basin, in 1870, were remains of three small Artiodactyles, each with selenodont dentition, the earliest then known in the country. One of these animals was described under the name *Agriochœrus pumilus*,* as the lower teeth and other portions secured resembled strongly the corresponding parts pertaining to that genus, as known from a higher horizon. Subsequent discoveries proved that these remains were distinct from those of *Agriochœrus*, the upper molars resembling more nearly those of *Ancodus* (*Hyopotamus*), but in reality representing a new genus, which was named by the writer *Eomeryx*, in the address already cited.†

18.

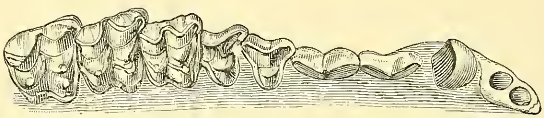

FIGURE 18.—Upper teeth of *Eomeryx pumilus*, Marsh; seen from below. Natural size.

In the address quoted, the writer defined the Uinta Artiodactyles with selenodont dentition, as follows: "In the *Diplacodon* horizon of the upper Eocene, the Selenodont dentition is no longer doubtful, as it is seen in most of the *Artiodactyla* yet found in these beds. These animals are all small, and belong to at least three distinct genera. One of these, *Eomeryx*, closely resembles *Homacodon* in most of its skeleton, and has four toes, but its teeth show well marked crescents, and a partial transition to the teeth of *Hyopotamus*, from the Eocene of Europe. With this genus, is another (*Parameryx*), also closely allied to *Homacodon*, but apparently a straggler from the true line, as it has but three toes behind. The most pronounced Selenodont in the upper Eocene is the *Oromeryx*, which genus appears to be allied to the existing Deer family, or *Cervidæ*, and if so is the oldest known representative of the group. These facts are important, as it has been supposed, until very recently, that our Eocene contained no even-hoofed mammals." Again in speaking of the Oreodonts in the Miocene, the following statement is made: "The least specialized, and apparently the oldest, genus of this group is *Agriochœrus*, which so nearly resembles the older *Hyopotamus*, and the still more ancient *Eomeryx*, that we can hardly doubt that they all belonged to the same ancestral line."

* This Journal, vol. ix, p. 250, March, 1875.
† *Ibid.*, vol. xiv, p. 364, November, 1877.

By subsequent researches in the Uinta basin, the writer secured many additional remains of all these three Artiodactyles, and in regard to *Eomeryx*, at least, nearly all the important characters can thus be determined. These specimens confirm in a decisive manner the original determination of the essential features and affinities of the animal described from the first fragmentary remains.

The skull of *Eomeryx* has the same general form as that of *Agriochœrus*, and the lower jaw and dentition are essentially the same. As in that genus, there is no lachrymal fossa, and the orbit is not closed behind. The complete dentition of forty-four teeth is a primitive character to be expected from a horizon lower than that of *Agriochœrus*. In this respect and in several others, especially in the feet, *Eomeryx* shows a nearer relationship to *Oreodon*, with which it certainly has strong affinities.

The upper molars, as shown above, natural size, in figure 18, have the characteristic fifth lobe on the front of the crown, as in the *Ancodontidæ*, or *Hyopotamus* family, and this feature alone, given in the original description of the genus, served to distinguish *Eomeryx* from any allied forms in the strata in which it was found. The lower molars are shown in figure 22.

19.

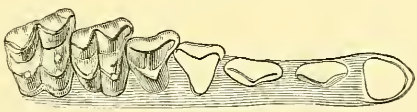

FIGURE 19.—Upper teeth of *Hyomeryx breviceps*, Marsh; seen from below. Natural size.

The limbs and feet of *Eomeryx* are of much interest. The radius and ulna are distinct, and of nearly equal size. There are four functional digits in the manus, and the first was also represented, although of little use. In the hind limbs, the fibula was slender, but complete. There were four functional toes in the pes, all well developed, and a remnant, at least, of the first was present. The digits were terminated by narrow hoofs, similar to those in *Oreodon*.

The genus *Eomeryx*, as thus determined, clearly represents a distinct family, which may be called the *Eomericidæ*. This group includes the genus *Hyomeryx*, described below, and contains the oldest selenodont suillines in this country. It had for its predecessors *Helohyus* and *Homacodon* from the strata of the Dinoceras beds.

The present genus and species, *Eomeryx pumilus*, were redescribed by Scott and Osborn, in 1887, under the name *Protoreodon parvus* (Proc. Amer. Philos. Soc., vol. xxiv, p. 257), and later, in 1889, by Scott, more in detail (Trans. Amer. Philos. Soc., vol. xvi, p. 487). No reference was made in either paper to the article by the writer, cited above, relating to the Uinta basin, and the statements made concerning the first researches in the basin are inaccurate. The description and figures are in the main correct.

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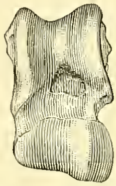

22.

FIGURE 20.—Upper molar of *Parameryx lævis*, Marsh; seen from below.
FIGURE 21.—Astragalus of same species; front view.
FIGURE 22.—Lower molars of *Eomeryx* (*Agriochœrus*) *pumilus*; top view.
The figures are all natural size.

Hyomeryx breviceps, gen. et sp. nov.

The present genus is nearly allied to *Eomeryx*, but represents a more specialized form. The skull is shorter, particularly in the facial region, but the most important difference is seen in the premaxillaries. In the present type, these are very much reduced, and thoroughly coössified with the maxillaries. They cover the canines in front, but contain no incisors. The upper canines are smaller than those of *Eomeryx*, and the maxillaries containing them are less robust. There is a diastema behind the upper canine, and the molars agree in form with those of *Eomeryx*. The lower jaws have the full dentition, the first premolar being caniniform, as in *Eomeryx* and *Oreodon*, but the lower jaws are less massive than in those genera, especially in front. Figure 19 shows the upper teeth of the type specimen.

There appear to be four functional digits in the fore feet, and the first is probably represented in a much reduced form. In the hind feet, also, there are four functional digits, and a remnant of the fifth is still retained.

The type specimen of the present genus is from nearly the same horizon as the type of *Eomeryx*. The present species was about two-thirds the size of *Eomeryx pumilus*.

Parameryx lævis, sp. nov.

The second genus of selenodont ungulates referred to in the address quoted is quite distinct from *Eomeryx*, but is known from less perfect remains. It may readily be distinguished from that genus by the upper molars that lack the extra fifth cone, and by the slender, compressed lower jaws, without a caniniform first premolar. The limbs and feet, also, show important differences. In the hind feet, there were but two functional digits, although the second was present in a reduced form. An upper molar and the astragalus of this species are shown in figures 20 and 21.

In size, the present species was smaller than the type of *Eomeryx*, and of more slender proportions. There appear to be one or two species of the present genus besides the type. One of these may be distinguished by the lower jaws, which have a deep groove on the inner face of the ramus, extending forward nearly to the symphysis. This form may be known as *Parameryx sulcatus.*

In the address already quoted, this genus was regarded as possibly related to the Camels and Llamas, but until additional remains are found, its exact affinities must remain in doubt.

In the two publications above cited, Scott and Osborn have given the name *Leptotragulus* to certain Artiodactyle remains from the Uinta deposits, but it does not appear from the descriptions or figures, that the specimens described are distinct from those on which the genus *Parameryx* was established. Some of them are apparently identical, although the species may be different. Others may pertain to *Oromeryx*, a genus certainly distinct from *Leptotragulus*, as described.

Oromeryx plicatus, sp. nov.

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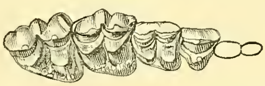


FIGURE 23.—Upper teeth of *Oromeryx plicatus*, Marsh; seen from below. Natural size.

The third genus of Artiodactyles with selenodont dentition found in the Uinta basin by the writer, and noticed in the address above quoted, is *Oromeryx*. This genus is represented by numerous remains, many of them in good condition, which afford characters for distinguishing it from those above described. They represent, moreover, animals somewhat smaller in size than those already noticed, and of proportions still more delicate.

The skull in the frontal region is broad and flat. The supra-orbital foramina are widely separated, with diverging grooves leading to them from the nasal suture. The upper molars have oblique crowns, with no antero-median cusp. The upper molar teeth are especially characteristic, as seen from those represented natural size, in figure 23 above. The enamel of the crowns is finely wrinkled, and this has suggested the specific name. This feature is seen also in the lower molars, especially in the teeth of animals not fully adult. The lower jaws are slender, and compressed in front, and there is no diastema in the dentition.

The bones of the skeleton are very hollow. The humerus is perforated above the distal condyle. The ulna is complete. The fibula is also complete, with the distal end much compressed. There are four functional digits in the manus, and possibly five. There are four usable digits, also, in the hind feet, with the lateral ones well developed.

The affinities of this genus, as already stated, appear to be with the Deer family, and it also has some points of resemblance to the Traguloids.

Miocene Artiodactyles.

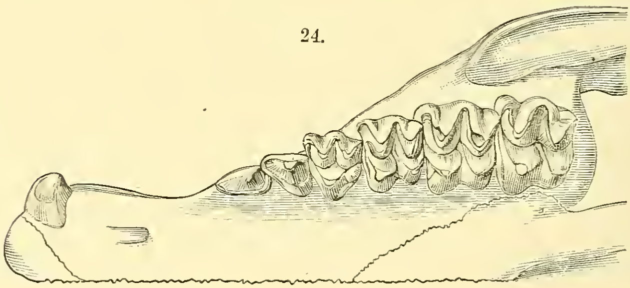


Figure 24.—Upper teeth of *Agriomeryx migrans*, Marsh; seen from below. Two-thirds natural size.

Agriomeryx migrans, gen. et sp. nov.

The present genus is most nearly related to *Agriochœrus*, Leidy, and appears to be its direct successor in a higher horizon of the Miocene. The two genera may be readily distinguished by the teeth. The older form has four premolars above and below, while *Agriomeryx* has but three. In figure 24 above, the left upper dental series of this species is shown two-thirds natural size. There are no upper incisors in the present genus. The lower jaws contain a full series of teeth, twenty-two in number. The first lower premolar has assumed the form and function of a canine, the true lower canine being quite small, and resembling the incisors. The type specimen figured is from the Protoceras horizon in South Dakota.

Thinohyus, 1875.*

25. 26. 27.

FIGURE 25.—Last upper molars of *Thinohyus socialis*, Marsh; seen from below.
FIGURE 26.—Last upper molar of *Thinohyus lentus*, Marsh.
FIGURE 27.—Second lower molar of *Thinohyus antiquus*, Marsh; top view.
All the figures are natural size.

28.

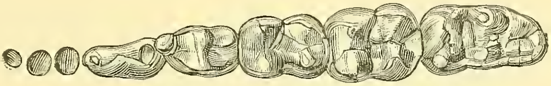


FIGURE 28.—Lower teeth of *Thinohyus nanus*, Marsh; top view. Natural size.

Thinohyus nanus, sp. nov.

The present species is the smallest of the genus yet discovered. The specimen selected as the type is represented in figure 28 above, natural size. It is a left lower jaw, with the third and fourth premolars and the three molars in place. The front of the jaw is not preserved, but the alveole of a large canine is present, and also those of the first and second premolars, which were evidently secant. There was apparently no diastema behind the canine, and the whole jaw was unusually short and robust. The type specimen is from the Miocene of South Dakota, but the exact horizon is not known.

Two other species of the present genus, from the Miocene of Oregon, have already been described by the writer, and in figures 25 and 26 typical specimens of both are shown. The largest species is *Thinohyus* (*Dicotyles*) *antiquus*, from the same horizon in New Jersey, and the type is shown in figure 27.

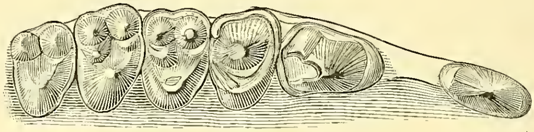
Leptochœrus gracilis, sp. nov.

The genus *Leptochœrus* was established by Leidy in 1856, the type specimen being the fragment of a small lower jaw containing two molar teeth, supposed to pertain to a suilline mammal.† Other remains subsequently referred to the same genus threw no additional light on the affinities of the animal, which up to the present time have remained in doubt.

* This Journal, vol. ix, p. 248, March, 1875.
† Proc. Acad. Nat. Sci. Phila., p. 88, 1856.

A specimen in the Yale Museum representing a different species, apparently pertains to the same genus, and proves, moreover, that the original suggestion as to the nature of the animal was probably correct. This specimen is in fine preservation, and consists of the skull and greater portion of the skeleton of an adult individual about as large as a rabbit. One interesting feature of the skull is the comparatively large size of the brain cavity, and the cast it contains shows well-marked convolutions. The dentition is of special interest. The upper molars resemble those of *Helohyus*, especially the last molar of that genus. They have each two outer cones, a single large inner cusp, and two intermediate lobes, the anterior uniting by wear with the inner cusp so as to form a crest. The fourth premolar has a single outer cone and one inner cusp. The third premolar is very large, and subtriangular in outline. The second premolar is secant, and behind it is a well-marked diastema. The teeth are shown in figures 29 and 30 below.

29.



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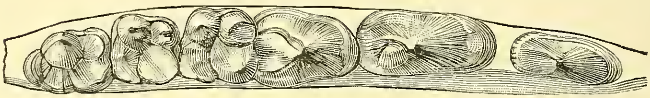


FIGURE 29.—Upper teeth of *Leptochœrus gracilis*, Marsh; seen from below.
FIGURE 30.—Lower teeth of the same skull; top view.
Both figures are twice natural size.

The lower jaws in the present species are slender, especially in front. The lower molars are very small, decreasing in size to the last. The fourth premolar is larger than the first molar. The anterior premolars are secant, and there is a diastema in front and behind the second. There is a deep groove on the inner side of the lower jaw, extending from the dental foramen nearly to the symphysis.

The radius and ulna are separate, and the latter well developed. There were apparently four functional digits in the manus. The fibula is much reduced. Its lower portion has coalesced with the tibia. The hind foot resembles that of *Homacodon*, having four usable digits, but the navicular and cuboid are coössified, an unexpected feature.

These remains prove that the animal they represent belonged to a distinct family, which may be called the *Leptochœridæ.* The type specimen of the present species is from the Miocene of South Dakota.

Calops cristatus, 1894.

The peculiar Artiodactyle described under the above name, in a late number of this Journal (p. 94), had many features of interest besides those mentioned in the original description. Some of these are as follows:

The brain was comparatively well developed, and an unusually large part of the cerebral lobes was covered by the parietals. The frontal region of the skull between the orbits was more or less concave. The antorbital depressions extend well forward. There is a diastema between the upper canine and the first premolar, and between the first and second premolars. The canines above and below are small. The first lower premolar appears to be wanting. The second and third premolars have secant crowns, much elongated fore and aft. The postglenoid process is quite small, but the paroccipital is large and robust. The lower jaw has a very short coronoid process, and the condyle is sessile. The angle of the jaw is well rounded and somewhat dependent.

Pliocene Artiodactyles.

31. 32.

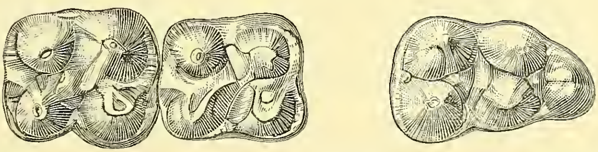


Figure 31.—First and second lower molars of *Platygonus rex*, Marsh; top view.
Figure 32.—Last lower molar of same species; young tooth; top view.
Both figures are natural size.

Platygonus rex, sp. nov.

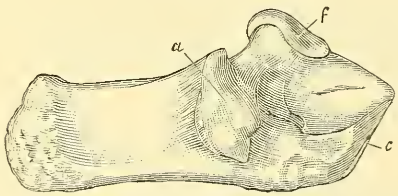
The present species is the largest of the genus yet discovered. The type specimen is represented natural size, in figure 31 above. In figure 32, a last lower molar of the same species is shown, but it is a young tooth which had not yet come into wear. The peculiarity of these molar teeth, aside from their size, is that the crowns are mainly composed of well-rounded, conical tubercles, few in number, and placed systematically. The crowns of the first and second molars are each composed of four large cones, nearly equal in size, and the last molar has five.

This simplicity of structure is characteristic of the Eocene suillines, as already shown in the present article. In lower Miocene forms, it is less distinct. The type specimen of the present species and other remains were obtained by the writer, in 1871, from the Pliocene deposits of eastern Oregon.

Procamelus altus, sp. nov.

In the same horizon in eastern Oregon in which is found the peccary last described, remains of a very large extinct camel also occur. Various portions of the skull and skeleton were secured by the writer, and these all appear to pertain to the genus *Procamelus*, as described by Leidy. These remains indicate a camel exceeding in size any previously described from this country, and one in which the extremities were especially elongated. In figures 33 and 34 below, the calcaneum of this animal is represented one-fourth natural size. The known remains of this species are from the Pliocene deposits, near the John Day River, in Oregon.

33.



34.

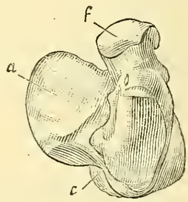


FIGURE 33.—Left calcaneum of *Procamelus altus*, Marsh; inner view.
FIGURE 34.—The same bone; front view. Both figures are one-fourth natural size. *a*, face for astragalus; *c*, face for cuboid; *f*, face for fibula.

CORRELATION OF MIOCENE HORIZONS.

In the July number of this Journal, the writer made the announcement that the horizon in the Miocene deposits of Oregon, which he had explored many years since, and named the Miohippus beds, was also represented east of the Rocky Mountains, and in the same relative position, various vertebrate fossils being common to both. In a previous number of the Journal (November, 1893), the writer had stated that a distinct horizon in the Miocene on the Atlantic coast, named by him the Ammodon beds, corresponded to one in the Rocky mountain region, in which the same genus, *Ammodon*, had been found. More recent researches have brought out the interesting fact that this horizon is essentially the same as the Miohippus beds of the central region, and as those on the Pacific coast as well, so that at last a definite horizon is determined in the Miocene, extending across the continent.

Yale University Museum, New Haven, Conn., August 15, 1894.

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VOL. XLVIII. OCTOBER, 1894.

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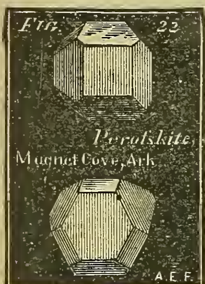

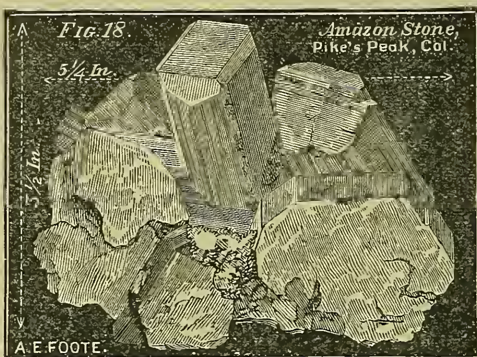

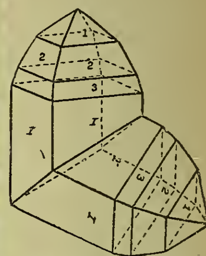

Twin Crystal Zircon.

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[THIRD SERIES.]

Art. XXXVII.—*An Auriferous Conglomerate of Jurassic Age from the Sierra Nevada;* by W. Lindgren.

Some of the largest quartz veins of the gold belt of the Sierra Nevada intersect the Mariposa beds, the most recent sedimentary member of the bedrock series of that range. The age of these beds has long been in some doubt but the latest investigations* appear to render it almost certain that they should be considered as belonging to the uppermost Jurassic. Hence the quartz veins of the gold belt have generally been conceded to have been formed shortly after the post-Mariposa mountain building disturbance; the time limits would be the end of the Jurassic on the one hand and the beginning of the Chico-Cretaceous on the other. The disintegration of these auriferous veins has furnished the material for the Cretaceous, Tertiary and Pleistocene gravel beds.

There is evidence that the Sierra Nevada has remained elevated above the sea since the beginning of the Chico Cretaceous, for beds of that age are found in nearly horizontal position along the western foot of the range. The accumulation of the auriferous gravels must thus have begun already during the earlier part of the Chico period; at Folsom, for instance, a small area of these Cretaceous sandstones is found in the deepest part of a depression occupied by Neocene gravel deposits; below them, on the granitic bedrock, a thin layer of auriferous gravel occurs. The configuration of the bedrock

* Alpheus Hyatt, Trias and Jura in the Western States. Bull. Geol. Soc. Am., vol. v, p. 395. James Perrin Smith, Age of the Auriferous Slates of the Sierra Nevada. Bull. Geol. Soc. Am., vol. v, p. 243.

at this point proves that already during the Cretaceous the river courses were outlined which, during the Tertiary, were further eroded and then filled with gravel. From the northern part of the State Mr. R. L. Dunn has recently, in a paper written for the State Mineralogical Bureau but not yet published, described an interesting occurrence of auriferous river gravel from underneath the Chico sandstones.

A most marked unconformity exists at Folsom between the horizontal Chico sandstones and the vertical and highly compressed Mariposa beds; the latter are besides cut off and metamorphosed by the adjoining intrusive mass of granodiorite.

In view of the facts presented above it is of some interest to find an auriferous conglomerate in the Mariposa beds indicating that at least some of the quartz veins antedate the post-Mariposa upheaval.

Before describing the occurrence it may not be amiss to devote a few lines to the sedimentary formations of the vicinity. The larger part of the sedimentary area of the gold belt is, as shown by the work of the U. S. Geological Survey, of pre-Jurassic age. Most prominent are the Paleozoic, probably mostly Carboniferous rocks and smaller belt only belong to the Trias, the Jura-Trias and to the Jura. Some of the results attained in the gold belt south of the fortieth parallel have been set forth by Mr. H. W. Turner in a paper published in the American Geologist, April, 1894.

The locality to be described here is found in Placer County, on the ridge between the North and Middle Forks of the American river at an elevation of about 2100 above the sea and is mapped on the Placerville atlas sheet, N.W. corner.

Beginning from the edge of the Great Valley there is first a broad area of granodiorite, followed by a belt of diabase and greenstone schists, which again are adjoined on the east by a series of Paleozoic sedimentary rocks, probably all Carboniferous (Calaveras formation). They consist of black, not very fissile clayslates and fine, dark colored sandstones, but besides these and characteristic of the formation in this vicinity, there are heavy beds and lenticular masses of crystalline limestone very frequently changed to a black or gray chert or phthanite. The strike is nearly N.–S., the dip 70°–90° E.

Adjoining this series on the east are the Mariposa beds. Through the southern part of Eldorado Co. they can be traced without difficulty as a belt from ½ to 2 miles wide. At Placerville they begin to widen and intrusive bodies of diabase and porphyritic in part made schistose by dynamo-metamorphic action appear in them, splitting the series into two and three belts. The eastern line of demarcation towards the Paleozoic beds adjoining again on the east, as laid down on Placerville sheet, is somewhat doubtful between Placerville and the northern edge of the sheet; both at Spanish Flat and at Georgetown, Mesozoic fossils have been found and the line has therefore been drawn so as to include both these localities. Up to the Middle Fork of the American river the prevailing rock of the Mariposa beds is a black fissile slate sometimes, as at Greenwood, alternating with thin beds of dark tufaceous sandstone. At the latter place the contact with the underlying Calaveras formation is well exposed with apparent conformity both dipping 70°–80° east. From here up to Colfax, a distance of about 12 miles the character of the Mariposa beds change. Conglomerates appear in places near the western contact, the black slates become less fissile and more jointed and contain abundant beds of dark tufaceous sandstones and breccias; the latter are composed of slate, phthanite and limestone from the Calaveras formation together with fragments of basic igneous rocks. Besides dikes and masses of the latter cut across the strata. The breccias appear mostly conformably in the series and should probably be explained as intercalated mud flows. Short distance north of Colfax a massive of diabase, gabbro and diorite cuts off the Mariposa beds, which here predominatingly consist of pyroclastic rocks. A breccia of diabase mixed with fragments of limestone, etc., extends from the massive and cuts across the beds at Colfax. It is most probable that the basic intrusive area to the north of Colfax represents the core of a volcano the eruptions of which were contemporaneous with the deposition of the Mariposa beds and the ejecta of which intermingled with the sediments.

The older rocks adjoining the Mariposa beds on the east extend northward but to the west of these where the continuation of the Mariposa beds should be sought no certain trace of them can be found. Diorites, diabases and other principally basic rocks occupy, on Smartsville sheet, nearly the whole area to the west down to the valley. Both the Mariposa and most of the western area of the Calaveras formation appear to be engulfed in the igneous rocks if indeed the former ever continued to the north of Colfax. The evidence appears to favor the theory that the Mariposa beds were deposited in a gulf or bay, enclosed on both sides by older rocks and ending in the vicinity of Colfax. In the igneous areas to the N.N.W. of Colfax and extending up towards Grass Valley and Nevada City some narrow bands and smaller areas of sedimentary rocks occur. The limestone and phthanite in most of them indicate that they belong to the Calaveras formation; there is however one narrow band of black tufaceous slates and sandstones, between Grass Valley and Nevada City which may possibly belong to the Mariposa beds.

Although the Mariposa slates usually show an apparent conformity with the older rocks, there is, between Colfax and the Middle Fork of the American river, some structural evidence strongly tending to show an unconformity. Between these two localities the Mariposa beds have about the same strike as the enclosing slates of the Calaveras formation, but while the latter nearly uniformly have a steep dip of from 75° to 90° to the east, the former show throughout a considerably smaller dip of from 50° to 60° in the same direction. Mr. H. W. Turner recognizes from evidence gathered in the southern counties, the probable unconformity of the two formations and brings the following points to support it:* First, the lithologic difference between the formations; second, the occurrence of a conglomerate with phthanite pebbles in the Mariposa beds near Texas ranch, Calaveras Co.; third, the occurrence of a narrow streak of the Mariposa beds cutting obliquely across the Calaveras formation; fourth, the large paleontologic break between the formations.

Coming up the ridge between the two forks of the American river, which here are not more than three miles apart, the Calaveras formation ends a quarter of a mile to the east of Sheridan's Ranch. Between this formation and the Mariposa beds is here intercalated an elongated body of diabase porphyrite and volcanic breccias extending nearly across the divide. The diabase porphyrite forms the westerly summit of Mile Hill; in the breccia accompanying it some well washed pebbles of phthanite are found. A thousand feet west of Mile Hill toll house the Jurassic sedimentary rocks begin and continue for three-quarters of a mile eastward when basic igneous rocks again are met with. The exposures are at first poor along the road which runs in a flat, broad gulch with much loose soil containing well washed pebbles derived from the conglomerate. On the hill south of the United States ranch (E. 2200′) the conglomerate shows in abundant outcrops both on the top and in the ravines. North of the road, on top of Mile Hill there are more outcrops though deep laterite mostly covers the ridge. At the United States ranch there is a good outcrop, part of it consisting of a hard, dark tufaceous sandstone and part of a dark, soft shale containing small but well washed pebbles of phthanite. From the hill mentioned south of the ranch there is a steep descent to the Middle Fork, the sedimentary area narrows greatly between two igneous masses and only black slates and sandstones are exposed in the bottom of the canyon. On the north side of Mile Hill there is also a steep descent of 1500 feet to the North Fork; the conglomerate from the top of Mile Hill can be traced down

* Loc. cit., p. 245.

some distance over the slope although the identification is made difficult by sliding rock masses and dense brush. In the bottom of the canyon of the North Fork, however, the sedimentary series is excellently exposed and here the conglomerate may again be found, in particularly fresh condition. Along the river the series mostly consists of dark sandstones and slates; the conglomerate is less developed than on the ridge and the pebbles are somewhat smaller, but otherwise it is identical with that from the former localities. Further east up the river the before-mentioned breccias begin to appear in the series. The conglomerate from the river is a very hard, dark-colored rock composed of small but very smooth and round pebbles (max. diam. 1^{cm}) of gray, white or black phthanite, gray limestone, black slate and white quartz, the latter being least abundant. The cement is black in color and very fine in texture, apparently a consolidated mud. The conglomerate from the summit of the ridge, somewhat softer from weathering, contains pebbles sometimes reaching 4^{cm} in diam.; the quartz pebbles occur in variable quantities, occasionally very abundant. Phthanite and limestone always make the bulk of the pebbles.

This conglomerate has not escaped the sharp eyes of the prospectors of early days and at three places at least shafts have been sunk in it. Considering the rock identical with the Tertiary, sometimes cemented, gravels found so abundantly higher up on the ridge their object in sinking these shafts was to attain the "bedrock" in the hope of there finding a paying deposit. Their efforts were in vain and abandoned long ago. One shaft south of the United States ranch was sunk 60′ deep about 40 years ago, also one of the shafts to the north of the road. The attempt was renewed about 20 years ago and the total depth attained in the north shaft about 80 feet. None who had been connected with the work could be found and conflicting reports were obtained as to whether any gold had been found in the conglomerate. It is said that the gulches in the vicinity had in early days yielded considerable gold in well worn grains and particles; the character of the gold would indicate that it had come from the conglomerate.

Numerous tests were made on specimens from three localities: first, rock extracted from the shaft south of the road; second, specimens from an outcrop about 300 feet west of that shaft, and third, rock extracted from the deep shaft north of the road on the ground belonging to the United States ranch. In none of these specimens could any seams or veinlets of quartz be seen, nor any indications noted that they had been subjected to the influence of auriferous solutions. A few pounds of each sample were repeatedly crushed in a clean mortar and washed in a miner's pan; in all instances gold was obtained; the particles—colors—were very fine and flaky but concentrated easily; sometimes only one or two, sometimes a great number of colors were obtained. Beside the gold there was invariably some iron pyrites nearly always found in conglomerates and as well known resulting from the reducing action of organic substance on circulating iron salts. The absence of magnetic and titanic iron ores—black sand—was very noticeable. In order to obtain a better idea of the amount contained Mr. G. F. Deetken kindly made duplicate assays for me of specimens from the two shafts with the result that the conglomerate from the south shaft was found to contain in average 36¢ pr. ton in gold while a distinct trace was obtained from that from the north shaft.

From the general character of the occurrence I believe it represents shore gravels accumulated near the mouth of some river draining the Carboniferous area and emptying into the muddy gulf in which the Mariposa slates were deposited. It is not likely that the deposit will ever be of economic importance though there is a possibility that by thorough prospecting and cross cutting the strata a richer bed might be exposed.

Conclusions:

(1) The Mariposa beds were deposited unconformably upon the rocks of the Calaveras formation, then a land area of considerable extent. From the abundant presence of phthanite pebbles in the conglomerate it is certain that this older series was already at that time considerably altered though the large quantity of limestone also contained makes it probable that the metamorphic action has progressed much further in it since that time. From the absence of igneous rocks in the conglomerate, accentuated by the absence of "black sand" in it, it may be concluded that the numerous basic igneous rocks now contained in the Calaveras formation in this vicinity have principally been intruded after the deposition of the Mariposa beds.

(2) The old land area at that time already contained auriferous quartz veins, the detritus of which enter into the composition of the Mariposa conglomerate.

(3) There are in the Sierra Nevada primary auriferous deposits of very different age. The oldest antedate the Mariposa beds; the greatest number were formed at the close of the eruptive activity following soon after the deposition and upheaval of the Mariposa beds; the most recent, found along the summit and along the eastern slope of the range were formed towards the close of the eruptive activity in late Tertiary time.

Art. XXXVIII.—*Antholite from Elzivir, Ontario;* by A. P. Coleman, Ph.D.

An asbestiform mineral occurring in large masses on lots 7 and 8, concession 11, in the township of Elzivir, Ontario, was sent to me for determination some time ago by Mr. Blue, Director of the Ontario Bureau of Mines. The specimen consists chiefly of irregular bundles of a strong, fibrous mineral resembling chrysotile mixed with a dull green one like serpentine, the two passing into one another. The serpentinous mineral has evidently been formed from enstatite, since it encloses at one or two places remnants of that mineral on which it has encroached. Small amounts of pale green fibrous talc are mixed with the tough fibrous mineral, and the talc sometimes occurs in small masses by itself. In addition one finds portions of carbonates, partly effervescing with cold dilute acid, and hence calcite; partly dolomite or perhaps a related carbonate.

In thin sections under the microscope, the enstatite, which is pale greenish brown with glassy luster, shows the usual characters, prismatic and brachy-pinacoidal cleavage, parallel extinction, and a biaxial interference figure, optically positive, on sections at right angles to the *c* axis. It is not pleochroic. At the edges the serpentinous mineral appears to have eaten its way inward along the cleavage planes and along a less regular set of fractures at right angles to the upright axis.

This secondary mineral is colorless under the microscope and shows the faintly polarizing confused mass of scales or vague fibers seen in true serpentine. The fibrous portions have all the appearance of chrysotile, parallel extinction or nearly so, etc. The talc and carbonates have the usual characters.

Analyses were made of the two fibrous minerals, 1 and 2 being of the strong fibers and 3 of the talc, and the results are as follows:

	No. 1.	No. 2.	No. 3.
Loss in drying at 110°	1·16	1·44	0·38
Further loss on ignition	4·25	9·83	7·42
SiO^2	55·89	53·98	56·87
Al^2O^3	0·71	(not det.)	0·09
FeO	6·09	5·61	1·70
CaO	2·22	2·14	2·67
MgO	29·33	29·52	30·05
Total	99·65	99·27	99·18

In regard to the talc (No. 3) it should be mentioned that most of the material effervesces slightly with acid, showing the presence of a little calcite. If the CaO obtained in the analysis (2·67 per cent) be reckoned as carbonate, and a corresponding deduction made from the amount of loss at a red heat for CO^2(2·09 per cent), the result shows combined water, 4·53 per cent, silica 59·58, and magnesia 31·48. This corresponds fairly with the usual composition. The amount of pure substance available for analysis was 709 milligrams.

The results of the first analysis of the mineral resembling chrysotile were surprising, and the second analysis was made to control the first. It was very difficult to obtain the fibrous parts quite free from talc, and the first analysis was made from 404·9 milligrams only, the material having been carefully selected with a lens. For the second analysis a still smaller quantity, 285·3 milligrams, was obtained by careful searching with a lens. A third, still smaller quantity was used to determine the loss at read heat, in which the two previous samples differed considerably.

For comparison the loss on ignition was determined in several other minerals, as in the following list. In all cases the amount taken was heated in a platinum crucible over a blast lamp.

	Per cent.	
Fibrous mineral, No. 1, loss at red heat plus hydroscopic moisture	5·41	Mean 6·59
No. 2	7·92	
No. 3	6·45	
Serpentinous mineral associated with the fibrous one	6·82	
Chrysotile, Thetford, Quebec	15·27	
Actinolite, Clarendon Tp., Ont.	2·93	
Actinolite, North shore L. Superior, Ont.	2·35	
Talc, Grimsthorpe Tp., Ont.	4·58	

The fibrous mineral analyzed in Nos. 1 and 2 effervesces scarcely at all with acid, so that no appreciable quantity of the loss on ignition can be attributed to the driving off of carbonic acid; but the fibers, which are greenish white in the specimen, turn brown and brittle, very much as chrysotile does, showing that combined water is driven off.

The results of the analyses correspond quite closely with the composition of enstatite, supposing its constituents to be rearranged and hydrated. They come less close to the orthorhombic amphiboles, such as anthophyllite, showing too little silica and iron, and too much magnesia and water; and they differ widely from chrysotile, having far too much silica and far too little combined water and magnesia. In physical characters however the resemblance between this fibrous mineral and chrysotile is very close. They are undistinguishable under the microscope, having the same silky fibers and parallel or almost parallel extinction. The greatest angle of extinction measured by the writer in specimens of chrysotile from Thetford, Quebec, was $1\frac{1}{3}°$, in the fibrous mineral under examination, 1°.

It seems to correspond most nearly in chemical composition to some of the fibrous forms of monoclinic amphibole, e. g. antholite or kuppferite. The analyses given of the latter mineral differ but little from those made by the writer; but the last edition of Dana's System of Mineralogy drops the name entirely and gives antholite only a very brief reference.* Probably if it is to be referred to any species beyond the broad one of "fibrous amphibole containing little or no alumina," the name antholite is the most appropriate. The amount of combined water, which varies however in different samples, seems the only objection to such a reference.

School of Practical Science, Toronto.

Art. XXXIX.—*On the Double Chlorides and Bromides of Cæsium, Rubidium, Potassium and Ammonium with Ferric Iron, with a description of two Ferro-ferric double Bromides;* by P. T. Walden.

Previous investigation on the double ferric halides seems to have been devoted exclusively to the chlorides, and the metal cæsium has not as yet been worked within this connection.

In view of these facts it appeared desirable to prepare, as far as possible, a complete series of the double halogen salts of the above named metals. Only negative results were obtained, however, when attempts were made to prepare double iodides, so that the work was necessarily confined to the chlorides and bromides.

The following compounds have been previously described:

Rb_3FeCl_6.	$K_2FeCl_5H_2O$.
	$(NH_4)_2FeCl_5H_2O$.
	$Na_2FeCl_5H_2O$.

The existence of the above potassium and ammonium salts has been confirmed in the present investigation but the com-

* Dana, System of Mineralogy, 6th ed., p. 391. In the 5th ed. Kuppferite is described on p. 230, and antholite on p. 236. Analyses 31–33, p. 237, are of antholite.

pound Rb_3FeCl_6 described by Godeffroy* could not be made although a hydrous salt of the same type was prepared with cæsium. A most careful series of experiments using large quantities of the constituent chlorides, was made in the attempt to prepare the rubidium salt just mentioned. It is not believed to be possible that Godeffroy obtained this compound and his error was probably due to his neglecting the water of crystallization in the salt $Rb_2FeCl_5H_2O$. There is not a great difference between the theoretical composition required by a 3 : 1 anhydrous compound and the 2 : 1 salt with one molecule of water, especially as far as the chlorine and iron are concerned. This can be seen from the following comparison.

	Calculated for Rb_3FeCl_6.	Calculated for $Rb_2FeCl_5H_2O$.
Rubidium	48·83	40·44
Iron	10·65	13·29
Chlorine	40·52	42·01
Water		4·26
	100·00	100·00

Since the hydrous 2 : 1 salt is easily prepared, it therefore seems certain that this must have been the single salt described by Godeffroy.

The following is a list of the salts obtained.

3 : 1 Type.	2 : 1 Type.	1 : 1 Type.
$Cs_3FeCl_6 . H_2O$	$Cs_2FeCl_5 . H_2O$	$CsFeCl_4 . \frac{1}{2}H_2O$
----------	$Cs_2FeBr_5 . H_2O$	$CsFeBr_4$
----------	$Rb_2FeCl_5 . H_2O$	--------
----------	$Rb_2FeBr_5 . H_2O$	--------
----------	$K_2FeCl_5 . H_2O$†	--------
----------	----------	--------
----------	$(NH_4)_2FeCl_5 . H_2O$†	--------
----------	----------	$NH_4FeBr_4 . 2H_2O$

It will be noticed that the type 2 : 1 is the most frequently recurring, being found in every case except with potassium and ammonium bromides. The salts of this type, as might be expected, are also the most stable and easily made, especially with cæsium chloride where it is formed through a very wide range of conditions leaving only a narrow margin for the other two members of the series. It is remarkable in view of these facts that this type should not have been obtained with ammonium bromide while the 1 : 1 type, which is comparatively unstable in other cases, is made without difficulty.

* Arch. Pharm. [3], ix, 343.

† These two salts have been previously described by Fritzsche, J. pr. Chem., xviii, 483.

This investigation furnishes another striking example of the fact, already noticed several times in this laboratory, that cæsium halides form more complete series of double salts than the halides of the other alkali-metals. With cæsium chloride we get a complete series, while with the chlorides of the other alkali-metals only one type appears. In the bromides no double ferric potassium salt could be isolated, whereas two well-defined and comparatively stable compounds were obtained with cæsium.

Wells and Campbell* have called attention to the fact, that, in a number of cases, double halides show an increase in ease of formation from the iodides to the chlorides. No better illustration could be had of this truth than the series of salts prepared in the present investigation, where the chlorides were made in greater number and with more ease than the bromides while no iodides at all could be obtained.

Preparation.—All these salts were made by mixing solutions of the simple halides, evaporating and cooling to crystallization. It was found necessary in all cases to use solutions slightly acidified with the corresponding halogen acid, in order to prevent the formation of basic salts. A record, as nearly exact as possible, was kept of the relative quantities of the constituents used and this has been indicated under each salt. The crystals were freed from the mother liquor by pressing between smooth filter papers, and in every case where it was admissible they were further dried by exposure to the air of the laboratory. Where the salt was at all deliquescent it was at once removed to a tightly stoppered tube whose weight had been previously determined and weighed without loss of time. In this manner a quite unstable body could be analyzed and satisfactory results obtained. The purity of all the simple alkali-halides was tested with the spectroscope before using. The very pure rubidium chloride used for this work was furnished to this laboratory for the encouragement of scientific investigation by Herr E. Merck of Darmstadt, through his agents, Messrs. Merck & Co. of New York, and our thanks are due to him for his unsolicited generosity.

Method of analysis.—Iron was weighed as Fe_2O_3 in all cases, after having been separated from the alkali-metal by precipitation with ammonia. The filtrate from this precipitation was evaporated to dryness, the alkali-metal converted into sulphate and weighed as such after ignition in a stream of air containing ammonia. Ammonium was estimated by distilling with a solution of potassium hydroxide, absorbing the NH_3 liberated in hydrochloric acid and determining its amount by

* This Journal, III, xlvi, 432.

alkalimetry. Water was determined by combustion behind sodium carbonate and absorption in a washed calcium chloride tube. With $(NH_4)_2FeCl_5H_2O$ the water was removed by subjecting the salt to a temperature of 150° C. in an air bath for one hour.

The Double Chlorides.—These salts are all red except $CsFeCl_4\frac{1}{2}H_2O$ which is straw yellow. There is a distinct gradation in the shades of the salts of the type 2:1 from $(NH_4)_2FeCl_5H_2O$ which is a deep ruby red, growing lighter through the cæsium, rubidium and potassium compounds until the last is very nearly the color of potassium dichromate.

3 : 1 Cæsium Ferric Chloride, $Cs_3FeCl_6H_2O$.—This salt is the only one of the 3 : 1 type which was prepared in the present investigation. It separated from a solution containing 50^{gr} of cæsium chloride and from $\cdot5^{gr}$ up to $2\cdot5^{gr}$ of ferric chloride. The following analyses were made from separate crops:

	A.	B.	C.	Calculated for $Cs_3FeCl_6H_2O$.
Cæsium	58·30	58·42		58·17
Iron	7·91	7·85		8·17
Chlorine	30·87	30·82	30·98	31·01
Water	2·74	2·72	2·64	2·65
	99·82	99·81		100·00

In color it closely resembles sodium dichromate. It is well crystallized in small prisms which are arranged in compact clusters radiating from a center.

2 : 1 Cæsium, Rubidium, Potassium and Ammonium Ferric Chlorides, $Cs_2FeCl_5H_2O$, $Rb_2FeCl_5H_2O$, $K_2FeCl_5H_2O$ and $(NH_4)_2FeCl_5H_2O$.—If solutions of the several alkali-chlorides, containing 50^{gr} each be made, it is necessary to add 3^{gr} of ferric chloride to make the cæsium salt of this type, 10^{gr} to make the rubidium salt, 15^{gr} to make the potassium salt and 70^{gr} to make the ammonium salt. The cæsium, rubidium and potassium compounds can be recrystallized unchanged, although with the last two there is a tendency to separate simple alkaline chlorides at the same time. Several separate crops were analyzed of each salt with the results shown below.

	A.	B.	C.	Calculated for $Cs_2FeCl_5H_2O$.
Cæsium	51·15	51·05		51·40
Iron	11·05	10·98		10·82
Chlorine	34·36	34·19	34·02	34·30
Water	3·55	3·59		3·48
	100·11	99·81		100.00

	A.	B.	Calculated for $Rb_2FeCl_5H_2O$.
Rubidium	40·51	40·69	40·44
Iron	13·28	13·33	13·29
Chlorine	41·91	41·92	42·01
Water	4·23	4·20	4·26
	99·93	100·14	100·00

	A.	B.	Calculated for $K_2FeCl_5H_2O$.
Potassium	23·66	23·54	23·73
Iron	16·86	16·99	16·98
Chlorine	53·56	53·35	53·84
Water	6·20	5·96	5·45
	100·28	99·84	100·00

	A.	B.	C.	Calculated for $(NH_4)_2FeCl_5H_2O$.
Ammonium	12·39	12·36	12·00	12·52
Iron	19·13	18·95		19·48
Chlorine	61·21	61·07	61·22	61·74
Water	7·39			6·26
	100·12			100·00

All these salts are well crystallized in short prisms. The cæsium and rubidium compounds are permanent in the air but the potassium and ammonium salts absorb moisture quite rapidly.

1:1 Cæsium Ferric Chloride, $CsFeCl_4\frac{1}{2}H_2O$.—This was made from a solution containing 50^{gr} of cæsium chloride and 180^{gr} of ferric chloride. Below are the analyses of separate crops.

	A.	B.	C.	Calculated for $CsFeCl_4\frac{1}{2}H_2O$.
Cæsium	38·39	38·53		39·39
Iron	17·03	16·85		16·48
Chlorine	41·76	41·73	41·98	41·77
Water	3·14	3·63	4·03	2·36
	100·32	100·74		100·00

This salt absorbs moisture in the air so rapidly that considerable difficulty was experienced in preparing samples for analysis. It is regarded as containing $\frac{1}{2}$ a molecule of water on the evidence of the analytical results, although it is not unreasonable to suppose that all the water found was absorbed, especially as the bromide, $CsFeBr_4$, is anhydrous. The crystals were slender needles which rapidly lost their yellow color in the air, turning red.

The Double Bromides.—These are all very dark green, almost black and quite opaque. Like the chlorides, the 2:1 cæsium salt is darker than the rubidum compound of the same type. As no corresponding potassium or ammonium salt could be made, the comparison can be carried no farther. The cæsium and ammonium 1:1 bromides are of nearly the same color. None of the double bromides are capable of recrystallization.

2:1 Cæsium and Rubidium Ferric Bromides, $Cs_2FeBr_5H_2O$ and $Rb_2FeBr_5H_2O$.—The first of these salts was made with the quantities of the constituent bromides abont equal, the second with 50^{gr} of rubidium bromide to 60^{gr} of ferric bromide. The following are the analyses.

	A.	B.	Calculated for $Cs_2FeBr_5H_2O$.
Cæsium	35·76	35·60	35·95
Iron	8·05	7·93	7·56
Bromine	54·20	54·15	54·05
Water	2·52	2·84	2·44
	100·53	100·52	100·00

	A.	B.	Calculated for $Rb_2F_2Br_5H_2O$.
Rubidium	26·20	26·14	26·51
Iron	8·86	8·99	8·68
Bromine	62·13	62·12	62·02
Water	2·90	2·88	2·79
	100·09	100·13	100·00

Both compounds were obtained in short doubly terminated prisms. The cæsium salt is comparatively stable while the rubidium salt decomposes rapidly in the air.

1:1 Cæsium and Ammonium Ferric Bromides, $CsFeBr_4$ and $NH_4FeBr_42H_2O$.—A solution of 50^{gr} of cæsium bromide and 100^{gr} of ferric bromide gave the first of these salts in slender needles. The second could not be obtained until 250^{gr} of ferric bromide had been added to 50^{gr} of ammonium bromide. Separate crops of each were analyzed with the results given below.

	A.	B.	Calculated for $CsFeBr_4$.
Cæsium	26·02		26·13
Iron	11·25	11·30	11·00
Bromine	63·01	62·99	62·87
	100·28		100·00

	A.	B.	C.	Calculated for $NH_4FeBr_42H_2O$.
Ammonium	3·98	3·92	3·83	4·19
Iron	13·48	13·59		13·02
Bromine..........	74·85	74·71		74·42
Water	7·69*	7·78*		8·37
	100·00	100·00		100·00

As the ammonium salt is so deliquescent that no satisfactory determination of water was possible, it was taken by difference and it is believed that the results warrant the acceptance of the formula as written above. Great care was exercised in an attempt to prepare a 2 : 1 ammonium bromide but without success. $NH_4FeBr_42H_2O$ and simple ammonium bromide were finally crystallized out together in the same solution. This is regarded as good evidence that no salt of a type higher in ammonium exists.

Ferro-ferric Salts: $RbBrFeBr_22FeBr_33H_2O$ and $KBrFeBr_22FeBr_33H_2O$.—While endeavoring to obtain a double ferric bromide with potassium a dark green body separated from a solution containing an excess of bromine, which gave a black hydroxide with ammonia. This was considered so remarkable that an effort was made to prepare corresponding salts with the other alkali-halides and ammonium, under the same conditions. This attempt resulted in the formation of only one other compound of the same kind, that with rubidium. The ferrous iron in those salts was determined by titration in the presence of hydrochloric acid with a standard potassium dicromate solution. It was found to be impossible to determine water satisfactorily on account of the extreme instability of both salts. It was therefore taken by difference. The rubidium salt resulted from the bringing together in solution of 50^{gr} of rubidium bromide and 150^{gr} of ferric bromide, the potassium salt from a solution of 50^{gr} of potassium bromide and 250^{gr} of ferric bromide. Below are the analytical results, A, B, and C being separate crops.

	A.	B.	C.	Calculated for $RbBr.FeBr_2.2FeBr_33H_2O$.
Rubidium	7·25			8·32
Ferrous iron ..	5·17	5·16	5·53	5·45
Ferric iron....	11·10	10·71	10·13	10·90
Bromine.......	68·83	68·37	68·48	70·07
Water	7·65*			5 26
	100·00			100·00

* Water by difference.

			Calculated for $KBr.FeBr_2.2FeBr_3.3H_2O$.
Potassium	3·47	3·92	3·98
Ferrous iron	4·31	4·26	5·71
Ferric iron	12·36	11·70	11·42
Bromine	73·15	73·09	73·39
Water	6·71*		5·50
	100·00		100·00

These salts are dark green in color and quite opaque like the double ferric bromides described above. The crystallization of the rubidium salt is apparently rhombohedral, that of the potassium cubical.

In conclusion the author wishes to express his sincere thanks to Prof. H. L. Wells, under whose direction the work has been carried on, for his kindly aid and many valuable suggestions.

Sheffield Scientific School, New Haven, Conn., July, 1894.

Art. XL.—*The Standardization of Potassium permanganate in Iron Analysis;* by Charlotte F. Roberts.

[Contributions from the Kent Chemical Laboratory of Yale College—XXXV.]

For practical work in iron analysis, the standardization of the potassium permanganate is naturally a very important problem. The best authorities agree in considering that it should be finally standardized on ferric chloride, but the difficulty consists in determining with accuracy the amount of iron in this solution. Though the purest iron which can be obtained commercially is used as the basis, the resulting ferric chloride still contains some silica and phosphorus, which must be eliminated or the amount determined gravimetrically. The process of determining the amount of iron in the ferric chloride solution, upon which the potassium permanganate is finally standardized, thus becomes long and tedious. To obviate this, the following experiments were undertaken in the hope of obtaining the same result by a shorter and more convenient method.

If the potassium permanganate could first be compared with a solution containing a known weight of iron which is finally brought into the same condition as the ferric chloride solution, and then this same potassium permanganate directly titrated with the ferric chloride itself, the necessary accuracy could be obtained without the gravimetric work on the ferric chloride recommended.† Since electrolytic iron is undoubtedly the

* Water by difference.

† Blair: The Chemical Analysis of Iron, pp. 212–216.

purest form of iron known, it would seem that potassium permanganate titrated against this might be expected to give trustworthy results for the first comparison.

For the production of a definite amount of electrolytic iron two different courses are open to us. Either a weighed amount of a pure iron salt, as ammonio-ferrous sulphate, may be taken and the iron completely precipitated by electrolysis; or an indefinite quantity of the salt may be taken and subjected to electrolysis for a time, and the amount of iron determined by weighing the electrolytic deposit. After some preliminary trials, this second method has recommended itself to me as being much more rapid than the first-mentioned method and also free from some manipulatory details which render the first difficult to be done with exceeding accuracy.

Some experiments were therefore undertaken to compare the amount of iron determined by direct weighing of the electrolytic deposit with the amount determined by titration of the solution of this same iron with potassium permanganate. The details of the experiments were as follows. The solution of potassium permanganate was first accurately standardized with ammonium oxalate which had been shown to give identical results with those obtained by the use of lead oxalate. About 10 grams of ammonio-ferrous sulphate were dissolved in about 150 cubic centimeters of water, 5 cubic centimeters of a saturated solution of potassium oxalate were added, and then the whole was heated with a considerable quantity of solid ammonium oxalate until a clear solution was obtained. This solution was decomposed in a beaker between two platinum electrodes, the iron being deposited on a piece of platinum foil of a size convenient to be inserted in a rather large weighing bottle, in which it was weighed both before and after the electrolysis. From $1\frac{1}{4}$ to $1\frac{1}{2}$ hours, with a current of 2 ampères, was in general found to be sufficient to precipitate from ·4 to ·5 grams of pure iron, and it was found unadvisable to use a current much stronger than 2 ampères, since a higher current showed a tendency to render the deposit less smooth and compact. After washing, drying and weighing in the usual way, the iron was dissolved in hydrochloric acid, the weighing bottle being used instead of the small flask ordinarily employed in this operation, the oxidized iron was reduced with zinc, and finally titrated with the potassium permanganate solution in presence of sulphuric acid and a large amount of water.

The following table shows the results obtained, the first column giving the weight of the electrolytic deposit of iron, and the second the weight of iron found in the solution of the preceding upon titration with potassium permanganate previously standardized on ammonium oxalate.

I.	II.	Difference.
·4357	·4364	·0007 +
·3551	·3559	·0008 +
·2552	·2550	·0002 —
·2898	·2890	·0008 —
·1590	·1599	·0009 +
·3528	·3534	·0006 +
·4498	·4494	·0004 —
·5086	·5085	·0001 —
·4462	·4457	·0005 —
·4226	·4222	·0004 —
·5170	·5165	·0005 —

These results show that the standard of potassium permanganate as determined from pure iron differs very slightly from that obtained with the ammonium oxalate, but the standard obtained in the former way would under ordinary conditions be more satisfactory for work in iron analysis than the latter. A simple and rapid method, then, for standardizing the potassium permanganate solution would be to determine its strength, first, by comparison with electrolytic iron in the manner above described, and then by immediate titration with ferric chloride to determine the exact amount of iron in each cubic centimeter of the latter solution. This being ascertained, the ferric chloride solution can be employed at any time for the standardization of potassium permanganate.

Art. XLI.—*The Detection and Approximative Estimation of Minute Quantities of Arsenic in Copper*; by F. A. Gooch and H. P. Moseley.

[Contributions from the Kent Chemical Laboratory of Yale College.—XXXVI.]

Sanger's recent successful application of the Berzelius-Marsh process to the quantitative determination of arsenic in wall-papers and fabrics,* by the comparison of test mirrors with standard mirrors carefully prepared under the conditions of the test, opens the way, naturally, to the similar estimations of minute amounts of arsenic in any substances which may be submitted to the process immediately or after suitable preparation.

The need of a rapid and at the same time trustworthy method for the determination of traces of arsenic in copper has led us to a study of the application of Sanger's process to this special case.

* Am. Chem. Jour., xiii, 431.

It has been shown by Headden and Sadler* that the presence of copper in the Marsh generator is instrumental in holding back the arsenic and our own experience is similar. It is obvious, therefore, that means must be employed for the complete removal of the copper from the arsenic before the solution of the latter is put into the reduction-flask. So far as our experience goes there is no method by which arsenic may be removed from copper easily, and without loss, aside from those methods which depend upon the volatility of arsenious chloride from solution in strong hydrochloric acid, and of such methods we give the preference on the score of rapidity in execution, accessibility of pure materials, and compactness of apparatus, to a process recently developed in this laboratory† and based upon the simultaneous action of strong hydrochloric acid and potassium bromide upon the salt of arsenic.

To get the copper into condition for the application of the process of separation from arsenic we find it sufficient to dissolve an amount not exceeding one gram in nitric acid somewhat diluted with water, to add to the solution two or three cubic centimeters of strong sulphuric acid, and to evaporate the liquid until fumes of the sulphuric acid are disengaged abundantly. A single treatment of this sort serves to remove the nitric acid so completely that no interference with the normal action of the Marsh apparatus is apparent in the subsequent operation. The residue after concentration is diluted with water to about 5 cm^3 and washed into the distillation flask with an amount of the strongest hydrochloric acid (sp. gr. 1·20) equal to that of the remainder of the liquid. It is desirable that the entire volume of the liquid should not much exceed 10 cm^3. The flask which has a capacity of forty or fifty cubic centimeters, is inclined at an angle of about 45° and joined by means of a pure rubber stopper to a bent pipette which serves as a distillation tube. The lower end of the vertical limb of the pipette dips beneath the surface of about 5 cm^3 of hydrochloric acid of half strength contained in a test tube which is cooled and supported by water nearly filling an Erlenmeyer flask. A single gram of potassium bromide is introduced, and the distillation (which may be completed in three or four minutes) is pushed nearly to dryness. The flask is washed out, another portion of potassium bromide is introduced, and the first distillate is introduced and redistilled as before excepting that the condensation is this time effected in pure water. This second operation serves merely to hold back traces of copper carried over in the first distillation, but experiment has shown that the addition of the potassium bromide in the second distillation is quite as necessary as in the first, since the bromine

* Am. Chem. Jour., vii, 342. † Gooch and Phelps. This Jour., xlviii, p. 216.

liberated in the process has the effect of reoxidizing the arsenic in the receiver and so making that element non-volatile under the conditions until the reducing agent is again introduced. The free bromine in the final distillate must be re-converted to hydrobromic acid before the contents of the receiver may be introduced into the reduction-flask, and we find that this effect may be most easily and unobjectionably accomplished by the addition of a little stannous chloride dissolved in hydrochloric acid of half-strength and purified from arsenic by prolonged boiling. Incidentally and simultaneously the arsenic is reduced to the arsenious form, and, though Sanger has shown that minute amounts of arsenic are completely eliminated from the solution in the reduction flask when that element is introduced in the higher form of oxidation, it is our experience that the rapidity of elimination of the arsenic is so increased by the introduction of the small amount of stannous chloride needed to bleach the bromine that the mirror appears in from five to ten minutes and is practically complete in half an hour, especially if the precaution is taken to add a little more stannous chloride, according to Schmidt's suggestion* after the operation has been in progress about twenty minutes.

It will be remembered that Schmidt has shown that the addition of stannous chloride to the Marsh apparatus in action not only does not effect the retention of arsenic, as many other metallic salts do, but actually brings about the final evolution in the form of the hydride of that portion of the arsenic which may have been deposited during the process in elementary form upon the zinc.

We have used the Sanger apparatus in form essentially unchanged; but we find it advantageous to fill the reserve generator with zinc coated with copper by the action of a solution of copper sulphate, instead of with pure zinc, since in this way the zinc is made more sensitive to the action of the dilute sulphuric acid, while the presence of copper (which is of course out of the question in the reduction-flask) can be of no disadvantage in the reserve generator and might even serve a useful end in fixing traces of arsenic if the zinc and acid employed were not absolutely free from that element. In the formation of the mirror too, it has proved to be an advantage to enclose the portion of the glass tube to be heated in a short thin tube of iron or nickel slightly larger than the glass tube and kept from contact with it except at the ends, which are notched and bent inward. By keeping the outer tube of metal at a low red heat it is possible to diminish the tendency, which shows more particularly when the amounts of arsenic are fairly large, toward the formation of a double mirror corres-

*Zeit. für Anorgan. Chem., i, 353.

ponding to the allotropic conditions of the arsenic. The exigency compels, moreover, the substitution of hydrochloric acid for the sulphuric acid usually employed in the reduction-flask; but, though the opinion is current that hydrochloric acid introduces difficulties in the Marsh test, we have been unable to discover any evidence of the formation of a zinc mirror in the ignition tube or to note other unfavorable action due to the use of pure hydrochloric acid. It is, of course, obvious that the hydrochloric acid used must be actually free from arsenic (as was ours) and not merely nominally so, as is often the case with the so-called arsenic-free hydrochloric acid of commerce.

The copper for our test experiments was prepared free from arsenic by electrolizing in ammoniacal solution the purest copper sulphate obtainable and stopping the deposition before the solution had become exhausted. In this manner we were able to procure copper in which we failed to detect arsenic. This copper was dissolved in nitric acid, arsenic in the higher condition of oxidation was added, and the process of the separation of the arsenic from the copper and conversion to the mirror carried out in the manner described. The results obtained are recorded in the accompanying table.

Copper taken, in grams.	Arsenic taken, in milligrams.	Mirror estimated (by comparison with standard mirror) in milligrams.	Error, in milligrams.
none	none	none	none
0·7	none	none	none
0·5	0·005	0·003	0·002 —
0·5	0·011	0·013	0·002 +
0·35	0·020	0·015	0·005 —
0·3	0·030	0·030	none
0·43	0·040	0·035	0·005 —
0·44	0·050	0·040	0·010 —

It is plain from these results that the method is capable of detecting sharply minute amounts of arsenic in copper and of effecting the estimation of quantities less than 0·05 mg. with some approximation to accuracy. There is, as Sanger has pointed out, a good deal of variation even in standard mirrors made with all possible care and precaution, and in the estimation of mirrors containing as much as 0·05 mg. of arsenic the uncertainty of comparison as well as the actual variation of the mirror is considerable.

When a sample of copper is under test which may contain more than 0·05 mg. of arsenic it is desirable to introduce into the reduction-flask the measured solution containing the arsenic gradually and in definite portions, and to judge by the formation of the mirror in an interval of ten minutes after the introduction of portions of this test solution whether it is wiser to add the entire solution or to estimate the arsenic in the entire solution from that found in an aliquot portion.

We append the results of the analysis of several samples of commercial copper, all of which were electrolytic, and of which the last two represented, presumably, the very purest electrolytically refined copper obtainable commercially.

	Copper taken, gram.	Arsenic found, milligrams.	Percentage of arsenic.
Sample A	0·3	0·015	0·005
" B	0·3	0·030	0·010
" C	1·	0·018	0·0018
	1·	0·015	0·0015
" D	1·	0·005	0·0005
	1·	0·005	0·0005

Art. XLII.—*Notes on the Miocene and Pliocene of Gay Head, Martha's Vineyard, Mass., and on the "Land phosphate" of the Ashley River district, South Carolina;* by Wm. H. Dall, Paleontologist to the U. S. Geological Survey.*

In 1844 Sir Charles Lyell printed† some notes on Tertiary fossils collected by him at Gay Head which led him to the conclusion that they were of Miocene age. In 1863 Dr. Stimpson described a fossil crab from these beds,‡ but without expressing a decided opinion as to its geological age. In 1890 Mr. David White, U. S. G. S., in discussing the Cretaceous plant-remains of the Gay Head section§ gave references to most of the literature relating to the Gay Head section, which is also discussed in Bull. U. S. Geol. Survey, No. 84, by Dall and Harris in 1892. It will not, therefore, be necessary to refer more fully to these well known publications here.

Notwithstanding the lapse of half a century since Lyell's announcement, the present writer is not aware that any attempt has been made to identify the fauna of the Gay Head Miocene and determine its horizon relatively to other Atlantic coast beds; or even to positively confirm from paleontologic evidence Lyell's determination, though on other grounds it has been very generally accepted.

* Published by permission of the Director of the Survey.
† This Journal, first series, vol. xlvi, pp. 318–320.
‡ Boston Journ. Nat. Hist, vii, pp. 583–9.
§ This Journal, vol. xxxix, pp. 93–101.

The writer recently visited Gay Head for the purpose of studying this fauna, and subsequently examined all the material collected at Gay Head and Chilmark in past years and now preserved in the collections at Harvard College. In this investigation material aid was rendered by Prof. N. S. Shaler and Mr. J. B. Woodworth, U. S. G. S.

The following species have been identified from the Miocene of Gay Head and Chilmark; the localities are indicated by G and C respectively.

VERTEBRATES.

Cystiphora sp. (Lyell) G.
Rosmarus sp. (Lyell) G.
Hyperoodon sp. (Lyell) G.
Balaena? sp. (Lyell) G.
Carcharodon angustidens Ag. G.
Lamna cuspidata Ag. G.
Hemipristis serra Ag. G.
Oxyrhina hastalis Ag. G.

Numerous unidentified remains of esseous fishes.

CRUSTACEA.

Archaeoplax signifera Stm. G. C.
Archaeoplax? sp. ind. G.
Balanus (*? proteus* Conr.) fragm. G.

MOLLUSKS.

Pecten (*irradians* Lam. young?) G.
Modiolaria nigra Gray? C. In gray clay.
Yoldia limatula Say. G.
Yoldia sapotilla Gould. G. C.
Nucula Shaleri n. s. G. C.
Astarte (like *sulcata* Da Costa) G.
Astarte (like *semisulcata* Leach) G.
Crassatella sp. G.
Cardium virginianum Conr. G.
Isocardia fraterna? Say. C.
Gemma purpurea Lea var. *Tottenii* Stm. G.
Venus (*Egesta*) *inoceriformis?* Wagner. G.
Venus sp. G.
Cytherea sp. (like *Sayana* Conr.) G.
Tellina (like *lusoria* Say) G.
Macoma Lyellii n. sp. G.
Solen sp. young, (like *ensiformis* Conr.) C.
Corbula sp. (like *disparilis* Orb.) G.
Mya arenaria L. G.
Mya truncata L. G. (Lyell).
Glycimeris reflexa Say, (*Panopœa*). G.
Chrysodomus Stonei Pilsbry. G.

Parts of the rock also contain numerous worn internal casts of foraminifera which have been reconsolidated after wear.

The shells are all represented by internal, or, in a few cases by external casts, and in several instances the identification though highly probable could not be made positive for want of the external characters. Several of the forms appear to be undescribed. One of the *Astartes* closely resembled *A. semisulcata* in sculpture, but was a more tumid and orbicular shell; the other not unlike *A. sulcata*, is, nevertheless, different from any recent or fossil species known to me; but in so difficult a group as this it is inadvisable to name species without a more generous supply of material.

The *Chrysodomus* seems without doubt to be identical with a species recently described by Pilsbry from specimens washed up on the coast of New Jersey from a submarine bed which also affords *Chrysodomus Stimpsoni* Mörch., *Buccinum undatum* L., and unusually large specimens of *Urosalpinx cinereus* Say. The New Jersey fossils have been cast up, after severe storms, at Cape May, Sea Isle City and Point Pleasant, in 1891–2. The two following species are sufficiently well represented to permit of description without imprudence; the *Macoma* is the most abundant fossil found at Gay Head.

Nucula Shaleri, n. s.

Shell ovate-trigonal, rather solid, moderately convex, with the anterior slope very short; internal margin distinctly and rather coarsely crenulated; anterior hinge margin with eight or nine > shaped teeth, posterior with about sixteen, which are less angular; muscular impressions small and the posterior somewhat impressed: escutcheon narrow, not deep, rather small; outer surface sculptured with numerous, rather irregular, coarse concentric ridges often discontinuous or bifurcating toward the ends of the shell, the umbonal slope of each ridge tending to be longer than the other; these are crossed by fine, sharp, interrupted grooves radiating from the beaks to the margin. Lon. of shell, 15; alt., 11: diameter, 7 ^{mm}.

This shell belongs to the group of *N. decussata* and *antiquata* Sby., which, with the exception of the small deep water southern *N. crenulata* Hinds, is hardly represented on our coast either recent or fossil. The typical specimens were collected by Professor Shaler at Chilmark in a ferruginous gravelly conglomerate.

Macoma Lyelli, n. s.

Shell short, high, rounded, rather tumid, with the posterior extremity strongly dextrally flexuous; anterior slope semicircular, passing evenly into the base; posterior slope longer, excavated behind the beaks, subtruncate obliquely, below; two obscure impressed lines radiate from the beak to the lower posterior margin; the valves appear to have been otherwise smooth; muscular impressions large, distinct; pallial sinus in the right valve rising before the adductor scar then suddenly sloping and rounded off but little in front of the beak; in the left valve the sinus is more evenly arched above and extends much further forward, nearly reaching the anterior adductor. Lon. of cast 45; alt. 40; diam. 17^{mm}.

This species is closely related to *Macoma obliqua* J. Sby. (sp.) of the English Crag, but is less produced in front and more excavated on the posterior dorsal margin. It is also more sharply flexed behind. This is the shell mentioned by Sir Chas. Lyell as "a *Tellina* resembling *T. biplicata*."

It will be observed that this is a distinctly northern assemblage; any of the species might be at home in the waters about Gay Head to-day, as far as we can judge by analogy in the case of extinct species.

As regards correlation with the divisions of the Southern Miocene it may be said 1: that the Gay Head Miocene is Chesapeake and not older; and 2, that it belongs in all probability to the upper part of the Chesapeake, certainly not lower than the St. Mary's fauna, and probably between that and the Yorktown beds.

About eighty feet above sea-level, in a layer of sand unconformably overlying the Miocene beds and involved in the Gay Head uplift, a small patch of shell fragments was discovered and carefully collected by Mr. J. B. Woodworth. The fragments were well preserved and not badly worn though broken, and the species identified were as follows:

Venericardia borealis Conrad.
Astarte castanea Say.
Spisula polynyma Stm.
Corbicula densata Conr.
Macoma Lyellii Dall?
Nucula Shaleri Dall, var.?
Purpura lapillus L.

The fragment of *Macoma* fits exactly upon the beak of one of the internal casts of *M. Lyellii* from the Miocene. The single valve of *Nucula* is larger than the Miocene specimens, has a slightly more rounded base and a few more teeth on each side of the hinge; but these are characters which denote greater maturity and there can be but little doubt that the shell is the same. *Corbicula densata* was described from the upper Miocene of Virginia and occurs in the Pliocene of South Carolina, and the *Venericardia* is of the recent type rather than the Miocene *V. granulata*. On the whole these specimens indicate a more recent fauna than the Miocene above described and may perhaps be regarded as representing the Pliocene.

THE PHOSPHATIC ROCK OF THE ASHLEY DISTRICT, SOUTH CAROLINA.

A year ago Mr. Woodworth had found on the southern shore of Block Island some fossiliferous pebbles which indicated for themselves a Tertiary origin. A visit to the island and subsequent enquiries showed that these were derived from the wreck of a vessel loaded with phosphate rock from the east bank of the Ashley river about ten miles from Charleston, S. C. It is of the variety known as "land phosphate," obtained by excavating. The wreck occurred July 17, 1877, but similar rock I am informed is being excavated and shipped to-day.

An examination disclosed some discrepancies between the rock with its contained fossils and the descriptions current in the literature relating to the South Carolina phosphates. The material consists of fragments of limestone rock, containing numerous casts of shells and small solitary corals (*Balanophyllia*), worn by the sea into irregular rounded lumps and bored by boring mollusks (*Gastrochæna*, etc.) This material (which has the appearance of having been phosphatized after being worn), lies on a bed of sand, or sand and clay, which is sometimes several feet thick and at other times disappears altogether, when the phosphatic nodules and other things associated with them lie directly on the worn surface of the Ashley and Cooper marls. Among the nodules are found many bones, teeth and other remains of animals, some of which are not older than the Postpliocene, and even relics of aboriginal man have been gathered from the same stratum according to Holmes,* who consequently assigned the aggregation to the Postpliocene, while recognizing the more ancient character of the rock from which the nodules were originally formed.

Penrose (Bull. U. S. G. Survey, No. 46, pp. 61–2, 1888) in discussing the South Carolina phosphates says "the nodules generally contain casts of Eocene shells and, in some cases, marine bones and sharks' teeth." In this he was probably following Holmes and others who, notwithstanding the usual intervention of the sand and clay beds between the top of the Ashley River marls and the bed of phosphatic nodules, have regarded the nodules as waterworn fragments of the Ashley marl rock. The latter was doubtfully referred to the Eocene by Tuomey (Geol. S. Car., p. 167, 1848) because three Eocene

* Phosphate beds of South Carolina, p. 62, 1870.

species were common to the Santee (Eocene) and Ashley beds. One of these species is inedited, another is an unrecognizable internal cast (*Conus gyratus*) the last is *Nautilus alabamensis.* Two other Eocene forms are mentioned by Tuomey as belonging to the Ashley River marl, *Pecten calvatus* and *Panopæa elongata.* The Cretaceous *Gryphæa mutabilis* and the very uncertain *Anomia jugosa* complete the list of known species among those which were named, but not described or figured, by Tuomey. It is by no means unlikely that such of these as are really Eocene may have been derived, like the *Gryphæa*, from subjacent deposits. Tuomey says in regard to the Ashley marl (op. cit. p. 165), "Mr. Ruffin was struck with the absence of all the more common Eocene forms of Virginia and even of the Santee" and (p. 167) "*Venus crassa* (T. mss.) bears so strong a resemblance to the Miocene species *V. lyrata* Conr. that it was not without hesitation that I separated them. *Cardita dubia* (T. mss.) can scarcely be distinguished from a species found in the Miocene of Pamunkey, Va. *V. proxima* (T. mss.) is like *V. cortinaria;* in a word, any one acquainted with our fossils would be struck with the Miocene aspect of these; and had I not found them associated with *Gryphæa mutabilis*, *Pecten calvatus*, *Conus gyratus* and *Panopæa elongata*, I would not have ventured to place them here."

The pecten referred to is not *P. calvatus*, and it is obvious that the Eocene age of the Ashley marl is in great need of confirmation. An examination of the casts of fossils in the phosphatic nodules shows about twenty species, of which the most common are an undescribed species of *Venus*, *Astarte vicina* Say, an *Amusium* not distinguishable from *A. mortoni* jr., *Lucina contracta* Say, *Dentalium attenuatum* Say, and a *Venericardia* different from but related to *V. granulata* Say. Beside these are species of *Corbula*, *Leda*, *Yoldia*, *Pecten* (*decemnarius* Say), *Tellina*, *Olivella*, *Marginella*, *Solen*, *Modiola*, and *Balanophyllia.* Lastly, among the gutta percha squeezes taken from the casts were two unmistakable fragments of *Ecphora quadricostata.* All the identified species are well known Miocene shells and all the others may well be Miocene. Not a single Eocene species, or characteristic Eocene type, occurred in the whole collection.

I have no hesitation in concluding therefore that the rock from which the phosphatic nodules are derived is of upper Miocene age, or at least that its fauna, while unmistakably Miocene, is more nearly related to the Chesapeake Miocene than to the older beds of the Chipola epoch. The phosphatization of the rock was of course later than its formation and perhaps might have taken place, like that of the very similar Peace River, Florida, phosphatic pebbles, during Pliocene time.

Washington, July 20, 1894.

ART. XLIII.—*On the Thermo-electric Properties of Platinoid and Manganine;* by B. O. PEIRCE.

DURING the last few years the attention of many physicists has been occupied with the attempt to discover an alloy in every respect suitable for making standards of electrical resistance. Such an alloy, it is evident, must be non-magnetic, ductile, not easily corroded and easily soldered to copper and brass. It must have a high specific resistance independent of the temperature and, when drawn into wire, its resistance must not be subject to secular change.

No one [1] substance is yet known to satisfy all these conditions completely and, since there is still some doubt about the permanency of artificially seasoned resistance coils made of manganine wire, many makers of standards prefer to use platinoid in spite of its comparatively high temperature coefficient.

I have been trying of late to reduce as much as possible the disturbing effects of thermo-electric currents in a certain standard slide wire bridge and have had occasion to determine the thermo-electric relations of copper to such [2] platinoid and [3] manganine as are to be obtained in the market. A few years ago such determinations would have had very little practical value, since different specimens of copper had very different positions in the thermo-electric scale, but this last statement is no longer true of copper bought in the American market. I have tested against each other many specimens of copper wire of different sizes, chosen at random from a rather large stock bought at intervals during the last five years, and the highest electromotive force that I have obtained was 0·06 microvolts per centigrade degree, and this was very exceptionally large. I believe that a thermal junction made of two specimens of annealed copper wire bought of different reputable makers would probably not yield more than one or two c. g. s. units of electromotive force per centigrade degree even if one were as large as no. 10 and the other as small as no. 36 on the American * Gauge. Professor E. H. Hall tells me that he has

[1] Feussner and Lindeck:—Zeitschrift für Instrumentenkunde, 1889, pp. 233–236.
Nichols:—This Journal, 1890, pp. 471–477.
Ahler, Haas and Angerstein:—Electrotechnische Zeitschrift, 1891, p. 250.
Feussner:—Electrotechnische Zeitschrift, 1892, p. 66.
Milthaler:—Wiedemann's Annalen, xliv, 1892, pp. 297–305.
Lindeck:—Wiedemann's Annalen, xlvi, 1892, pp. 515–516.
Weichert:—Wiedemann's Annalen, lii, 1893, pp. 67–75.

[2] Bottomley and Tanakadaté:—Phil. Mag., xxviii, 1889, pp. 163–169.

[3] Englisch:—Wiedemann's Annalen, l, 1893, pp. 88–110.

* The diameter in inches of wire no. n in the American Gauge is approximately $(0{\cdot}32)\, 2^{-\frac{n}{6}}$.

tested several specimens of commercial copper wire of different sizes against plates of electrically deposited copper and that the electromotive force of every one of these combinations was extremely small or insensible. When such results as these are compared with those obtained fifteen or twenty years ago,* it is evident that great progress has been made in the manufacture of copper wire for electrical uses and that commercial copper has now a pretty definite thermo-electric position.

The platinoid wire which I used was of two sizes (nos. 19 and 28 of the American Gauge) and was bought about four years ago of Messrs. Elliott Brothers of London.

The so-called "manganine" wire was of seven sizes bought at different times through Messrs. Gillis & Gleeson, of Messrs. Bradford, Kyle and Co. of Plymouth, Mass. The largest size (no. 18) was hard drawn, the other sizes were all annealed. Three specimens (nos. 18, 26 and 30) showed when examined qualitatively only a trace of nickel in combination with copper and manganese.

Each of the wire thermal junctions when in use was immersed close to the bulb of a thermometer in a bath containing about a litre and a half of heavy paraffine oil and furnished with a stirring apparatus. Each oil bath was set into and jacketed by a vessel of about 10 litres capacity into which ice or warm water or steam could be introduced or which could be used as an air bath. The electromotive forces of the different combinations were determined by compensation on a potentiometer. When, for the purpose of obtaining a rough check on the other results, quicksilver was opposed to platinoid or to manganine, the lower end of a very large test tube containing about 40 grams of redistilled mercury was deeply immersed in each oil bath and the contents of the two tubes were connected by a long glass siphon filled with mercury. The bulb of a thermometer and an end of a piece of wire of the kind to be examined were immersed in the mercury of each test tube and obvious precautions were taken to prevent undue loss of heat from the contents of the tubes. The following table gives the results of observations made in this way with platinoid wire no. 19 and with hard drawn manganine wire no. 18. In each case the current passes across the hot junction from the first named metal to the second, the electromotive forces are measured in microvolts and the temperatures of the junctions are given in centigrade degrees.

* See Everett's Physical Constants, p. 151.

TABLE I.

Temperatures of the Junctions.	Electromotive Forces. Mercury vs. Manganine.	Platinoid vs. Mercury.
0° and 10°	66	123
0° and 20°	136	246
0° and 30°	209	372
0° and 40°	283	500
0° and 50°	359	631
0° and 60°	438	766
0° and 70°	524	906
0° and 80°	613	1048
0° and 90°	704	1190
0° and 100°	797	1331

When the hard drawn manganine wire no. 18 in a thermal junction was for the first time raised to the temperature of boiling water and then slowly cooled, the results of a series of observations of electromotive force taken during the cooling were sometimes rather irregular though they agreed in general fairly well with the regular results (in complete agreement with one another) obtained on a second, third, or subsequent heating. The platinoid wire always gave regular results from the first and these were repeated with a given specimen as often as the junctions were brought to the same temperatures. The annealed manganine wire showed no irregularities on first being heated. The results of a large number of completely accordant observations with thermo elements made of copper and either platinoid wire no. 19 or manganine wire no. 18 are given in the next table.

TABLE II.

Temperatures of the Junctions.	Electromotive Forces. Copper vs. Manganine.	Platinoid vs. Copper.
0° and 10°	4·3	189
0° and 20°	9·2	379
0° and 30°	14·1	572
0° and 40°	19·6	769
0° and 50°	25·7	971
0° and 60°	32·6	1179
0° and 70°	40·2	1391
0° and 80°	48·1	1609
0° and 90°	56·4	1834
0° and 100°	64·9	2063

The thermo-electric effects at the junctions with their copper terminals of resistance coils would evidently be far less under given conditions if the coils were made of this specimen of manganine than if they were made of the platinoid. Moreover this hard drawn manganine wire could advantageously be used as a slide wire, since accidental heating of a portion of the wire would not alter its resistance appreciably and since the thermo-electric effects at the junctions of the slider would be insensible. On account of its high specific resistance very fine manganine wire has been much * used as slide wire in potentiometer work.

A pair of thermo-electric junctions made of copper wire and a piece of the manganine wire no. 18 which had been kept for about a minute at red heat and then suddenly cooled gave an electromotive force of 65·9 microvolts when one junction was kept at 23° and the other at 93°. It is instructive to compare this result with the results of experiments mentioned below which were made with manganine wire thoroughly annealed in the manufacture.

The numbers given in Table II for the electromotive force of platinoid against copper do not agree very well with the results obtained by Messrs. Bottomley and Tanakadaté who, found for the electromotive force of this combination the two expressions $-1246 - 5{\cdot}44t$ and $-1294 - 4{\cdot}88t$ in c. g. s. units. My experience seems to show, that as these gentlemen suspected, different specimens of platinoid wire have different places in the thermo-electric scale. A number of thermopiles made of platinoid wire no. 28 and copper gave results which agreed with one another perfectly, except for such extremely slight differences as might properly be charged to errors of observation, but these results were quite different from those obtained with the larger platinoid wire and much closer to those of Messrs. Bottomley and Tanakadaté.

Table III.

Temperatures of the Junctions.	The Electromotive Force of Platinoid Wire no. 28 vs. Copper.
0° and 10°	152
0° and 20°	306
0° and 30°	465
0° and 40°	628
0° and 50°	799
0° and 60°	973
0° and 70°	1159
0° and 80°	1356
0° and 90°	1569
0° and 100°	1787

* H. M. Goodwin:—Zeitschrift f. Physikalische Chemie, xiii, 4, 1894.

Of annealed manganine wire I had considerable quantities of nine different specimens and these were of six different sizes, 22, 26, 28, 30, 33, and 36. Of this wire Mr. C. J. Shanahan and I made a very large number of thermo-electric junctions, sometimes opposing one specimen of manganine wire to another and sometimes to copper. Experiments with these junctions showed that one specimen (no. 22) differed rather widely from the others, which were thermo-electrically pretty close together, and that the thermo-electric position of the abnormal wire was in no way changed by heating it repeatedly red hot and cooling it suddenly.

Table IV gives the results of numerous experiments upon thermo-electric junctions made of annealed manganine and copper. The numbers in the first column of electromotive forces were obtained with the no. 22 wire just mentioned: the numbers in the last column are the averages of corresponding numbers in a table where each of the other eight specimens of wire had a column for itself. There were slight persistent differences between these last mentioned wires but there was no apparent relation between the size of a wire and its thermo-electric position. It will be noticed that the electromotive force of no one of the manganine-copper combinations experimented on was greater than about one-seventh that of the weakest of the platinoid-copper combinations under similar circumstances.

TABLE IV.

	Electromotive Forces of	
Temperatures of the Junctions.	Copper vs. Manganine Wire no. 22.	Copper vs. Ordinary Annealed Manganine.
0° and 10°	24·0	17·3
0° and 20°	48·0	34·7
0° and 30°	72·5	52·3
0° and 40°	97·4	70·1
0° and 50°	123·0	88·0
0° and 60°	149·0	106·0
0° and 70°	175·0	124·4
0° and 80°	202·0	143·0
0° and 90°	229·0	161·4
0° and 100°	257·0	180·0

Jefferson Physical Laboratory, Cambridge, Aug. 1894.

Art. XLIV.—*Change of Period of Electrical Waves on Iron Wires;* by John Trowbridge.

In an investigation upon the damping of electrical waves on iron wires* I endeavored to detect a change of periodicity as well as a damping of these waves. On account, however, of the strong damping effect exerted by the magnetic nature of the conductors, not a sufficient number of oscillations could be set up in the conductors to enable one to make conclusive measurements. With more powerful means of experimenting I returned to the subject; and I have detected a marked change in the period of electrical waves which is produced by the magnetic nature of the wire. At the same time Mr. Charles E. St. John, working in the Jefferson Physical Laboratory, by an entirely different method has shown a change in wave length on iron wires even for the very rapid periods of the Hertz vibrator. It will be remembered that Hertz believed that iron wires behaved like copper wires when transmitting very rapid electrical oscillations. Stefan† in a recent paper gives an analysis of electrical oscillations in which he proves that rapid electrical waves on iron wire circuits have the same wave length as those on a copper circuit of the same geometrical form—the electrostatic capacity of the two circuits being the same.

With reference, therefore, both to the theory of electrical waves and to the theories of magnetism, it seemed important to determine whether there is a lengthening of electrical waves on iron wires.

The method of investigation I employed was the same as that which I have described in my paper on the damping of electrical waves on iron wires. A Leyden jar was discharged through the given wires and the resulting spark spread out by a revolving mirror, was photographed. The apparatus was also modified as I have described in my paper on electrical resonance and electrical interference.‡

It was important in this investigation to be able to compare the times of oscillation on the iron circuits and the copper circuits, and it seemed best to employ some method of imprinting, so to speak, the time of a standard circuit on each photograph, beside the photograph of the spark produced on either the iron circuit or the copper circuit; for if the speed of the mirror changed this change could be readily detected by the measure-

* Phil. Mag., Dec., 1891.
† Ann. der Physik und Chemie, xli, 1890, p. 422.
‡ Phil. Mag., Aug., 1894.

ment of the oscillations of the standard time spark. At first thought it seemed a comparatively simple matter to arrange a suitable time circuit. In Hertz's electrical waves,* appendix, p. 271, it is stated:

"Let the primary coils of two induction coils be placed in the same circuit, and let their spark gaps be so adjusted as to be just on the point of sparking. Any cause which starts sparking in one of them will now make the other begin to spark as well; and this quite independently of the mutual action of the light emitted by the two sparks, which indeed can easily be excluded."

I therefore slipped two induction coils of exactly the same self-induction on a long electro-magnet, placing them symmetrically upon it. In the circuits of these induction coils I placed the same amount of capacity. The spark gap on the time circuit was made of the same length as that on the circuit of iron or copper wire which was under examination. I expected thus to obtain a photograph of the spark on my standard circuit at the same instant as that of the spark on the trial circuit of iron or copper. To my surprise I found that the two induction coils did not respond at the same instant to the impulse in the electro-magnet, when the spark gaps were of the same length. It was necessary to make a careful adjustment of these lengths and to modify the amount of capacity in the two circuits. This want of isochronism may have been due to irregularities in the hard rubber condensers which I employed as condensers. This, however, does not seem probable. The condensers were made of sheets of hard rubber $\frac{1}{8}$ of an inch in thickness, covered with tin foil, and the set of condensers in the time circuit did not differ geometrically appreciably from the set on the trial circuit. The electrical disturbances on such a connected system is evidently a complicated one when its various reactions are considered; and the statement given by Hertz, which I have quoted, must be modified if there is any capacity in the circuits of the two Ruhmkorf coils which have a common primary.

The capacity in the time circuit was the same geometrically as that in the circuit which included the wires under examination. A suitable amount of self-induction was placed in the time circuit. To ascertain whether the time circuit could be relied upon, I made many measurements of the ratio of the oscillations in the time circuit to those in the trial circuits which contained copper wires and the same geometrical capacity. I had no reason to suspect a change in the self-induction in my time circuit; a change might occur, however, in the capacity of the India rubber condensers, due possibly to hysteresis or to

* Electric waves, Dr. Heinrich Hertz, translated by D. E. Jones, B.Sc.

electric strains and deformations. I could not detect, however, such effects. I was dealing with single discharges, not repeated ones, such as are employed in obtaining wave lengths along wires, and the photographs of such single discharges showed no evidence of inconstancy in the capacity of my condensers. If there was any effect of electrical hysteresis it affected both my time circuit and my trial circuit alike.

As an example of the degree of accuracy that can be obtained in the measurement of the distances between the oscillations on the negatives, the following table is given. The distances between different numbers of oscillations is given in the first column and the average length of the oscillation is given in the third column.

Distance in mm. between the first and last oscillation.	Number of oscillations included in this distance.	Average length of oscillations in mm.
22·5	6	3·75
26·1	7	3·73
30·	8	3·74
15·1	4	3·77

Repeated measures between the same number of oscillations give closer measures; but one is apt to set the measuring instrument each time on the same points on the negative. It is evident that measuring each time the space between a different number of oscillations gives the fairest result. It is surprising how close one can set the measuring instrument upon the serrations of the negative.

It will be noticed below that the ratio between any two determinations of the time on the time circuit is the same as that between the corresponding times on the trial circuits. When iron wire of suitable diameter, however, was substituted for copper wire of the same diameter and same geometrical form, in the trial circuit, the ratio of the determinations of time in the time circuit and the ratio of the oscillations on the iron circuit were no longer constant. This inconstancy I desire to dwell upon as my strongest proof that the period of electrical oscillations on iron wires is not the same as that of oscillations on copper wire of the same geometrical form.

The arrangement of a suitable iron circuit gave me considerable trouble. The problem was to obtain a sufficient length of iron wire to show any effect of change in periodicity and also to obtain a sufficient amount of self-induction in order that the distances between the oscillations on the photographs should be measureable. The strong damping effect of iron did not permit of my using more than four or five meters of wire. It was not a simple matter to arrange two circuits, one of iron and one of copper, which would have exactly the same geometrical form. After many trials I arranged my trial circuit as follows:

a cylinder of very porous wood 11·5^{cm} in diameter, 15^{cm} long, was boiled in paraffine, and a spiral was cut upon its surface. The turns of the spiral were 1^{cm} apart. On this cylinder, and in these spirals, the wires under examination were wound. After a determination had been made with a copper wire it was unwound from the cylinder and an iron or steel wire was wound in the grooves occupied by the copper wire. Exact geometrical similarity was thus obtained with good insulation. Several hundred determinations were made with wires of different sizes. With iron wires larger than ·0312 inch in diameter no marked change in period could be noticed. If a great number, however, of photographs were measured an inconstancy of ratios was noticed which never appeared when the copper circuits were compared. It seemed as if at certain times the iron exerted a magnetic effect and at other times failed to do this. The most marked changes in period I obtained with iron wires of ·0312 inch in diameter.

I give the following example. The lengths of the oscillations are expressed in millimetres.

IRON.		COPPER.	
A. Length of oscillation on iron circuit.	B. Length of oscillation on time circuit.	C. Length of oscillation on copper circuit.	D. Length of oscillation on time circuit.
3·7	6·08	3·5	6·14
3·7	6·08	3·4	6·00
3·7	5·9	3·3	6·00
		2·7	5·26
4·	6·1	3·4	6·1
3·3	5·16	3·37	6·56
2·8	3·6	2·68	3·72

When the ratios of A to B and of C to D are compared it will be seen that the time of electrical oscillations on an iron circuit of the same geometrical form as a copper circuit are longer than those on the copper circuit.

The rate of oscillation was not far from that I employed in my investigation on the damping effect of iron wires. Since the inductance appears under the square root in the formula $t = 2\pi\sqrt{Lc}$. The changes in induction due to the iron indicated by the above table may amount to from five to ten per cent.

Thus my results confirm those of Mr. Charles E. St. John, who has shown by an entirely different method that the wave lengths sent out by a Hertzian vibrator on iron wires differ in length from those transmitted on copper wires of the same geometrical form as the iron wires. His results are even of more importance in the theory of magnetism, for they deal with more rapid electrical oscillations than those I employed.

Jefferson Physical Laboratory.

ART. XLV.—*Wave lengths of Electricity on Iron Wires;* by CHARLES E. ST. JOHN, A.M. With Plate IX.

THE question whether the magnetic properties of iron are called into play under extremely rapid alternations of the magnetizing forces has been an interesting one, and has received various answers.

Hertz found negative results when he replaced one side of a rectangular copper resonater* by an equal iron wire, and in a later paper on the "Finite velocity of Electro-magnetic Action,"† when he compares the rate of propagation along copper and iron wires, he concludes "that the rate of propagation in all wires is the same, and we are justified in speaking of it as a definite velocity. Even iron wires are no exception to this general rule; hence the magnetic properties of the iron are not called into play by such rapid disturbances."‡

Dr. Oliver J. Lodge attacked the question by means of his experiment on the alternate path. In his "Lightning Conductors and Lightning Guards" (1892)§ he remarks: "But everyone will say—and I should have said before trying—surely iron has more self-induction than copper. A current going through iron has to magnetize it in concentric cylinders, and this takes time. But experiment declares against this view for the case of Leyden jar discharges."

Prof. John Trowbridge has shown that the magnetic character of iron wires exercises an important influence upon the decay of electrical oscillations of high frequency, and that currents of such frequency as occur in Leyden jar discharges magnetize the iron. The spark in geometrically similar oscillating circuits of copper and iron was photographed by means of a revolving mirror and the number of oscillations on the negatives compared.

Prof. J. J. Thompson has shown‖ that the presence of iron can affect the rapidly oscillating electric discharges through a rarified jar by absorbing the energy of the discharges.

In a paper upon the Absorption Power of Metals for the Energy of "Electric Waves," V. Bjerknes has also given results that prove the great damping power of magnetic metals upon electric oscillation of very high frequency (100,000,000 double oscillations per second).

* Annalen xxxi, p. 429, 1887. † Annalen. xxxiv, p. 351, 1888.

‡ Electric Waves, p. 113.

§ Proceedings of American Academy of Arts and Sciences, vol. xxv, May 27, 1891.

‖ Phil. Mag. (V), lxxxii, p. 456, July, 1891.

If the damping power of iron is due to the fact that its magnetic properties are brought into play, under such rapidly alternating forces, it still remains an interesting question whether the self-induction of an iron circuit is measurably greater than that of a similar copper circuit, and whether the wave length remains constant for oscillations of the same period.

In the determinations of the wave lengths due to the Hertzian vibrator, the arrangement originated by Hertz* and modified by Lecher† and by Sarasin and De La Rive‡ has been very generally employed. In this arrangement secondary disks were placed face to face with the plates of the vibrator and near to them, to each secondary disk a long wire was attached; and these wires carried through the air parallel to each other, with, sometimes, an additional disk on the free ends.

With such an arrangement no exact adjustment of the length of the secondary circuit was required in order to excite powerful oscillations in it, for the direct electrostatic induction between the plates of the secondary and the disks on the ends of the primary wires was so great that vigorous oscillations were produced along the secondary wires whatever their length might be, and several systems of waves could be detected which seemed to give experimental grounds for believing that the wave system sent out from the Hertzian vibrator was very complex.

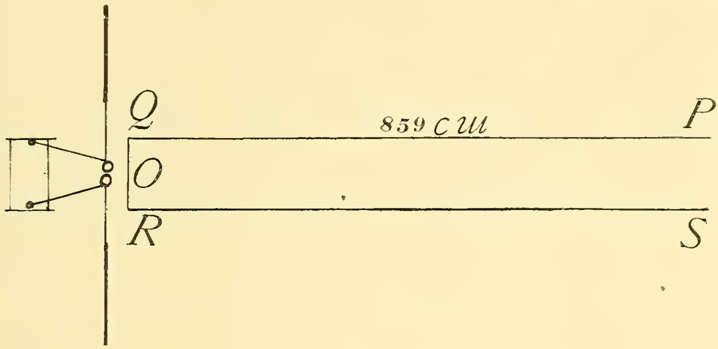
The capacity of the vibrator is increased by the presence of these secondary disks so near to the vibrator plates, so that the wave length found under these conditions is not that due to the simple Hertzian vibrator but that due to a very complex oscillating system with somewhat obscure internal reactions. Especially is this true when the wires are bridged as in the Lecher arrangement. The latter calls attention to the change in the sound of the primary spark when the secondary wires are bridged by a conductor. There is a very marked difference in the spark when the secondary circuit is removed entirely. The spark then loses much in body and explosive character. The secondary circuit under these conditions exerts apparently a strong reaction upon the primary.

It seemed desirable to devise some form of secondary depending more directly upon the principle of electrical resonance, the use of which would not increase the capacity of the vibrator and whose reaction upon it would be a minimum. This was done by omitting the secondary disks and using simply a single long wire as shown in fig. 1*a*.

* Annalen, xxxiv, p. 551, 1888.
† Annalen, lxi, p. 850.
‡ Archives des Sciences physiques, t. xxiii, p. 113, 1890.

The secondary circuit consists of the long rectangle PQRS which is carefully adjusted to resonance before any other measurements are made.

1*a*.



For determining the occurrence of resonance and for exploring the wires to obtain the wave form, the bolometer as described by Paalzow and Rubens* was used in connection with Rubens'† adaptation of it.

The exploring terminals of the bolometer are shown at P, fig. 2*a*. They consist of two capillary glass tubes set in a frame of wood, the tubes slide over the wires to be explored, and around each tube is wrapped by a single turn one of the leading wires to the bolometer. Electric oscillations in the secondary circuit cause inductively alternating currents along the leading wires through one arm of a balanced Wheatstone bridge, which forms the bolometer. This arm of the bridge is made of fine iron wire and so arranged that the bridge current and the oscillating currents traverse it without affecting each other. The bridge is thrown out of balance by the increase of resistance caused by the heat generated from the alternating currents, and a corresponding throw of the galvanometer is produced.

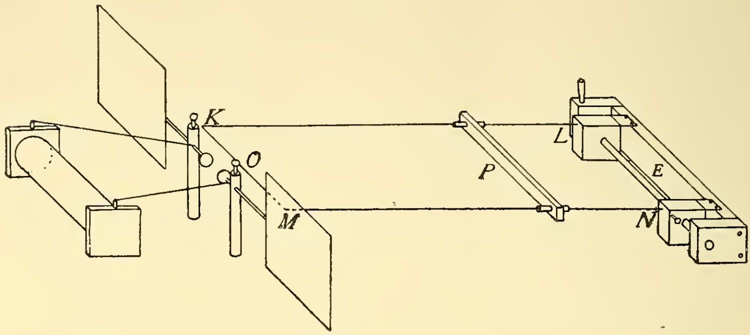
To adjust the circuit to resonance the exploring terminals were placed at PS (fig. 1*a*.) The induction coil was put in action, and the reading of the bolometer taken for this length of wire, a few centimeters of wire were cut off and the reading again taken. This operation was repeated until a maximum point was passed. The wires were renewed and the operation repeated again and again. A sharp and unmistakable maximum was formed when PQ was 859^{cm} long. The effect fell

* Anwendung des bolometrische Princips auf electrische Messungen, Annalen xxxvii, p. 529.

† Ueber stehende electrische Wellen in Drähten und deren Messungen, Annalen xlii, p. 154.

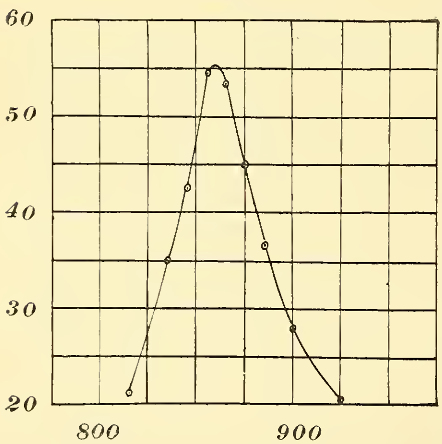
off rapidly when the wires were lengthened or shortened from either point. The result is shown graphically in fig. 2, where

2*a*.



distances from Q are used as abscissas and deflections of the galvanometer as ordinates. When the circuit is thus arranged, there is little effect produced upon it by the vibrator unless it is near the point of resonance. The period of the vibrator is the controlling factor and the influence of the secondary circuit is greatly reduced.

3*a*.



To determine the character of the vibrations along the wire, the lengths QP and RS, fig. 1*a*, were fixed at 859^{cm}, the exploring terminals were moved along the rectangle and the bolometer reading taken for each position of the exploring terminals. The graphic representation of the results is given in fig. 1, of the plate where, as in all the curves, the abscissas are the length of the sides of the rectangle and the ordinates the bolometer readings. The character of the curve indicates a simple form of vibration. The total length of the wire is equivalent to 7 half wave lengths. The minimum points occur at nearly equal intervals, and the distance from the minimum at 748^{cm} to the center 0 of the side QR may be taken as three half wave lengths. This furnishes a ready means of calculating the half wave length.

QR = 30^{cm}. 748 + 15 = 763^{cm}. 763 ÷ 3 = $254·3^{cm}$. = a half wave length. The distance from this minimum to the end of the wire P should be a fourth wave length or $127·15^{cm}$. The actual distance is 859 − 748 = 111^{cm}, so that the correction for the free end of the wire is about 16^{cm}.

To adjust the length of the wire under this arrangement was a work of considerable difficulty, but the possibility of using a single wire circuit free from disturbing capacities would overbalance much inconvenience. To remove this source of inconvenience, the ends P and S, fig. 2*a*, were wound upon wooden bobbins so that shortening and lengthening could be produced without cutting the wire; this was a marked gain in convenience; but the changing size and form of the coils, as the wire was shortened or lengthened, varied the capacity at the end slightly and somewhat irregularly. This led to the adoption of the arrangement shown in fig. 2*a*.

The secondary circuit consisted of the rectangle KLMN with the side LN open. The lengths of the sides KL and MN could be varied between 15^{cm}, and 1000^{cm}. The ends were really formed by the small copper boxes M and N. These were 10^{cm} square and 4^{cm} thick and mounted upon the wooden bar E by insulating supports. Within the boxes were wooden bobbins fixed on a hard rubber axle, and each capable of holding 10^{m} of the largest wire experimented upon. In the front of each box was a small opening for the passage of the wire, but to assure a firm contact, between the wire and the boxes, a brass block was soldered on the inner side of the front and a binding screw passed in from the side of the box. The bar E was fastened to a wooden support resting upon a car which ran on a wooden track extending the entire length of the room. The car carried a brake so that the wires could be drawn taut and the wooden screw held the axle from turning. With this arrangement the length of the wire could be varied at pleasure while the end capacities remained constant. The end capacities are not a desirable feature for their own sake, since they destroy the perfect simplicity of the plain rectangular circuit, and seem to detract somewhat from the sharpness of the maxima, but the gain in convenience, and the possibility of obtaining a large number of observations whose average values can be used may overbalance these considerations.

For making and breaking the current through the induction coil, an interruptor which would work with certainty and regularity was much needed. With the assistance of the mechanician of the laboratory I devised an interruptor which gave very satisfactory results.

A small electric motor (fig. 4*a*) was used to produce the necessary motion, this was actuated by the current from two storage cells, and ran at a fairly constant speed. The armature of the motar was in three sections, and was free from dead points, giving it the great advantage for the present purpose that it could be set in action simply by closing the circuit, making it possible to control it from the observer's station.

4*a*.

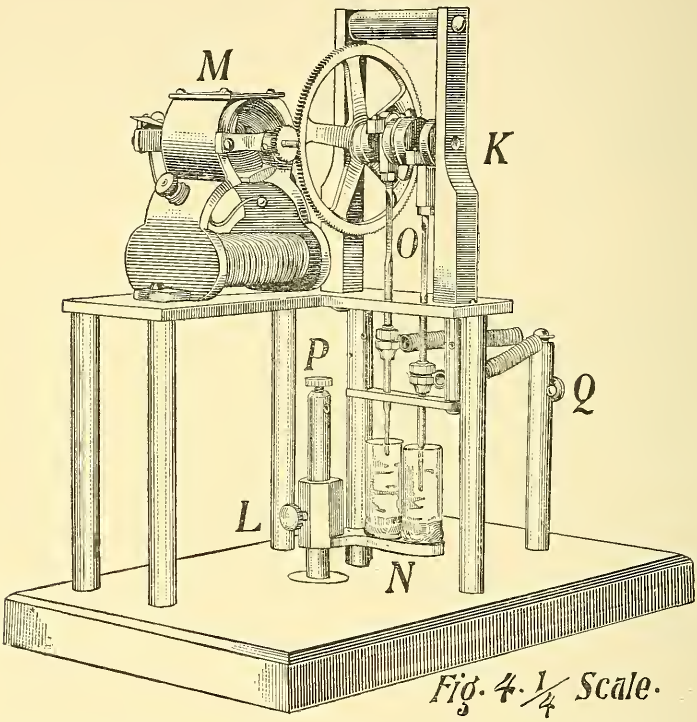


Fig. 4. 1/4 Scale.

The motor was geared to the two-crank shaft K by means of a wheel and pinion. The speed of the shaft K was about 750 revolutions per minute, so that about 25 breaks were made per second. The plunging rods was thinned at O so that they were flexible and gave the required freedom of motion; they ran through the bed plate and the brass bar below which served as guides. The plunging rods carried binding screws by which the flexible coils leading the current from the brass post Q were attached. The lower ends of the plungers were of No. 18 platinum wire. The brass bottoms of the glass mercury cups screwed into the brass arm N which was adjustable by means of the collar and binding screw L along the pillar P. At P was attached one pole of the battery actuating the coil and also one pole of the condenser in the base of the coil; and at Q was attached one pole of the coil and the other pole of the condenser. The cups were filled with mercury to a height of 8^{mm} and then filled with alcohol to within a few millimeters of the top. They usually required cleaning only after several hours' use, when the surface of the mercury consisted of very fine globules, and sharp breaks were not made at each stroke of the plunger as was indicated by the occasional failure of its spark. The character of the spark depended much upon the exact height of the mercury cups. The adjustment was best made while the coil was in action by raising or lowering the cups until the spark had a white body and a peculiar snap.

The plates of the Hertz vibrator were 40^{cm} square and fixed at 61^{cm} apart. The spark gap was supplied with platinum-faced balls (3^{cm} in diameter) which worked with less trouble than the usual brass ones. The side KM of the secondary circuit was parallel to the conductor forming the vibrator plates and fixed at 6^{cm} distance with its center 0 opposite the spark gap. The long sides of the rectangular secondary lay in a horizontal plane and ran through the center of the room at a height of $1{\cdot}6^{m}$ above the floor. They were held by their end supports at 30^{cm} apart. The induction coil was 53^{cm} long, 19^{cm} in diameter, and was excited by the current from five storage cells. A sparking distance of about 6^{mm} was most effective in producing oscillations in the secondary circuit. The following method was pursued in taking the observations. The interruptor was set in action, the circuit closed through the induction coil and an observation taken of the first swing of the needle. The circuits were broken as soon as the needle reached the end of its first swing, and the extent of this excursion was the reading recorded. In accordance with the experience of Paalzow and Rubens, it was found that a steady deflection could not be obtained, but this first swing was, under like conditions, satisfactorily constant, and a preliminary calibration of the instrument by passing currents of known strength through it showed that the square root of the deflection taken in this manner was in a constant ratio to the current.

The same copper wire (diameter $0{\cdot}1201^{cm}$) that had been used in the secondary without end capacities was used for the rectangle KLMN in fig. 2*a*, and with the exploring terminals close to L and N, the maximum point was found by lengthening and shortening the wire. Bolometer readings were taken for each length used. To assure the constant activity of the spark, a convenient length was taken as a point of reference, and observations taken at this point before and after a series of readings. If the spark had remained constant the readings were retained. A maximum point was found when KL was 818^{cm}. The sides were fixed at this length, and the form of the wave was obtained by sliding the exploring terminals along the wire, and taking bolometer observations for each position. The result is shown in fig. 3, of the plate. The critical points were determined several times, and the steadiness of the spark assured by choosing, as before, a point of reference. The curve shows three minima at 240, 496, and 752^{cm}, starting from 0 these give half wave lengths of 255, 256, and 256^{cm}, with an average of $255 \cdot 6^{cm}$. The third minimum at 752^{cm} was determined with care, as it was to be used as a basis for calculating the half wave length. An error in determining the position of this minimum would be divided by three, since the distance from 0 to this minimum was three half wave lengths. The total length of the circuit was seven half wave lengths, and it was the equivalent of one-fourth of a wave length from the third minimum to the end. The actual distance to the end was $818-752=66^{cm}$. $127 \cdot 8-66=61 \cdot 8^{cm}=$ the equivalent of the capacities in centimeters of wire.

A comparison of the curve (fig. 1, of plate) obtained from the plain wire circuit with the curve (fig. 3, of plate) obtained when capacities were fixed on the free ends shows a quite satisfactory agreement, which tends to create confidence in both methods. The half wave length by the first is $254 \cdot 3^{cm}$, and by the second it is 255·6, values which differ by about one-half of one per cent. There is a marked difference, as was to be expected, in the form of the curve next the free ends. When end capacities were used, the accumulation of charge seemed largely confined to them out of reach of the exploring terminals, while with the plain wire it seemed distributed over a greater distance. In each case the effect of the ends was to make the curve depart from the normal form along the free wire.

The theory of my investigations rests upon the principle of electrical resonance. The sides of the rectangle KLMN (fig. 2*a*) were shortened to a few centimeters in length, so that it could be safely assumed that the period of the secondary was considerably shorter than that of the vibrator. The exploring terminals were kept at LN and bolometer observations taken for each small addition to the length of the sides KL and MN. When best resonance was found with the shortest length of the secondary circuit that gave a maximum, it was assumed that the secondary had the same period as the vibrator, and that its equivalent length was a half wave length, its actual length depending upon the effect due to the free ends. The occurrence of resonance is a very marked phenomenon even with a vibrator that damps as rapidly as the

Hertzian. The accompanying table shows two series of readings for the first maximum when an iron wire was used.

Length of sides of rectangle,	15	25	35	40	42·5	45	50	60	75
Deflections of galvanometer,	107	145	156	194·3	199·2	181·5	140	81	42
" "	94	119	161	185	191	178	136	76	34

There can be no free motion of electricity at the ends of the secondary circuit, but an accumulation alternately positive and negative, and a resulting alternation of potential, the phase at L being always opposite to the phase at N in case of resonance. Elsewhere along the circuit the electricity moves with more freedom and less accumulation. The point 0 may be called the electrical middle of the circuit where the accumulation is least and the movement more unrestrained. The electro-motive impulses from the vibrator act directly upon the side KM so that 0 remains a point of free motion or the ventral segment of the wave, while L and N are always places of no electric movement, or the nodal points. The shortest circuit being a half wave length, a second resonating circuit ought to be found by increasing each side of the rectangle by a half wave length, making the circuit 3 half wave lengths long, and a third when the circuit is 5 half lengths and so on.* It is known that the change of period produced by replacing copper by iron does not exceed two per cent. The difference in length between a copper and an iron circuit of the same period would be very small with circuits a half wave length long; but this difference would be 3 times as great with circuits 3 half wave lengths long, and there might be a cumulative difference that would become measurable by the use of circuits of still greater length. To examine this question, a copper wire (diameter $0{\cdot}1201^{cm}$) was used as the secondary circuit in fig. 2*a*. The sides were taken 15^{cm} long and gradually lengthened to 875^{cm}, and bolometer readings taken for each addition, the exploring terminals being always at the ends L and N. The result is shown graphically by the upper curve in fig. 4, of the plate. The critical points in the curve are the results of many separate determinations. The unsteadiness of the spark in the vibrator made the determinations somewhat laborious, though a single series of observations would locate a maximum very closely. After this had been done, the space of about a meter including the maximum point was worked over forward and back; the constancy of the spark was assured by choosing a convenient point of reference as already described.

An examination of the curve shows four maxima occurring when the sides of the rectangle were 45, 306, 562·5 and 818^{cm}

* J. J. Thompson, Recent Researches in Electricity and Magnetism, p. 297.

long. The additions of wire for the successive maxima after the first were 261, 256·5 and 255·5. These should be half wave lengths. The last two agree well, but the first differs from the average of the last two (256^{cm}) by 5^{cm}. The sides were fixed at 818^{cm}, and the wave form fig. 3, of plate was obtained, from this the half wave length was found to be $255·6^{cm}$, and the total length of the circuit 7 half wave lengths. By fixing the sides of the rectangle at $562·5^{cm}$ and 306^{cm} a similar investigation showed the circuits to be respectively 5 and 3 half wave lengths long.

An explanation of the fact that the distance between the first and second maxima was anomalously large may possibly be this: for the first maximum the sides of the rectangle were but 45^{cm} long, so that the effect of the closed end was relatively great and the maximum appeared earlier than it otherwise would, but when the rectangle was 300^{cm} long, the influence of the closed end became relatively small, and the second and future maxima came in the normal positions. Besides in the first case the capacity was largely local, while in the others it was mainly distributive. This same effect appeared in every case and seemed a constant phenomenon.

The maximum I omitted from the above discussion was not constantly present, but appeared when the primary spark was especially active, and seems to belong to a circuit whose period is to the period of the vibrator in the ratio of 5 : 3. The sides of the rectangle were $127·5^{cm}$ long, and the end capacities equivalent to 62^{cm} of wire. The half wave length was $30+127·5\times2+62\times2=409^{cm}$. $409\div255·6=1·6$ nearly. This was the only indication observed of the complexity in the vibration of the oscillator. It appears that when the oscillation is particularly active it can excite a circuit having this ratio to itself, or that the vibration is not a simple one. Sufficient time was not at my disposal to decide this point which is left for future investigation.

An annealed iron wire (diameter $0·1186^{cm}$) was put in place of the copper and the same series of observations repeated. The results are shown in the lower curve of the upper pair in fig. 4 of the plate. The maxima E, F, G, H, appear at 42·5, 301, 553 and 805^{cm}: in each case before the corresponding maxima with the copper, and the difference is seen to increase with the length of the circuits. The successive additions were 258·5, 252, and 282^{cm}. The last two agreeing, but the first as with the copper is much larger. With the sides of the rectangle fixed at 805^{cm}, the form of the wave was found as shown in fig. 2 of the plate. The third minima occurs at 740^{cm}. Calculated as before the half wave length is $740+15 = 756$, $755\div3=251·6^{cm}$. This agrees well with the value

252 given above by the last two additions, but differs by 4^{cm} from the value found when the copper was used.

The same series of observations was repeated with a second pair of finer wires, diameter of copper wire $0·07836^{cm}$, diameter of iron wire $0·0785^{cm}$. The results are shown in the lower pair of curves in fig. 4 of the plate. A comparison of the curves shows the same general result which appears more distinctly from the following table:

	1st Maxima.			2d Maxima.			3d Maxima.			4th Maxim.		
	Cu.	Fe.	Difference.	Cu.	Fe.	Difference.	Cu.	Fe.	Difference.	Cu.	Fe.	Diff.
Upper pair	45	42·5	2·5	306	301	5	562·5	553	9·5	818	805	13
Lower pair	40	37·5	2·5	300	294	6	552	540	12	799	784	15

The successive differences should be in the ratio of 1, 3, 5, 7 if the theory of the present investigation is correct. The differences for the first two maxima are very small, so that the experimental error in their determination would be relatively large, and in the case of the fourth maximum the damping was so great that it was difficult to fix the point with certainty. The difference for the third maximum was relatively large and the determination of the point was sharp. Taking this difference as a point of reference, the calculated and observed values are shown in the accompanying table:

	1st Maxima.		2d Maxima.		3d Maxima.		4th Maxima.	
	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.
Upper pair	1·9	2·5	5·7	5	9·5	9·5	13·3	13
Lower pair	2·4	2·5	7·2	6	12	12	16·8	15

The observed half wave lengths for the four series are:

{ Copper (diameter 0· 1201^{cm}) $255·6^{cm}$
{ Iron (diameter 0· 1186) 251·6
{ Copper (diameter 0·07836) 251·6
{ Iron (diameter 0·07850) 246·8

The wires in each pair were as near the same diameter as could be found, the iron of the larger pair having slightly the smaller diameter, but the copper being the smaller one in the second case. In other respects the circuits compared were as nearly identical as possible. The capacity per unit length being the same for wires of the same diameter, the shortening of the wave length when iron displaced copper must be caused by an increased self-induction due to the magnetic properties of the iron. This implies that the magnetization of iron can be reversed 115 million times per second. This reduces the "time lug" of magnetization to very narrow limits, if forces of such duration can magnetize the iron.

In the case of extremely rapid oscillations Prof. J. J. Thompson has shown (Recent Researches in Electricity and Magnetism, § 295) that approximately $y^2 = \frac{2}{L' C}$, where $\frac{y^2}{4\pi^2}$ is the square of the frequency, and L′ is the self-induction for very rapid oscillations, and C the capacity of the system. It is easy from this to calculate an approximate value for the ratio between the self-induction per unit length of the iron and copper circuits.

Let L = the self-induction of the copper per unit length.
Let L′ = the " " " iron " "
Let C = the capacity of either per unit length.

Using as a basis of calculation the data from the third maximum of the curves in fig. 4 of the plate, the total length of the copper circuit (diameter 0·1201^{cm}) is:

The sides,	562·5 × 2 =	1125^{cm}
The closed end,	=	30
The equivalent of the end capacities,	62 × 2 =	124
		1279

For the iron (diameter 0·1186^{cm}) the length is:

The sides,	553 × 2 =	1106^{cm}
The closed end,	=	30
The equivalent of the end capacities,	62 × 2 =	122
		1258

Since the two circuits have the same frequency the products of the self-induction and capacity are equal.

$$1258^2 \, L' \, C = 1279^2 \, LC$$

$$\frac{L'}{L} = 1{\cdot}034$$

In the same manner for

$$\left\{ \begin{array}{ll} \text{Copper} & \text{(diameter } 0{\cdot}08840^{cm}) \\ \text{Iron} & \text{(diameter } 0{\cdot}08847 \quad) \end{array} \right. \frac{L'}{L} = 1{\cdot}041$$

$$\left\{ \begin{array}{ll} \text{Copper} & \text{(diameter } 0{\cdot}07836 \quad) \\ \text{Iron} & \text{(diameter } 0{\cdot}07850 \quad) \end{array} \right. \frac{L'}{L} = 1{\cdot}043$$

By the use of Lord Rayleigh's formula for inductance under very rapid oscillations, it is easy now to calculate a value for the permeability of the iron.

Lord Rayleigh's formula is

$$L' = l\left(A + \sqrt{\frac{\mu R}{2pl}}\right)$$

where L is the total length of circuit; A a constant depending only on the form of the circuit, or l A is the inductance of a similar copper circuit; μ the permeability; R the ohmic resistance; $p=2\pi n$ where n is the number of complete oscillations per second.

The value of $p=2\pi n=36\times 10^7$

R for iron wire (diameter	$0\cdot1186^{cm}$)	$=\cdot1328$ ohms per meter.
" " " "	$0\cdot08847$	$=\cdot227$ " "
" " " "	$0\cdot0785$	$=\cdot301$ " "

For iron (diameter $0\cdot1186^{cm}$)

$$L'=1\cdot034\ L=l\left(A+\sqrt{\frac{\mu R}{2pl}}\right)$$

$$L+\cdot034\ L=L+l\sqrt{\frac{\mu R}{2pl}}$$

$$\cdot034\ L=l\sqrt{\frac{\mu R}{2pl}}$$

Calculating the value of L for a similar copper circuit l units long, substituting the value in the above equation, and solving for the three cases we get

For the iron wire, diameter	$0\cdot1186^{cm}$,	$\mu=430$
" " "	$0\cdot08847$	$\mu=389$
" " "	$0\cdot0785$	$\mu=336$

These values for the permeability all fall within a reasonable limit and have for an average $\mu=385$. These are the values found for different specimens of wire made by the same company, but the specimens were wound and unwound and stretched many times during the series of observations.

Besides the shortening of the wave length there is shown a decided increase in the damping as has already been observed by Trowbridge and Bjerknes. In fig. 4 of the plate the curves for iron fall below the corresponding ones for copper, but owing to the change in the activity of the spark no exact measurement was made. It was only observed that the bolometer throws with the copper circuit were always greater than with the iron circuit of the same dimensions, when the spark was constant as far as the eye and the ear could judge.

A value can readily be calculated for the damping factor $\varepsilon^{-\frac{Rt}{2l}}$ in the case of the iron and copper. Lord Rayleigh's formula for the resistance under very rapid oscillations is:—

$$R'=\sqrt{\tfrac{1}{2}\,pl\mu R}$$

For the iron wire circuit (diameter 0·1186^{cm}) $l=1258$; $\mu=430$; $R=1·67\times10^9$; $p=36\times10^7$ whence $R'=403\times10^9$. $L=34\times10^3$.

The damping factor becomes $\varepsilon^{-6\times10^6t}$ approximately.

The time required for the amplitude to fall to one-half its maximum value is $t=0·000,000,115$ sec. On the basis of 115×10^6 alternations per second, the number of complete oscillations during this time is 6·5. A like calculation for the corresponding copper circuit gives about 60 times as many.

The following table shows the results when copper circuits are compared in which wires of different diameters are used.

				3d Maximum.
Copper wire	(diameter		0· 1201^{cm})	562·5^{cm}
"	"	"	0· 0884)	553·5
"	"	"	0·07836)	552·0
"	"	"	0·03915)	534·0

The half wave lengths calculated from this maximum are:

Copper	(0·01201^{cm})	255·8^{cm}
"	(0· 0884)	252·2
"	(0·07836)	251·6
"	(0·03915)	244·8

These are found by dividing the total length of the circuit by 5.

$535\times2=1070$ length of sides.
30 " closed end.
$62\times2=$ 124 equivalent of end capacities.
1224

$1224\div5=244·8^{cm}=$half wave length.

The range of wires suitable for the study of the phenomena is rather limited. If the wires have a greater diameter than 1^{mm} the difference between iron and copper is slight; while with wires less than 0·5^{mm} in diameter the damping is so great that long wires cannot be used, and the advantage cannot be taken of the cumulative effect.

I wish to express my great obligations to Professor John Trowbridge for the encouragement and suggestions that I have received from him.

Conclusions.

1. The self-induction of iron circuits is greater than that of similar copper circuits under very rapid electric oscillations (115×10^6 reversals per second). The change in self-induction varies from 3·4 to 4·3 per cent in the present investigation and increases with decreasing diameters.

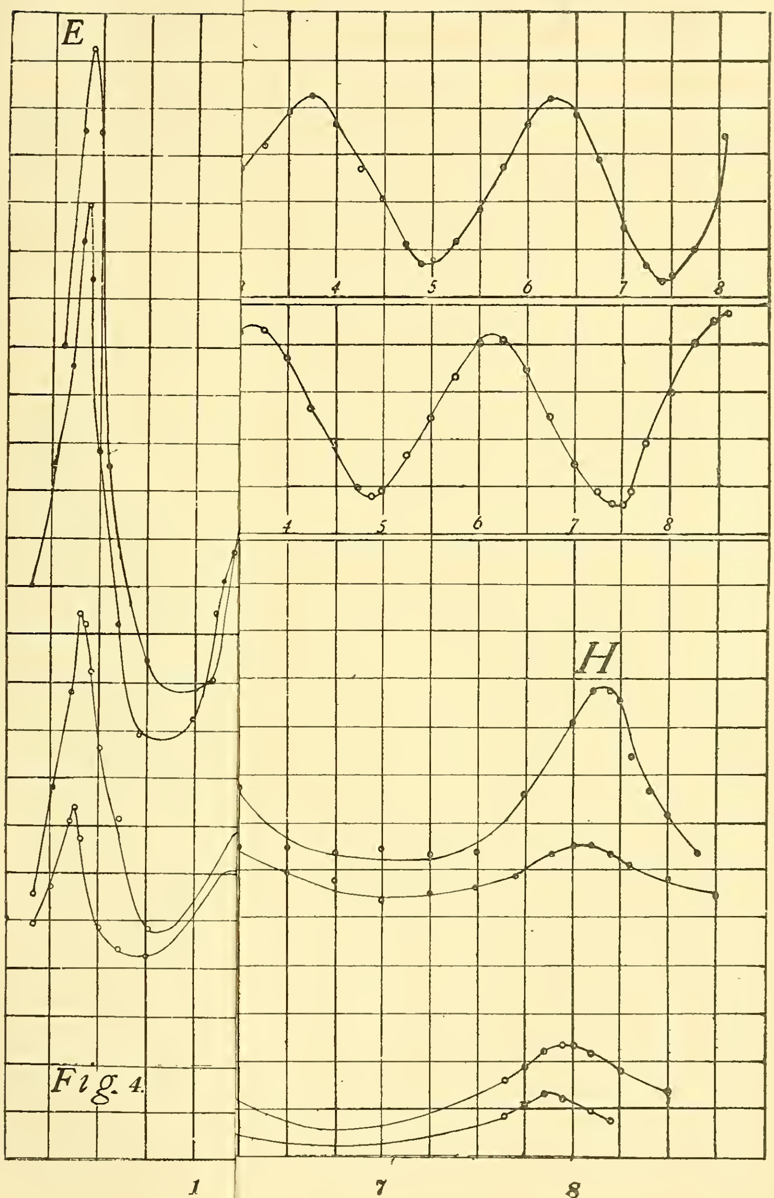

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Fig. 4.
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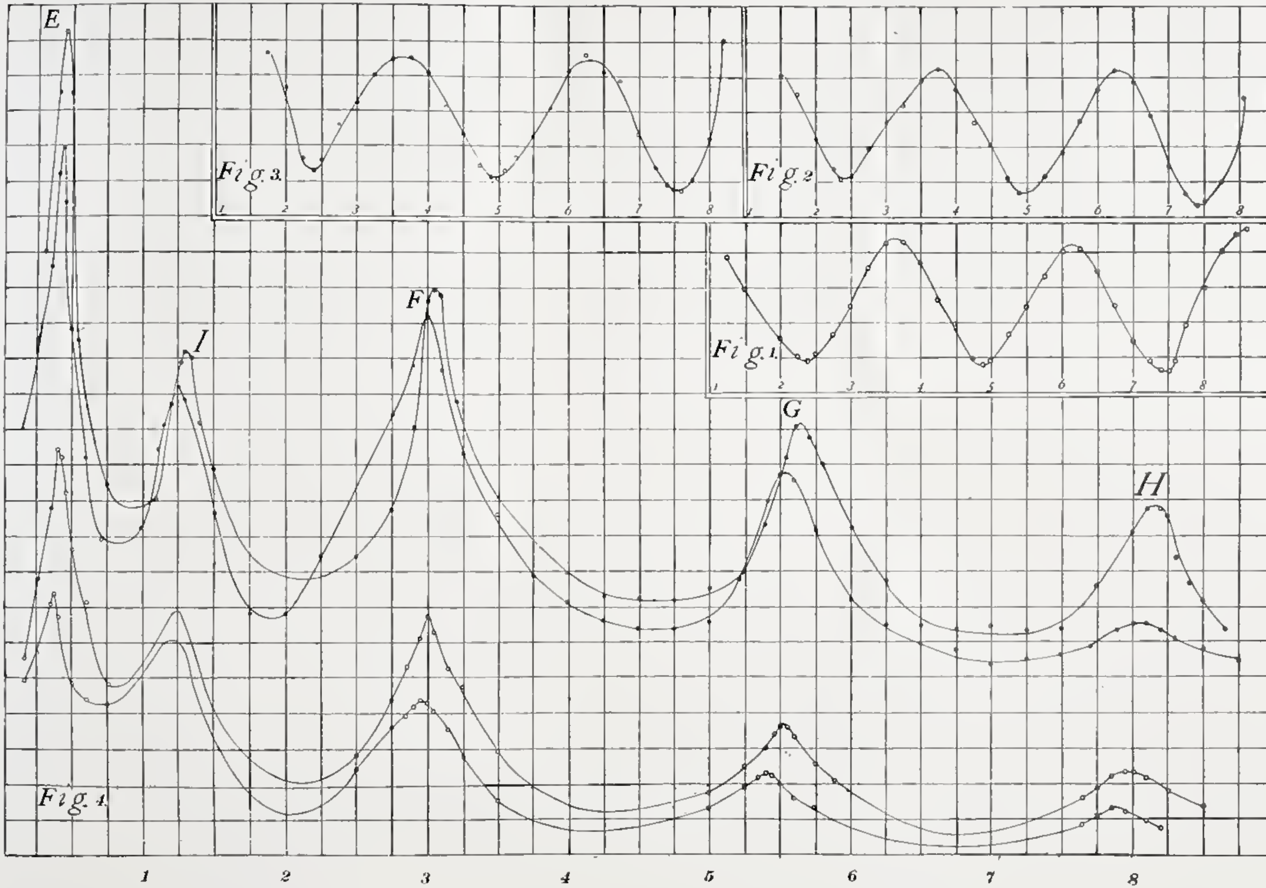

E
I
F
G
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Fig. 3.
Fig. 2.
Fig. 1.
Fig. 4.
1
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2. The increase in self-induction produces greater damping and a shortening of the wave length of 1·5 to 2 per cent.

3. The permeability μ of annealed iron wires under this rate of alternation is about 385.

4. For oscillations of the same period, the wave length along parallel copper wires varies directly with the diameter of the wires. Range of wires used $0{\cdot}03915^{cm}$ to $0{\cdot}1201^{cm}$. The maximum decrease observed is 5 per cent.

Jefferson Physical Laboratory, July 24, 1894.

ART. XLVI.—*On the Age of the Manganese beds of the Batesville Region of Arkansas;* by HENRY S. WILLIAMS.

THE following quotations from his admirable monograph on Manganese* represent the chief points of Dr. Penrose's interpretation of the origin and age of the Batesville manganese ores.

The Batesville ores were precipitated, from surface waters draining southward from the Archæan region of Missouri. The area of precipitation was originally a region of comparatively quiet water bounded on either side by rapidly flowing currents; this condition allowed the excessive accumulation of marine sediments and caused a greater thickness of the St. Clair limestone than to the east or west; the detritus from the land was carried down and mixed with the calcareous materials, the gradual accumulation of these mixed sediments caused shoals and then created lagoons and swamps into which the surface waters from the land emptied, and by a process of oxidation and evaporation deposited the metaliferous matter that they carried in solution. (l. c., p. 595.)

The process of formation of the manganese deposits as they now exist is supposed by him to have been by the decay, *in situ*, of the St. Clair limestone.

The deposits of manganese ore in the Batesville region *that can be profitably worked* are not found in place in the limestone. [The Cason property excepted] . . . it is only when the limestone or "gray rock," as it is commonly called, has been decayed, the carbonate of lime carried off in solution, and the masses of ore with the residual clay thus set free and concentrated, that profitable mining can be done. This decay has taken place on an immense scale, and all the deposits that are being worked, and all that have been worked in the past, with the exception of the Cason mine, represent such products of decay. (l. c., p. 174.)

*Ann. Rept. of Geol. Surv. of Arkansas for 1890, vol. i. Manganese: its uses, ores and deposits, by R. A. F. Penrose, Jr., Ph.D.

The age of the St. Clair limestone is described as intermediate between the Trenton and Niagara, based upon the determination of fossils made by me. Referring to these identifications Dr. Penrose says:

> Fossils collected on Polk Bayou four miles north of Batesville have been determined by him as undoubted Trenton forms, while fossils from St. Clair Springs, eight miles northeast of Batesville, and from elsewhere in the country to the west, are considered by him to be intermediate between those of Trenton and Niagara. (l. c., p. 114).

This quotation indicates the part I had contributed, at the time the Report was written, toward determining the age of the deposits in question.

I differed with Dr. Penrose and the geologists of the Arkansas Survey in holding the opinion that two distinct limestones were confused under the name St. Clair limestone.

Since the year 1890 I have had considerable correspondence with the director of the survey Dr. Branner, and with Dr. Penrose regarding this perplexing question; and about a year ago in order to make certain that the collections were from typical localities Mr. T. C. Hopkins, who was still in Arkansas, collected for us a set of test samples from some of the mines particularly described in the Report. These I examined, and was able as the result of a preliminary study to report about a year ago that all of the limestone samples from below the manganese beds were of Trenton age or older; and that all the limestone described as St. Clair, but lying above the Manganese beds, was of the age of the Clinton-Niagara formation; and that in neither limestone was there confusion of the two faunas. Mr. Hopkins referred to this decision in his Report on Marbles,* and other references have been made to my interpretation, but I have not, hitherto, published the evidence upon which it was based.

I have recently re-examined the whole evidence with the hope of making a more exact determination of the case, and have succeeded to the following extent.

1. The highest formation underlying the Batesville manganese beds is a limestone containing a fauna of neoördovician age, about equivalent to that of the Nashville group of Tennessee or the Cincinnati group of Ohio. This is the lower part of the *St. Clair limestone* of Penrose and may well retain the name.

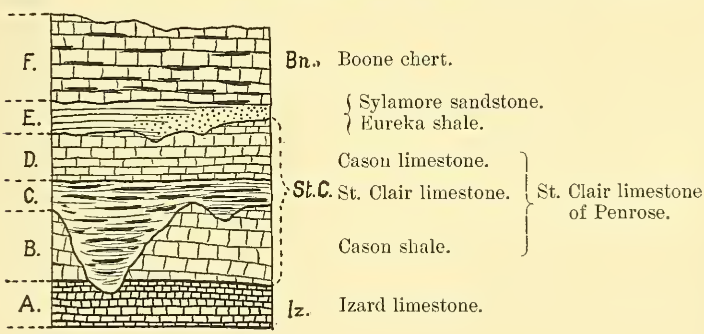
2. The formation immediately overlying the manganese bed, where the rocks are in their original position, contains a fauna

* Ann. Rept. Geol. Surv. Ark. for 1890, vol. iv, Marbles and other Limestones. By T. C. Hopkins. 1893, pp. 213 and 225.

of distinct eosilurian age (about equivalent to the Waldron fauna of Indiana and the Clinton-Niagara fauna of New York). This formation has been heretofore confused with the St. Clair limestone of Penrose, but as it is of different geological age it may appropriately receive a distinct name. I propose for it the name *Cason limestone*, in recognition of the fact that the two limestones may be clearly distinguished on the Cason tract as described in the Manganese Report of Dr. Penrose.*

The samples of ore from the Cason mine are in a calcareous shale immediately underlying the Cason limestone and are of special interest because of the evidence that the deposit is in its original position and condition. Not only is there no indication of decay of the rock but the concretions found in the rock are flattened and their long axes now lie in the plane of the stratification. In the section of the O'Flinn mine the ore appears also to be in its original position between the two limestones.

The following figure will illustrate the facts as they are here explained and the way in which they contrast with the interpretation given in the Manganese Report of Dr. Penrose.



The Izard limestone (A) is probably correct as it stands in the Reports. Over the Izard limestone lies the St. Clair limestone. As described in the Annual Reports up to 1890, the St. Clair limestone includes all the strata between the Izard below, and the Boone chert of the east, or, further westward, the Sylamore sandstone, or, in the western part of the State the Eureka shale, above.

According to the interpretation required by the fossil faunas this "St. Clair limestone" must be separated into three formations. The lowest division (B) is that part of the St. Clair limestone of the Reports lying below the manganese horizon.

* Ann. Rept. Ark., 1890, vol. i, Manganese, p. 124, etc.

The name *St. Clair limestone* can be retained for only this lower part lying below the manganese deposit. When I made the identification referred to in the Report it was not clear to any of us what different relations the manganese deposits bore to the two limestones which I interpreted by these fossils to be of different age. The reference made to the identification of the upper limestone as "intermediate between Trenton and Niagara" was based upon the judgment as to the age of a single species,—*Spirifer radiatus* Sow., var. near that described by Hall from the Clinton group near Louisville, Ky.* Comparison of the specimens with it and with typical forms from the Niagara suggested that the Arkansas form was of a still earlier horizon than that of the specimens from Kentucky.

3. Later studies have conclusively shown that, in all the cases described of which I can get any information, the manganese beds lie either upon this restricted St. Clair limestone, in hollows in it, or in hollows in the underlying Izard limestone. I have seen no specimens of this limestone containing manganese in which there is not indication of the manganese having been deposited in cracks or cavities or on the surface of fossils after the limestone was formed.

4. The second division (C), which I have named the *Cason shale*, lies immediately upon this St. Clair limestone or some lower rock, and at the Cason mine it is a stratified shaly calcareous deposit with concretionary masses of the manganese in the rock, flattened in the plane of the stratification as above stated, and undoubtedly in place as originally deposited. There are also, according to Dr. Wolff, rounded and angular fragments of quartz, feldspar and mica in this shale. (l. c., p. 170.) In the more calcareous layers a few minute fossils have been detected, indicating the beginning of the fauna of the overlying limestone. The same fauna is found in samples from the O'Flinn mine. These two mines are the exceptional cases in which Dr. Penrose finds the ore in place. The position, condition and fossils of this Cason shale are evidence that the original accumulation of the manganese-bearing ore was made at an age later than that of the formation of the St. Clair limestone.

5. Above the Cason shale, at the typical locality on the Cason tract is seen in place a hundred or a hundred and ten feet of limestone capped above by the chert; and "the ore-bearing stratum runs under the limestone" as described by Dr. Penrose.† This limestone, which I have called the *Cason limestone*, contains the pure eosilurian fauna, equivalent to the Waldron fauna of Indiana, or to the Clinton-Niagara fauna of New York, as shown by specimens collected by Mr.

* 27th Regent's Report on State Museum, Albany, p. 196.
† Manganese Report, p. 220.

Hopkins from immediately above the manganese deposit and from about one hundred feet above. The fauna of this limestone is now being studied. Over seventy species have already been detected; over twenty species are identical with Waldron species. Among the rare forms may be mentioned *Streptis grayi*, which has not, so far as I can learn, been hitherto reported from American rocks.

6. From this description, it will be noticed that a line of unconformity, or at least an interval of erosion and cessation of deposits, separates the top of the St. Clair limestone from the base of the Cason shale.

This interpretation of the facts involves the following revision of the view advanced by Dr. Penrose in the Manganese Report already mentioned.

The breaking up of the St. Clair limestone of the Report into three members. (A) a lower limestone of neoördovician (Trenton) age for which the name St. Clair limestone in restricted sense may be retained; (B) an overlying irregular shale, containing the deposit of manganese, separated from the former by a line of erosion and unconformity, and of eosilurian (early Niagara) age and here named the Cason shale; and (C) an upper member, a limestone of at least one hundred feet thickness in the Cason tract containing a pure eosilurian fauna, called the Cason limestone. The settlement of the age of the original manganese deposits seems further to require the abandonment of the theory that the present masses of ore are derived from decay of the St. Clair limestone, because the ore, when found undisturbed in place as originally deposited, is not only of later age than the St. Clair limestone, but was evidently formed after that terrane had been elevated above the surface, eroded and again depressed, thus separating the two by a line of unconformity. The general principle set forth in the quotation at the opening of this paper regarding the mode of original accumulation of the magnanese is not questioned, but the facts above cited give a simpler means of explaining the accumulation in the position where it is, i. e.: the sinking of the terrane from a position of elevation above sea level, the accumulations taking place during the stage of shallow waters and swamps. When the depression was greater the manganese deposit ceased to appear in the deposits.

The close resemblance between *Orthis elegantula*, which is abundant in the Waldron fauna, and *Orthis testudinaria* of the Trenton and Cincinnati faunas, suggests the importance of stating the reasons for the belief in the ordovician age of the lower limestone as seen at Polk Bayou, the Trent mine and the O'Flinn mines, where it is a pink or purple marble often containing manganese.

At the Polk Bayou locality four collections are in my hands: one made by Dr. Branner marked (74/13), second, specimens collected by myself from the same cliff, with Dr. Branner and Dr. Penrose (1235A),* third, a collection made by Mr. Weller (1235A′) from the light colored limestone below A, and B′ from a ledge of the same color up the creek a quarter mile, and the fourth made by Mr. T. C. Hopkins.

The purple marble (A) contains great numbers of the *Orthis* (*Dalmanella*) *testudinaria*, which I so identify; it also resembles *O. elegantula* of the Niagara. Davidson states in his description of *O. elegantula* that he has found well characterized examples of *O. elegantula* in rocks of both lower and upper Silurian age.†

It also contains the following species:

Rhynchonella capax.

Leptæna (*Plectombonites*) *sericea*, of the typical lower Silurian type.

Orthis (*Dinorthis*) *pectinella.*

Strophomena (*Raphinesquina*) *alternata.*

This is the typical manganese-stained limestone called St. Clair limestone by Dr. Penrose.

In the lower beds not so stained, but yellowish white or occasionally pinkish, A′ of Weller's section, are seen the same Orthis, called *O. testudinaria*, the same type of *Leptæna*, called *L. sericea*, *Rhynchonella capax*, *Strophomena alternata* and also unmistakable specimens of *Orthis* (*Platystrophia*) *biforata*, of the *laticosta* type, and other species which taken together leave no doubt as to the Ordovician (Trenton-Hudson River) type of the fauna.

In the other limestone (B of Weller's section), are the specimens of *Rhynchonella capax* and what appears to be the eye and part of the cheek of a large *Asaphas gigas*.

This seems to leave no question as to the age of the lower limestone.

The *Rhynchonella* of the "Rhynchonella beds" of the O'Flinn mine is the *R. capax* in a similar limestone as 1235A′ of the Polk Bayou section.

The proof of the age of the upper limestone is found in the following species:

Spirifer radiatus. The type seen in the Clinton group near Louisville. Pl. 9, figs. 17, 18, and 19 of the 24th Regent's Report, Albany, published first with the 27th Report.

L. (*Plectambonites*) *transversalis* var. *elegantula* Hall (see Foerste's fig. 6, pl. 17, vi, B. S. N. H. xxiv.)

* Locality number of collections of the United States Geological Survey.

† Brit. Foss. Brac., III, p. 212.

Strophomena (*Leptæna*) *rhomboidalis.*
Meristina nitida.
Cornulites proprius.
Calymene niagarensis.
Dalmanites limulurus.
Encrinurus phlyctainoides.
Illænus ioxus.
Lichas breviceps.
Streptis grayi and others.

The linking of the manganese deposit with this fauna is by the species *Leptæna* (*Plectambonites*) *transversalis* of the variety *elegantula*, figured by Foerste (see reference above) and presenting also the characters previously figured and defined by Davidson, after Angelin as *Leptæna segmentum* Ang. (Brit. Foss. Brac. vol. iii, Pl. xlviii, figs. 28–30.) This species is from the Wenlock and Dudley. But when we look at the specific peculiarities we find the same characters in a slightly modified form in the *Leptæna quinquecostata* McCoy, of the Bala and Caradoc. (See same plate, figs 23–27.)

The association of species in either of our faunas is sufficiently distinct to indicate a change of faunas during the interval separating them, but when we examine each species and note its already recorded range we are struck with the number of species which have been recorded from both lower Silurian (Ordovician) and upper Silurian rocks. The lower Llandovery fauna of Europe, and the Clinton with us, have referred to them species which were first seen in the lower rocks. And the Anticosti limestone is another case, presenting a mixture of the species generally found either at lower or at higher horizons. The study of the fossils indicates therefore that the manganese ore is (*a*) associated with deposits of a particular age, (*b*) at an horizon which is definite in the sections examined, (*c*) between two limestones containing two distinct faunas, (*d*) the lower one of which contains Ordovician species of which almost every species has been reported in rare cases, here and there, in deposits which have been called upper Silurian in age. (*e*) On the other hand, the fauna of the upper limestone, while it contains an unmistakable upper Silurian fauna, contains a few species which have been reported from lower Silurian horizons.

The locating of the age of the deposit of manganese near to that represented by the Clinton of New York points to the wide spread influence of the disturbance which closed the sedimentation of the Ordovician (lower Silurian) for North America. The elevation which left the Cincinnati axis above sea level, affected the faunas of the Arkansas region less because further removed from large masses of land, and the faunas above and below the interval differ less, as may be supposed, because the ocean was near at hand, not more than a few hundred miles, when the elevation was at its extreme.

ART. XLVII.—*The Present Status of High Temperature Research*; by CARL BARUS. With Plate X.

1. *Preliminary.*—Some time ago* I adduced reasons for supposing that the electromotive force, e, of a thermocouple, can be expressed by an equation of the form

$$e + e_0 = 10^{P + Q\theta} + 10^{P^1 + Q^1\theta}, \quad . \; . \; . \; . \; . \; . \; . \quad (1)$$

where P, Q, P^1, Q^1, are constants, θ denotes temperature, and where e is zero, when $\theta = \theta_0$. I wish now to test this equation by the aid of data formerly found† in direct comparisons of the iridioplatinum thermocouple‡ with the porcelain air thermometer, and therewithal to exhibit the degree of accordance of known results in the region of high temperature.

Inasmuch as e must pass either through a maximum or a minimum, Q and Q^1 must have different signs; for θ_m, the temperature of this point, is

$$\frac{\log(-Q/Q^1) - (P^1 - P)}{Q^1 - Q}$$

when the sign connecting the two terms in (1) is positive.

2. *First extreme case.*—The simplest form which the above equation takes is the catenary, and it is interesting to note in what respect this curve falls short of reproducing the experimental results. Taking therefore the equation $y = k \cos \text{hyp}\; x/k$, it is necessary to shift the vertex to the position $(-a, -k^1)$ in order that the curve may pass through some fiducial point near the origin; or in other words, that the electromotive force may be zero when the hot junction has the stated temperature of the cold junction. The equation then becomes $e + k + k^1 = k \cos \text{hyp}\; (\theta + a)/k$, where e is the electromotive force for the temperature θ of the hot junction, k the constant of the catenary, and where $(-a, -k^1)$ are the coördinates of the vertex or the position of the thermoelectric minimum. In the absence of suitable tables it is then possible to find the constants involved by actually using a chain in connection with a carefully constructed and mounted chart of results. For if $e + k + k^1 = y$, then the length of the arc from the vertex to the end of the ordinate e is $s = \sqrt{y^2 - k^2}$; and therefore since a and k^1 are obtained by direct measurement, k can be computed from the measured length s of the arc or chain in question.

Constants so obtained are of course approximate and they must be improved by successive trials. Doing this I found for

* This Journal, xlvii, p. 366, 1894. † See § 4.
‡ One metal containing about 20% of iridium, the other being soft platinum.

the 20% iridioplatinum-platinum couple, when electromotive forces are expressed in units of 10 microvolts,

$$a = 2160,$$
$$k^1 = 985,$$
$$k = 2560,$$

values which may be accepted for the time being, though they are by no means the best obtainable.

Above 500° this curve will then be found in remarkably good accord with the observations, § 4. Below 500° degrees, however, the agreement is less good, and the computed values lie as much as 10° above the observed values. Indeed to fully express the case one would have to use a string which grows successively heavier per unit of length towards the vertex; i. e. one would have to introduce another parameter conformably with the occurrence of two metals in the thermo-couple. It is difficult to reach this case practically.

Anticipating §§ 5 and 6, however, I may state that the catenary takes a mean course (above 500°) between the extreme curves there given.

3. *Second extreme case.*—Waiving the symmetrical method of finding suitable constants in equation (1), one may proceed by a process which is nearly the converse of this, and compute

$$e + e_0 = 10^{P + Q\theta} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

first, and thereafter add the second term

$$10^{P^1 + Q^1\theta}$$

in accordance with the insufficiencies of equation (2). This may be done preferably with a table of Gaussian logarithms, by the aid of two pairs of observed data, when the thermal distance apart of each pair is the same. For in Gauss's tables pairs of values of A and B for two numbers a and b, are tabulated so that

$$B = \log a - \log b,$$
$$A = \log (a - b) - \log b.$$

If therefore for four temperatures θ, θ', θ_1, θ'_1, where $\theta - \theta' = \theta_1 - \theta'_1$, e_0 be eliminated from equation (2), the values B and A will take the form

$$B = Q\,(\theta - \theta'), \qquad B_1 = Q\,(\theta_1 - \theta'_1),$$
$$A = \log\,(e - e') - (P + Q\theta'), \qquad A_1 = \log\,(e_1 - e'_1) - (P + Q\theta'_1).$$

But since $B = B_1$, $A = A_1$. Hence, as is otherwise evident,

$$Q = \log\,((e - e') / (e_1 - e'_1)) / (\theta' - \theta'_1).$$

Q being given, B is given, and therefore A can be found from the tables so that P is known. Finally e_0 may be found from the equation (2).

Having found the constants of equation (2), the values of the second term of (1),

$$10^{P' + Q'\theta},$$

which now merely expresses the shortcomings of (2), may be found by the same process. But in this case inspection will usually suffice.

From this point it would then be desirable to proceed in such a way as to give the two terms of equation (1) (second member) individual importance in their relation to the two metals of the couple; but as my present purposes are sufficiently met by the above constants I will not enter further into the work of finding characteristic parameters for each metal.

4. *Observations.*—To test the equations given I have made use of direct comparisons of the 20% iridioplatinum thermo-couple and the porcelain air thermometer published in my Report on high temperature measurement,* and referring to an interval of temperature between about 350° add 1100°. Virtually the calibration is made determinate by observations of the boiling point of zinc† taken at 930°; for although the air thermometer is based wholly on independent volume measurements, and although the boiling points of both mercury and sulphur are well reproduced in the lower part of the curve, I do not derive much assurance from this without having quite eliminated the stem error in a way which I hope soon to describe.

A second series of measurements, made more recently, is contained in the following table. Here the electromotive force e_{20} in microvolts, while the cold junction is kept at 20° C., is given for a series of known melting and boiling points due to Regnault (Hg′ and S′) to Deville and Troost, (Zn′), to Troost (Se′), to Violle (Zn′, Ag, Au, Cu, Pd, Pt) to LeChatelier (Al, Zn inferred), to Carnelley and Williams (Cd′, Ni, Se′ inferred). Accents denote boiling points. References will be found in the Bulletin cited.

MELTING POINTS.

Substance.	Temperature.	e_{20}.
Zinc	415°	4260
Aluminum	625°	7090
Silver	954°	11960
Gold	1045°	13520
Copper	1054°	13585
Nickel	1450°	19630
Palladium	1500°	21430
Platinum	1775°	24470

BOILING POINTS.

Substance.	Temperature.	e_{20}.
Mercury	357°	3466
Sulphur	448°	4580
Selenium	665° / 683°	7850
Cadmium	760° / 775°	9037
Zinc	930°	11105
Bismuth	1100° / 1500°	18930?
Water	100°	680

* Barus: Bull. No. 54, U. S. Geolog. Survey, Washington, 1889, pp. 226–227.
† See § 6.

The platinum melting point merely refers to the fusion of the junction of the couple and is not very reliable. Metals whose boiling points show wide margins, like cadmium, are found by Carnelley's interpolation methods. Troost's Se′ at 665° is probably too low.

5. *Constants.*—Applying the methods of § 3 to the air thermometer referred to in the preceding paragraph, the following mean results are available for the computation:

$\theta = 400°$ C.	$e = 3950$ microvolts.
$\theta_1 = 600°$	$e_1 = 6560$
$\theta' = 800°$	$e' = 9310$
$\theta'_1 = 1000°$	$e'_1 = 12200$

and from low temperature work,

$\theta = 0$	$e_{20} = -150$
100	+ 680
200	1650
300	2760

The constants corresponding to these values as a whole are

$$(3) \quad . \; . \; e_{20} + 45680 = 10^{4.6515 + .0001106\theta} + 10^{2.849 - .00301\theta}.$$

Applying the same method to the data given in the above table, the following values are available in addition to the low temperature data just mentioned.

$\theta = 357°$ (Hg′)	$e = 3466$ microvolts.
$\theta_1 = 457°$ (near S′)	$e_1 = 4690$
$\theta' = 954°$ (Ag)	$e' = 11960$
$\theta'_1 = 1054°$ (Cu)	$e'_1 = 13585$

The constants deduced are then

$$(4) \quad . \; . \; e_{20} + 23376 = 10^{4.3563 + .0002004\theta} + 10^{2.7084 - .00301\theta}.$$

Both equations (3) and (4) are given graphically in the accompanying chart, the former (the lower of the two curves), with all the observational data inserted. The abscissæ are temperatures in hundreds of degrees centigrade, and the ordinates electromotive forces, in thousands of microvolts. Horizontal lines drawn across the curves show the electromotive forces found by special experiments for the divers melting and boiling points of the metals marked on the line, the latter points being distinguished by accents. For points marked *R* see next paragraph.

6. *Conclusion.*—According as the one or the other of these curves is taken, the following sets of values are reached. Interpolations are made graphically with an accuracy of a few degrees.

MELTING POINTS.			BOILING POINTS.		
Substance.	Equation (4).	Equation (3).	Substance.	Equation (4).	Equation (3).
Zinc	420°	420°	Mercury	357°	357°
Aluminum	635°	638°	Sulphur	446°	446°
Silver	956°	986°	Selenium	687°	694°
Gold	1048°	1091°	Cadmium	770°	782°
Copper	1054°	1096°	Zinc	905°	929°
Nickel	1382°	1476°	Bismuth	1346°	1435°
Palladium	1472°	1585°			
Platinum	1614°	1757°			

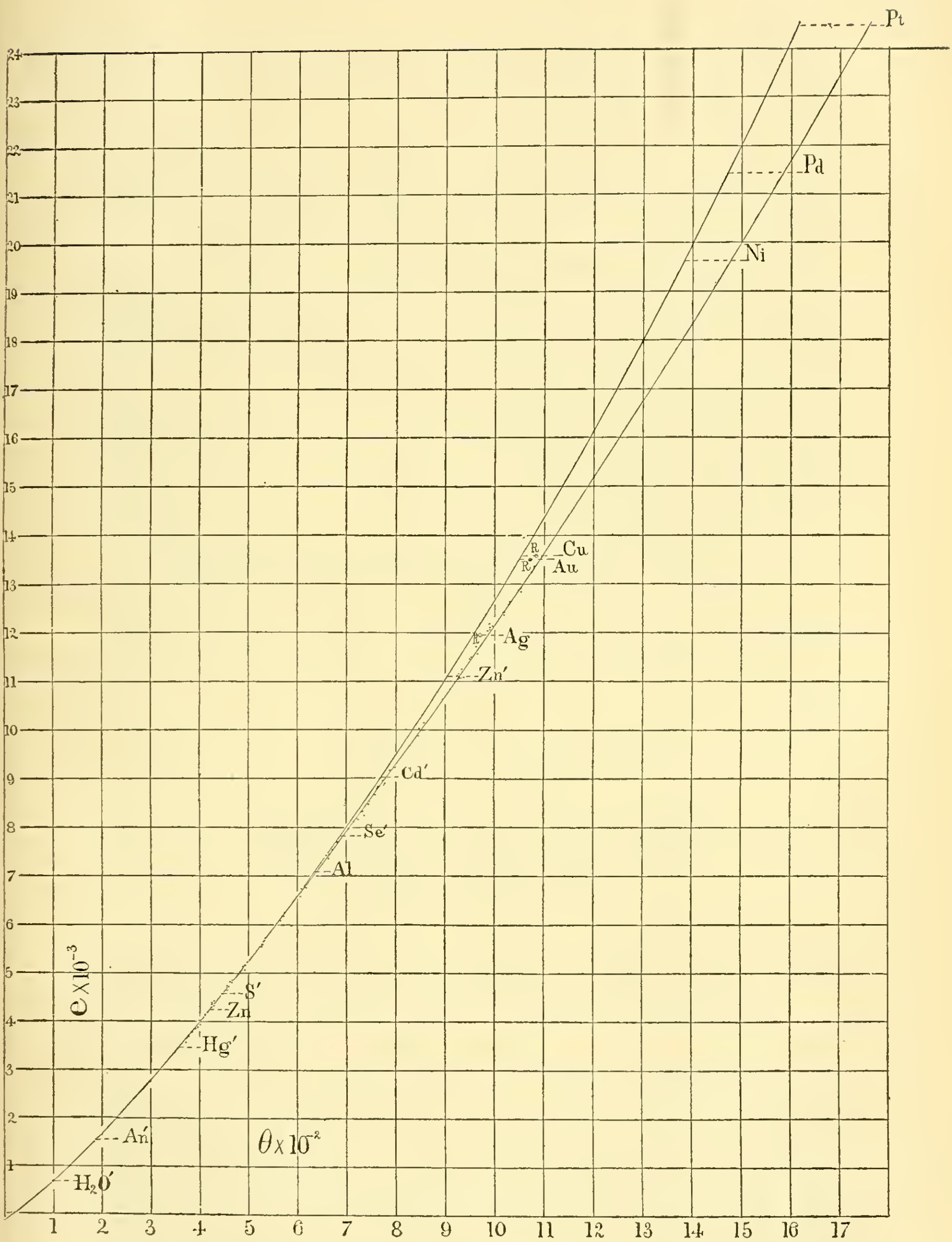
With regard to preferences in choosing between these two curves there is, at present, little opportunity for discretion. The lower temperatures are determined by the melting points of silver, gold and copper, systematically investigated by Violle; while the higher temperatures are in accordance with the boiling point of zinc as found by Deville and Troost, Violle, Mensching and Meyer, and in a measure by myself, some of the researches being remarkably elaborate. As is usual in such cases, the truth is to be sought somewhere between the extremes; and thus one finds in the recent work of Holborn and Wien* at the Reichsanstalt that silver, gold, and copper melt at 970°, 1082° and 1070° respectively; or at temperatures 16°, 25° and 28° higher than given by Violle. These points are indicated by the letter *R* in the chart and they lie quite within the limits indicated by the two curves. It will be seen too, that if I were to neglect outlying stragglers in my data at very high temperatures, where measurements are made under increasing difficulties, my results could be nearly reconciled with those of Holborn and Wien.

The purpose of this paper, however, is to show in a systematic way that to clear away the anomalies now existing in high temperature data either the boiling point of zinc must come down from 930° to 905°, or else the melting points of silver, gold and copper must move up 30° to 40°, or both must move towards each other by corresponding amounts. I hope myself to make some contributions toward a solution of these discrepancies.

I desire in conclusion to express my indebtedness to Prof. Alexander Graham Bell, by whose generosity I have in the past year, materially profited.

Washington, July, 1894.

* Holborn and Wien: Berl. Acad., June, 1892.


Pt
Pd
Ni
Cu
Au
Ag
Zn′
Cd′
Se′
Al
S′
Zn
Hg′
An′
H_2O'
$e \times 10^{-3}$
$\theta \times 10^{-2}$
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

ART. XLVIII.—*The recent eruption in the Crater of Kilauea;* by L. A. THURSTON. (From the Pacific Commercial Advertiser, July 23, 1894.)

THE great lava lake in the southern extremity of Kilauea, Halemaumau, has been steadily rising since the last great discharge in March, 1891, when an area 2500 feet long by 2000 feet wide sunk in one night a distance of over 500 feet.

The rising and overflowing of the lake filled this pit last fall. Since that time the activity of the lake has been intense, as many as twenty-three overflows of liquid lava having taken place in a single day, and the walls surrounding the lake have been rapidly raised by continued overflows.

Accurate measurements of the lake were made by Mr. F. E. Dodge of the Survey Department in August, 1892, and March, 1894. He has recorded in the Volcano House book the result of his observations, as follows:

"In August, 1892, the outer rim of the pit surrounding the lake was 282 feet below the level of the Volcano House.

"The surface of the lake was 240 feet below this line.

"In March, 1894, the surface of the lake was 207 feet above this line, making a rise of 447 feet in nineteen months.

[The profile view of the lake at the two periods is shown by figure 1.]

1

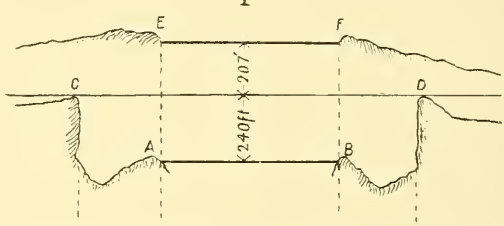


Fig. 1; A B, surface of lake, Aug. 1892; C D, rim of pit in 1891, when its level was 280 ft. below volcano house; E F, surface of lake, March, 1894.

"The area of the lake was somewhat larger in 1894 than in 1892, being 1200 feet long by 800 wide."

Upon arriving at the volcano on July 5, 1894, the principal change since Mr. Dodge was there was found to be the sudden rising of the north bank of the lake, covering an area of about 800 feet long by 400 wide, which, on the 21st of March last was suddenly and without warning elevated to a height of 80 feet above the other banks and the surface of the lava, the lake being then full.

The raised area was much shattered, and two blowholes shortly afterward made their appearance on the outer line of fracture.

On the 18th of April the hill thus formed began to sink, and on July 5th was only about 30 feet above the other walls of the lake.

On the evening of the 6th of July a party of tourists found the lake in a state of moderate activity, the surface of the lava being about 12 feet below the banks.

On Saturday, the 7th, the surface of the lake raised so that the entire surface was visible from the Volcano House. That night it overflowed into the main crater, and a blow-hole was thrown up some 200 yards outside and to the north of the lake, from which a flow issued. There were two other hot cones in the immediate vicinity which were thrown up about three weeks before. On Sunday, Monday and Tuesday, July 8th, 9th and 10th, the surface of the lake rose and fell several times, varying from full to the brim to 15 feet below the edge of the banks.

The profile view of the lake on Tuesday night, July 10th, was approximately as shown in figure 2.

2

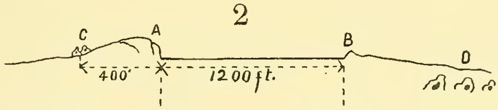
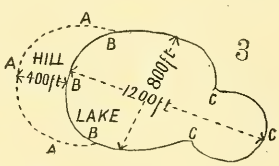


Fig. 2; A B, surface of lake, July 10, 1891; C and D, blow holes.

On the morning of the 11th the hill was found to have sunk down to the level of the other banks, and frequent columns of rising dust indicated that the banks were falling in. At 9:45 A. M., at which hour a party reached the lake, a red hot crack from 3 to 6 feet wide was found surrounding the space recently occupied by the hill; the hill was nearly level; the lake had fallen some 50 feet, through the escape of the lava by some subterranean passage, and the wall of the lake formed by the hill was falling in at frequent intervals. The outline of the lake at this time was as in figure 3.

3



The lava in the lake continued to fall steadily, at the rate of about 20 feet an hour from 10 o'clock in the morning until 8 in the evening. At 11 A. M. the area formerly occupied by the hill, marked A, A, A, in the diagram, began to sink bodily, leaving a clean line of fracture; the line of this area, marked B, B, B, was continuously leaning over and falling into the lake. From about 12 until 8 in the evening there was scarcely a moment when the crash of the falling banks was not going on. As the level of the lake sank, the falling rocks of the banks, undermined by the escape of the lava, caused a constantly increasing commotion in the lake as they struck the surface of the molten lava in their fall. A number of times a section of the bank from 200 to 500 feet long, 150 to 200 feet high, and 20 to 30 feet thick would split off from the adjoining rocks, and with a tremendous roar, amid a blinding cloud of steam, smoke and dust, fall with an appalling down plunge into the boiling lake, causing great waves and breakers of fire to dash into the air, and a mighty "ground swell" to sweep across the lake dashing against the opposite cliffs like storm waves upon a lee shore.

Most of the falling rocks were immediately swallowed up by the lake, but when one of the great downfalls referred to occurred, it would not immediately sink, but would float off across the lake, a great floating island of rock. At about 3 o'clock an island of this character was formed, estimated to be about 125 feet long, 25 feet wide, and rising 10 to 15 feet above the surface of the lake. Shortly after, another great fall took place, the rock plunging out of sight beneath the fiery waves. Within a few moments, however, a portion of it, approximately 30 feet in diameter, rose up to an elevation of from 5 to 10 feet above the surface of the lake, the molten lava streaming off of its surface, quickly cooling and looking like a great rose-colored robe, changing to black. These two islands, in the course of an hour, floated out to the center and then to the opposite bank. At 8 in the evening they had changed their appearance but slightly. They had disappeared the next morning.

About noon the sinking lava disclosed the fact that the small extension at the right of the lake was only about 80 feet deep, and it was soon left high and dry, simply a great shelf in the bank, high up above the surface of the lake. As the lava subsided, most of the surrounding banks were seen to be slightly overhanging, and as the lateral support of the molten lava was withdrawn, great slices of the overhanging banks on all sides of of the lake would suddenly split off and fall into the lake beneath. As these changes took place the exposed surface, sometimes 100 feet across and upward, would be left red hot, the break, evidently having taken place on the line of a heat-crack which had extended down into the lake.

About 6 o'clock the falling bank adjacent to the hill worked back into a territory which, below 50 feet from the surface, was all hot and in a semi-molten condition. From 6 to 8 o'clock the entire face of this bluff, some 800 feet in length and over 200 feet in height, was a shifting mass of color, varying from the intense light of molten lava to all the varying shades of rose and red to black, as the different portions were successively exposed by a fall of rock and then cooled by exposure to the air. During this period the crash of the falling banks was incessant. Sometimes a great mass would fall forward like a wall; at others it would simply collapse and slide down making red hot fiery land slides; and again enormous bowlders, as big as a house, singly and in groups, would leap from their fastenings and, all aglow, chase each other down and leap far out into the lake.

The awful grandeur and terrible magnificence of the scene at this stage are indescribable. As night came on, and yet hotter recesses were uncovered, the molten lava which remained in the many caverns leading off through the banks to other portions of the crater, began to run back and fall down into the lake beneath, making fiery cascades down the sides of the bluff. There were five such lava streams at one time.

The light from the surface of the lake, the red hot walls and the molten streams lighted up the entire area, bringing out every detail with the utmost distinctness, and lighted up a tall column of dust and smoke which arose straight up. During the entire period of the subsidence the lava fountains upon the surface of the lake continued in action, precisely as though nothing unusual was taking place.

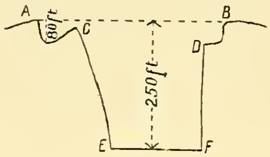
Although the action upon the face of the subsiding area was so terrific, that upon the portion between the falling face and the outer line of fracture was so gradual that an active man could have stood on almost any portion of it without injury. Enormous cracks 20 to 30 feet deep, and from 5 to 10 feet wide, opened in all directions upon its surface, and the subsidence was more rapid in some spots than in others, but in almost all cases the progress of the action was gradual, although the shattered and chaotic appearance of the rocks made it look as though nothing but a tremendous convulsion could have brought it about.

Another noticeable incident was the almost entire absence of sulphurous vapors, no difficulty in breathing being experienced directly to leeward of the lake.

At 8 o'clock P. M., when the party left the lake, its profile was approximately as shown in figure 4.

At 9 o'clock the next morning the lake was found to have sunk some 20 feet more; the banks at the right and left of the subsiding area, which had been the chief points of observation the day before had disappeared into the lake for distances varying from 25 to 100 feet back from the former edge, and the lower half of the debris slope had been swallowed up in the lake, disclosing the original smooth black wall of the lake beneath at a considerable overhanging angle, making the profile of the lake approximately as in figure 5.

4



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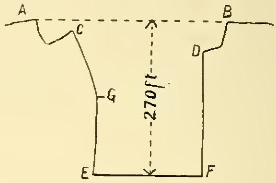


Fig. 4, Profile view of the lake, July 11, 1894; A B, extreme outer margin; C D, inner margin; E F, surface of lake, 8 P. M., July 11; C E, debris slope.
Fig. 5, Profile at 9 A. M., July 12; C G, debris slope; G E, solid rock.

At the level of the lake and half-filled by it was a great cavern extending in a southeasterly direction from the lake. The dimensions were apparently 75 feet across and 15 feet from the surface of the lake to the roof of the cave. It could be seen into from the opposite bank for about 50 feet. This may have been the duct through which the lava had been drained, although it manifestly was not at the bottom of the lake, for up to July 16th, that had continued to rise and fall from 5 to 10 feet a day, and constantly threw up fountains, somewhat more actively than before its subsidence. The entire area of subsidence is estimated to be a little less than eight acres, about one-half of which fell into the lake.

While the discharge was taking place there were many slight tremors of the banks, generally resulting in the precipitate retreat of the observers from the edge, but although the danger was great the spectacle was so grand and fascinating that the party returned again and again to watch it.

At the Volcano House two slight earthquakes were felt on the afternoon of the 11th and one vigorous one at 2 A. M. on the 12th. During the week several slight shocks were felt in the town of Hilo, thirty miles away, although none were felt at Olaa half-way between, nor at Kapapala, fifteen miles in the opposite direction, although the latter is a place peculiarly susceptible to earthquakes.

This is believed to be the first discharge of Kilauea in the presence of observers, those prior to 1868 being before the establishment of the Volcano House, and those of 1868, 1886, and 1891 and several minor ones, all having taken place at night when no one was present.

Art. XLIX.—*On Solutions of Metallic Silver;* by M. Carey Lea.

The solutions of metallic silver which I have described in previous numbers of this Journal are all colloidal. Since publishing those papers I have examined all the varieties with the result that none of them will pass through membranes. One of these forms of silver solution, that obtained by the action of ferrous citrate has also been examined by Mr. Prange and by Dr. Barus with the same result.

The silver solutions are colloidal. But as to whether they are polymerized seems doubtful. Polymerized substances have this property in common that they are more indifferent than the same substances in their ordinary molecular condition. Now all the varieties of allotropic silver including the soluble form are more easily oxidized and chlorized than is silver in its ordinary form. This does not look like polymerization.

These colloidal solutions of silver are at the least as perfect as those of any other perfectly soluble colloidal substance. A good way of testing for perfect solubility is to observe the liquid under a skylight, letting the incident light make a right angle with the line of view. Many substances which viewed by transmitted light are not only transparent but brilliantly clear, when examined in the manner just mentioned show unmistakable turbidity.

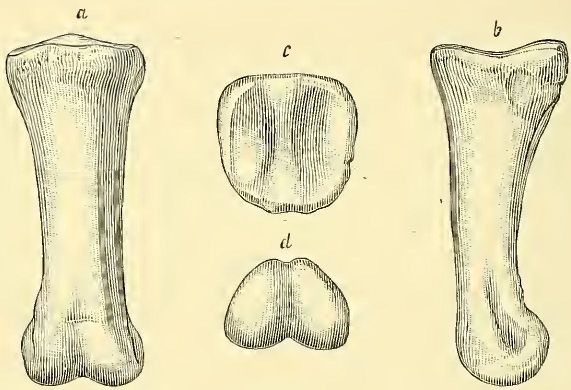
The solutions of silver stand this test perfectly. This experiment seems to disprove the conclusion arrived at by Drs. Barus and Schneider that this form of silver is not allotropic but ordinary silver in a state of very fine division. (Zeitschrift für Physikalische Chemie, viii, 298.) When carefully made they are also very permanent. I have some silver solution made by the action of alkaline hydroxide and dextrine which, after three years standing, is still strongly colored. A considerable part of the silver has separated but as this separation has taken place in the form of bright white metallic silver and has occurred where the light was strongest (the bottle having stood on a table in a well lighted room) the change seems to have been due principally if not wholly to the action of light.

This solution thus maintained so long seemed to afford an opportunity for the rigorous determination of its colloidal nature. Placed in a dialyzer at the end of two weeks not a trace had passed through.

These results seem to lead to the conclusion that the silver solutions are colloidal and yet of a very perfect character inasmuch as they will bear the same tests for absolute transparency as solutions of crystalloids.

Art. L.—*A Gigantic Bird from the Eocene of New Jersey;* by O. C. Marsh.

A very large extinct bird, about the size of an Ostrich, and apparently allied to that group, is indicated by a few remains now deposited in the Yale Museum. These fossils are in good preservation, and were obtained by the writer several years since in the upper marl beds, of Eocene age, near Squankum, N. J. The most characteristic specimen, a first phalange of the third digit of the right foot, is represented half natural size in the accompanying figures.



Phalange of *Barornis regens*. Marsh; half natural size. *a*, front view; *b*, side view; *c*, top view; *d*, bottom view.

In comparing this specimen with the corresponding bone of the existing Ostrich, the shaft is found to be more slender, less constricted, and straight in front, rather than concave. The upper end, also, is more rounded in outline. The lower end has a distinct groove, dividing the articular surface into nearly equal parts. This groove is not seen in the recent Ostrich, but is present in *Dinornis*. It indicates a ridge on the opposing face of the second phalange, as in the feet of many living birds.

These characters, well shown in the above figures, appear distinctive, and indicate, among the early Struthious birds, a new form which may be called *Barornis regens*. Its nearest allies will probably be found in *Diatryma*, and *Gastornis*, from essentially the same geological horizon.

Yale University Museum, New Haven, Conn., Sept. 20. 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a new Gaseous Constituent of the Atmosphere.*—At the recent meeting of the British Association at Oxford, Lord Rayleigh announced that in conjunction with Professor Ramsay, he had succeeded in isolating from atmospheric air a new gaseous substance. His experiments on nitrogen had shown that the density of this gas varied considerably according to the source from which it was obtained. Supposing this to be due to a variable mixture of some other and unknown gas, he added to the air an excess of oxygen and passed through it an electric discharge. The density of the nitrogen gradually increased and finally reached 19·8. Ramsay operated by removing the oxygen from air and then passing the nitrogen over heated magnesium, which was thereby converted into nitride, leaving a residual gas having a density of 20·8. It is thus more inert than nitrogen. It exists in the air to an amount of one per cent and has some peculiarities in its spectrum. Its elementary character is yet in doubt, Professor Dewar suggesting that it may turn out to be an allotropic form of nitrogen. G. F. B.

2. *Die wissenschaftlische Grundlagen der analytischen Chemie;* by W. Ostwald, Leipsic (Engelmann), 1894. 12mo, viii+187 pp. Price 4 marks.—The appearance of each new work by Professor Ostwald causes astonishment at the remarkable fertility of his pen. The present book is an elementary treatise on analytical chemistry, written especially from the standpoint of the new theories of solutions. A very clear exposition of the theory of ions and the laws of chemical equilibrium is given, and from these some general laws and rules, applicable to chemical analysis, are derived. These rules are suggestive and they give a satisfactory explanation of certain well-known facts which heretofore have been somewhat empirical. The larger part of the book is devoted to a systematic classification of the ordinary analytical operations, and to a description of well-known methods. It must be said that not all of the latter are the most recent or the best of their kind, but the intention of the author has not been to furnish instruction to beginners, but to give an example of his method of treating the subject, based on the idea that nearly all analytical reactions are ion reactions.

The author criticizes the usual practice of inorganic analysts, of giving results in terms of metallic oxides and acid anhydrides, as being based on antiquated chemical ideas, and he objects especially to the customary way of "combining" constituents in analyses of mineral waters and other solutions. He advocates the statement of analyses in terms of the elements, or, in the case of solutions, in terms of the ions. It seems probable that, for the sake of simplicity of calculation and easy comparison with previous analyses, the mineral analysts will be slow to give up the convenient and tangible oxides and anhydrides. The present method of calculating a mineral water analysis shows what actual salts would make a similar water, while an analysis stated in the ion form would be of little use, without recalculation, to physicians or others who wished to know its character. H. L. W.

3. *Note on the telephonic measurement of electromotive force;* by C. BARUS.—According to de la Rue, Ferraris, Pellat and others, currents as small as 10^{-9} are still audible in the telephone. One is therefore warranted in replacing the galvanometer in a shunted circuit for the measurement of electromotive force (zero method) by the telephone, seeing that the sensitiveness stated would suffice for measurements much exceeding the constancy of any galvanic cell. Devising a special key for the purpose, I made this test; but I did not find the extreme sensitiveness stated. Even in specially wound telephones of 6000 turns of wire, the best result I could obtain was an audibility of 10^{-7} amperes, under the following remarkable conditions: For increments of current amounting to $3{\cdot}1\times10^{-7}$ on either side of zero the telephone did not respond at all. On both margins of this silent field, however, the response came in a way to make further increments of only 10^{-7} amperes quite distinguishable in loudness. Here therefore is a true discontinuity, for the extent of the interval of silence is at least 5 times the sensitiveness of the telephone on and beyond the margins of this interval. In the great variety of experiments made this result was the invariable feature, the silent interval being in some cases even 10 or 20 times the marginal sensitiveness.

I interpret this to mean that the diaphragm of a telephone when in a state of rest initially resists deformation with a kind of molecular *quiescent friction;* and that this inertness must first be overcome by the actuating field before the diaphragm responds nicely to fine gradations of stress.

4. *A Laboratory Manual of Physics and applied Electricity;* arranged and edited by EDWARD L. NICHOLS. Vol. I, 294 pp. Vol. II, 444 pp. (New York, Macmillan & Co., 1894.)—The recent development or Laboratory practice and the important place now assigned to experimental physics in the college curriculum causes us to welcome this present work.

The manual is divided into two volumes, each of which constitutes a complete and separate work in itself covering its particular field.

Volume I is entitled a Junior Course in General Physics and is the work of E. Merritt and F. G. Rogers. The field of mechanics, heat, light, electricity and magnetism is covered by well selected experiments arranged in groups according to the subject matter. This volume, intended as it is for first year students, admits of little originality as to material and the sole value of such a work depends upon the method of presentation and in this the work merits commendation; it is free from dead wood, is clear and definite. Text books in science are so often brought out by those who are not masters of the subject of which they treat, that it is particularly pleasing to turn over the pages of this volume, elementary as it is, and to note the scientific development of the subject which is manifest on every page.

The second volume covers a new field, being intended for advanced students with particular attention to the needs of students of electricity. It is arranged in four parts, written by different members of the department of physics at Cornell University. Part I, the work of G. S. Moler, H. J. Hotchkiss and C. P. Matthews, is devoted to experiments with direct current apparatus and pertains to electrical engineering rather than to physics. It consists of a systematic course of instruction in dynamo practice and satisfies for the first time the demands of engineering colleges for this line of work.

Part II. is written by Frederick Bedell and is devoted exclusively to experiments with alternating currents, a subject of interest to the physicist as well as the electrical engineer; the treatment is systematic and quite complete considering the newness of the subject. Many of these experiments are now published for the first time and contain methods of alternating current measurement which have been developed to a large extent by Dr. Bedell. The formulation of experiments in a field developed as rapidly as that of alternating currents, is peculiarly difficult and the work may be open to criticism which can be traced to this source. Part II. is scholarly in treatment and contains much that is new.

Part III. consists of a carefully prepared course in photometry and heat, by C. P. Matthews. The experiments in heat are not new, for this subject has been gone over and over by different writers, but the presentation is good. The experimental work in photometry is new in the sense that it is new to text books, and consists of methods which have been developed during recent years dating back to the exhibition in Philadelphia in 1884.

Part IV. consists of outlines of advanced work arranged by Dr. Nichols and is based chiefly upon recent researches conducted at Cornell University; the chapters on light sources and spectrophotometry are especially valuable inasmuch as the writer has devoted so much of his time to experimental research in this direction. In this part are described the most recent researches in the various lines of work taken up, with references to original memoirs.

The work has been carried through the press by Dr. Bedell. The arrangement of the work is admirable; the mechanical execution all that could be desired. There is no old material; the illustrations are new.

The method of treatment throughout the two volumes is one well suited for the requirements of college and university instruction. In the junior course of the first volume, specific experiments are arranged for the student and the exact requirements for each are given. The early portion of the second volume consists of separate experiments for senior work, in which the general subject matter of the experiment is clearly given, but greater scope in performance is given to the student. In the last part, the student is dependent entirely upon his individual efforts.

The work does credit to the department from which it emanates; Dr. Nichols and his collaborators are to be congratulated upon the result of their labors. F. B.

II. Geology and Mineralogy.

1. *The Geological Society of America.*—The sixth summer meeting of the geological society was held in Brooklyn, N. Y., Tuesday and Wednesday, August 14 and 15. The following papers were read:

J. F. Kemp: The nickel mine at Lancaster Gap, Pa, and the pyrrhotite deposit at Anthony's Nose, on the Hudson.

Alfred C. Lane: A connection between the chemical and optical properties of amphiboles.

C. H. Smyth, Jr.: On a basic rock derived from granite.

Edmund Otis Hovey: A study of the cherts of Missouri.

Arthur Hollick: Dislocations in certain portions of the Atlantic coastal plain strata and their probable causes.

J. W. Spencer: Reconstruction of the Antillean continent.

N. S. Shaler: Evidences as to the change of sea-level.

W. J. McGee: The extension of uniformitarianism to deformation.

D. F. Lincoln: Drumlins in the vicinity of Geneva, N. Y.

George H. Barton: Channels on drumlins caused by erosion of glacial streams.

James Perrin Smith: The Trias and Jura of Shasta County, California.

Henry S. Williams: The age of the Manganese deposits of the Batesville region of Arkansas.

Abstracts were read of the following papers in the absence of their authors, viz:

Harold W. Fairbanks: Review of our knowledge of the geology of the Californian coast ranges.

Chas. S. Prosser: The Permo-Carboniferous and Permian rocks of Kansas.

The winter meeting of the society is to be held at Baltimore, Md., notice of which will be sent to the fellows by the Secretary.

2. *A New Miocene Tapir;* by O. C. Marsh.—An interesting ungulate mammal, probably an ancestor of the modern Tapirs, is indicated by a pair of lower jaws in good condition recently found in the *Miohippus* beds of South Dakota. This specimen shows the same form, and essentially the same dentition as in *Tapirus*, but the last premolar only is like the molars. There is a small secant canine close to the outer incisor, and behind it a long diastema. The extent of the premolar and molar series is four inches, and of the entire dentition six and one-half inches. From *Colodon*, an allied form, this specimen may be distinguished by the presence of a canine, and absence of a heel on the last lower molar. The known remains indicate an animal about half the size of the existing Tapirs. It may be called *Tanyops undans*.

Yale Museum, September 22, 1894.

3. *Channels on Drumlins: Caused by erosion of glacial streams;* abstract of a paper read before the Geological Society, Aug. 15, 1894, by George H. Barton.—Owing to the very symmetrical form of the drumlin, with its smooth, flowing outlines, it has been able by the very equal distribution of its watershed to resist the attacks of ordinary atmospheric erosion more strongly than other forms of surface. Hence to-day it presents little evidence of post-glacial erosion and it is very difficult to estimate the amount it has undergone during this time.

On the other hand, of the nearly eighteen hundred drumlins studied in Massachusetts under direction of Prof. N. S. Shaler for the U. S. Geol. Survey, some three hundred present very interesting features of erosion that took place after the hill had been fully formed, but before the complete disappearance of the continental ice-sheet.

These consist of channels varying from a few feet in width and depth to those having a depth of a hundred or more feet and a corresponding width. With extremely rare exceptions their beds invariably slope toward the south. Very exceptionally indeed the slope is toward the north and then only to a very slight degree.

On the ordinary typical drumlin they are found cutting along either side at any elevation from base to summit, always parallel, or nearly so, with its axis, or very commonly directly upon the summit and coincident with the axis. A typical example of this is seen on Gleason's Hill, just west of the mill, at Rockbottom, Mass., where a channel, about twenty-seven feet at its greatest depth, cuts directly along the axis beginning at the north end of the hill at two-thirds its height and sloping southward to the southern end. The hill is a symmetrical drumlin with the exception of this channel.

In cases where the till is more complex in outline consisting of several drumloid forms massed together, side by side, so as to produce an east-west ridge as is quite common, channels of various sizes occur with their beds nearly always inclined to the south. Often they begin their course on the north side at one half or two-thirds of the altitude, pass directly through the east-west axis and down the south slope.

In many instances eskers are found in direct linear connection with the channels in such manner as to imply a relation in origin. Near Worcester, Mass., there are three drumlins, each of which is cut by a channel, while in the lowlands between are eskers which together with the channels form a nearly continuous serpentine line. Here it seems evident that the stream that formed the esker must also have cut the channel.

The streams that eroded the channels must have been super- or en-glacial, to the northward of the hill, they could not have been sub-glacial. Against the north end of the hill at Rockbottom the ice-sheet lay massed, on or in which the stream having an ice-bed had its channel. To the south the ice had disappeared or had so melted from the southern slope of the hill as to allow the stream to flow down this slope to the lowlands beyond.

Previous to the beginning of my work Prof. Shaler had noted a similar channel on Forbes Hill in Milton, Mass., and to which he had ascribed a nearly similar origin.

4. *Trias and Jura of Shasta County, California;* abstract of a paper read before the Geological Society of America, Aug. 15, 1894, by JAMES PERRIN SMITH.—The columnar section of the metamorphic series of the Klamath mountains is given in the paper; this is made up of strata from Devonian to Jurassic age.

The presence of Middle Trias is shown by fossils. This is overlain comformably by slates and limestones with a rich fauna of Upper Triassic age, directly comparable to that of the zone of *Tropites subbullatus* and *Trachyceras aon* of the Karnic in the Tyrolean Alps. This fauna is shown by its affinities to Himalayan and Tyrolean species to belong to a prolongation of the fauna of the Mediterranean and Indian Triassic provinces, and not to the Arctic-Pacific province. The occurrence of Jurassic fossils is mentioned, and new localities given.

The widespread Jura-Cretaceous unconformity in the Coast Range, Klamath mountains, and Sierra Nevada, is considered a proof that these three ranges belong to one great mountain system, in which the disturbances were closely associated.

5. *The Carboniferous Strata of Shasta County, California;* abstract of a paper read before the A. A. A. Sci., Aug. 1894, by JAMES PERRIN SMITH.—The general structure of a portion of the Klamath mountains was briefly discussed, and the systems of faults and folds indicated.

The oldest strata of the region are of Devonian age, overlain by the Baird shales which belong to the Lower Carboniferous. The latter have a fauna analogous to that of the Eureka district of Nevada, and thus have many Devonian species commingled with the Carboniferous. Faunally these are thought to be homotaxial with the Waverly, but stratigraphically they belong higher in the section.

Above the Baird shales lie about 2000 feet of limestone with a carboniferous fauna, probably equivalent to the Coal measures. Above this limestone lie calcareous shales with a fauna equivalent to that of the Robinson beds, Plumas County, and thus probably Permo-Carboniferous in age.

6. *Some anomalies in the growth of Alum Crystals.*—Mr. H. A. MIERS read a paper before the British Association on a new method of measuring crystals, containing the following interesting facts:

The two fundamental laws of crystallography—namely, (1) the constancy of the angle in crystals of the same substance, and (2) the law of simple rational indices seem to be violated by those crystals which are liable to irregular variations in their angles, or those which have the simple faces replaced by complicated "vicinal" planes. Both these anomalies are exhibited by potash- and ammonia-alum. Brilliant and apparently perfect octahedra of these salts show large variations in the octahedron angle; other crystals show low vicinal planes in place of the octahedron faces. If it be true, as is supposed, that the octahedron angle varies in different crystals, it would be interesting to ascertain whether progressive variations can be traced during the growth of a single crystal, and whether some or all of the octahedron faces change their direction in space if the crystal is held fixed during growth.

In order to solve this problem a new goniometer has been constructed, in which the crystal is fixed at the lower end of a vertical axis, so that it can be immersed in a liquid during measurement. This device is in reality an inversion of the ordinary goniometer with horizontal disc; the liquid is contained in a rectangular glass trough with parallel-plate sides; one side is placed rigidly perpendicular to the fixed collimator, and the other is perpendicular to the telescope, which is set at 90° to the collimator. The trough is supported on a table which can be raised and lowered, so that the crystal can be placed at any required depth in the liquid. If the liquid used be its own concentrated solution the crystal can be measured during growth, and the changes of angle, if any, can be observed at different stages. In order that it may be held rigidly, the crystal is mounted, when small, in a platinum clip, which it envelops as it grows larger.

The results derived from the measurement of a large number of alum crystals are as follows :—

(1) The faces of the regular octahedron are never developed upon alum growing from aqueous solution.

(2) The reflecting planes (which are often very perfect) are those of a very flat triangular pyramid (triakis octahedron) which overlies each octahedron face.

(3) The three faces of this triangular pyramid may be very unequal in size.

(4) The triakis octahedron which replaces one octahedron may be different from that which replaces another octahedron face upon the same crystal.

(5) During the growth of the crystal the reflecting planes change their mutual inclinations; the triakis octahedron becomes in general more acute, *i. e.* deviates further from the octahedron which it replaces, as the crystal grows.

(6) This change takes place not continuously, but *per saltum*, each reflecting plane becoming replaced by another which is inclined at a small angle (generally about three minutes) to it.

(7) During growth the faces are always those of triakis octahedra; if, owing to rise of temperature, re-solution begins to take place, faces of icositetrahedra are developed.

These observations prove that the growth of an alum crystal expresses an ever-changing condition of equilibrium between the crystal and the mother liquor. It does not take place by the deposition of parallel plane layers; new faces are constantly developed: since these succeed one another *per saltum* they doubtless obey the law of rational indices, though not that of *simple* rational indices. From the mutual inclinations of these vicinal faces it is possible to calculate with absolute accuracy the angle of the faces to which they symmetrically approximate. This angle is found to be that of the regular octahedron 70° 31¾′. The octahedron angle of alum is not, therefore, as appeared from the observations of Pfaff and Brauns, subject to any variation.—*Nature*, vol. l, p. 411, August 23, 1894.

III. Astronomy.

1. *Verzeichniss der Elemente der bisher berechneten Cometenbahnen, etc.*, by Dr. J. G. Galls. 8°, pp. xviii, and 316. Leipzig, 1894. This volume is a new edition by the veteran astronomer of the work published by him in 1847 and later in 1863. The earlier edition was a continuation and completion of the like Catalogue of Olbers in 1823. The first half of the present volume is a tabular catalogue of all computed elements of the cometic orbits up to the present year. The second half consists of historical, descriptive and bibliographical notes upon the several comets.

2. *Gesammelte Werke von* Heinrich Hertz, *Band III; Die Prinzipien der Mechanik in neuene Zusammenhange dargestellt.* 8°, pp. xxix, 312. Leipzig, 1894, (Barth.)—This volume of the collected works of the greatly lamented physicist contains in the preface by von Hemholtz a generous tribute to Hertz. The work consists of two books, 1st, the geometry and kinematics of material systems, and 2d, the mechanics of material systems. The first part was in completed form, but the second the author intended to rework but was prevented by his illness which proved fatal. He placed his manuscript in the hands of Ph. Lenard under whose care the present volume is published.

IV. Miscellaneous Scientific Intelligence.

1. *The American Association for the Advancement of Science.*—The retiring President, William Harkness, delivered the address at the opening of the Brooklyn meeting in August, "On the Magnitude of the Solar System," (this Journal, pp. 230–250). The subjects of the vice-presidential addresses were as follows: Section A, "Binary Stars," by G. C. Comstock; section B, "Obscure heat as an agent in producing expansion and contraction of metals under air contact," by William A. Rogers; section C, "The Battle with fire," by Thomas H. Norton; section D, "Paradoxes in the resistance of materials," by Mansfield Merriman; section E, "The Niobrara Chalk," by Samuel Calvin; section G, "The Evolution of the Hepaticæ," by Lucien M. Underwood; section H, "Human faculty as determined by Race," by Franz Boas; section I, "A stable Monetary Standard," by Henry Farquhar.

Changes in the constitution of the association were proposed which would add Social science to the scope of the section of Economic science and Statistics, and separate the section of Geology from Geography, creating a separate section for the latter. These will be acted upon next year. The Committee on Grants set apart from the fund for research $100 for a table in the Biological Laboratory, at Wood's Holl, Mass., $100 to Professors Morley and Rogers for inferential comparisons, and $200 to Dr. Boas to continue and complete anthropometric measurements of Indians. It is probable that the next meeting will be held in San Francisco.

2. *The British Association.*—The sixty-fourth meeting of the British Association was held at Oxford, beginning August 8th. The inaugural address of the president, the Marquis of Salisbury, was an admirable presentation of the limitations of human knowledge in the field of the ultimate nature of matter, of motion and of life, as indicated by the terms atom, ether and life. The opening addresses before the several sections were by Prof. A. W. Rücher, Mathematics and Physics, on "Terrestrial Magnetism"; Prof. H. B. Dixon, Chemistry, "An Oxford School of Chemists"; L. Fletcher, Geology, on Crystallography; Prof. L. B. Balfour, Biology, on "Forests and Forestry"; Captain Wharton, Geography, "The Sea"; Prof. A. B. W. Kennedy, Mechanical Science, "The Critical side of Mechanical Training"; Sir W. H. Flower, Anthropology; Prof. E. A. Schæfer, Physiology. The attendance reached the total of 2321 members, of which 77 were foreigners; and nearly 1100 pounds were awarded in aid of scientific research. The Biology section was divided, and in the future there will be separate sections of Zoology and of Botany. Section I is to include Physiology, Experimental Pathology and Experimental Psychology. The meeting next year will be held at Ipswich under the presidency of Sir Douglas Galton.

3. The *University of Oxford*, England, on the occasion of the meeting of the British Association, conferred the degree of D.C.L. *honoris causâ* upon Professor S. P. Langley, secretary of the Smithsonian Institution. The same degree was conferred on the following eminent scientific investigators: Prof. Edouard Van Beneden, Prof. Ludwig Koltzmann, Dr. E. Chauveau, Prof. Cornu, Prof. Theodor W. Engelmann, Prof. Wilhelm Förster, Prof. C. Friedel, Prof. L. Hermann, Prof. Gosta Mittag-Leffler, Prof. G. Quincke and Prof. E. Strasburger.

OBITUARY.

Josiah Parsons Cooke, for many years an associate editor of this Journal, was born in Boston, Oct. 12, 1827, and died in Newport, Sept. 3, 1894. When he was a student in Harvard College, the chemical department was so thoroughly disorganized that his teaching in this branch was confined to a few disjointed lectures, and to these he added after graduation some months of study with Regnault in Paris. With these meagre exceptions his chemical knowledge was acquired by his unaided efforts, and these had been so successful even in his boyhood and youth that at 22 he was appointed Ewing Professor of Chemistry and Mineralogy in Harvard University, a position which he held till his death.

His first important chemical paper was on a theoretical subject, as was to be expected from a self-taught man; it was an attempt at a classification of the elements, in which he approached the periodic system, since so brilliantly developed by Mendelejeff and by Lothar Meyer; but his most important pieces of work, published rather late in his life, the redeterminations of the atomic weight of antimony and of the ratio between oxygen and hydrogen, proved that he had given himself the fullest and best of chemical educations, as they required a profound knowledge of the most delicate and difficult manipulations supplemented by great ingenuity in devising new and more advanced methods. Perhaps, however, these should not be called his most important work, but that title should be given rather to his research on the iodides of antimony, in which he furnished an experimental explanation of the isomerism of these inorganic salts.

As a teacher he has had a deep and lasting influence on the characters of a multitude of students by means of his elementary lectures given for over forty years to the whole of each class which has passed through Harvard College; and his advanced students have drawn from him the best instruction and inspiration. The chemical department of Harvard College he has raised from the state of entire collapse, in which he found it, to one of the strongest and best equipped departments in the college established in one whole building and part of another, both of which together with the rich mineral cabinet were presented to the college principally through his exertions.

But his influence was not bounded by the college walls; his brilliant popular lectures have spread a taste for science and a knowledge of chemistry in the outside world, and his numerous books, ranging from abstruse college text-books to popular expositions of his favorite subject and scientific essays, have reached even a wider audience.

These labors have met with recognition by his election to numerous learned societies, and especially by the degree of doctor of laws, which he received from the University of Cambridge, England, and by his selection as president of the American Academy, a position which he held at the time of his death.

The eminence of which I have tried to give an outline was due to his complete and loving devotion to his chosen science, his brilliant talents, his remarkable executive ability, and to his ceaseless and unwearied industry. He leaves a gap in Harvard University and the scientific world, which it will be hard to fill.

C. T. J.

BARON HERMAN LUDWIG FERDINAND VON HELMHOLTZ, the eminent German Scientist, died on September 8th, at Berlin.

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[THIRD SERIES.]

Art. LI.—*On Variations and Mutations;* by W. B. Scott.

Very interesting and instructive analogies exist between the history, aims and methods of comparative philology, on the one hand and those of animal morphology, on the other. In both sciences the attempt is made to trace the development of the modern from the ancient, to demonstrate the common origin of things now widely separated and differing in all apparent characteristics and to establish the modes in which and the factors or causes by which this evolution and differentiation have been effected. At the present time morphology is still far behind the science of language with regard to the solution of many of these kindred problems and can hardly be said to have advanced beyond the stage which called forth Voltaire's famous sneer: "L'étymologie est une science où les voyelles ne font rien, et les consonnes fort peu de chose." Of the animal pedigrees, now so frequently propounded, few have any better foundation than the "guessing etymologies" of the last century and for exactly the same reason. Just as the old etymologists had no test to distinguish a true derivation from a false one, except a likeness in sound and meaning in the words compared, so the modern morphologist is yet without any sure test of the relationships of animals except certain likenesses or unlikenesses of structure. How much weight is to be allowed a given similarity and how far this is offset by a dissimilarity which accompanies it, we have, as yet, few means of determining and have still to discover those laws of organic change which shall render the same service to morphology as Grimm's law has done to the study of the

Aryan tongues. Doubtless the analogy may be pushed still farther and we may say with some confidence that just as sound principles of etymology were deduced by tracing the changes of words step by step back from their modern forms to their ancient origins, so the existing animal forms must be traced back, noting all the gradations, to their far distant ancestors.

The great problems of morphology have been attacked by the aid of many distinct methods, each of which has its own drawbacks and its own particular advantages. Most of them suffer from the fact that they deal only with the present order of things and thus somewhat resemble the attempt to work out the derivations of languages which have no literature or only one that is so falsified and vitiated with forgeries that the order of succession is hopelessly lost. Final results can be hoped for only by a combination of all the methods, but such combination becomes more and more difficult because of the continual accumulation of immense numbers of facts, which requires strenuous labor to keep track of, even in a single department, not to mention the theoretical taint now attaching to nearly all morphological work and which causes hesitation in fully accepting the results of any inquiry. While the immensity of the task and its manifold variety necessitate specialization of research, too narrow a specialization of knowledge is a great evil and many an investigator might save himself from serious blunders, could he but learn the results gathered by fellow workers in somewhat different fields, results which have a most important bearing upon his own.

The principal methods of morphological inquiry have been comparative anatomy, embryology and palæontology, each with the limitations and advantages peculiar to itself. Not long ago, and to some extent still, embryology was looked upon as the final arbiter in all morphological questions, but the many difficulties in the way of applying the method to particular cases and the lack of any generally accepted canons of interpretation, have led to a reaction against embryological deductions, which perhaps undervalues this method as much as it was overestimated before.

Comparative anatomy suffers from the drawback that it cannot with certainty distinguish between resemblances due to genetic affinity, on the one hand, and those which are the results of convergence or parallelism, on the other, and it possesses no trustworthy criterion, by which it can test the taxonomic significance of structural characters. Besides, this method deals only with the recent animal world, a mere disjointed fragment of what has existed in times past. It is a language without a literature to register its changes.

Palæontology has its manifest deficiencies, as well as the other methods. Of these the most important is the well known and oft commented on imperfection of the geological record and another almost equally grave consists in the fact that, except under the rarest and most favorable circumstances, only the hard parts of an animal can be preserved in the fossil state and very important structures and organs can only be inferred from scanty data. In spite of these defects, the method has certain preëminent advantages. It does not profess and never can hope to yield us the whole history of life, but certain chapters in that history have been preserved with wonderful completeness and fullness of detail. While it is still impossible to avoid all preconceived ideas in the construction of phylogenies, there are, nevertheless, some series so complete, so intimately connected, that no one doubts the real relationships of their members to one another. These series, which are fortunately in widely separated phyla (mammals, cephalopods, brachiopods, crustacea and echinoderms are the most important in this connection) offer important evidence as to the actual steps of organic descent, and consequently as to the mode in which organic changes may be brought about. They represent the literature by means of which the changes of words have been traced from the ancient languages to the modern and which have enabled etymologists to deduce the laws of change and establish criteria by which derivations can be thoroughly tested.

Of late a new method of attacking the problems of morphology has been suggested by Bateson,* viz: the study of variation. This book has hardly received from palæontologists the recognition which it deserves; it is especially admirable for its freedom from dogmatism, the perfect candor of spirit with which it has been written and the keen criticism which brushes away many of the obscuring cobwebs that have gathered about zoological inquiry. The author recognizes the deadlock which seems to threaten morphology as carried out along its present lines and exposes the hollowness of the prevalent modes of "explaining" the facts of evolution by means of the glib use of elaborate phrases, which too often serve as a mere disguise for ignorance. These elastic terms may be so manipulated as to "explain" anything and everything, but in reality they explain nothing at all and only darken counsel by diverting attention from the actual difficulty. Out of this labyrinth of speculation and uncorrelated facts, Bateson believes that the best chance of escape lies in the study of

* Materials for the Study of Variation, treated with especial Regard to Discontinuity in the Origin of Species. London and New York, Macmillan & Co. 1894.

variation. "Those who reject the particular inferences, positive or negative, here drawn from that study, must not in haste reject the method, for that is right beyond all question." (p. XI.) "It is submitted that the study of variation gives us a chance and perhaps the only one, of arriving at this knowledge" [i. e. of the facts of evolution] (p. 13). "In introducing the method of the study of variation, I have said that it alone can supply a solid foundation for inquiry into the manner by which one species arises from another. The facts of variation must therefore be the test of phylogenetic possibility. Looking at organs instead of species, we shall now see that the facts of variation must also be the test of the way in which organ arises from organ and that thus variation must be the test of homology" (p. 30).

Bateson's entire argument is founded upon the assumption that individual variations form the material, out of which new species are constructed, an assumption which has almost passed into an axiom. "It is upon the fact of the existence of this phenomenon of variation that all inductive theories of evolution have been based" (p. 3). He has entirely omitted any consideration of the palæontological facts and appears not to be familiar with the literature of this subject. Had he been so, he would hardly have said: "It is really a strange thing that so much enterprise and research should have been given to the task of reconstructing particular pedigrees—a work in which at best the facts must be eked out largely with speculation—while no one has ever seriously tried to determine the general characters of such a series" (p. 14). Palæontologists have repeatedly endeavored to do this and it is much to be regretted that workers in other lines of morphology should pay so little attention to their results. Progress cannot be hoped for except by combining all classes of facts. The object of this paper is to compare Bateson's methods and results with those drawn from a study of fossil mammals, with special reference, of course, to those phyla which may be regarded as fairly well established. The outcome of such a comparison is an unpleasant alternative: either the study of variation offers us little hope of learning the real facts of evolution and the assumption upon which it is founded is radically faulty, or all the palæontological phyla have been erroneously arranged and must be thoroughly reconstructed, though no reconstruction at present possible would bring about any greater harmony of results. Such rearrangement is necessarily limited by the geological succession.

Bateson's definition of variation may be accepted as an exact statement of the significance to be attached to the term. "To this phenomenon, namely, the occurrence of differences between the structure, the instincts or other elements which compose the mechanism of the offspring and those which were proper to the parent, the name variation has been given" (p. 3). In most species, while no two individuals are exactly alike, the greater part of them resemble one another very closely and thus make a normal from which few individuals depart very widely; the magnitude of such departures is in general proportionate to their infrequency. The phylogeny of a species is given by the shifting of this normal, or center of "organic stability" (to use Galton's phrase) *not* in all the variations of the successive species, which are more or less different in every generation. While the species remains stable, the variations tend to balance and correct one another through the operation of what Galton has called the regression to mediocrity, while a material change in the position of the normal, either sudden or gradual, results in the formation of a new species. The fact that the variations of the species may be so arranged as to form a complete transition between them, does not, as Bateson very pertinently shows, prove that the actual change was along the lines indicated by such a selected series of variations.

Turning now to the examination of Bateson's results, we find that the one upon which he lays most stress is the proof of discontinuity in variation. "The existence of discontinuity in variation is therefore a final proof that the accepted hypothesis is inadequate . . . . For if distinct and 'perfect' varieties may come into existence discontinuously, may not the discontinuity of species have had a similar origin? If we accept the postulate of common descent, this expectation is hard to resist. In accepting that postulate it was admitted that the definiteness and discontinuity of species depends upon the greater permanence or stability of certain terms in the series of descent. The evidence of variation . . . . . suggests in brief that the discontinuity of species results from the discontinuity of variation. This suggestion is in a word the one clear and positive indication born on the face of the facts. Though as yet it is but an indication, there is scarcely a problem in the comparison of structures where it may not be applied with profit." (p. 568).

The mammalian phyla do not support this view of discontinuity in the origin of species and genera. Remembering that the significant fact in the history of a group is not so much the character of its variations at any one stage as the gradually shifting positions successively occupied by the normal or center of stability, we find that any mammalian series at all complete, such as that of the horses, is remarkably continuous and that the progress of discovery is steadily filling up what few gaps still remain. So closely do the successive stages follow upon one another, that it is sometimes extremely difficult to arrange them all in order and to distinguish clearly those members which belong in the main line of descent and those which represent incipient side-branches. Some phylogenies actually suffer from an embarrassment of riches. In the case of intimately connected formations, which follow upon one another with little or no break, such as the White River and John Day, or in the successive strata of an uninterrupted horizon, the progress of this normal is by almost imperceptible gradations, though the variations may and often do describe a wide circle around the normal at every stage of its descent, circles which have a striking tendency to repeat themselves in the successive stages. Disregarding side branches, such as *Anchitherium*, *Hipparion* (probably) and *Hippidium*, the equine series from the Eocene on consists of eight well defined genera, and though they are well defined in one sense, the gradual change from one into the other is almost without a break. The same is true of other phyla and in general the continuous nature of a phylum, as at present known, is apt to be proportional to the relative abundance of its representatives in the strata, which is as much as to say that well known series are continuous, while apparently discontinuous series are those which are imperfectly known. Indeed, the most striking fact about any well established phylum is the directness of its advance towards its final goal, however greatly or in however many different directions it may be varying at any or all stages of its history. This does not imply that a line may not give off side branches or may not bifurcate into two lines. But while we represent such ramifications by branching lines in our genealogical trees, it must not be forgotten that each of the branches, considered only with reference to itself, forms a direct line from ancestor to descendant.

Continuity in the advance of a series of animals is not peculiar to mammals; it recurs wherever the phyla can be worked out in detail. Thus Waagen says of Ammonites: "Sehr häufig zeigt sich nämlich bei den hierher gehörigen Ammoniten, dass mehrere auf einander folgende Schichten Formen ein und desselben Bildungstypus beherbergen, welche einander äusserst nahe stehen, die mit einander näher verwandt sind, als mit allen übrigen in den gleichen Schichten liegenden Arten, bei denen endlich nur bei sehr eingehenden Studien und sehr reichhaltigem Materiale endlich Unterschiede gefunden werden können, die sich in allen Fällen als stichhaltig erweisen. Solche Bildungstypen kann man oft durch eine grosse Zahl von Schichten hindurch verfolgen, aber in jeder Schicht zeigen die Individuen eine von den vorhergehenden und nachfolgenden etwas abweichende Gestalt; das Ganze bildet eine zusammenhängende Reihe, die man am besten mit dem technischen Ausdrucke 'Formenreihe' belegen könnte." "Gewöhnlich sind die Unterschiede zwischen den einzelnen Mutationen um so minutiöser, je inniger verbunden die Schichten erscheinen, denen die Stücke entstammen."*

That variations are often discontinuous may be freely granted, without at the same time admitting such discontinuity to be a frequent characteristic of phyletic history. On the other hand, such a case as the transformation of the Texan species of *Saturnia*, when taken to Switzerland and reared on a new food-plant, into what might almost be called a new species, is a remarkable instance of the possibilities of abrupt change (Moritz Wagner, Die Entsteh. d. Arten, etc., Basel, 1889, pp. 307–310). Though the results of palæontology are too few to prove a negative, they strongly suggest the advisability of caution and reserve upon this point.

II. The second class of Bateson's results refers particularly to homologies. As these require somewhat extended consideration it will be most convenient to allow the author to state his case as fully as the limits of these brief notes will admit. "Thus to compare the members of a series [i. e. of repeated parts or organs] containing different members it is first assumed that the series consisted ancestrally of some maximum number, from which the formula characteristic of each descendant has been derived by successive diminutions. . . . . . If it is true that each member of a series has in every form an individual and proper history, it follows that if we had before us the whole line of ancestors from which the form has sprung, we should then be able to see the history of each member in the body of each of its progenitors. In such a series the rise of an individual member and the decline of another should then be manifested" (pp. 31–32). Our author then proceeds to give large numbers of cases of variations in the number and character of the vertebræ and ribs, of the teeth, of the digits, and of the carpal and tarsal elements, which he believes to confirm the view of homology formulated above. The consideration of the vertebræ and ribs will be omitted here, because the palæontological evidence as to these organs is too scanty to be available, the number of altogether complete skeletons of fossil mammals which have been found, being of course very limited.

With regard to the teeth Bateson arrives at the following conclusions: (1) Domestication is not a factor in causing frequency of variation. (2) Dental variation may be symmetrical

* W. Waagen, Die Formenreihe des Ammonites subradiatus. Benecke's Geognost.-Palæontol. Beiträge Bd. II, pp. 179–256.

on the two sides of the mouth or with regard to the upper and lower jaws, but much more frequently is not so. (3) In many cases of increased number of teeth it appears that two teeth in the variant represent one in the normal and have arisen by the division of a single tooth-germ. (4) Most cases of numerical variation of teeth affect those standing at the beginning or ends of series. (5) New teeth arising in particular places have a more or less constant size and the size of such a tooth is often related to that of adjacent teeth and to the general curves of the series. (6) The teeth next to which new ones arise may vary in correlation with them. (7) A few cases show the members of a series to have been remodelled so that their supposed individuality has been lost. (8) Individuality should not be attributed to members of a series which has normally a definite number of members.

The results of the examination of varying digits may be summed up as follows: (1) The frequency of digital variation differs greatly in different animals. (2) In particular animals the variation tends to approximate particular types. (3) The variation may affect both sides similarly and simultaneously, though usually differing in degree on the two sides. Similar and simultaneous variations frequently occur in both manus and pes, though rarely identical in the two. (4) When a digit is added, the adjacent one may be modified in accordance with its new place in the series. (5) There is no sharp distinction between the duplicity of a given digit and other modes of addition to the series. (6) Digital variation is often markedly discontinuous. (7) No distinction can well be drawn between those variations which resemble the normal condition of other animals and those which do not.

"The attribution of strict individuality to each member of a series of repeated parts leads to absurdity and in variation such individuality may be set aside, even in a series of differentiated members. It appears that the number of the series may be increased in several ways not absolutely distinct, that a single member of the series may be represented by two members, that a terminal member may be added to the series, and also that the number of the members may change, no member precisely corresponding in the new total to any one member of the old series; in short, that with numerical change resulting from meristic variation [i. e. variation in the number of repeated parts] there may be a redistribution of differentiation." (p. 570).

These are most important and far reaching conclusions, which, if established, will profoundly modify many of the current conceptions of morphology. That they follow fairly from the evidence of variation presented in the body of the work must be admitted, provided only that the fundamental assumption upon which the entire argument depends be granted, namely, that individual variations form the starting points of new species.

Let us now proceed to examine these results in the light of palæontology, confining our attention principally to those mammalian phyla whose history is known with some degree of completeness. Little confidence may, perhaps, be felt in these phyla by those who have not especially studied them and it may be imagined that more complete knowledge will require them to be altogether remodelled. Granting all that may be said with regard to the incompleteness of the record and the danger of building ambitious hypotheses upon such narrow foundations, nevertheless we cannot avoid seeing that several facts stand out clearly and are not in the least likely to be overthrown by new evidence. A certain limit of error in the construction of phylogenies is established by the order of geological succession. So far as the lacustrine Tertiary formations of North America are concerned, the evidence derived from the actual superposition of strata fails at only three points. As yet, no contact between the Uinta and White River, White River and John Day, or between the Deep River and the Loup Fork, has been observed, and yet in all these cases indirect evidence of almost equal cogency is available and there can be very little doubt that this order of geological succession is known with sufficient accuracy. This order being admitted, there is no room for any very radical reconstruction of the phylogenies. By no possibility can *Hyracotherium* be derived from *Equus* or *Poëbrotherium* from *Auchenia*, and whatever changes in the details may be necessitated by further knowledge, such changes are not likely to revolutionize the inferences to be drawn from a study of the phyla as now constructed. Few observers, if any, would now uphold the arrangement of the equine phylum proposed by Kowalevsky, namely, *Palæotherium—Anchitherium—Hipparion—Equus*, and yet it is surprising to see how the general character of this series and the inferences as to the modes of evolution drawn from it agree with those deduced from a study of the equine phylum as we now have it. Kowalevsky's mistake merely consisted in putting certain representatives of side branches into the main line of descent and that a similar error has been made in phylogenies now accepted is not at all improbable. But the correction of such errors will change the general result but little and we may appeal with considerable confidence to the inference from these phylogenies.

The study of the mammalian phyla brings out a number of facts which I have elsewhere* endeavored to set forth and which do not at all agree with those inferences drawn by Bateson from an examination of the individual variations of existing mammals. One is greatly tempted to conclude that the two orders of facts are not, so to speak, commensurable. Thus, Bateson hesitates to attribute to any one the explicit maintenance of the thesis already quoted, namely, "that a series [of parts or organs] consisted ancestrally of some maximum number, from which the formula characteristic of each descendant has been derived by gradual diminution. Here, again, I do not doubt that many who employ this assumption would hesitate to make it in set terms, but nevertheless it is the logical basis of all such calculations." The mammalian palæontologist, however, need not hesitate to adopt this thesis, not as an assumption, but as an inference from many facts and to defend it with a great array of evidence, though always remembering that nature declines to submit to our rigid systems and in such matters will make exceptions to modes of procedure which are, on the whole, remarkably constant. Thus, there can be very little doubt that the numerous uniform teeth of the toothed whales are not primitively simple forms inherited from reptilian ancestors, but as *Zeuglodon* indicates, the dentition has been simplified and greatly increased in numbers since the differentiation of the order. It would be a fruitless task to attempt to homologize any of the teeth of *Delphinus* with those of *Zeuglodon*. Kükenthal has suggested with much probability that the numerous teeth of certain edentate genera $\left(\frac{20-25}{20-25}\right)$ have been derived from the subdivision of complex molars of the glyptodont type. These facts, so far as they go, agree with Bateson's conclusions, but then it should not be forgotten that they are very exceptional. Among heterodont placental mammals there is but one case known as to which it can be maintained with any show of probability that it has developed an additional tooth, and that is *Otocyon*. Though, for reasons which cannot be discussed here, I believe the fourth molar of *Otocyon* to have been added since the separation of the canine phylum, we cannot attribute much weight to this case until the history of the genus has been determined, for it is quite within the bounds of possibility that this form has retained the marsupial formula, not reacquired it. This is the view held by most writers on the subject. The vast

* On the Osteology of Poëbrotherium, Journal of Morphology, vol. v, pp. 1–78. On the Osteology of Mesohippus and Leptomeryx, Ibid., pp. 301–406.
The Mammalia of the Deep River Beds, Trans. Am. Phil. Soc., vol. xvii, pp. 55–185.

majority of placental mammals have another mode of dental evolution, viz: that of reduction, the ancestor in nearly all cases having a larger number of teeth than the descendant. The early Eocene representatives of all the placental orders, except the rodents, have a uniform dental formula, $i\frac{3}{3}\ c\frac{1}{1},\ p\frac{4}{4},\ m\frac{3}{3}\times 2 = 44$, a maximum which is never exceeded. Tracing the various phyla down from their Eocene progenitors, we find that in nearly all cases there is a gradual reduction in the number of teeth, never (with the one doubtful exception) an increase. Throughout the history of the phyla we may and often do find just such individual variations as those which Bateson has described, of abnormal increase or decrease in the number of teeth, but these in no way affect the march of successive species and genera, as indicated by the character of the normal or position of the center of stability, a march which is almost invariably in the direction of reduction, though in a few cases the original number is retained. Wortman's dictum: "there are no cases known to me in which teeth have been added. On the contrary, I am firmly of the opinion that not so much as a single tooth has even been added to the diphyodont mammalian dentition in the course of development, but that specialization has invariably gone in the other direction," is perhaps too strongly expressed, but is, on the whole, supported by the facts of palæontology.

Further than this, the individuality of the teeth is preserved in a remarkable way. One tooth may, it is true, assume the form and function of another; thus, in the oreodonts the lower canine has taken on the shape and character of the incisors, while the place of the canine is assumed by the first premolar, which has become caniniform, but as this tooth bites *behind* the upper canine, these changes do not in the least disguise the homologies. Whenever the successive members of a phylogenetic series have been recovered, there is no difficulty in determining what teeth have been lost. While reduction usually affects first the ends of the series, it does not always do so. For example, the camels have retained the first premolar, though losing the second. Throughout the whole history of the Carnivora, from the earliest dog-like forms with undiminished dental formula to the cats, in which the cheek-teeth have been greatly reduced in number ($p\,\frac{3}{2},\ m\,\frac{1}{1}$) the individuality of the sectorials has been preserved. These teeth, when present at all, are always the fourth upper premolar and the first lower molar. This invariable homology is shown both by the steps of the reduction, all of which can be followed in many lines, and also by the relation of these teeth to the milk-dentition.

After these general statements, we may examine Bateson's conclusions with regard to the teeth somewhat more in detail. (1) The effects of domestication are of course not significant in the present connection. (2) Dental variation is more commonly unsymmetrical on the two sides of the same jaw and with reference to the upper and lower jaws. The mammalian phyla show no such lack of symmetry in dental reduction, though the upper and lower jaws do not necessarily keep pace with each other in this respect. At any stage in the phylum we may find *individuals* with such unsymmetrical dentition, but they are always rare, the normal form having almost invariably an equal number of teeth on the two sides of the mouth. The only exception to this rule, if it can fairly be called so, is to be found in the minute incisors of *Titanotherium*, which are on the point of disappearing altogether and in many individuals are present in different numbers on the two sides of the jaws, both upper and lower, but whether this asymmetry characterizes the normal of any species has not yet been determined.

(3) While in variation two teeth in the variant may represent one in the normal, being formed by the division of a single tooth-germ, no such process is of phylogenetic significance in any of the heterodont phyla, except, perhaps, the true whales. As a variation however, it is not unknown among fossils; specimens of *Amphicyon* have been described by Schlosser, in which a fourth upper molar is preserved.

(4) Numerical variations in the dentition usually affect the ends of series; this is likewise true of phylogenetic reductions in the number of teeth, but certainly does not apply to such cases of increase as occur among the Cetacea and Edentata.

(5) and (6) The conclusions as to the character of new teeth and their effects upon adjacent teeth have no application to the phylogenetic history of any of the heterodont phyla whose history is known, because, as we have already seen, such new teeth rarely, if ever, arise.

(7) In no heterodont group has any such remodelling of the dentition occurred as to obscure the individuality of the separate teeth.

(8) While the facts of variation seem to show "that individuality should not be attributed to members of a series which has normally a definite number of such members," the facts of palæontology lead to a diametrically opposite conclusion, so far as the mammals are concerned, though there is no reason to maintain that such individuality is fixed beyond possibility of change. It further seems likely that such individuality is more or less due to differentiation and is less distinctly marked

in a series of repeated parts consisting of numerous and uniform members.

In considering the structure of the extremities, we shall find the same discrepancy between the facts of variation and those of phylogenetic progress. The history of the changes in foot-structure has been worked out in several mammalian phyla with great minuteness of detail, palæontological material being particularly rich in this respect. Just as in the case of the teeth, there is a marked individuality in the elements which compose the manus and pes, an individuality which may be traced unchanged throughout vast periods of time. Indeed, we may speak with perfect propriety of the history of the astragalus or of the third digit and such history might be written, for many groups, with much accuracy and fullness. The limits of phylogenetic change in the extremities are more narrowly fixed than in the case of the teeth. Here it is demonstrably true that "the series consisted ancestrally of some maximum number, from which the formula characteristic of each descendant has been derived by successive diminution." In the Cetacea, however, the number of phalanges has, in all probability, been greatly increased beyond that found in the ancestors of the order and in the Sirenia the same process seems to be in an incipient stage, but in the terrestrial mammals there is no such increase of parts. In every such phylum the Eocene ancestors have the largest number of carpal, tarsal and digital members and from these the successive changes are always by means of the gradual diminution and loss of elements, partly through the coössification of members originally distinct, partly through the entire suppression and loss of members. These changes are, as has been said, extremely gradual and rudiments often linger a very long time after they have lost all obvious functional importance.

It may be objected that the phyletic series have been arranged on this presupposition and that a different arrangement would bring forth a different result. But this is not the case. As we have already seen, the geological order of succession is a bar to any wholesale reconstruction of the phylogenies, and I know of no case in which there is any reason to derive a four-toed genus from a three-toed genus. Didactyl forms, it is true, do occur in the Oligocene and upper Eocene, perhaps even earlier, as, for example, *Anoplotherium*, *Xiphodon*, *Diplopus*, *Elotherium*, etc., but these are all types, which for reasons independent of their foot-structure, we must regard as terminating their several series and as having died out without leaving any descendants behind them. That exceptional cases of the addition to parts to the extremities, or of the reacquisition of lost elements, may hereafter be discovered, is quite possible, but they have not been found yet and the large number of phyla in which the law of reduction has been demonstrated is evidence that this law represents the normal method of procedure in the lines of descent of the terrestrial mammals.

In the case of the horses we may trace the gradual reduction of five digits to one and throughout all the many species which compose this great line there is no loss or even obscuring of the individuality and homology of the parts involved. Nothing is ever added, and what is lost disappears gradually, by successive well recognized steps. The phalanges first dwindle and are then suppressed, accompanied by the distal portion of the metapodials. The latter become splint-bones, which in some cases shorten to nodules and then vanish. Last of all the change affects the carpus and tarsus. So far as the horse is concerned, the only podial element which is actually suppressed is the trapezium, but in the tarsus the ankylosis of the ento- and mesocuneiforms brings about a similar diminution of the number of separate elements, though there is no actual loss of parts. While the lateral digits are thus gradually dwindling away, the median or third digit is being gradually enlarged in the same proportion, until it alone bears the entire weight of the body. This change requires a gradual readjustment of the carpal and tarsal bones to the altered character of the strains transmitted by them and all of these transformations may be followed step by step in the successive species. In the ruminants and the camels analogous changes have been produced in the same slow and steady manner, with a remarkable directness of development, individual variations apparently not affecting the result.

If the facts of digital variation, as Bateson has collected them, possessed any real phylogenetic significance, we should expect to find a close correspondence between these facts and those exhibited by the extinct forms, but nothing of the kind is observable. Indeed the utterly different character of the two classes of facts is obvious on the most superficial comparison. The cases of polydactylism which are so far from infrequent among the recent horses, demonstrate their radical difference from the processes at work in the phyletic history of that species by the fact that the carpus and tarsus in such cases are unlike those of any normal form whatever. For this reason Gegenbaur very properly refused to admit such cases as examples of "reversion."

Examining Bateson's conclusions as to digital variation more in detail, we reach the following results. (1) The frequency of digital variation differs greatly in different animals; the same is true of digital reduction. (2) In each kind of animal variation tends to produce a particular type of structure, which also is observable in the phyletic series. Upon such correspondences, however, little stress can be laid. (3) Digital variation may be similar and simultaneous on the two sides, but usually differs in degree. In the phyletic succession, on the contrary, there is no such difference of degree. Individuals may and do vary in this way; the normal does not, but always keeps perfect symmetry and balance. In the changes of manus and pes phylogenetic change agrees with variation in showing a certain independence in the two extremities. As a rule, the pes changes first, while the manus is more conservative and lags behind, though sometimes this relation is reversed. While there can be little doubt that in the earliest mammals, or in their reptilian ancestors, the hand and foot were composed of the same number of parts arranged in the same way, yet in all the lines of descent there has been a constant divergence from this condition, though the correspondence, even in the most highly differentiated forms, is still remarkable. It may not be "necessary to suppose an independent evolution for the legs of the horse, since in the light of the facts of variation it is as easy for all to take on the new characters as for one," (Bateson, p. 27), and so far as the two hind-legs or the two fore-legs are concerned, this agrees with the facts of the evolutionary history, but, on the other hand, the fore- and hind-legs, not only of the horse, but of nearly all other mammals, pursue very independent ways of their own. Thus, the Eocene *Hyracotherium* had four digits and a rudiment in the manus while the pes had already been reduced to three. This tridactyl condition of the pes persisted till the end of the Miocene by which time the manus had attained the same degree of reduction, and in the next change, which consisted in the diminution of digits II and IV to splint bones, the two extremities keep equal pace. It is hardly necessary to observe that such independence of the manus and pes is limited and conditioned by the unity of the organism and its needs as a whole.

(4) and (5) When a digit is added, the adjacent ones may be modified according to their new place in the series. There is no sharp distinction between the duplicity of a given digit and other modes of addition to the series. These results apply only to variations; in the phylogenetic history of mammals new digits never are added, by doubling or otherwise.

(6) Digital variation is often markedly discontinuous. In the history of the terrestrial mammalian lines the facts lead to exactly the opposite conclusion. One of the most remarkable and striking features in the reduction of digits is the perfect continuity of it; it is often very slow, but gradual and steady, and its completion is often delayed for incredibly long periods

of time. Even *Hipparion* and the modern rhinoceroses retain a rudiment of the fifth metacarpal, though in neither line has this digit been functional since the Oligocene, and in other series similar facts have been observed.

(7) No trustworthy distinction can be drawn between those variations which resemble the normal condition of other species and those which do not. Bateson has been criticised for not making this distinction, but his critics have overlooked the fact that he has discussed the question and shown that such a discrimination cannot but be arbitrary. This emphasizes the difference between the facts of variation and those of phylogenetic change. No normal form of extinct mammal ever developed six digits, or three phalanges on pollex or hallux, or four cuneiforms in the tarsus. The possible modes of connection between the carpus and tarsus, on the one hand, and the metapodials, on the other, are strictly limited and when they change, they do so very gradually, allowing every step of the way to be identified. The change from what Kowalevsky has called the "inadaptive" to the "adaptive" mode of such connection may be shown to have occurred independently in all of the following artiodactyl groups; the Pecora, Tylopoda (probably) Tragulina (probably), *Suidæ* and *Oreodontidæ*, and when the phylum has been completely recovered, the change is invariably found to be very gradual. To say that natural selection has permitted only certain variations to persist, eliminating the others, is simply to beg the whole question and to cheat ourselves with an "explanation" which is only an assumption. If variations are actually the material out of which new species are made, then as Bateson well shows, the "perfection" of such variations is not the work of selection. The study of a complete phylum, each stage of which is represented by large numbers of individuals, does not favor such a view of evolution. The direct, unswerving way in which development proceeds, however slowly, is not suggestive of many trials, and failures in all directions save one.

If we may express in one sentence the most strikingly apparent difference between the facts of variation and those of phylogenetic change, it will be found in the comparatively lawless and uncontrolled character of the former. Addition of parts, coalescence or subdivision of parts, almost anything may happen, and if the facts of variation are "the test of phylogenetic possibility" then such possibilities are far wider and less rigidly controlled than we have hitherto been accustomed to believe. In phylogenetic change, on the contrary, we are impressed by the orderly advance toward the final goal, deviating very little from the direct line, though not always progressing at the same rate. By this it is not meant that the direction of advance is something unalterably fixed ; change of direction is not an infrequent phenomenon, but it is a deflection of the path, and not a zig-zag or meandering course that results. For example, the true ruminants (Pecora) were at one time provided with formidable weapons in the shape of canine tusks, which the hornless forms (e. g. *Moschus Hydropotes*, etc.) and the small-antlered muntjaks still retain, but in the other modern groups the development of another kind of weapon in the horn or antler has been accompanied by a reduction or loss of the canines. *Chalicotherium*, *Agriochœrus* and many other genera are examples of a change in the. direction of development originally taken. It should be noted, however, that when such a marked deflection once occurs, it is permanent and the old course is never regained. Minor deviations, such as the peculiar elbow-joint of *Mesohippus*, may be eliminated, but even this is not usual.

How are we to reconcile such discordant evidence as to the modes of evolution as that presented by the facts of variation and that given by a study of the mammalian phyla ? The difficulty perhaps lies in the fundamental assumption that individual variations are or may be incipient species. Many years ago Waagen, in the paper already quoted, made a distinction which has found little favor, but which may yet prove to be the key to the solution which all morphologists are seeking. At all events his suggestion is worthy of serious consideration. "Dabei ist nun aber wohl zu berücksichtigen, dass die einzelnen, in den betreffenden Individuen und Schichten zum Ausdrucke gelangten Erscheinungsweisen dieser Formenreihe oder Collectivart von Varietaten streng zu unterscheiden seien ; sie eben sind die Arten, die einerseits zusammen die Collectivart bilden, andererseits aber selbst wieder in mehrere Varietäten zerfallen können ; denn es lässt sich gewiss nicht leugnen, dass jeder dieser Formen in dem Zeitalter in welchem sie auftrat, eine von allen mit vorkommenden wohl unterschiedene Art bildete. Im Verhältnisse zu der früher vorhandenen Form des gleichen Bildungstypus mag die spätere vielleicht als Varietät erscheinen, doch ist dann das etwas ganz Verschiedenes von unseren heutigen, zoologischen oder botanischen Varietäten, welche in einer und der gleichen Zeitperiode neben einander auftreten : man muss daher streng unterscheiden zwischen räumlichen oder zeitlichen Varietäten. Um jene zu beschreiben wird der schon lange gebrauchte Name 'Varietät' hinreichen, für diese dagegen möchte ich der Kürze halber einen neuen Ausdruck "Mutation" vorschlagen. Die Art kann also an und für sich als Art, mit Rücksicht auf ihren Zusammenhang mit früheren oder späteren Formen aber als Mutation aufgefasst und betrachtet werden.

Aber auch in Bezug auf den Werth dieser beiden eben festgestellten Begriffe (Varietät und Mutation) wird sich bei näherer Betrachtung ein ganz verschiedener Werth herausstellen. Während die erstere höchst schwankend, von geringem systematischem Werth erscheint, ist letztere, wenn auch in minutiösen Merkmalen, höchst constant, stets sicher wieder zu erkennen; es ist deshalb auch auf die Mutationen ein weit grössere Gewicht zu legen, sie sind sehr bestimmt zu bezeichnen und mit grosser Consequenz festzuhalten" (pp. 185–6).

In a former paper I called attention to the fact that the history of mammalian phyla lends some support to this view, "These facts at least suggest the possibility that individual variations are not incipient species, but that the causes of transformation lie deeper and act with considerable uniformity upon large numbers of individuals. It may, perhaps, be the outcome of future investigation that, while variations are due to the union of changing hereditary tendencies, mutations are the effect of dynamical agencies acting long in a uniform way and the results controlled by natural selection. While this *may* be true, a great many facts must be gathered in its support, before it can be regarded as more than a suggestion," (Osteology of Mesohippus, loc. cit. p. 388.) At the time this passage was written, no very great importance was attached to the suggestion contained in it. At present, I am even less inclined than before to regard "Amphimixis" as the principal source of individual variations. But with regard to the validity of the distinction between variation and mutation the case stands differently; Bateson's results as compared with those of palæontology, confirm this distinction in many significant ways and emphasize strongly the difference between variation and that steady advance along certain definite lines which Waagen called mutation.

Neumayr reached the same conclusion from an examination of certain gasteropod phyla, in which every step of the successive changes could be followed "Noch andere Eigenthümlichkeiten stellen sich ein, welche die Mutationen als etwas von den Varietäten Verschiedenes bezeichnen, so in erster Linie dass in der Regel eine bestimmte Mutationsrichtung in jeder Reihe vorhanden ist, indem durch eine längere Aufeinanderfolge von Schichten hindurch immer dieselben Charaktere in demselben Sinne von einander abweichen. . . . . . Ein anderer bisweilen beobachteter Fall von grosser Wichtigkeit ist der, dass die verschiedenen Glieder einer Reihe Variationen derselben Art zeigen; während also ein Theil die Merkmale gleichmässig nach einer Richtung im Laufe der Zeit mutirt, zeigen andere

Charaktere regellose Abänderungen und jede Mutation entwickelt denselben Varietätenkreis."*

All this might have been written of mammalian phyla, to which it exactly applies. Another fact of general application is that there is no necessary proportion between the variability of a group and the amount of mutation through which it passes. On the contrary, such groups may exist substantially unchanged through long periods of time, but being nevertheless extremely variable in all stages of their history. Others again may show little variation at any one stage and yet by steady advance experience complete transformation.

This mode of viewing the facts of development may be expressed by an analogy. The track of a cyclonic storm is determined by the path of the storm center, around which the winds circulate, blowing in every direction. These circulating winds would represent the variations which occur at every stage in the history of a phylum, while the course of the storm-center would represent the phylogenetic change, or mutations. Thus the cycles of variation tend to repeat themselves, though the center around which they revolve has a course of its own, dependent, not on the accumulation of these winds which happen to be blowing in the right direction, but upon factors of a much wider significance.

I am very well aware that any such view as that here suggested is opposed to many facts which appear to show that the distinction between individual variation, variety, species, genus, etc. is one only of degree and not of kind, the inconstant differences between variants being very much the same, and often greater in amount, as the more or less stable differences between species. As every one knows, it is often most difficult to determine the bounds of a natural group and systematists differ radically on such questions. But the problem is one as to factors of change. The distinction between variation and mutation does not necessarily imply an objective reality for species which does not extend to variations ; there may be such a difference, but it cannot be demonstrated. What is meant is that the march of transformation is the resultant of forces both internal and external which operate in a definite manner upon a changeable organism and similarly affect large numbers of individuals. That phylogenetic advance does not consist in the selection of a few favorable variations out of a large number of haphazard changes, is irresistibly born in upon the student of real phyla. This view in no way impugns the importance of natural selection as ennunciated by Darwin, though of course it is irreconcilable with the omnipotence of

* Neumayr, M. Die Stämme des Thierreiches. Bd. I, pp 60–61.

that process, such as is maintained by Weismann and his followers. The difficulties involved in this theory are very well brought out by Bateson who says that it "asks us to abrogate reason." The particular value which attaches to the facts of palæontology in this connection, is that they give us what we have every reason to believe are the actual steps of descent in the history of a genus or species. On the other hand, no one has ever observed the birth of a new species through the gradual accumulation of individual differences. How these apparently contradictory classes of evidence are to be reconciled must be determined by wider and fuller knowledge, but the way to obtain such knowledge is not to dogmatically enunciate a theory and then refuse to consider the facts which do not favor it.

Another very obvious objection to the mode of evolution here suggested lies in its apparent appeal to a mystical directing force which makes for differentiation or simplification, as the case may be, the nature of which we can hardly even hope to learn. Such mysterious forces are to be admitted only when there is absolutely no escape from them. This notion of a directing factor in evolution may be altogether illusory and yet it is difficult to shake it off. It is continually reappearing in one form or another in the writings of those who do not explicitly acknowledge it and are perhaps hardly conscious that their views imply it. The later theories of Weismann necessitate its assumption in some shape. But this force may after all be only the expression of some general law which has not yet been formulated, but if it be real, we shall not advance our science by shutting our eyes to it. We have then to endeavor to learn the facts of nature and having learned them, attempt to explain them. Many current explanations have been devised to account for assumed facts and these we can afford to neglect.

In making the suggestions contained in this paper, I am very far from desiring to propound a new theory of evolution or to dogmatically insist upon the interpretations of the facts as given. These interpretations profess to be nothing but suggestions which are not even novel, but they are derived from well established facts, which indicate in the plainest manner that we can no longer assume as a fundamental and self-evident truth, that individual variations are the material from which new species are constructed.

Geological Museum, Princeton College, Sept. 3, 1894.

Art. LII.—*An Iodometric Method for the Estimation of Telluric Acid;* by F. A. Gooch and J. Howland.

[Contributions from the Kent Chemical Laboratory of Yale College—xxxvii.]

In his valuable and extended study of possible volumetric methods for the estimation of tellurium, Brauner* has investigated the action of iodine upon an alkaline tellurite and finds that the oxidation is slow and incomplete at ordinary temperatures, while at 100° C. and in presence of a sufficient excess of iodine complete oxidation takes place, though the difficulty of estimating the excess of iodine not directly utilized in the reaction is so great as to render the method practically inapplicable to the determination of tellurium. The difficulty in effecting oxidation in alkaline solution naturally suggests the reversal of the reaction in an attempt to reduce telluric acid by the action of hydriodic acid in acid solution. Upon putting the matter to the test we find the reduction of telluric acid does take place, but we have been unable to prevent its going too far. Thus, on boiling a solution made by adding 10 cm^3 of sulphuric acid of half-strength and 3 grm. of potassium iodide in 90 cm^3 of water containing a little more than 0·1 grm. of telluric acid, the liquid darkened, deposited dark gray crystalline scales and evolved iodine which, when collected and titrated with sodium thiosulphate proved to be twenty per cent in excess of the theoretical yield assuming that the reduction should result in the production of tellurous acid. A similar experiment made in like manner excepting that the liquid was heated for fifteen minutes in a closed bottle on the water-bath instead of being subjected to boiling, with the idea that the presence of the free iodine might tend to prevent excessive reduction of the tellurium, indicated a yield of free iodine about six per cent. in excess of what it should be if tellurous acid is the sole product of reduction. In this case the titration of the free iodine was made by sodium thiosulphate in the presence of the reduced tellurous acid, but we found by independent experiment that the determination of free iodine associated with tellurous acid may be accomplished with a fair degree of accuracy provided the solution be cold and dilute, and the final reaction secured by adding the thiosulphate in slight excess and restoring the color permanently by standard iodine. Even under the most favorable conditions the tellurous acid is somewhat acted upon by sodium thiosulphate even before the free iodine is entirely bleached and the reaction in the reverse titration by standard

* Jour. Chem. Soc., 1891, pp. 58, 238.

iodine is slow in coming, though finally definite; but if the solution is hot the thiosulphate precipitates tellurium in flocky condition.

The excessive action of the iodide suggested the substitution of potassium bromide—an agent which proved of value in reducing arsenic acid as described in a recent paper from this laboratory—and, the preliminary experimentation proving to be encouraging we set about the preparation of telluric acid of definitely known strength. We weighed out accurately tellurous oxide, prepared by oxidizing presumably pure crystallized tellurium with nitric acid and igniting the product at a low red heat, dissolved the weighed oxide in a few cubic centimeters of a strong solution of potassium hydroxide, precipitated the tellurous acid by the careful addition of dilute sulphuric acid, and dissolved the precipitate in 10 cm^3 of sulphuric acid of half-strength. The solution thus obtained was treated with potassium permanganate in excess, the manganic oxide and the excess of permanganate were bleached by oxalic acid added to the hot solution, and the excess of oxalic acid was destroyed by the addition of a dilute solution of the permanganate until the faintest possible blush of color appeared. For the experiments involving the treatment of the larger amounts of tellurium every preparation was made individually in the manner described; for the experiments with smaller amounts a single preparation was made and the solution thus obtained was diluted to a half liter and portions of this standard solution were drawn from a burette as occasion required.

The equivalent of the so-called element tellurium is, as Brauner has shown* so variable with the mode of determining that constant and the preparation of material that we employed a preparation of tellurous oxide which had been tested as to its equivalent weight by Brauner's excellent method of oxidation by potassium permanganate. The results of these tests are recorded in the accompanying table. In series I the alkaline solution of the oxide was diluted to 100 cm^3 and oxidation was effected in it by standard permanganate added in excess. Sulphuric acid of half-strength was added to neutralization and then 5 cm^3 more, the liquid was heated, a solution of oxalic acid of known value was introduced to an amount slightly in excess of that needed to destroy the manganic oxide and excess of permanganate, and the surplus of oxalic acid was removed by standard permanganate. In series II the alkaline solution of the oxide was neutralized with dilute sulphuric acid and 1 cm^3 of sulphuric acid of half-strength was

* Jour. Chem. Soc., 1889, 382.

added. The oxidation was accomplished from this point exactly as in series I, the only difference being that it took place in the presence of a slight excess sulphuric acid instead of in alkaline solution. The permanganate used in both series was standardized ultimately against lead oxalate.

SERIES I.

TeO_2 taken. grm.	Oxygen required for oxidation.	Molecular weight of TeO_2 when O=16.	Mean.
0·1200	0·01202	159·7	158·88
0·0783	0·00785	159·6	
0·0931	0·00940	158·7	
0·1100	0·01119	158·	
0·0904	0·00909	159·5	
0·1065	0·01078	157·8	

SERIES II.

0·0910	0·00935	159·2	159.03
0·0910	0·00910	159·9	
0·0911	0·00924	157·7	
0·0913	0·00915	159·6	
0·0912	0·00915	159·4	
0·0914	0·00923	158·4	

The mean value of these determinations assigns to the tellurous oxide which we employed a molecular weight of about 159 and to the element tellurium an atomic weight of 127, when oxygen is 16. Brauner advocates the application of a correction made necessary by the excessive decomposition of the permanganate in the oxidation; but inasmuch as the oxidation in series I took place in alkaline solution under conditions in which we have no absolute proof that unused oxygen is liberated to any considerable degree from the permanganate, while in series II, the excess of sulphuric acid was purposely restricted to the lowest limit—the sulphuric acid having been shown in a previous paper from this laboratory* to be the chief agent in inducing the excessive decomposition of the permanganate—we incline, provisionally at least, to accept in this case the result of the analysis without correction.

In the test experiments the telluric acid, prepared in the manner described, was introduced into the apparatus for distillation with 3 grms. of potassium bromide, care being taken to insure in the 50 cm^3 or more of liquid the presence of 10 cm^3 of sulphuric acid of half strength. A current of carbon dioxide was passed through the apparatus, the solution was boiled to set free the bromine which was absorbed in

* Gooch and Danner, this Journal, xliv, 301.

potassium iodide and estimated by standard sodium thiosulphate. In handling the larger amounts of tellurium we found it desirable to make the preparation of the telluric acid in the distilling flask and to boil out the oxygen and ozone set free in the preparation before proceeding with the operation. The apparatus which we used consisted of a Voit's gas-washing flask, with sealed-in inlet tube and ground-in outlet tube, used as the distillation flask, to which was joined by a sealed joint the inlet tube of a Drexel washing bottle to the outlet tube of which was sealed a Will and Varrentrapp absorption apparatus. The washing bottle and attached bulbs contained a solution of 3 grams of potassium iodide and the former was kept cool by standing it during the distillation in a vessel of cold water. The absorption of the bromine took place almost entirely in the bottle, only traces of iodine being set free in the bulbs. The results of our experiments are recorded in the accompanying statement; Te=127, O=16.

	Initial volume. cm^3.	Final volume. cm^3.	TeO_2 taken. grm.	TeO_2 found. grm.	Error. grm.
(1)	50	20	0·0102	0·0098	0·0004 —
(2)	50	20	0·0102	0·0099	0·0003 —
(3)	50	20	0·0102	0·0098	0·0004 —
(4)	50	20	0·0102	0·0098	0·0004 —
(5)	100	40	0·1000	0·0994	0·0006 —
(6)	80	40	0·1001	0·1001	0·0000
(7)	100	20	0·1002	0·1001	0·0001 —
(8)	50	20	0·1000	0·1003	0·0003 +
(9)	50	25	0·5011	0·5008	0·0003 —
(10)	50	25	0·5002	0·5006	0·0004 +
(11)	50	25	0·5000	0·4998	0·0002 —
(12)	50	20	0·5000	0·4994	0·0006 —

The results of experiment agree fairly well with one another and with theory based upon the assumption that the atomic weight of the tellurium which we employed was 127. It is evident that the reducing action of the hydrobromic acid developed in the distillation is regular and that that agent is well adapted to the reduction of telluric acid to tellurous acid. The formation of tellurium tetrabromide in the concentrated acid liquid makes it impossible to tell by the color when all the bromine has been distilled, but the evidence of the experiments goes to show that the boiling of the liquid from a volume of 50 cm^3 to 25 cm^3 is sufficient, while concentration from 100 cm^3 to 20 cm^3 apparently does no harm.

ART. LIII.—*Resonance Analysis of Alternating Currents;**
by M. I. PUPIN, Ph.D., Columbia College.

I. *Introduction.*

THE presence of upper harmonics in an alternating current wave is a fact which deserves careful consideration both on account of the purely scientific interest which is attached to it, and also on account of the technical bearing of electrical resonance upon the construction of conductors possessing appreciable distributed capacity.

That alternating current and electromotive force waves of a very great variety of forms can be produced by properly designing the pole-pieces of the field magnet, and the iron core of the armature of an alternator is a fact nearly as old as the discovery of electromagnetic induction. Fully as old is also the knowledge that a great variety of alternating current and electromotive force waves can be obtained by the induction of an intermittent current.

A careful investigation of these waves was first made more than forty years ago by Lenz† and Koosen,‡ who employed alternators with iron in the armature. They plotted these waves from the instantaneous values of current and electromotive force obtained by means of the now well-known *revolving sliding contact.* Employing the same method of investigation Joubert§ showed in 1880 that the electromotive force wave obtained from an eight pole Siemens alternator without iron in the armature is very nearly a sine wave. *The method is now known as Joubert's method of the sliding contact.* The name "*indicator diagram*" has been applied to the wave curves of current and electromotive force obtained by Joubert's method, and very properly, I think, because they do very clearly indicate the action of alternating current apparatus.

Our knowledge of the action of alternating current apparatus has been extended quite considerably by these indicator diagrams.

Although much must be said in favor of the sliding contact method of obtaining indicator diagrams, yet it must be also acknowledged that the method is a very laborious and uninteresting process of investigation. Many attempts have been made to devise some optical or some automatic method, but

* Read before the Annual Meeting of the American Institute of Electrical Engineers at Philadelphia, May 17th, 1894.

† Pogg. Ann. lxxvi, p. 494, 1849; xcii, p. 128, 1854.

‡ Ibid., lxxxvii, p. 386, 1852.

§ Comptes Rendus, vol. xci, p. 161, 1880; Ann. de l'école super. 10, p. 131, 1881.

with little success. There is another reason why a new method of studying alternating current waves seems desirable. It is this: the method of sliding contact is not sufficiently sensitive to detect small deviations from a true sine wave, and consequently it is not capable of following up the causes of these deviations, when the effects seem to be absent. For instance, the primary current of a transformer can differ very much from a true sine form when the secondary circuit is open, but when a large current is flowing through an approximately non-self-inductive secondary circuit, then the primary current can be made to differ inappreciably from a true sine wave. *The question arises now, what becomes of these causes when the secondary carries a heavy non-self-inductive load?*

This question is of deep scientific interest; it is also of considerable technical importance. For, if these causes are present at all loads and only hidden by the principal wave, then, considering that these hidden small causes can produce large effects when conditions favoring resonance arise, it is evident that they must be carefully watched and guarded against in the construction of lines possessing appreciable distributed capacity. I do not think that indicator diagrams obtained by the method of sliding contact are capable of giving a definite answer to this important question.

The method of analyzing alternating current waves by electrical resonance which I employed in the following investigation was suggested by me a year ago.* It is the object of this paper to describe this method at some length and to illustrate, by some of the more definite results so far obtained and relating principally to the causes which produce distortions in simple harmonic waves, the simplicity, sensitiveness, and reliability of the method. I shall also point out that this method of resonance analysis works quite satisfactorily even in those cases, alluded to above, where the sliding contact method would in all probability fail to detect any distortion whatever.

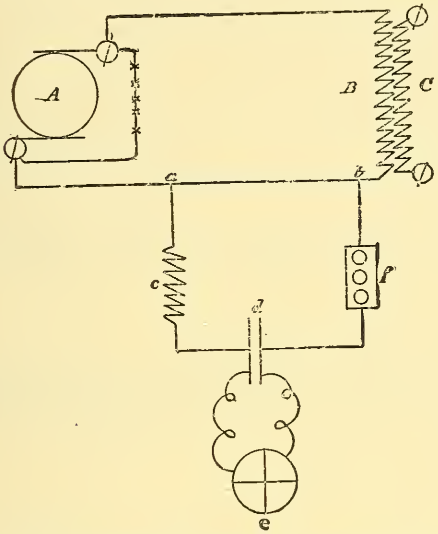
II. *Description of the Method.*

Consider the following arrangement of circuits:—The non-self-inductive resistance, *ab*, fig. 1[a], is inserted in the circuit of an alternator A and the primary B of a transformer. In shunt with *ab* is a circuit *acdb* consisting of an inertia coil *c* of large number of turns of copper wire of low resistance, about 10 ohms, but containing no iron, and a mica condenser *d* divided into subdivisions ranging from ·001 *M.F.* up. In shunt with the condenser *d* is an electrostatic voltmeter *e*. The self-induction of the coil *c* can be varied by throwing a larger or a smal-

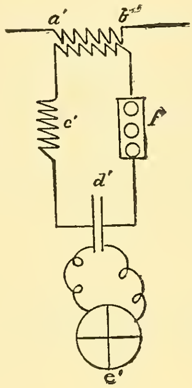
* M. I. Pupin, "Electrical Oscillations of low frequency and their Resonance," this Journal, vol. xlv, p. 429, May, 1893.

ler number of its sections into the circuit. The resistance can be varied by a rheostat *f*. Suppose now that the self-induction of *c* is kept constant, and that the capacity of the condenser *d* is gradually increased from zero up. Whenever a capacity has been reached which with the self-induction of the circuit *acdfb*

1a.



1b.



produces resonance with one of the harmonics in the main circuit then the resonant rise of potential will produce a large deflection in the voltmeter. In this manner all the harmonics which are present in the current of the main circuit can be detected in the course of a few minutes. If the resonator circuit *acdfb* is placed in shunt with the non-self-inductive circuit *g* (this circuit is represented in fig. 1a by a line beaded with asterisks and running from one pole of the alternator to the other) consisting of a bank of incandescent lamps then the harmonics of the impressed electromotive force can be detected in the same manner. The ratio of the amplitudes of these harmonics to that of the fundamental can also be determined by this method, *if desirable*, provided the conditions of the experiment are properly arranged. For let the current in the main circuit be

$$x = a_1 \sin pt + a_3 \sin 3pt + \ldots\ldots + a_{2a+1} \sin(2\alpha+1)pt + \ldots$$

then the drop between *a* and *b* can be represented by

$$e = b_1 \sin pt + \ldots\ldots + b_{2a+1} \sin(2\alpha+1)pt + \ldots$$

$$\text{where } b_{2a+1} = a_{2a+1} r$$

and r = ohmic resistance between *a* and *b*. Denoting now by :

L the self-induction of the resonator *acdfba*
R the resistance " " "
C the capacity " " "

then it can be easily shown* that the current in the resonator will be:

$$y=\sum_{0}^{\infty} \frac{b_{2a+1}}{\sqrt{(2\alpha+1)^2p^2\left\{\frac{1}{(2\alpha+1)^2p^2C}+L\right\}^2+R^2}} \sin\left[(2\alpha+1)pt+\varphi_{2a+1}\right]$$

If, therefore, the capacity C is adjusted in such a way that

$$\frac{1}{(2\alpha+1)^2p^2C}-L=0$$

then the circiut will be in resonance with the harmonic of frequency $\frac{(2a+1)p}{2\pi}$; and if L is sufficiently large and R sufficiently small (two conditions which are very easily fulfilled) the current y will in general to within a small fraction of a per cent be given by

$$y=\frac{b_{2a+1}}{R}\sin(2\alpha+1)pt$$

The amplitude of the potential difference in the condenser which is measured by the voltmeter e is then given by

$$P_{2a+1}=\frac{(2\alpha+1)pL}{R}b_{2a+1}$$

In the same way we obtain for the fundamental frequency

$$P_1=\frac{pL}{R}b_1$$

Hence

$$\frac{P_{2a+1}}{P_1}=(2\alpha+1)\frac{b_{2a+1}}{b_1}$$

This gives the ratio of the amplitude a_{2a+1} of the harmonic of frequency $\frac{(2a+1)p}{2\pi}$ to that of the fundamental. Let $a=2$, then,

$$\frac{1}{5}\frac{P_5}{P_1}=\frac{b_5}{b_1}=\frac{a_5}{a_1}$$

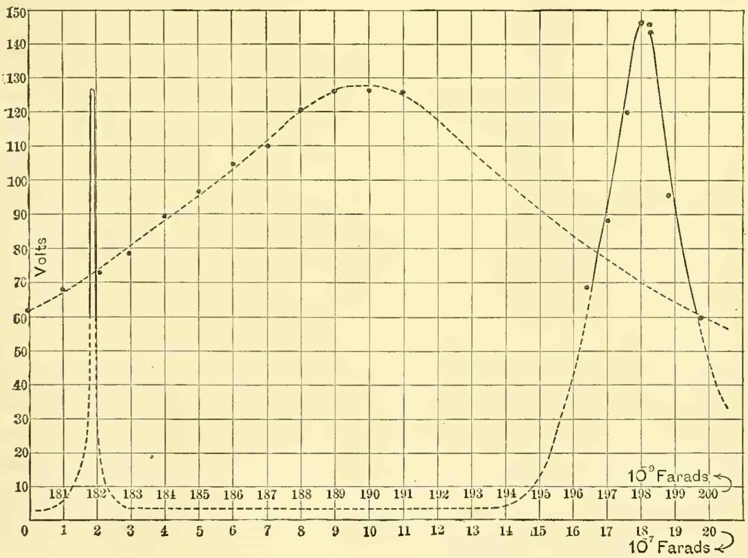
The voltmeter readings which give P_5 and P_1 magnify that ratio five times, in the case of the fifth harmonic, and it can be easily seen that a similar relation holds true for other harmonics. This is a very desirable feature of the method, considering that the amplitudes of the upper harmonics are generally small in comparison to the amplitude of the fundamental, especially when the secondary circuit of the transformer carries a load.

* For further information see author's paper cited above.

When quantitatively very accurate results are desired then a low resistance, say one ohm, should be used for the section *ab* and an electrometer capable of giving a large deflection for ten volts.

The principal interest, however, *in the study of the distortion of alternating current waves, is centered* not so much in the exact ratio of the amplitudes of these harmonics to the amplitude of the fundamental wave, as it is *in the causes producing these harmonics and the conditions which modify the effects of these causes.* Hence a quantitatively less accurate arrangement will do, provided that it is very sensitive, simple, and easily manageable. Such an arrangement is given, fig. 1[b]. It differs from that given in fig. 1[a] in the substitution of an air core transformer coil *a′b′* for the non-self-inductive resistance *ab*. The secondary of this coil forms a part of the resonator circuit. For every harmonic of the inducing current we shall have a harmonic electromotive force of the same frequency in the resonant circuit. By varying the capacity in the resonator and watching the voltmeter needle, we can tell by the deflection of the needle, whenever we have reached the capacity which with the self-induction of the resonator brings this circuit into resonance with one of the harmonics. A reference to fig. 2 will explain this more clearly.

2.



In this figure the lower horizontal row of figures refers to the two-peaked curve; the upper row refers to the dotted flat-peaked curve. The vertical row denotes the voltmeter readings in volts. Consider now the two-peaked curve. It expresses the law of variation of the voltmeter readings when the capacity of the resonator circuit is varied from 0 to 2 microfarads, the self-induction being kept constant. The readings are recorded in Table I.

TABLE I.

Capacity of the condenser in microfarads.	Voltmeter readings in volts.
·18	62
·181	68
·182	73·5
·183	79
·184	89
·185	96
·186	104
·187	110
·188	120
·189	126
·190	127
·191	125
·194	99
·198	71
·202	very low
1·65	69
1·70	89
1·75	120
1·80	146
1·808	146
1·817	145
1·897	96
1·976	60

The voltmeter employed in these experiments was a Sir William Thomson's multicellular voltmeter with a range from 60 to 240 volts. The curve was obtained from a 10 H. P. Fort Wayne 8 pole alternator with a smooth core armature feeding a 5 K. W. Stanley transformer (closed magnetic circuit), the secondary circuit being open. It is seen that resonance took place at ·190 M. F. and 1·8 M. F. The capacity of the inertia coil c', fig. 1^b and of the voltmeter as gathered from all experimental data was about ·011 M. F., so that the real capacities at which resonance took place were ·201 M. F. and 1·81 M. F., that is in a ratio to each other as $1:3^2$. It will be seen, however, that a very accurate knowledge of capacity is not required in the experiments described in this paper.

The frequencies detected by the two-peaked curve, which I shall call the *resonance diagram*, were therefore the fundamental and the 1st odd harmonic, that is the harmonic of three times the frequency of the fundamental. The resonance diagram has, of course, as many peaks as there are harmonics in the inducing current.* The dotted curve (flat-peaked) in fig. 2 was plotted on an enlarged scale from the readings taken in detecting the first harmonic represented by the sharp peak of the resonance diagram, and represents this peak spread out, so as to show how the various readings fit into a well defined and symmetrical curve such as required by theory. It also shows that a condenser of small subdivisions should be employed in detecting higher harmonics.

III. *Description of Experiments.*

The *resonance diagram* obtained by the method of fig. 1[b] gives the number of harmonics which are present in the inducing current. It does not give the exact value of the amplitudes of these harmonics. It would be somewhat premature to discuss the theory of the resonance diagram obtained by this arrangement and to show how the ratio of the amplitudes of the harmonics to that of the fundamental frequency in the inducing current, that is the exact color of this current, could be calculated from the ratio of the height of the peaks in the resonance diagram. Suffice it for the present to mention only that the peaks of this diagram represent the amplitudes of the harmonics magnified about proportionally to the square of the frequency. For instance, the resonance diagram of fig. 2 tells us that the amplitude of the 1st odd harmonic in the inducing current is about one-ninth of the amplitude of the fundamental. The determination of the exact value of this ratio was not the object of the following experiments. *Their aim was to detect the presence of harmonics, to trace their origin and to study their variation with the variation of the load, and of other variable elements of the circuit on which these harmonics seem to depend.*

Preliminary Tests.

In order to form an estimate in how far the experimental data obtained by the arrangement of fig. 1[b] agreed with the theory the following tests were applied:

*I have never detected an even harmonic in alternating current waves produced by ordinary commercial alternating current apparatus, and conclude, therefore, that these harmonics do not exist in such cases. For asymmetrical machines this would obviously not hold true. Alternators with slotted armatures give waves in which all the odd harmonics up to the harmonic of nine times the frequency of the fundamental can be detected. As a rule the first odd harmonic is the strongest.

a. *Study of the damping effect of the dielectric in the condenser.*

Let L = self-induction of the resonator circuit.
R = resistance of the resonator circuit.
P = amplitude of the difference of potential in the condenser when point of resonance has been reached for a given frequency.
E = amplitude of impressed electromotive force in the resonant circuit.

then according to theory

$$P = \frac{pL}{R} E.$$

Hence if R alone is varied P will vary also but in such a way that

$$P\,R = \text{constant.}$$

That is to say if we vary the resistance of a resonant circuit and tabulate the voltmeter deflection for every particular resistance and then plot a curve taking the resistance for abscissae and the voltmeter readings for ordinates we should, according to theory, obtain an equilateral hyperbola. Curves II and III, fig. 3, were obtained in this manner, the frequency employed was that of the 10 H. P. alternator, that is 130 p. p. s.

3.

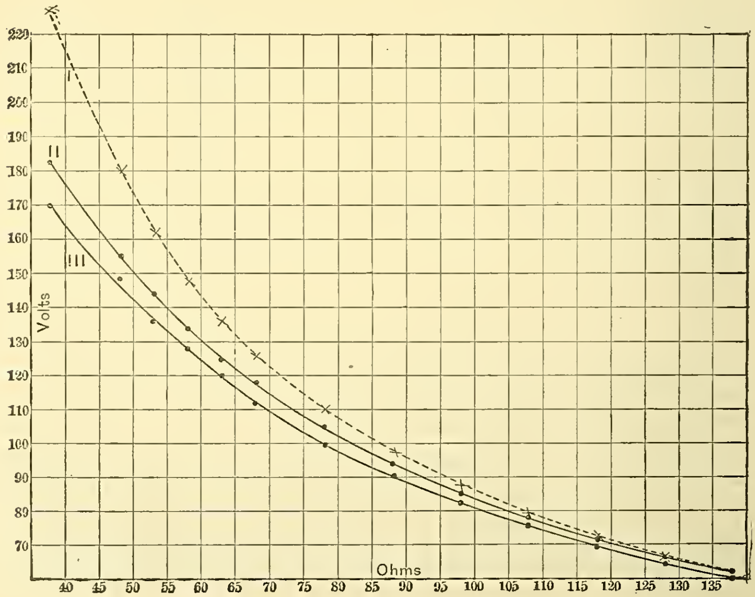


TABLE II.

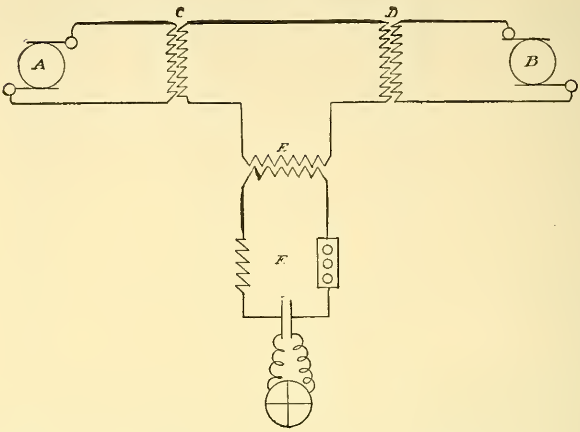
Resistance in ohms.	Voltmeter readings with a mica condenser.	Voltmeter readings with a paraffin condenser.	Theoretical value of voltmeter readings.
38	183	170	225·6
48	155	148	178·6
53	144	137	161·8
58	134	128	147·8
63	125	120	136
68	118	113	126
78	105	101	110
88	94	91	97·4
98	85	83	87·5
108	78	76	79·4
118	72·5	70	72·6
128	67	65	65·5
138	62	60	60

The experimental data from which these curves were plotted are given in Table II. Curve II was plotted from voltmeter readings obtained with a mica condenser, Curve III represents the corresponding readings obtained with a paraffin condenser and given in the third column of Table II. Curve I represents the theoretical curve, that is the curve which would have been obtained if the law of variation of the voltmeter readings with the resistance had been the same throughout as it was at low readings. On account of the damping effect due to dielectric viscosity in the condenser a deviation from the above mentioned hyperbolic relation was of course expected, but it was quite a pleasant surprise to find a perfect regularity of these deviations. These curves indicate a rapid increase in the dielectric damping with the voltage and also the superiority of mica to paraffin, especially at higher voltages. They also suggest that at low voltages and frequencies over a hundred periods per second this difference between the two substances becomes less and less marked. It was also found in a similar way that the damping effect of the magnetic viscosity of iron is small at low magnetizations, such, for instance, as would be produced by a telephonic current in a telephone receiver, and at frequencies which are well within the range of higher telephonic frequencies, say 750 periods per second.

Similar curves and similar results were obtained with higher harmonics. These experimental tests show, therefore, that the relative values of the amplitudes of the harmonics to that of the fundamental frequency are not seriously modified by the dielectric damping of the condensers, especially when one operates with moderate voltages as was the case in the following experiments.

b. Second test of the resonator indications.

4.



This test is represented graphically by diagram fig. 4. Two transformers C and D had their secondaries connected in series. The primary of the air-core transformer E formed part of their circuit. The secondary of the transformer E was a part of the resonator F. The transformer C, a Stanley 5 K.W. (closed magnetic circuit), was fed by the 10 H. P. alternator mentioned above (130 p. p. s.), the transformer D of induction coil type with a cylindrical core of fine iron wire was fed by a 1 H. P. alternator with slotted armature (278 p. p. s.) Both alternators were run simultaneously at full excitation. First, the primary circuit of the large alternator was broken, so that the current in the circuit CDE was due to the action of the small machine alone. The resonator detected a resonant rise of 240 volts at capacity ·407 M. F. and another of 150 volts at capacity ·044 M. F. These were evidently the fundamental and the first odd harmonic. Then the circuit of the small machine was broken and that of the large machine closed, so that the current in the resonator was due to the action of the large machine alone. The resonator detected a resonant rise of 220·1 volts at capacity 1·78 M. F. This corresponded to the fundamental frequency (130 p. p. s.) of the large machine. Finally both circuits were closed, so that the current in the resonator was due to the simultaneous action of the two machines. The same resonant rises of potential were detected by the resonator and at the same capacities as before, in perfect agreement with theory.

This experiment afforded another opportunity of testing the theory which underlies this resonance method of studying the wave curves of current and electromotive force. It is this: If two or more electromotive forces of different frequencies are impressed upon the resonator circuit and their resonant rises of potential are determined for a given resistance in this circuit, then according to theory the ratio of these rises should remain the same for all other resistances within the limits within which the periodicity of the circuit is practically independent of the ohmic resistance. Accordingly, the resistance of the resonator F, fig. 4, was varied gradually from 100 to 250 ohms (the self-induction of inertia coil in the resonator circuit was about ·75 Henrys) and the resonant rises of potential produced by the fundamental frequencies of the two machines (130 and 278 p. p. s.) were carefully determined for each particular resistance. The ratio of these rises remained constant to within five per cent but the deviations were now in one direction and now in the other. They were undoubtedly due to the variation in the excitation and the speed of the small machine, both of which depended on the potential of the electric mains of the College plant which, of course, could not be kept very constant for so long an interval of time as is necessary for this experiment, which was about 15 minutes.

These preliminary experimental tests demonstrate clearly that a resonator of the type given in fig. 1^b is quite capable of detecting all the frequencies that may exist in an alternating current wave, that its indications are in good agreement with the theory as far as the fundamental frequency is concerned and that it gives a fairly approximate idea of the relative strength of the harmonics.

(To be continued.)

Art. LIV.—*On the Origin of Bitumens. A Retrospect;* by S. F. Peckham.

It is now nearly thirty years since I first directed my attention to this subject, and during this long period of time the discussion of the question has proceeded along the same lines that were quite clearly outlined in 1868.*

The chemical theories, notwithstanding the ability with which Mendeljeff treated this aspect of the question in 1877,† are at present receiving very little attention and will be passed by without further notice. In this connection may properly

* Proc. American Phil. Soc., x, 445; Rep. Geol. Sur. Cal., Geology, II; Appendix, pp. 73–90.

† Bull. Soc. Chem. de Paris, i, 501; Buer. d. Deut. Chem. Ges., 1877, p. 229; Wag. Ber., 1877, p. 1037.

be included the idea that polymerization has played any important part in the formation of natural bitumens; an idea that has lately been so ably discussed by Prof. Henry Wurtz.*

The organic origin of bitumens may therefore at present be accepted as practically undisputed. The question then recurs, are bitumens distillates or are they indigenous in the rock formations in which they are found—in other words, have they been produced *in situ?*

Twelve years ago, when preparing the essay on the Origin of Bitumens which forms a part of my report to the 10th Census of the United States, I wrote, that the derivation of bitumens had not in my judgment been uniform. That opinion took form in my own mind as a growth which was determined by many years of thought and a wide experience. This experience began with a very careful study of all the phenomena attending the occurrence of bitumen in Southern California during 1865–6, and the preparation of a report upon the same for the Geological Survey of California. I left California fully convinced that petroleum was of animal origin and formed *in situ.* Soon after I had returned to the Atlantic coast, I met Dr. J. S. Newberry in his office in New York and with Baron v. Koschkull held a long conversation upon Russian and American petroleum and incidentally upon their origin. Dr. Newberry then for the first time awakened my interest in the distillation hypothesis and based his argument upon the results that had been obtained in technical operations in Ohio in the distillation of coals and shales prior to the discovery of petroleum in Pennsylvania. The argument is all to be found in his celebrated paper on "The Rock Oils of Ohio";† but no one could resist the persuasive eloquence with which he developed the idea of that vast Sargossa sea that, gathered in the Devonian ocean, produced the Devonian shales from which the petroleum of eastern Ohio and western Pennsylvania was distilled. His speculation stopped at this point, with the idea that the oils were distillates.

Later, I was for a time in frequent intercourse with Cyrus M. Warren, whom we all remember with so much affection. He described to me in great detail the experiments he had made by saponifying menhaden oil with lime and distilling the lime soap. The amount employed was several tons, and he obtained the distillate in such quantity that a part was refined into illuminating oil, and the remainder was fractionated in Warren's apparatus. In fact, the experiment was made for technical purposes: but the results are only of

* Engineering, various dates.

† Ohio Agricultural Report, 1859, p. 605.

interest since the discovery of petroleum, for scientific purposes. This distillation yielded the hydrides of the monatomic alcohol radicals, and benzole and its homologues.

Later, Luther Atwood constructed a sort of kiln in the form of a tobacco pipe. The bowl held several tons of Cannelton cannel coal. A fire was kindled on top of the coal and the draft was urged by a jet of steam. In this apparatus distillation proceeded of necessity at the lowest possible temperature, the products of combustion expelling all the volatile matter as the combustion proceeded downward. The distillates more nearly resembled petroleum than any that had been produced by methods of distillation previously employed, apparently, *because* the distillation proceeded at the lowest possible temperature.

While this subject engrossed my thoughts I was led to consider the occurrence of bitumen in veins. I read reports on Grahamite and Albertite and Cuban asphalt and they all seemed to me to be distillates that were injected into crevices that resulted from an upheaval of the crust of the earth. At that time I had never visited the locality where Grahamite occurs, but I had seen the masses of asphaltum of vast extent that occur on the Pacific coast.* No one who has seen them doubts that they were injected into earthquake crevices. I made this question the subject of a communication to this Journal and years after, I had the pleasure of a careful inspection of the locality in which the Grahamite was obtained and talked with the men who mined it out. I saw nothing there that led me to question for an instant the relation of the Grahamite and Albertite veins to the other veins of bitumen and also to petroleum.

But distillation requires heat and the source of heat occasionally occupied my thoughts. No satisfactory conclusion was reached upon this point until one afternoon I met two of the men who helped drill Jonathan Watson's deep well. They told me their story all unconscious of what it meant to me. They said they drilled through all of the oil sands and struck the soapstone (Devonian shale) and kept on with the intention of reaching the limestone (corniferous limestone) which they believed they struck at the bottom of the well, just as, for some reason, the work was suspended and never resumed. They said the "soapstone" became harder as they went down and was redder in color, in fact had been burnt like brick. Their language at once recalled the metamorphosed shales that are so abundant in Santa Barbara (now Ventura) county, Cal., that are often as sonorous as porcelain. One day not long after, to wile away a few moments while waiting for a friend,

* This Journal, II, xlviii, p. 362; Am. Journal of Gas Lighting, xi, p. 164.

I took from a library shelf Prof. James Hall's report on The Geology of New York, and glancing at the introduction, my eye fell upon his clear description of the trend of the currents in the Silurian ocean.* First came Newberry's Sargossa Sea, which formed, when buried, one thousand feet of shale, so filled with fucoids that where the shales outcrop at Erie, Pa., it is impossible to obtain a piece of appreciable size that does not contain a seaweed. On visiting Erie and talking the matter over, I found that, at the time the distillations of coal were made in southern Ohio with which Dr. Newberry was familiar, attempts had also been made to utilize the Erie shale as a source of illuminating oil, and fifty gallons of distillate to the ton had been obtained.

The idea of metamorphism as a source of heat grew apace —heat, steam and pressure and unlimited quantities—cubic miles—of material on which to act. I had been familiar with the anthracite of Rhode Island from boyhood, and with the crystalline schists of eastern New England. I had been down in the coal mine at Portsmouth on the island of Rhode Island, and had seen the immense chambers from which the coal had been mined. All traces of bedding had disappeared, and the coal, almost graphite, had been seggregated into masses almost spherical and connected only by a thread, by which the miners traced the coal from one mass to another.

At the Palisades the molten interior mass has punctured the surface. Through eastern Pennsylvania the coal is metamorphosed into anthracite. At Saint Mary's, where the Philadelphia and Erie railroad crosses the summit of the Alleghanies, the coal is semi-anthracite. In the most easterly county of Pennsylvania in which petroleum is obtained—McKean county —the petroleum occurs at a depth of two thousand feet under a pressure estimated at four thousand pounds to the square inch and filled with paraffine, just as it ought to be if produced by metamorphism. Farther west, the petroleum becomes lighter, until, at Smith's Ferry, it is almost burning oil in its natural state. The products of distillation are all present in proper sequence along the entire line from Point Gaspè to Lookout Mt., and the porous sand bars and pebbly riffles, formed by the currents of the primeval ocean, are now filled with the oil because they afford a receptacle adequate to receive and store the vast accumulations of distillate.

Now, while I have received many very pleasant and favorable comments upon the provisional hypothesis which I ventured to propose in my Report, to the 10th Census, I have for some time had a critic who seems to partly disagree with me.†

* Nat. Hist. New York, Paleontology, iii, 45–60.

† Rep. 10th Census U. S., x, p. 59. This Journal, 1885 (?)

My friend, Prof. Orton, has in the kindest manner shown that in Ohio there is no evidence that any rocks are changed by metamorphic action. While I do not for a moment think Prof. Orton ever intended to be unjust to any one, I do think he has hardly given either Dr. Newberry or myself the position that belongs to us.*

Wise men hold any theory tentatively, no matter what it may be. When Dr. Newberry, in 1859, proposed to account for the origin of petroleum by considering it to be a distillate, very little was known concerning the occurrence of rock oil compared with our present knowledge. When I prepared my essay for the Census Report the Trenton limestone was almost an unknown factor in the production of petroleum; yet, enough was known concerning its occurrence with oil in the cavities of its fossils, to lead Dr. T. Sterry Hunt, in the same manner as other local observers; to conclude that all petroleum originated in limestone, *in situ*, and that the Trenton limestone was *par excellence* the home of petroleum.† As I have said before, when I left California in 1865, with the positiveness born of observation within a limited horizon, I was ready to declare that petroleum was formed by the decomposition of fossil animals. I first wrote the paper read at the meeting of the National Academy of Sciences at Northampton, in 1867, maintaining that narrow view; but I afterwards included vegetable remains as a precaution.‡ It has been many times demonstrated that each observer may be correct as to his own locality and wrong as to others; yet, when the consensus of opinion has been reached, the symposium may have presented a many-sided question from many points of observation, and truth may be discerned in the midst.

I therefore repeat, that in my judgment the derivation of petroleum has not been uniform. Let it be admitted that the earliest horizon of petroleum is the Trenton Limestone, in which petroleum is indigenous, having been formed by some peculiar sort of decomposition from animal remains at the bottom of a deep, excessively hot, and saline sea. If any one can prove that the Trenton Limestone extends beneath eastern Ohio and western Pennsylvania, lying beneath the Devonian shales, I am not prepared to dispute the assertion that the different varieties of petroleum found in that region have been fractionally distilled from the content of the limestone rocks, buried from three to four thousand feet beneath the present surface. I am confident that the heat required was to be found in the gradual dying out of the heated area which involved the Appalachian System. Accompanying this distillation, and a

* Rep. Geol. Surv. Ohio, vi, p. 60–83.

† This Journal, II, xxxv, p. 157–168; xlvi, p. 361. ‡ See note 1.

consequence of it, was an immense accumulation of gas. Some of it escaped into the air during the upheaval that produced the White Oak anticlinal of West Virginia, including the Grahamite vein near by, and some of it remained enclosed. There is little reason to doubt, that whether or no the oil found north of the Ohio and Kanawha rivers is distilled from the Trenton Limestones, the oils of eastern Kentucky have been. Therefore, admitting that Prof. Orton is correct in his conclusions that the sporangites of the shales are a source of oil, and that the Trenton Limestone still contains petroleum *in situ*, I still maintain my thesis, that the metamorphic action to which the Appalachian system has been subjected furnished the heat that has fractionally distilled all of the different varieties of Appalachian petroleum, either from their original source in the Trenton Limestone or through the decomposition of the shales. And further, that any consideration of the chemical constitution of these oils must show, that the oils found east of Central Ohio and north of the Ohio and Kanawha rivers are nearly pure paraffines, and that the western Ohio and Indiana oils—the Trenton Limestone oils—are mainly paraffines containing sulphur compounds from which the other oils are free; and still further, that the oils of southeastern Kentucky and Tennessee partake of the characteristics of both the Appalachian and Trenton oils.

I have lately returned to the region in Ventura County, Cal., that I visited in 1865, and that is so rich in all the phenomena that attends the occurrence of bitumen. During the years that have intervened between these visits, large quantities of petroleum have been brought to the surface, much of which has been burned as fuel. The refining of these oils still presents many interesting and involved problems. Of chief scientific importance is the discovery, lately made, and which I discussed in the paper that I read at the Mid-Winter Fair Congress of Chemists, of the manner in which the nitrogen content of these oils is chemically combined with the hydrocarbons.*

While this subject is of great interest to chemistry and technology, it is of supreme interest as related to the study of the origin of bitumens, and it is with some satisfaction that I note the sign boards that I have set up along the path that led to this discovery. While Warren produced the paraffines from menhaden oil soap, Dippel had a hundred years before produced pyridin by the destructive distillation of the gelatine of bones and the tissue of highly organized animals; but nowhere in nature had Dippel's oil been discovered until within the last two years it has been extracted from all the different varieties of bitumen found in Ventura county and its vicinity and from their distillates. These bitumens occur

*This Journal, Oct., 1894

in vast quantities in rocks that are filled with the remains of the marine mammalia that swarmed in the Miocene Ocean.*

Shall we apply Hunt's theory, and regard these wonderful compounds that appear nowhere else in nature as the product of some sort of ill-defined, inexplicable decomposition to which the animal remains have been subjected; or shall we believe that the metamorphic action which has converted into gneiss the sandstones and shales that flank the low mountains of that region, which gradually passes by insensible degrees into the granite core of the same hills in which the bitumens occur, has distilled the mixture of benzoles and Dippel's oil of which they apparently consist? To my mind the latter hypothesis alone conforms to the experience of technology and the demands of a logical scientific enquiry.

I do not wish to enter here upon any intricate inquiry concerning the nature and origin of metamorphism. I would, however, note by the way, that in addition to that unknown quantity, the internal heat of the earth, the spontaneous generation of heat by chemical action within the influence of the atmosphere has played an important part in the metamorphosis of shales in the region in which the bitumens of Ventura county occur. Locally such action has often been very recent, while, at the same time, the major portion of it belongs to a very remote past. I do not consider it necessary to represent in terms of Fahrenheit's thermometer the temperature at which any particular sample of petroleum was produced, nor do I intend to produce the coke that resulted from the distillation. The coke, if there is any, is where the distillation left it. It is not possible to furnish the details of a natural process the conditions of which are unknown to us. Nor can we reason from the processes of technology, bounded as they are by time and space, to the infinity of nature, which it is impossible to imitate. In order to establish the hypothesis that anthracite was once bituminous coal, it is not required that the distilled gases, and possibly petroleum, shall be produced, nor that it be stated where they now are. Let it be constantly borne in mind that time has always entered into the operations of nature, in sufficient quantity, and that heat, steam and pressure have invaded immense areas of the crust of the earth through vast cycles of the infinite past and the vision becomes clear:

"For a thousand years in thy sight are but as yesterday when it is past, and a watch in the night."

University of Michigan, Ann Arbor, Michigan, July 12th, 1894.

* In the course of an afternoon ramble in one of the small cañons of the mountains on the south side of the Santa Clara Valley near Bardsdale, Ventura Co., Cal., portions of three whales' vertebræ were found, one of them quite perfect. Also in one mass of rock, three vertebræ were found in contact that appeared to be those of a saurian. Besides these were innumerable fragments of ribs and other bones, in a stratum about 18 in. in thickness.

Art. LV.—*A Simple Chronograph Pendulum;* by C. Barus.

To give time to the chronograph, a break-circuit chronometer or a seconds clock is usually employed. Frequently, however, one is not in possession of this elaborate apparatus, or it is not expedient to make use of it. The following simple mechanism by which an ordinary seconds pendulum is both kept in motion and made to record its oscillations on one or more chronographs sharply, may therefore merit description.

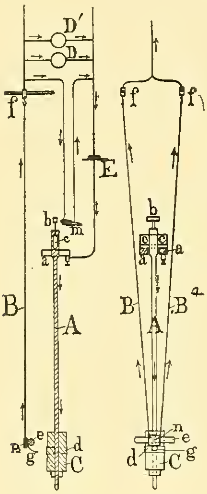


Fig. 1. Fig. 2

Figure 1 gives a sectional elevation of the device, figure 2 a side view with electric parts omitted. *A* is the seconds pendulum consisting of a light wooden rod (*A*) joining the heavy metallic bob *C* and the knife edge *c*. The latter is supported by the metallic plates *a*, and these and the bob are electrically connected. The top of the pendulum is surmounted by a soft iron armature *b*, actuated by the electromagnet *m* in the way presently to be described.

B is a longer and very much lighter pendulum, consisting of a flat bob *n* joined (bifilarly) by two very thin metallic wires (*B*, *B*) to the adjustable suspension *f f*. The bob *n* is prevented from oscillating toward the right by a rigid post *e*. A ribbon of platinum *d* is wrapped around the bob *C* and a quadrantal spring *g* of thin platinum foil projects from the bob *n* for the purpose of securing reliable electric contacts. The bob *n* consists of two small square parallel plates, between which the wires *B B* and the platinum strip *g* are clutched by a single central screw.

Current is obtained from batteries at *E* (two or more Leclanché cells) and circulates when the circuit is closed as shown by the arrows. *D*, *D′*, etc., are the chronographs to which time is to be given, these and the electromagnet *m* being joined in multiple arc.

The mode of action is easily intelligible. Whenever the circuit is closed by the bobs at *g d* a current passes through *m*, *D*, *D′*, etc.

Suppose the post *e* and the strip *g* to be removed, and the bobs *n* and *C* to be in inelastic contact. Then on moving *A* to the left, this pendulum will push the pendulum *B* in front of it because the *time of oscillation of n is greater.* There will therefore be a magnetic pull in *m* throughout this motion. Conversely when both pendulums having reached their extreme elongation begin to return to the right, the bob *C* will run away from the bob *n*, and hence there will be no magnetic pull in *m*. Since the bob *n* is very light as compared with *C*, the result of these unilateral impulses applied at the proper time at *b* is to keep up the motion of the pendulum *A*.

In practice however the bobs *n* and *C* are never inelastic; neither is it at all desirable to keep up the contact for so long a time. In other words the record made at *D* would be irregular from interferences and the batteries would soon run down. Therefore the bob *n* is hung so that it would meet *C* when the latter is virtually at the end of its elongation, and a stop *e* prevents *n* from swinging further towards the right. Furthermore the spring *g* causes *n* to be hurled off ballistically and the contact is now quite momentary. Indeed *n* is made flat and in falling against *e* there is *no rebound.* I have found it advantageous to surround *e* with an end of rubber hose, and also to surround the ends of the armature *b* in the same manner to prevent them from sticking to the electromagnet. Again the pendulum *B* is made to lean slightly against the stop *e*, a slide at *f* being provided for this purpose.

The records show that the time of contact does not reach 0·1 sec., and this is the result which I wish to communicate. It is desirable to use electromagnets of high resistance to prevent exhausting the battery, though I have run the pendulum for days continuously with such means as I possessed. The apparatus can easily be made symmetrical by placing a second electromagnet similar to *m*, on the other side of *b*. This would furnish another set of records differing by about half a second from the first set.

Washington, D. C.

Art. LVI.—*(1) On some new Methods of obtaining Platinochlorides. (2) Probable Existence of a Platinum Subchloride;* by M. Carey Lea.

The methods now in use for obtaining potassium platinochloride are: 1. Heating platinic chloride to 250–300° C. and treating with potassium chloride. 2. Passing sulphurous acid through a boiling solution of platinic chloride and treating with potassium chloride. To these older methods Thomsen has added: 3, treatment of potassium platinichloride with cuprous chloride.

All these have objections—With (1) it is not easy to obtain a uniform conversion. (2) requires to be very closely watched to catch the exact moment at which the change is complete. (3) is liable to a vexatious reverse action by which platinous salt is reconverted into platinic salt at the expense of the cupric chloride present. Thomsen mentions this danger as occurring in hot solutions. It probably depends however more on concentration than on temperature. The larger the proportion of cupric chloride present in any solution the greater the tendency to reversal. In one case a half liter of mother water containing platinous salt was set aside for spontaneous evaporation. In a few days large crystals of the red salt began to form, in a few days more instead of these increasing, there was not a crystal of the platinous salt left.

These objections led me to look for something different. I have found two methods, either of which gives good results.

First Method. Potassium Acid Sulphite.

Potassium platinic chloride is to be moderately heated with solution of the acid sulphite; convenient proportions are, platinum salt 12 grams, acid sulphite 9 grams, water 160^{cc}. The mixture can be placed over a hot water bath in a covered vessel and left to itself. The reduction takes about 10 to 12 hours and is known to be complete when the solution has a pure red color free from yellow. The cover is then removed and the liquid evaporated to the crystallizing point.

If, as may happen the red chloride and the other salts crystallize out together, it is best to redissolve them by heat in a small quantity of water saturated with potassium chloride. The red salt then crystallizes out first.

Second Method. Alkaline Hypophosphites.

By reason of its great reducing powers a very small proportion of alkaline hypophosphite is capable of converting the yellow platinum salt to the red; theoretically one part of hypophosphite should reduce nine or ten parts of platinum salt. We can hasten the operation somewhat by using an excess of hypophosphite, but then must work at a lower temperature. Both methods will be given.

In using an excess of hypophosphite it is convenient to take 10 grams of platinum salt, 2 grams or even more of potassium hypophosphite, and 600^{cc} of water. These are placed in a flask and very gently heated. The best temperature is 66° to 70° C.

There is a very easy way of obtaining this temperature and of keeping it perfectly constant for any length of time, by taking an ordinary water stove of the kind in which a chamber is surrounded on five sides by water. Such a stove is to be furnished with a Kekulé constant level, regulated to keep the water jacket half full. If now the heat is turned on so as to keep the water gently boiling, it will be found that solutions placed *on the top* maintain a perfectly steady temperature, varying from 55° to 72° C. according to the shape of the vessel, but constant for any one shape. The lowest temperature, about 55°, is obtained with an open, flat porcelain basin. It rises gradually as the shape of the vessel tends more to check evaporation. When a liter flask has about 2 inches of solution the temperature will remain steady at about 66° and this temperature is very suitable for the treatment just described.

Even with this excess of reducing agent 10 or 12 hours will be required. The solution must not be allowed to evaporate to less than one-half its original bulk.

The completion of the operation is known by the solution showing a perfectly pure ruby red color. The slightest shade of orange indicates the presence of the yellow platinic salt. It is much safer to allow the solution to evaporate spontaneously. If evaporated by heat there is always a chance that the reduction may go too far.

There is not much to choose between these two methods. The first, with acid sulphite, is the safest, because there is no danger of carrying it too far. On the other hand in the second method the red salt separates more easily and completely in crystallizing.

On the whole the method which I prefer is to keep down the hypophosphite and use a higher temperature and longer heating. For this, a weighed quantity of platinum salt may be placed in a flask with 30^{cc} of water for each gram of the salt and a quantity of potassium hypophosphite equal in weight to $\frac{1}{9}$ of the platinum salt. The flask is to be placed in a water bath which is kept at 80° to 90° C. In consequence of the small proportion of hypophosphite the action is slow, requiring about 18 or 20 hours for complete conversion. No attention during this time is required and the advantages are that the solution becomes sufficiently concentrated to crystallize on cooling and that the very small quantity of foreign matter introduced renders it easy to obtain a pure product.

At 100° C. the reduction to red salt takes place in about fifteen minutes. This method is practicable, but requires great circumspection. If the boiling is continued a little too long, the solution suddenly turns brown; the reduction has gone too far.

If a quick reduction is desired it is better to use an acid sulphite as a reducing agent and the following method gives satisfactory results. In a flask is placed 300^{cc} of water, 24 grams of potassium platinic chloride, 12 grams each of potassium acid sulphite and potassium chloride. Sodium acid sulphite should not be used. The introduction of sodium salts interferes with the crystallization; not indeed with the first crop of crystals, but later. These are made to boil rapidly together for twenty-five minutes, reckoned from the time when actual boiling begins. The solution is allowed to cool, filtered if necessary and placed in a large flat bottomed glass or porcelain vessel. In a day or two the red salt will commence to form large crystals. The addition of the potassium chloride causes the red salt to crystallize out first.

It has seemed worth while to give these methods in some detail because the red platinum salt is likely to find a constantly increasing use in photography not only for platinum printing but as a substitute for gold in toning. There is no doubt that platinum is a much better metal for toning silver prints than gold. Its tones are better and its action is much more reliable.

By all these methods this beautiful salt is obtained in fine ruby red prisms.

Probable Existence of a Platinum Subchloride.

If in obtaining potassium platinochloride with the aid of a hypophosphite in excess, the heat is continued after complete conversion to the red salt, the solution in a few minutes changes from red to dark brown. The substance which gives the solution this dark brown color exhibits the following properties.

It is very deliquescent and cannot be crystallized. There is no satisfactory method of separating it from the other substances in solution. An oxid of platinum appears to be precipitated by the addition of potash and this precipitate when freshly made dissolves easily in hydrochloric acid, but if it is thrown on a filter and washed, almost the whole of it runs through. This difficulty it is true can be avoided by washing with a dilute solution of potassium chloride. But the precipitate after washing is no longer soluble in hydrochloric acid, except that the acid dissolves out a little protoxid derived from the red salt, some of which is apt to escape reduction.

The brown solution exhibits the following reactions.

Hydrochloric acid has no effect.

Nitric acid decolorizes it.

Potash produces a brown precipitate soluble in an excess of the precipitant.

Ammonia a brown precipitate insoluble in an excess.

The solution itself is opaque by reason of its intense color. When largely diluted it is yellowish brown and perfectly transparent.

From the method of obtaining this substance there seem to be only two possible explanations of its nature. First, that it is metallic platinum in a state of solution; this is decisively negatived by the reactions just described. Second, that it is a chloride containing less chlorine than platinous chloride; therefore a sub-chloride. If the precipitate obtained by potash could after washing be dissolved in hydrochloric acid its constitution could easily be determined. But during the washing it seems to be converted into metallic platinum.

I have noticed that when a solution of the ruby red salt 2KCl, $PtCl_2$ is spread on paper and exposed to sunlight it does not blacken but assumes a yellowish brown color; it would seem therefore that light acts upon it much in the same way as a hypophosphite, reducing it probably to a sub-chloride. If the reduction was to metallic platinum this would be shown by the production of an intense blackness.

In all this, analogy with silver salts is unmistakable. Pure silver chloride is not reduced to metal by the action of light, for after exposure it yields nothing to nitric acid. Both metals seem to form sub-chlorides, the oxids corresponding to which are very unstable.

ART. LVII.—*A Study of the Cherts of Missouri;** by EDMUND OTIS HOVEY.

THE investigations herein reported were carried forward on material collected by the officers of the State Geological Survey of Missouri and kindly furnished me by Mr. Arthur Winslow, when State Geologist, together with a long list of references to the literature on the subjects of flint and chert. The chemical analyses which will be quoted were made, unless otherwise stated, at the office of the survey, by Mr. J. D. Robertson. Thirty-eight specimens from different parts of the State, and fifty thin sections made from them, were examined.

The material falls naturally into two groups according to geological age. About half of the specimens came from the Lower Magnesian Series† (Cambrian?), and the rest from the

* Read before the Geol. Soc. Am., August, 1894.

† The Missouri strata which have long gone by the name of the "Magnesian Limestone Series" have been designated the "Ozark Series" by Prof. G. C. Broadhead (Amer. Geol., vol. viii, 33, 1891) and the term has been adopted by the Missouri Geological Survey.

Lower Carboniferous. It is aside from the purpose of the writer to discuss the geologic relations of the cherts, but the Lower Magnesian cherts present some features which separate them more or less sharply, lithologically, from the Lower Carboniferous ones. The former contain few fossils or moulds of fossils, while the latter are usually crowded with stems and plates of crinoids and other fossils, or the cavities left by their removal, though occasionally a Lower Carboniferous chert is found which shows no indication of organic remains. In both groups the color varies very much from pure white to gray, while very many of the cherts are stained brown or black by iron, and one Lower Magnesian specimen is a decided pink. The texture, likewise, is very various, some specimens being very dense, aphanitic to the naked eye, and without fossils or cavities, while others are vesicular from the solution of pebbles or are full of cavities from the removal of fossils. There is great difference, also, in the state of preservation of the chert, much of it being almost perfectly fresh except for an outer shell of decomposition, while other has suffered alteration throughout its mass, as is shown in several Lower Magnesian specimens and in the heavy beds of "tripoli" in the Lower Carboniferous at Seneca and elsewhere.

Petrography.—These cherts consist almost entirely of chalcedony or silica in the chalcedonic state, but quartz and opal are present to some extent in some of the specimens. The slides are almost colorless and featureless under the microscope in ordinary light, but in polarized light the structure of the rock is very clearly indicated and is shown to be a very fine grained mosaic, mottled by reason of variation in fineness of grain. In several of the specimens from the Lower Magnesian series, notably one from Morgan County, the material is aggregated into small spherules. These are optically negative, which proves that they are made of chalcedony. Chalcedony has a higher index of double refraction than quartz, but the polarization colors in these sections rarely rise above gray of the first order, because the grains, whether in mosaic or in concentric spherule, are too small to give the thickness required for the higher colors. For photo-micrographs showing the mosaic and concretionary or oölitic structures of chert the reader is referred to Irving and Van Hise's treatise on "The Penokee Iron-Bearing Series of Michigan and Wisconsin," 10th Ann. Rep. U. S. G. S., 1890, Pt. 1, Pl. 24, fig. 2, and Pl. 28, fig. 2. The presence of opal silica is indicated in some of the slides by apparently amorphous areas, but possibly with more definiteness in other specimens by the solubility of a portion in KOH (caustic potash), though, as will be shown, even this is not a certain criterion. Quartz occurs in the cherts as well terminated crystals of some size more or less completely filling cavities in the chalcedony, as drusy coatings to cavities, and as well rounded grains which may or may not form the nuclei of spherules. The crystallized quartz seems to be secondary to the chalcedony in its deposition, or to form the last phase in the aggregation of the cherts, the latter appearing to be the case where seams of coarsely granular chalcedony grade into lenses of finely granular or crystallized quartz. The strictly secondary quartz lines or fills cavities in the chert without having any apparent connection with the chalcedony. The rounded grains are evidently quartz sand which has been caught within the chalcedony as it was depositing or aggregating. From the frequent occurrence of inclusions in them they are probably granitic in their origin, and this view is strengthened by the rare presence of a grain showing the multiple twinning lamellæ of microcline. Dr. C. R. Keyes* describes cherts from the Lower Carboniferous (Burlington) of the northeastern part of the State which "upon exposure to the weather quickly slacken like quicklime to a fine, intensely white powder." This would indicate that the silica in them was amorphous, but specimens of this character were not sent the writer. Scattered through all the slides there are minute irregular scales and specks of a yellowish brown to black substance which may be referred to amorphous iron oxide (limonite) though some of them are more probably grains of magnetite. A noteworthy feature of most, if not all, of the thin sections, is a "dusty" appearance as seen in ordinary light. This dust disappears to a considerable extent when the light is cut off from the upper side of the section. The phenomenon may be due to clayey matter present in the rock. In view of the discovery by Professor H. A. Nicholson† and Dr. G. J. Hinde‡ of radiolaria in chert from the Lower Silurian (Ordovician) strata of Scotland, and by Professor W. J. Sollas§ and Dr. Hinde,‖ of sponge spicules in Carboniferous chert from Ireland, very careful search was made through these Missouri cherts for indications of anything of a similar nature. Nothing whatever of this kind was found, with the possible exception of some slender cylindrical rods in a specimen from the Lower Carboniferous at Webb City in Jasper County. The rods are noticeable in cavities in the rock, and the one which was measured was 2^{mm} long by $0{\cdot}12^{mm}$ in diameter, but it seemed to have been thickened by some

* This Journal, III, xliv, 451, 1892.
† Trans. Edinb. Geol. Soc., vol. vi, pt. 1, p. 56, 1890.
‡ Ann. and Mag. Nat. Hist., VI, vol. vi, p. 40, 1890.
§ Ann. and Mag. Nat. Hist., V, vol. vii, p. 141, 1881.
‖ Geol. Mag., N. S., Dec., III, vol. iv, p. 435, 1887.

extraneous deposit. What appear to be the cross-sections of these rods have nuclei of brown matter surrounded by clear chalcedony, but sometimes several exactly similar nuclei string themselves together within a common shell of chalcedony. Between crossed nicols there is no line of demarkation between these bodies and the matrix, all is granular chalcedony. I hesitate, therefore, to refer these rods to sponge spicules. Many of the Lower Carboniferous cherts are highly fossiliferous, being more or less crowded with the remains of crinoids, brachiopods and corals. These remains, however, are calcareous in nature and form a breccia with the chalcedony of the chert as the cement, though in the cherts described by Dr. Keyes* the fossils have been silicified. A specimen from this group at Grand Falls, Newton County, shows several sections of a branching form of *Stromatopora* and this genus also occurs in chert from Sulphur Springs, Arkansas. The chalcedony occasionally shows a tendency to form concretionary granules. In the specimen just cited there are true fibrous sphærocrystals which give a black cross in polarized light. The pronounced granular or oölitic character is confined to five of the Lower Magnesian specimens in the suite under discussion. In some of these the chalcedony has formed granules without any apparent foreign nucleus, while in others rounded grains of quartz were the nuclei of deposition. Siliceous oölite was noted by G. W. Featherstonhaugh† in Wayne County, Missouri (?), Tennessee and Kentucky and reported as "silicified oölite" of Carboniferous age, but his stratigraphy is not to be depended upon. Concretionary or granuliferous chert is one of the three divisions made by A. Renard‡ in his study of the Carboniferous cherts of Belgium. A preliminary microscopical and chemical investigation of siliceous oölite was made by E. H. Barbour and J. Torrey§ on specimens sent them from Center County, Pennsylvania. Since then the rock has been reported a second time from Tennessee‖ and it appears probable from an able discussion of the Pennsylvania oölite by Dr. W. Bergt,¶ which first came to the present writer's knowledge some months after his own article** on the same subject had been published, that several rocks from widely separated parts of the world and described under other names really belong in this category. Our specimens, therefore, add five localities for

* Loc. cit.

† Geol. Rept. of an examination of the elevated country between the Missouri and the Red Rivers, 1835, pp. 54, 55.

‡ Recherches lithologiques sur les phthanites du calcaire carbonifère de Belgique. Bull. de l'Acad. Roy. des Sciences, etc., de Belgique, II, xlvi, 1878, p. 494.

§ This Journal, III, xl, Sept. 1890, p. 246.

‖ G. R. Wieland in the Mineralogist's Monthly, vol. vi, Nov. 1890, p. 2.

¶ Abhandlung d. Isis in Dresden, 15, 1892.

** Bull. Geol. Soc. Am., vol. v, p. 627.

this interesting rock: Wright County, Camden County, Morgan County, Osage River, and Taney County, in Missouri. Mr. Winslow reports that the oölitic chert of the Missouri Lower Magnesian strata is of common occurrence and that frequently the beds are more than a foot thick. One of the Lower Magnesian localities furnishes a rock which is partly oölitic in structure and two others give rocks in which rounded grains of quartz have been cemented in an abundant matrix of chalcedony, without the formation of concretionary spherules about them. In one of the latter, however, the chalcedony shows that there was some tendency within it to form shells about the quartz grains, and an occasional small spherule of chalcedony may be seen in the matrix.

Chemistry.—As was to be expected from the microscopic characteristics, the cherts, when not fossiliferous, are almost pure silica. The analyses made by the Missouri Geological Survey show a much higher percentage of alumina and iron-oxide than is present in the cherts from the same strata and the same general region which were analyzed by the U. S. Geological Survey, but this difference is probably due to the fact that the specimens analyzed by the Missouri survey were selected more to illustrate the transitions between cherts and other rocks than to exemplify pure chert. Mr. Robertson reports that in making the analyses the $Al_2O_3+Fe_2O_3$ was redissolved after the first precipitation and precipitated again to make sure that no SiO_2 was included in the amount. The percentage of soluble silica was determined in only four of these analyses: Prof. Seamon, in his report on No. 11 for the Tripoli company, says that "7·28 per cent of the silica was soluble in a 10 per cent solution of caustic soda on boiling for three hours;" the U. S. Survey reported 4·52 per cent in No. 13, 3·99 per cent in No. 14 and 3·35 per cent in No. 18, and that the determination was made in the following manner: the solution used was made up of one part solid caustic potash to three parts water, and one gram of the finely powdered chert was heated in each case with fifty cubic centimeters of the solution for one hour on the water bath. No. 14 was somewhat porous, Nos. 13 and 18 were compact, the last showing occasional cavities filled with quartz crystals.* These percentages, however, cannot be taken as the measure of the amorphous silica present in these rocks, for undoubted quartz is noticeably soluble in caustic potash, Rammelsberg† finding from 5 to 7·75 per cent of vitreous massive quartz thus soluble, and quartz crystals and quartzite tested for the Arkansas Survey‡ gave from 2·59 to 6·28 per cent soluble in this medium.

* Ark. Geol. Surv., Ann. Rep., 1890, vol. iii, Novaculites, p. 161.
† Quoted in Dana's Syst. Mineralogy, 5th ed., p. 193.
‡ Op. cit, p. 164.

Analyses of Missouri and other similar Cherts.

Analyses of Missouri and other similar cherts.	1. Chert, Lebanon, La Clede Co., "decomposed."	2. Decomposed chert. Olden, Howell Co.	3. Chert, 72 ft. below surface, Roaring Spgs., Newton Co.	4. Chert, Henderson Mines, Barry Co.	5. Chert, Grand Falls, Newton Co., calcareous.	6. Calcareous chert, Sulphur Springs, Ark.	7. Calcareous chert, Aurora, Lawrence Co.	8. Ditto.	9. Decomposed chert, Webb City, Jasper County.	10. Decomposed chert, Joplin, Jasper Co.	11. Decomposed chert, ("tripoli") Seneca, Newton Co.	12. Ditto.	13 Chert, unaltered, Bellville, Jasper Co.	14. Chert, altered, Bellville, Jasper Co.	15. Ditto.	16. Chert, gray, unaltered, Joplin, Jasper County.	17. Chert, blue, unaltered, Galena, Kan.	18. Chert, white, altered, Galena, Kan.	
Silica (SiO_2)	96·88	89·45	94·91	98·33	63·67	71·29	91·25	88·92	97·03	96·14	98·100	98·28	98·17	98·71	98·92	99·46	99·23	99·13	SiO_2
Alumina (Al_2O_3) } Iron oxide (Fe_2O_3) }	2·48	0·94	2·85	2·18	2·20	2·43	1·28	1·25	2·32	1·44	0·240 0·270	0·17 0·53	0·83	0·43	0·48	0·29	0·22	0·16	{ Al_2O_3 } Fe_2O_3
Carb. lime ($CaCO_3$)	1·11	9·44	0·75	--	33·12	26·24	6·56	10·02	1·10	2·16									$CaCO_3$
" magnesia ($MgCO_3$)	*tr.*	0	*tr.*	--	0·57	*tr.*	0·17	*tr.*	*tr.*	*tr.*									$MgCO_3$
Lime (CaO)											0·184	*tr.*	0·05	0·03	0·03	0·04	0·02	*tr.*	CaO
Magnesia (MgO)												*tr.*	0·01	0·02	0·02	*tr.*	*tr.*	0·01	MgO
Potassa (K_2O)												0·17							K_2O
Soda (Na_2O)											0·230	0·27							Na_2O
Water (Ignition)											1·160	0·50	0·78	0·50	0·42	0·34	0·50	0·20	Ign.
Organic matter											0·008								Org.
Totals	100·47	99·83	98·51	100·51	99·56	99·96	99·26	100·19	100 45	99·74	100·192	99·92	99 84	99·69	99·87	100·13	99·97	99·50	Totals.

Notes on the analyses.—Nos. 1 and 2 were from the Lower Magnesian strata; Nos. 3 to 18, from the Lower Carboniferous. Nos. 1 to 10 were made at the laboratory of the Missouri Geological Survey by Mr. J. D. Robertson; No. 11, at the Mo. School of Mines, Rolla, by Prof. W. H. Seamon, for the American Tripoli Co., of Seneca, Mo.; No. 12, by the Arkansas Geol. Survey, and it is quoted from their Annual Report for 1890, vol. iii, p. 397; Nos. 13 to 18, by the U. S. Geological Survey, and they are quoted from the same volume of the Arkansas reports, p. 161.

The amounts given above for the Missouri cherts are below these maxima and, therefore, do not necessarily indicate the presence of opal (amorphous) silica, since chalcedony is held to have the same chemical characteristics as quartz. When a large percentage of the silica is soluble in caustic potash the presence of opal silica is indicated; e. g., the Arkansas Survey chemist found 30·72 per cent of a Silurian chert, 35·56 per cent of a Tertiary chert and 88·38 per cent of a geodized coral from Tampa, Florida, to be thus soluble. These geodized corals are known to be opal and the two cherts must contain large amounts of amorphous silica. Edward T. Hardman* analyzed a series of twelve specimens of chert from the Upper Carboniferous strata of Ireland. He tested the rocks in hydrochloric acid and found traces of soluble silica in several and 1 per cent, 1 22 per cent and 1·5 per cent in three cases. All the Cretaceous chalk flints contain much opal silica and show high percentages of silica soluble in caustic potash.†

It will be seen from the table that the chemical difference between "altered" and "unaltered" chert is so very slight that they can be distinguished only by physical characteristics. The most completely altered chert is that from Seneca, which is minutely porous, breaks to pieces readily between the fingers and may be ground to an impalpable powder in an ordinary mill. There is an extensive bed 18 ft. thick of this material at this locality and it is quarried for the manufacture of filtering disks and tubes and of a high grade of polishing powder. A similar rock occurs near Seneca in the Indian Territory, at Dayton, Newton Co., Mo., and in township 4 S., 26 W. in central Arkansas.‡ The Arkansas rock disintegrates to a fine powder on exposure to the atmosphere, but the Seneca rock does not. Another item of interest in the analyses is the very low percentage of water (by ignition) which was found, especially in the pure cherts, whether altered or unaltered. This would argue against the presence of more than a very small amount of opaline silica. Mr. Hardman's analyses of the Irish Carboniferous cherts brought out the same fact regarding the presence of water.

Origin of the chert.—There has been much speculation as to the origin of flint, hornstone and chert. The Cretaceous flints of the chalk formation in England and elsewhere contain so many remains of originally siliceous animal organisms (skeletons of siliceous sponges and polycystines) that some authors claim that all their substance has come from this source,

* Sci. Trans. Roy. Dub. Soc., I, vol. i, pp. 85, 1878.

† Vid. Geology, J. Prestwich, vol. ii, pp. 321 and 322.

‡ Ark. Geol. Surv., Ann. Rep., 1890, vol. iii, p. 384.

while others contend that the silica of the flints is entirely due to chemical precipitation. Other theories lie between these extremes. A concise summary of the various theories which have been proposed to account for the flints is given by Prof. Prestwich,* who gives as his own opinion the theory that silica in the colloid or soluble state was present as a chemical precipitate in the mud of the Chalk seas and that this colloid silica, having a strong affinity for other forms of silica, gelatinous substances (like the sarcode of sponges) and other foreign bodies, aggregated about sponge spicules, replacing the sarcode as that decayed, and about the tests of echinoderms and the shells of molluscs. The irregular masses thus produced continued to grow as long as there was any colloid silica within the range of attraction.

The Corniferous hornstone partakes so largely of the characteristics of the Chalk flints that it probably had its origin in the same way.†

The Upper Carboniferous cherts of Ireland were studied by Messrs. Hull and Hardman,‡ who came to the conclusion that the chert was "essentially a pseudomorphic rock consisting of gelatinous silica replacing limestone of organic origin chiefly foraminiferal, crinoidal and coralline," the silica being a chemical precipitate from the sea water of the period. M. A. Renard§ came to a similar conclusion for the cherts of Carboniferous age in Belgium. This view has been vigorously combatted by Dr. Geo. J. Hinde,‖ who, starting from the discovery made by Prof. Sollas that there were sponge spicules in the Irish cherts, had numerous thin sections of the rocks made for himself. From the study of these Dr. Hinde decided that the cherts were wholly organic in origin and that they were due to the aggregation and disintegration of the skeletons of siliceous sponges.

Pre-Cambrian cherts have been studied by Irving and Van Hise¶ in their work on the Penokee iron-bearing series of Michigan and Wisconsin. This series belongs to the Huronian subdivision of the Algonkian system and two of its four members contain much chert. The author's conclusion regarding the origin of the chert is, "First, that the chert was mainly deposited simultaneously with the iron carbonate with which it was so closely associated; and, second, that it is probable that the chert is of organic origin, although we have no posi-

* Op. cit., pp. 320–324. Vid. also, Ark. rep't cit., pp. 177–187, where an extended summary of theories is given.

† Cf. Manual of Geology, J. D. Dana, 3d edition, 1880, p. 257.

‡ Sci. Trans. Roy. Dub. Soc., II, vol. 1, pp. 71 and 85, 1878.

§ Op. cit.

‖ Geol. Mag., N. S., Dec., III, vol. iv, p. 435, 1887.

¶ Tenth Ann. Rep. U. S. G. S., p. 347.

tive proof that it is not an original chemical sediment, while it may in part be from both sources." This statement is made to apply with equal force to the other chert-bearing member of the series.*

Regarding the Lower Magnesian and Lower Carboniferous cherts from southern and southwestern Missouri, the present writer's conclusion is, that they are due to chemical precipitation, probably at the time of the deposition of the strata in which they occur or before their consolidation.

Am. Mus. Nat. Hist., N. Y. City, July, 1894.

Art. LVIII.—*The Qualitative Separation of Chromium from Iron and Aluminium;* by R. B. Riggs.†

The separation of chromium from iron and aluminium depends on the conversion of chromium compounds, by oxidation, into soluble chromates. This oxidation is generally effected, either by fusing the hydroxide or basic acetate precipitates with sodium carbonate and potassium nitrate, or by dissolving them in concentrated nitric acid to which potassium chlorate has been added. In the hands of the general student the latter is probably the more satisfactory of the two methods. It is somewhat complicated however, involving, as it does, the separation of the aluminium by means of potassium hydroxide, solution of the residue in a potassium chlorate-nitric acid solution, and a reprecipitation of the iron.

In many cases the efficiency of hydrogen peroxide, in alkaline solutions, as an oxidizing agent, is well known. Its use in converting chromium hydroxide into the chromate was a natural suggestion. A few experiments showed that, under favoring conditions, this change is easily and completely brought about. Solutions, containing the equivalent of 0·05 grm. of chromium as hydroxide, 0·3 grm. of sodium hydroxide and quantities of hydrogen peroxide (15 per cent) varying from 5 to 20$^{c.cs.}$, varying in volume from 50 to 500$^{c.cs.}$, were digested

* Ib., pp. 397 and 368.

† Since writing this note my attention has been called to an article by Clark (Jour. Chem. Soc., 1893, i, 1079), on "The use of Sodium peroxide as an Analytical agent." He makes very successful use of this reagent in decomposing ferro chromium ores, and says that it may be used for the qualitative separation of chromium from iron and manganese, in alkaline solutions, when it acts quickly even in the cold. As compared with hydrogen peroxide, sodium peroxide is the more powerful oxidant, and if the former has any advantage, it is to be found in convenience and, possibly, economy.

until oxidation seemed* complete. This required from five to fifteen minutes: the more dilute the solution the longer the operation. 5$^{c.cs.}$ of the peroxide was sufficient for the oxidation.

The availability of hydrogen peroxide, as an oxidizing agent, having been determined, the influence of its presence on the iron and the effect of dilution, on the solubility of aluminium hydroxide in sodium hydroxide solutions, remained to be ascertained. Filtrates from ferric hydroxide, which had been digested in sodium hydroxide solutions containing hydrogen peroxide, gave no sign of the presence of iron except to the sulphocyanide test, showing the influence to be rather favorable than otherwise.

In determining the effect of dilution on the solubility of alumina, quantities of the hydroxide, equivalent to 0·05 grm. of the element, were severally treated with 0·5 grm. of sodium hydroxide in solutions varying in volume from 50 to 500$^{c.cs.}$ In every case solution was effected within five minutes. The influence of dilution was however appreciable.

Experiments, made, to test the practical workings of the method, on mixtures of the three substances, confirmed the observations made in connection with their separate treatments, except that the presence of large quantities of iron hinders somewhat both the oxidation of the chromium and the solution of the aluminium. As to the limits of the method the impurities, of even the best of available reagents, render the detection of very small amounts of either iron or alumina uncertain. In mixtures, containing the equivalents of 0·2 m.grm. each of iron and chromium, and 0·5 m.grm. of aluminium, separations were made and the several constituents

* In a majority of the experiments, in the more concentrated solutions, the precipitates disappeared quickly and completely. Where it was necessary to continue the heating for more than ten minutes, there remained an unoxidizable residual which increased rather than diminished on further heating. In all cases prolonged digestion resulted in a precipitation of what proved to be silica. The amount of this precipitate was found to be proportionate to the quantity of peroxide added and the following experiments showed that it came from the corrosive action of an alkaline solution of the peroxide on the glass. 50$^{c.cs.}$ of water, containing 1 grm. of sodium hydroxide, digested for an hour in glass, remained clear to the end. 50$^{c.cs.}$ of hydrogen peroxide, similarly heated, remained clear, evaporating quietly. 50$^{c.cs.}$ of the peroxide, containing 0·5 grm. of sodium hydroxide, was also similarly digested (the alkaline solution effervesces energetically on being heated). In fifteen minutes the solution had become perceptibly clouded. At the end of an hour, the effervescence having ceased, a considerable precipitate had formed. From 200$^{c.cs.}$ of the peroxide, containing 2 grm. of sodium hydroxide, 4 m.grm. of silica (carrying a trace of iron) were obtained. 500$^{c.cs.}$ of the peroxide, containing 5 grm. of sodium hydroxide, heated in platinum for an hour, remained perfectly clear.

The reagents used were Rosengarten's 15 per cent hydrogen peroxide. 500$^{c.cs.}$ of which gave, on evaporation, a residue of 0·2908 grm. (silica 0·1067 grm., alumina 0·02 grm.,) and sodium hydroxide made from sodium.

were identified beyond a doubt. With half the above quantities the results were not so satisfactory. The color tests for both iron and chromium are sufficiently delicate to detect even smaller amounts. The sulphocyanide test will, under favorable conditions [a solution containing not over $\frac{1}{10}$ per cent of hydrochloric acid and an excess of sulphocyanide ($5^{c.cs.}$ 1 : 15)], show the presence of 0·01 m.grm. of iron in $100^{c.cs.}$ of water (depth of liquid in cylinder 14^{cm}). The yellow color of sodium chromate is unmistakable in $100^{c.cs.}$ of solution containing the equivalent of 0·2 m.grm. of the element.

Summary.—The following is an outline of the method of treatment. Given a mixture of the hydroxide or basic acetate precipitates equivalent to 0·1 grm. of each of the three elements. Digest this precipitate in $100^{c.cs.}$* of water, to which $10^{c.cs.}$ of hydrogen peroxide and 1 grm. of sodium (or potassium) hydroxide have been added, until effervescence ceases.† Separate the iron by filtration. Acidify the filtrate slightly with acetic acid and precipitate the alumina by means of ammonia. (Where small quantities are present long continued boiling and a concentration of the solution may be necessary.) Filter off the alumina and test the filtrate for chromium. The yellow color of either the iron or alumina filtrates is characteristic. A confirmatory and more delicate test may be made by acidifying the filtrate from alumina slightly and adding a few c.cs. of hydrogen peroxide, obtaining the blue color so characteristic of chromium compounds thus treated.

Chemical Laboratory, Trinity College,
Hartford, Aug., 1894.

ART. LIX.—*On Copper Crystals in Aventurine Glass;* by HENRY S. WASHINGTON.

ONE of the most curious products of the world-renowned glass-works at Murano near Venice is the so-called "aventurine glass" (*vetro avventurino*), which owes its name, according to the story, to its discovery by chance (*all' avventura*), some brass filings having been dropped accidentally into a pot of molten glass. This however was not the process by which it was subsequently made, though the secret of its manufacture was lost in the decline of the glass industry towards the end of

* The volume will not materially influence the results. Unnecessary dilution is however to be avoided.

† If the peroxide be not decomposed there is danger, on acidifying the filtrate containing chromium and alumina, of a reduction of the chromate and consequent precipitation.

the last century, and was only re-discovered after the recent revival of the art some thirty years ago, due chiefly to the late Dr. A. Salviati of Venice. The glass finds now quite an extensive use in the manufacture of mosaics and of brooches and other cheap jewelry.

According to Vogt* it was one of the first substances of a mineralogical nature ever examined with the microscope, since in 1807 I. G. Gahn in Fahlun called Hausmann's attention to the fact that small three- or six-sided tables were visible in it under the microscope. Wöhler† was the first to show that these tabular crystals were of metallic copper, to whose brilliant reflections and metallic luster the peculiar appearance of the glass is due. Although, to judge from a remark of Vogt's (see below), the glass has been several times examined, yet I can find but two references to it in the literature at my disposal here. Fouqué and Lévy‡ simply mention Wöhler's determination of the character of the crystals, while J. H. L. Vogt§ devotes a couple of pages to it, and gives a few figures, but goes little into details.

Through the kindness of Signor G. Boni of Rome, to whom I desire to express my thanks, I was enabled to obtain at the works of the Venezia-Murano Glass Co. at Murano specimens not only of the finished perfect product, but of a mass that was the result of an unsuccessful melting, as well as fragments of the melting pots both before and after their exposure to the intense heat of the furnaces. The results of a microscopical examination of this material seemed worthy of publication, especially since they add to our knowledge of the crystallization of copper.

The perfect glass is of a copper brown color, and transparent to translucent in thin flakes, showing on the edges a pale brown color. It is filled with innumerable small flakes and spangles of a slightly brownish yellow color and brilliant metallic luster. This is best seen apparently in sections or fracture surfaces of the glass parallel to the original surface in the melting pot, showing that the majority of the flakes lay horizontally in the molten glass. The specimens also show streaks of comparatively flakeless material.

The imperfect glass is slightly darker in color and is less transparent, showing at the thin edges a greenish color. The spangles and glistening points are almost entirely wanting and those present much smaller than in the perfect examples. A specimen taken from the surface of the mass solidified in the

* Vogt, Mineralbildung in Schmelzmassen. Kristiania, 1892, p. 238.
† Wöhler, Gött. gelehrt. Auz., v, 1842, p. 1785.
‡ Fouqué et Lévy, Synth. d. Min. et d. Roches. Paris, 1882, p. 367.
§ Op. cit., pp. 237–9.

melting pot shows a smooth uppermost layer, about $0{\cdot}2^{mm}$ thick, of a clear dark greenish blue color, the surface of this being covered with minute rounded pits and indented six-rayed stars.

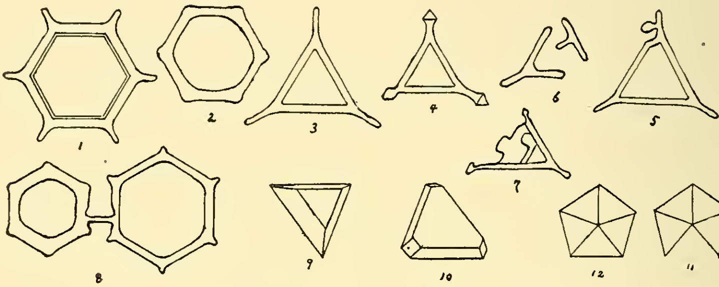
Microscopically the perfect glass may be first described. This shows under the microscope a porphyritic structure, the groundmass being composed of a perfectly clear and colorless glass basis, which in the parts where the phenocrysts are best developed is quite clear and free from microlites, in other places and in streaks being "dusty" through the presence of large numbers of the minute octahedral microlites to be described presently.

The crystallized portion of the mass consists entirely of copper and may be divided sharply into three distinct groups, large phenocrysts, small phenocrysts, and microlites, which differ greatly from each other both in the size and the habit of the individuals.

All of the large phenocrysts, which range in diameter from $0{\cdot}05$–$0{\cdot}12^{mm}$, are tabular and extremely thin, the thickness scarcely exceeding $0{\cdot}002^{mm}$ and often less than half this, being perfectly opaque notwithstanding their excessive tenuity. Most of them are hexagonal in outline, the hexagons being of almost ideal symmetry, and equilateral triangles, which occasionally show truncated angles, also occur. They show a rather yellowish copper color and in reflected light a brilliant metallic luster. The edges are perfectly sharp and straight, except those of the plates lying obliquely in the section and which are due to the making of the slide, which are rough and somewhat granular or ragged. Seen "end on" the edges show, when thick enough, a face not quite normal to the plane surface of the crystals, though they are too thin to make measurements at all exact.

The faces of these hexagons and triangles are in general perfectly smooth and plane, but a number show a peculiar appearance which is represented in figs. 1–5. In such cases we see that the central part of the face is depressed forming a very shallow hexagonal or triangular pit, symmetrical with the crystal outline, and surrounded by a salient edge about $0{\cdot}004^{mm}$ broad, and with sloping and rounded sides. The angles of these shallow depressions are generally rounded, so much so in some cases that they assume an almost circular form (fig. 2). It may be remarked that such shallow pitted surfaces with salient edges are not rare in native copper crystals and quite common in gold.

This peculiar form, which seems to be due to a skeleton growth, is almost always accompanied by projections of greater or less length at the outer angles of the tabular crystals, as shown in the figures, the projection being always in the direction of the bisectrix of the angle. These projections are in general rounded and show no crystal faces, but in a few cases (fig. 4) they are seen to be minute octahedra, an apex being outward and two of the dodecahedral interaxes being parallel to the plane of the tabular crystal. Some of these small octahedra show replacements of the solid angles by cubic planes, and they all gradually run into the salient edges of the main crystal.



FIGS. 1–12.—Copper Crystals in Aventurine Glass, × $\frac{200}{1}$.

In addition to these more regular forms some skeleton crystals are to be seen (figs. 5, 6, 7) which are made up of narrow ridges and show that the pit-like depressions are due to incomplete growth, and not to corrosion. A curious and quite unique form is shown in fig. 8. This is a "Siamese twin" of the hexagonal tables joined together by a narrow ridge.

The tendency of copper to forms flattened in the direction of a normal to an octahedral plane is well known and has been clearly brought out by Prof. E. S. Dana, in an article on the copper of Lake Superior.* These flattened forms are shown by him to be generally twins with the twinning plane an octahedral face. Though owing to the small size and especially the extreme thinness of the tabular crystals in the aventurine glass no direct evidence of twinning, such as reëntrant angles on the edges, is to be seen, yet from analogy with the copper crystals described by Dana and others it is probable that they are also twins. Vogt† expresses the opinion that the plates are simple distorted crystals, but gives no reasons for this view.

* Dana, On the Crystallization of Native Copper. This Journal, xxxii, 1886, p. 413.

† Op. cit., p. 238, note 2.

As will be seen presently twinned forms are common among the smaller crystals.

The copper crystals making up the second group are smaller than the preceding, varying from 0·01–0·03^{mm} in diameter, and are not only quite different in habit but much more diverse in crystalline form. They may be divided into three distinct types, each being about equally abundant; cubo-octahedral forms, octahedra, and twins.

To the first of these generally belong the largest individuals and their form is that of the combination of the cube and octahedron, with both about equally developed, or more rarely the combination of the dodecahedron with these, the individuals being evenly developed and showing no signs of distortion or flattening. In addition to these an occasional trisoctahedral plane with other indeterminate forms are to be seen as replacements of the angles of the combinations above. The symbols of the trisoctahedra could not be determined by measurement, but they are tetragonal and are presumably 211 and 311. These crystals though, rarely show sharp edges, the forms being much rounded and only the octahedral and cubic planes remaining flat in most cases; this rounding being occasionally carried so far that the crystals assume an almost spherical shape. The crystals of this type are occasionally partially surrounded by irregular trichitic growths.

The crystals of the second type of this group are rather smaller than the preceding, varying in diameter from 0·01–0·02^{mm}. They are in almost every case perfectly sharp and ideally symmetrical octahedra, cubic and dodecahedral replacements of the angles and edges being rare, and when present very small.

The third type, that of twinned forms, while of about the same size as those just described offer much more variety. The twinning plane is in every case the usual one, an octahedral face, and the twins are either simple or repeated. The simple forms are composed of trigonal cubic twins (fig. 9), and octahedral twins with cubic planes on the angles (fig. 10), both of which are much flattened parallel to the twinning plane. These forms are identical with some described and figured by Dana in the paper already referred to.*

The polysynthetic twins are either fourlings or fivelings (figs. 11 and 12), formed of four or five octahedra grouped about a common center, the first showing a reëntrant angle at one side, and the last forming almost symmetrical pentagonal bi-pyramids, since the octahedral angle (70° 32′) is almost one-

* Loc. cit., pp. 424 and 426, Pl. 11, fig. 28, Pl. 12, fig. 41.

fifth of 360°. Similar forms have been described by v. Lasaulx* and W. G. Brown.†

It has already been said that the tabular phenocrysts occur in a vitreous groundmass which is almost absolutely free from smaller crystals and microlites. The same is true in a certain way of these smaller phenocrysts which have been just described. They occur generally in parts of the glass that are free from the tabular crystals but very thickly strewn with the minute microlites which form the third group, being immediately surrounded, however, by a more or less broad circular zone (Hof) of perfectly clear glass basis, exactly as is seen to be the case with magnetite and other minerals in volcanic rocks. These microlites which are extremely small, running from 0·005–0·0005^{mm} or even less, are seen under high powers to be sharp and perfectly symmetrical octahedra. Forms other than octahedra were not seen even with the use of the highest powers, and the angles are only rarely replaced by cubic planes.

The imperfect glass shows under the microscope the same colorless glass basis as the perfect, but is almost absolutely free from the tabular crystals, only one or two being seen in the slide, and these very small. The copper crystals are in an overwhelming majority the microlites of the third group, which are exactly like those just described. Crystals of the second group are rare and these mostly of the simple octahedral type, with a few cubo-octahedra and scarcely any twins.

The thin greenish blue top layer already spoken of, which is sharply distinct from the brown glass beneath, but which throws projections into the latter, offers some special peculiarities. The surface is, as has been said, covered with very minute pits and small indented stellate forms with generally six rays, then crossing in most cases at about 60°, but in others at irregular angles, and some stars having fewer than six rays. I had a slide from this prepared by Messrs. Voigt and Hochgesang, this smooth original surface being used as one face, while the other was ground down parallel to it.

With low powers under the microscope the centers of these stars are seen to be occupied by holes, and the rays are seen to be less regular than they appear to the naked eye or with the lens. They are seen to be composed of long groups and clusters of black opaque trichites which are either straight or curved. With these are sometimes associated small irregular specks of a pale brown non-pleochroic mineral, which shows marked double refraction. Its precise nature could not be determined, but it seems to be augite. In the pale blue ground-

* Lasaulx, Ber. nied Ges., xxxix, 1882, 95.
† W. G. Brown, this Journal, xxxii, 1886, p. 377.

mass of glass, which is much cracked, are many smaller clusters of the same trichites.

The blue color of this layer is obviously due to the oxidizing action of the atmospheric air on the copper, analogous to the action of the oxidizing flame of the blowpipe on a borax bead containing copper, and the black trichites may be with great probability supposed to be Tenorite, CuO.

Although some writers have thought that the crystals described in the preceding pages are not metallic copper but a silicate of copper or Cu_2O, yet Wöhler's original determination has been since confirmed,* and their color, luster, opacity, crystalline form and habit, and twinning forms leave no doubt of their nature, even apart from chemical tests.

Vogt has already pointed out the fact that the copper has evidently crystallized from solution in the molten glass exactly like a salt from water, and this view is confirmed by such facts as the blue upper layer, the presence of the clear zones around the crystals of the second group, as well as the fact that they seem to follow the laws of crystal growth in solutions as laid down by O. Lehmann.†

This author shows by numerous examples that crystals tend to grow most rapidly at the most sharply pointed parts, and this we find beautifully exemplified in the projections at the angles of the hexagonal and triangular plates as well as in the salient ridges along the thin edges. Also in accordance with this law is the generally observed fact that the projections on the triangles are on the whole relatively longer than those on the hexagons.

He also shows‡ that the crystal habit varies with the concentration and temperature of the solution and with the rapidity of crystallization, the more irregular forms, such as skeleton crystals, being produced by greater concentration and quicker crystallization among other conditions. The formation of twins seems to be due to disturbing influences on the regular crystallization.§

On such grounds the diverse habits of the various crystal groups are to be explained; the tabular phenocrysts being first formed from a more concentrated solution, some of these, as the conditions changed, tending to grow by additions at the angles and edges, while more copper crystallized out as the smaller phenocrysts, till finally in the last stages only the minute regular octahedral microlites were formed.

The manufacture of this glass being a trade secret I could extract no information from the foreman who gave me the

* Vogt, op. cit., p. 237, note 5.

† Molecular physik. Leipzig, 1888, i, pp. 337 ff.

‡ Op. cit., p. 303.

§ Op. cit., p. 416.

specimens as to the process or details of its manufacture; a fact which is greatly to be regretted since, for instance, a knowledge of the circumstances to which the failure in the case of the imperfect glass was due would throw light on the crystallization of the copper.

It seems that the glass is produced by melting together glass, cuprous oxide and some reducing agent, such as siderite,* and that FeO is in this case the reducing agent is shown by the greenish color of the imperfect glass, which is not the blue green of copper but the yellow green of ferrous glass, and perhaps due to too large a quantity of reducing agent. This part of the subject, however, as well as the chemical composition of the glass I must for the present leave aside.

Venice, Italy, Aug. 25, 1894.

ART. LX. — *On the Cæsium-Cobalt and Cæsium-Nickel Double Chlorides, Bromides and Iodides;* by G. F. CAMPBELL.

As a continuation of the work in this laboratory on double halogen salts, the investigation of the above-mentioned compounds has been taken up. The study has been made in a systematic manner with the view of preparing as complete a series as possible. The salts obtained belong to three types, and are as follows:

3:1 Type.	2:1 Type.	1:1 Type.
Cs_3CoCl_5	Cs_2CoCl_4	$CsCoCl_3 . 2H_2O$
Cs_3CoBr_5	Cs_2CoBr_4	
	Cs_2CoI_4	
		$CsNiCl_3$
		$CsNiBr_3$

The results show that cobalt forms double salts with much greater facility than nickel, for with the latter metal only the chloride and bromide of a single type could be obtained.

The series illustrates the increase in ease of formation of double salts from the iodides to the chlorides, which has been previously observed, especially in the case of the cæsium-magnesium salts by Wells and Campbell.† No cæsium-nickel iodide could be prepared.

It should be noticed that the two salts of the 3:1 type are exceptions to Remsen's law concerning this class of bodies.

* Wagner-Fischer, Handb. d. Chem. Tech., 1889, pp. 707 and 741, quoted by Vogt.

† This Journal, xlvi, 432.

The previously described double halogen salts of cobalt and nickel, as far as I have been able to learn, correspond to two types of the cæsium salts, and are as follows:

2:1 Type.	1:1 Type.
$(NH_4)_2CoF_4 . 2H_2O$	$NH_4CoCl_3 . 6H_2O$
$(NH_4)_2NiF_4 . 2H_2O$	$NH_4NiCl_3 . 6H_2O$
	$KCoF_3 . H_2O$
	$KNiF_3 . H_2O$
	$NaCoF_3 . H_2O$
	$NaNiF_3 . H_2O$

The following table gives approximately the composition of the solutions from which the cæsium salts under consideration were crystallized by concentration and cooling.

	Cs : Co or Ni (Atoms.)			
Cs_3CoCl_5	From	12 : 1	to	6 : 1
Cs_2CoCl_4	"	6 : 1	"	0·4 : 1
$CsCoCl_3 . 2H_2O$	"	0·4 : 1	"	syrupy solution of $CoCl_2$
Cs_3CoBr_5	"	2 : 1	"	1 : 1
Cs_2CoBr_4	"	1 : 1	"	syrupy solution of $CoBr_2$
Cs_2CoI_4	"	1 : 4	"	1 : 16
$CsNiCl_3$	"	12 : 1	"	syrupy solution of $NiCl_2$
$CsNiBr_3$	"	2·5 : 1	"	syrupy solution of $NiBr_2$

More or less of the corresponding halogen acid was present in each case, and an increase of this was apparently equivalent in effect to the addition of the cæsium halide. In the case of the two nickel salts, a rather large amount of the acid was desirable, for if it was not present, the salts appeared only upon heating the concentrated solutions and dissolved when they cooled.

The color of the chlorides containing cobalt is a magnificent blue, the bromides and the iodides containing the same metal are green, while the two nickel salts are yellow. The two nickel salts form almost microscopic crystals. The two salts of the 3 : 1 type were obtained in crystals having a diameter of about 5^{mm}, apparently combinations of the cube and octahedron. The salts of the 2 : 1 type form large plates or prisms, the habit evidently depending upon the composition of the solutions from which they crystallize. The salt $CsCoCl_3 . 2H_2O$ forms rather small plates. Besides the blue salt just mentioned, a red cæsium-cobalt chloride of the 1 : 1 type was obtained which lost water of crystallization so readily, with change of color, that it could not be analyzed in its original condition.

The compound Cs_2CoI_4 is deliquescent, while the other salts, here described, are stable. All the salts are whitened when brought into contact with water or alcohol, evidently on account of decomposition.

The following analyses were made :

Cs_3CoCl_5.

	Cæsium.	Cobalt.	Chlorine.
Found	62·79	9·16	27·83
Calculated	62·82	9·24	27·74

Cs_2CoCl_4.

	Cæsium.	Cobalt.	Chlorine.
Found	56·86	12·53	30·40
Calculated	56·99	12·58	30·43

$CsCoCl_3 . 2H_2O$.

	Cæsium.	Cobalt.	Chlorine.	Water.
Found	38·64	17·67	32·07	10·94
Calculated	39·80	17·56	31·87	10·77

Cs_3CoBr_5.

	Cæsium.	Cobalt.	Bromine.
Found A	46·65	6·88	46·33
" B	----	7·44	46·97
" C	45·81	7·08	46·52
Calculated	46·52	6·84	46·64

Cs_2CoBr_4.

	Cæsium.	Cobalt.	Bromine.
Found A	41·21	9·49	49·43
" B	----	9·20	49·60
" C	----	9·25	49·32
Calculated	41·26	9·10	49·64

Cs_2CoI_4

	Cæsium.	Cobalt.	Iodine.
Found A	29·69	7·10	----
" B	----	7·34	60·24
" C	----	7·31	60·29
Calculated	31·93	7·09	60·98

$CsNiCl_3$.

	Cæsium.	Nickel.	Chlorine.
Found A	44·42	19.70	35·78
" B	----	19·14	35·57
Calculated	44·61	19·66	35·73

$CsNiBr_3$.

	Cæsium.	Nickel.	Bromine.
Found A	29·93	13·83	55·84
" B	30·60	13·58	55·49
Calculated	30·81	13·58	55·61

The author takes pleasure in expressing his indebtedness to Prof. H. L. Wells for valuable advice in connection with this investigation.

Sheffield Scientific School,
New Haven, Conn., September, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Electric Conductivity of Gases.*—The question whether gases can conduct electrification, has been investigated by Braun, under various conditions. He examined first, compound gases at the moment of their formation, using (1) mixtures of nitrogen dioxide and air and (2) mixtures of chlorine and hydrogen; their union being effected by the influence of heat or of diffuse daylight. For the conductivity measurements, a Leyden battery was employed, having an electromotive force of about 4000 volts. No conduction was detected. In the second set of experiments the gases were examined during the time of explosion, a mixture of carbon monoxide and oxygen being employed, the electromotive force used being that of from seven to twenty Grove cells. Under these conditions, there appeared to be unmistakable conduction through the exploding gas. The last experiments were made with gases heated to high temperatures, about 1000°—1200°, in porcelain tubes, the electromotive force being that of a single Leclanche cell. It was observed that ammonium chloride and cadmium iodide conducted well, ammonia, iodine and hydrogen chloride conducted fairly, while hydrogen iodide, hydrogen bromide and mercuric oxide (probably) conducted only very slightly. No conduction at all could be observed with carbon dioxide, water, or nitrogen tetroxide. In concluding his paper the author expresses the opinion that the electric charges of flames are due to the separation of positive and negative ions.—*Zeitschr. physikal. Chem.*, xiii, 155, February, 1894. G. F. B.

2. *On the connection between the Atomic masses of metals and the Crystallographic characters of their Isomorphous salts.*—A comparative crystallographic study of the normal sulphates of potassium, rubidium and cæsium has been made by Tutton with a view to determine the relation between the atomic masses of these metals and the crystallographic characters of their isomorphous salts. After an elaborate summary of the results obtained the author concludes that "a regular progression is observed in the crystallographical characters of the three sulphates under consideration, corresponding to the progression in the atomic weight of the metal which they contain. With regard to every property whether morphological or physical, the rubidium salt stands intermediate between the potassium and the cæsium salt. The replacement of rubidium by cæsium, however, is generally accompanied by a greater modification of the crystallographical characters than when potassium is replaced by rubidium, the heavier atom exerting an influence greater than in mere simple proportion to the increase in atomic weight. The comparative results for the different properties are all in line with each other, the relations of the amounts of change along the directions of the three crystallo-

graphic axes being similar with respect to all. Moreover the progression according to the atomic weight of the alkali metal is perceptible with regard to the minutest details of the physical phenomena presented by the crystal and is entirely independent of the temperature. It may therefore be finally stated that *the whole of the crystallographical properties of the strictly isomorphous, rhombic, normal sulphates of potassium, rubidium and cæsium, are functions of the atomic weight of the metal which they contain.*"—*J. Chem. Soc.*, lxv, 628–717, July, 1894.

G. F. B.

3. *On the Influence of Moisture on Chemical Change.*—It is well known that certain chemical reactions can take place only in presence of the vapor of water. BAKER has extended the number of these reactions and has investigated the conditions under which they take place. His first experiment was made with lime and sulphur trioxide. The lime was prepared by the ignition of precipitated chalk mixed with sugar. While still warm it was placed in a small bulb blown on a tube, at the other end of which some phosphorus pentoxide was placed. The ends of the tube were sealed; and after three days, the bulb, which had been heated at intervals to drive any moisture into the pentoxide, was sealed off and introduced into one end of a carefully dried glass tube, some phosphorus pentoxide being placed in the other. This tube after exhaustion was sealed and allowed to stand for two days. One end of it was then connected with a tube containing sulphur trioxide, by means of a joint made of previously ignited asbestos, the point of the sealed end was broken and the trioxide was distilled into the tube. After a week, this portion of the tube containing the pentoxide was sealed off and the bulb containing the lime was broken. Not a sign of combination appeared, though on breaking the tube and allowing a little moist air to enter, combination at once took place and the mass became vividly incandescent. On repeating the experiment with black copper oxide in place of lime, the sulphur trioxide crystallized on the black powder, apparently without converting any of it into the white anhydrous copper sulphate. The action of lime upon ammonium chloride was next examined. This was of interest because water is a product of the reaction. No ammonia gas was evolved on mixing them when the materials were perfectly dried. A mixture of dry hydrogen and dry chlorine did not explode when exposed to sunlight; and more than a quarter of the mixture remained uncombined after exposure to diffused sunlight for two days and to direct sunlight for two days. Nitrogen dioxide and oxygen, when pure and dry, do not react on each other. Carefully dried hydrogen chloride and ammonia gases do not combine on being mixed. And conversely perfectly dry ammonium chloride does not undergo dissociation when heated to 350°. As to the explanation of these results, the author is inclined to the physical view of the matter suggested by Vernon Harcourt rather than to the chemical one proposed by Dixon. Indeed he has long

believed in an electrochemical theory of combination; and hence considered it desirable to ascertain whether molecules capable of combining are at different potentials and whether this difference of potential increases as they are brought nearer to the point of union. Moreover, whether also the conditions which affect chemical change affect in the same direction the passage of electric discharge. A mixture of dry hydrogen chloride and dry ammonia in equal volumes was introduced into a glass tube about a meter long, divided in the middle by a threeway tap, and provided at the ends with electrodes of platinum plate. On opening the tap and connecting the electrodes with the terminals of a Wimshurst machine giving 3 inch sparks in air, for three hours, it was found that a separation of the gases had taken place; the gas surrounding the anode reddening litmus and that about the kathode blueing it. Air, dried over sulphuric acid, showed after electrification 1·8 per cent more oxygen at the anode end of the tube; and a mixture of dried hydrogen and oxygen showed 2·3 per cent excess of oxygen at this end. Since then mixed gases can be partially separated by the attraction of their molecules for oppositely charged plates, it seems probable that the molecules themselves are charged. Moreover experiment showed that the electric discharge takes place more readily in moist than in dry air; and further that the electric glow obtained by shaking mercury in different rarefied gases gradually diminishes as the gas is dried by phosphorus pentoxide and finally disappears altogether. Hence the author concludes that with regard to the presence of moisture, electric discharge is affected in the same way as chemical combination. If it can be regarded as proved that substances which are capable of chemically combining are electrically charged, the great significance of this result is obvious.—*J. Chem. Soc.*, lxv, 611–624, July 1894. G. F. B.

4. *On the Production of free Fluorine by Chemical means.*—The isolation of fluorine by Moissan it will be remembered, was effected by means of electrolysis. BRAUNER has now succeeded in obtaining this gas by a method purely chemical. He had observed twelve years ago, that the compounds CeF_4H_2O and $(KF)_3(CeF_4)_2(H_2O)_2$ when heated, first evolve water and then a gas having the odor of hypochlorous acid and possessing the property of setting iodine free from potassium iodide. He now describes a new series of analogous salts, the fluorplumbates, derivations of fluorplumbic acid; the first member of the series having the composition $(KF)_3 . HF . PbF_4$, and being produced in one of three ways: (1) by treating the oxide $Pb_5O_7 . (H_2O)_3$ freshly precipitated, with a mixture of hydrogen-potassium fluoride and hydrogen fluoride and crystallizing from hydrogen fluoride; (2) by fusing lead dioxide with potassium hydroxide in the proportion $(KOH)_3 : PbO_2$ in a silver crucible, dissolving the moistened mass in excess of hydrogen fluoride and crystallizing; and (3) by dissolving three gram-molecules of $KF . HF$ in excess of hydrogen fluoride and adding one gram-molecule of lead tetrace-

tate, and evaporating; the acetyl being thus displaced by fluorine. The substance is obtained in the form of needle shaped crystals, often a millimeter in diameter and a centimeter long, grouped radially and probably monoclinic, analogous to the fluostannate of Marignac. It is permanent in dry air, but turns brown in moist air, being decomposed by water so as to yield hydrated lead peroxide, hydrogen potassium fluoride, and hydrogen fluoride. Heated to 100°–110° for some hours the mass remains constant; but at 200° hydrogen fluoride is evolved, and at higher temperatures, but much below a red heat, a gas is set free having the characteristic odor of fluorine, and liberating iodine in large quantity from iodide of starch paper. Small crystals of silicon placed in the open end of the evolution tube burn with vivid incandescence, sometimes with explosive violence, in the issuing gas. There can be no doubt that this gas is really fluorine. If the potassium fluorplumbate loses only its hydrogen fluoride at 230°, with traces only of fluorine, one gram should give 47^{cc} of fluorine; the admixed hydrogen fluoride being removed by passing the gas over potassium fluoride. If the sodium salt now under investigation proves to be $(NaF)_2PbF_4$ it would yield fluorine pure at once. The author also describes the preparation of fluorplumbic acid and lead tetrafluoride.—*J. Chem. Soc.*, lxv, 393–402, June, 1894. G. F. B.

5. *On the Structure of the Flame of Cyanogen.*—The structure of the flame of burning cyanogen has been studied by SMITHELLS and DENT according to the method proposed by the first named chemist in connection with Ingle. The cyanogen was prepared by heating mercuric cyanide and was collected over mercury. When burned in the cone-separating apparatus, the flame at the top of the outer tube consists of two parts, an inner cone-shaped region having a bright peach blossom tint, and an outer or enveloping cone, shading off from a bright blue to a greenish-grey. As air is gradually added the inner cone becomes smaller and soon enters and descends the outer tube, being surrounded by a rosy halo, which disappears and is replaced by a blue one as the amount of air increases. The outer cone retains its place at the top of the outer tube and remains of the same color. More air still, extinguishes the outer cone and causes the inner one to become bluer and its halo greener. Examination of the interconal gases showed the presence of carbon dioxide and monoxide, cyanogen, nitrogen, nitrogen dioxide and tetroxide. Analysis gave CO 25·4, CO_2 0·8, $(CN)_2$ 6·1, N_2 66·9, NO 0·3, NO_2 0·4, when the proportion of air to cyanogen was 3·52 : 1. From their results the authors conclude: (1) that the cones may separate when the ratio of air to cyanogen is 3·3 : 1; (2) that when cyanogen is burning with the minimum quantity of air, carbon monoxide is practically the only oxidation product; (3) that as the air supply increases the quantity of carbon dioxide increases, until it equals one half the volume of the monoxide; (4) that cyanogen is present in the interconal gases

amounting to $7\frac{1}{2}$ per cent with the minimum of air, disappearing as the air supply increases; (5) that small but variable quantities of nitrogen oxides are present. In the inner cone therefore carbon monoxide is the main product, and in the outer one carbon dioxide.—*J. Chem. Soc.*, lxv, 603–610, July, 1894. G. F. B.

6. *Select Methods in Chemical Analysis;* by WILLIAM CROOKES, Third Edition (Longmans, Green, & Co.)—The new edition of this well-known work, though no more bulky than its immediate predecessor, includes the description of many new processes of analysis in place of methods which have been superseded or which have become so widely known that they need no mention in a work which aims merely to bring together novelties. Processes of technical importance only, such, for example as methods of furnace assaying or processes of analysis of iron, steel, and ores of iron, have been displaced because such topics are now fully treated elsewhere. The chief additions have been in the line of electrolytic analysis. Only such methods as have been put to the test in the author's own laboratory are admitted, and it is of course to be expected that many developments of the nine years intervening since the issue of the second edition find no mention. This edition will no doubt be as welcome to practical chemists as was each of the preceding issues in its time.

F. A. G.

7. *An Elementary Manual of Chemistry;* by F. H. STORER, Professor of Agricultural Chemistry in Harvard University, and W. B. LINDSAY, Professor of General and Analytical Chemistry in Dickinson College. Being a Revision and Rewriting of Prof. W. R. Nichol's Abridgment of Eliot and Storer's Manual. New York, Cincinnati and Chicago: American Book Company, pp. 453.—The rapidly increasing rate of progress of the experimental sciences renders necessary frequent issue of newly posted text-books, and among the many serviceable handbooks of chemistry, none is likely to be found superior to this "lineal descendant" of Eliot and Storer's Manual whose appearance nearly thirty years since first rendered systematic laboratory instruction to large classes in general chemistry practicable and pleasant both to student and teacher. The original Manual was rather bulky for the most advantageous use. In Nichol's abridgment we thought much of the excellence of the Manual was sacrificed and are glad to find in this less condensed revision and rewriting the touch of master hands evident throughout.

The book is equally valuable in the class room and the laboratory. The instructor will find in it the essentials of chemical science developed in easy and appropriate sequence, its facts and generalizations expressed accurately and fully but concisely as well as forcibly and elegantly. A large number of those fundamental or important facts of chemistry that are inaccessible through ordinary experience are demonstrated in 258 experiments mostly so simple and so well described and illustrated (by 125 engravings) that any intelligent youth provided with the cheap outfit catalogued on pp. 428–431, may without other aid, make them an intimate part of his personal knowledge. On this surest foundation the demonstrated laws and current hypotheses of the science are skilfully constructed and displayed,

The short Introduction of three pages in four paragraphs with a single experiment defines the province of chemistry, Chapter I in 5 pages, 11 paragraphs and two experiments, sets forth the material and complex nature of common air and shows the making of oxygen from "mercury rust." Chap. II of 4 pp. in 5 ¶¶ with 2 exp's. develops the properties of oxygen in some detail. In Chap. III of 3 pp. 3 ¶¶ and 1 exp. the isolation of nitrogen is exhibited, its physical and chemical properties and its occurrence in nature are stated and the laws of Charles and Boyle are very clearly enounced. Chap. IV of 13 pp. 19 ¶¶ and 10 exps. gives an admirable exposition of the chemistry and chemical physics of water. The caloric and thermal unit, the laws of definite proportions by weight and volume, molecules, atomic weights, the distinction between elements and compounds, distillation, solution, supersaturation and water of crystallization are very suitably developed, described or demonstrated. Chap. V, 12 pp., 13 ¶¶, 6 exps. treats of hydrogen and its dioxide with explanation of reactions, substitution or replacements, molecular weights, crith, vapor density, gas-diffusion and heat of formation are here explained.

Compounds of Nitrogen; Hydrochloric Acid; The Halogens; Ozone; Sulphur, Selenium and Tellurium, are the subjects of Chapters VI to X. In them are considered incidentally Multiple Proportions, by weight and volume; Acids, Bases and Salts; Distinction of Metals from Non-metals; Nascent State; Valence and Replacing Power; Chemical Calculations; Allotropism; Crystal Systems; Dimorphism; Dissociation.

Chapter XI of 8 pp. is purely doctrinal and is paragraphed as follows: Combination by Volume; Molecular Condition of Elementary Gases; Volumetric Interpretation of Symbols; Variation in the Number of Atoms in the Molecule of the Same Element; Atomic Weight and Specific Heat. The law of Avogadro and that of Dulong and Petit are here set forth.

Chapter XII of 8 pp. and 8 ¶¶ is devoted to Formulas, Empirical and Rational; their Determination; a brief account of Dualistic and Typical formulas, and a fuller statement of the character and uses of Structural or Graphic Formulas.

The next three chapters are occupied respectively with Phosphorus, with Arsenic, Antimony and Bismuth and Silicon and Boron. Four chapters, aggregating 128 pp. are devoted to Carbon and its Compounds. In Chap. XVI the properties of Carbon and of its oxides and sulphides, and the subjects of Combustion and Illumination are fully discussed while decay, putrefaction, fermentation, compound radicals, the blowpipe, and kindling temperatures, are more briefly noticed. Chapters XVII, XVIII and XIX are an excellent epitome of organic chemistry.

The remaining chapters save the last treat of the metals. The work concludes with Chapter XXXII which in seven pages comprises a Table of Atomic Weights wherein hydrogen is the unit and oxygen has the value 15·88 and gives a remarkably lucid exposition of the Periodic Law.

8. *Movements of the Solar Atmosphere.*—M. H. DESLANDRES has discovered by comparison of many photographs of the solar lines H and K a variation in the bright line which is found in the dark space embraced by these lines. This bright line can be separated into two enclosing a dark line. The bright lines correspond to the lower layers of the chromosphere while the dark line belongs to the higher layers. These bright lines often show dissymmetry, sometimes one and sometimes the other becoming the narrower. Spectra of the faculæ do not usually show this dissymmetry but it is a common condition on the remainder of the surface, and is more pronounced near the equator than in the neighborhood of the poles. Near spots the observed dissymmetry is often in the opposite direction on opposite sides, and the narrowing of the line is sometimes irregular. The phenomena can be explained on the hypothesis of a continued circulation of the sun's atmosphere, but it is worth noting that a less marked dissymmetry has been obtained in the calcium spectrum produced by the induction spark. Resemblances are pointed out between these phenomena and those observed in the spectrum of Nova Aurigæ.—*Comptes Rendus*, Aug. 27; *Nature*, Sept. 6, 1894, p. 468. J. T.

9. *Luminous effects produced by electric oscillation.*—H. EBERT describes a luminescence lamp made of a glass globe containing luminous paint. Oscillations are produced on tin foil strips placed on the globe and vivid luminescence is produced. The energy consumed was in the millionths of a watt, and this economy of the lamp was very striking. To avoid the great losses due to inductive resistances a transformer with small capacity and small inductance could be attached directly to the lamp.—*Ann. der Physik und Chemie*, No. 9, 1894, pp. 144–161. J. T.

10. *The resistance of Bismuth in strong magnetic fields.*—Since the resistance of bismuth is increased when it is placed in a magnetic field, it has been suggested that the metal might serve to measure the strength of the field. H. J. B. HENDERSON states that the curve which shows the relation between the resistance and the field intensity was a straight line between a field intensity of 4000 C. G. S. to a field of 15,000 C. G. S. and this relation holds for still more extensive fields. The resistance of a bismuth wire spiral rose at the ordinary normal temperature from 10 ohms with a null field to 33 ohms with a field of 39,000 C. G. S. With lower temperatures the change is relatively greater. With higher temperatures less. It may be that at a certain temperature the change of resistance in the magnetic field disappears. Whether this temperature coincides with the melting point of bismuth can only be decided by experiment.—

Physical Society of Berlin, June 1, 1894; *Ann. der Physik und Chemie*, pp. 57, 58. J. T.

11. *Motion of dielectric bodies in a homogeneous electrostatic field.*—LE GRAETZ and L. FOMM describe a dielectric volmeter which consists of a thin disc of sulphur or paraffin suspended between the plates of a condenser. The disc tends to place its axis along the lines of electrostatic force. The rotations depend on the size of the charge on the plate, and the oscillations are proportional to the square of the difference of potential.—*Ann. der Physik und Chemie*, No. 9, 1894, pp. 86–94. J. T.

12. *Maxim's flying machine.*—Mr. HIRAM S. MAXIM gives in the National—an English magazine—a description of his experiments on flying by means of an æroplane. His flying machine when finished and loaded with water, fuel and three men, weighed nearly 8000 lbs. The actual horse power developed on the screws was 363 horse power, with a screw thrust of about 2000 lbs. The total width of the machine was over 200 feet. On running the machine at 30 miles an hour very little load remained on the track and at 36 miles an hour the whole machine was completely lifted.—*Nature*, Sept. 13, p. 489. J. T.

13. *A Treatise on the Measurement of Electrical Resistance.* By WILLIAM ARTHUR PRICE, M.A., A.M.I.C.E. 8°, pp. xvi, 199. Oxford, Clarendon Press, 1894.—This volume is an exposition of the theory and practice of the measurement of electrical resistance, with especial reference to those considerations that arise in actual work, and which are either altogether omitted in ordinary general treatises, or very insufficiently presented. In the first chapter the meaning of resistance, its laws, and units of measurement are considered. This is followed in the second chapter by a discussion of the materials best suited for resistance coils, their temperature coefficients, their variation with time, and attention is drawn to the special qualities of some of the newer materials, as platinoid and manganin. In succeeding chapters the construction of bobbins, the best methods of winding resistance coils, and the precautions to be observed in order to secure accuracy and permanence are taken up. The various forms of commutators and switches, Wheatstone's bridge, the meter bridge in its later modifications, with the various accessories and adaptations, the most suitable arrangements for very low or very high resistance are discussed in detail.

In several Appendices are contained the mathematical theory of Wheatstone's bridge, Lord Kelvin's modification of it for low resistances, electromotive forces at the junctions of meter bridges, the discharge of a condenser through a high resistance, Mance's method of measuring the resistance of a battery, and the electrostatic analogue of Wheatstone's bridge.

The pages of the book contain many interesting remarks and practical suggestions derived from experience, and will be a valuable aid to those studying the subject in a general way, and especially to those engaged in the construction of standard coils and instruments, or in the actual work of electrical measurement.

A. W. W.

14. *Practical Work in General Physics.* By W. G. WOOLLCOMBE. Crown 8°, pp. xii, 83. Oxford, Clarendon Press. 1894.—This is a collection of some fifty practical exercises, with descriptions of instruments and methods for the measurement of lengths, areas, volumes, and densities. Other topics are the barometer, the simple pendulum, capillarity and surface tension. The theory of the balance and the methods of determining weights are briefly indicated, with practical directions sufficient to prepare the experimenter for such use of the balance as is required in many of the exercises. The experiments, which are mostly of rather simple character, are clearly described with considerable detail, and, for the limited range of subjects, the book will be a useful guide to the student. A. W. W.

II. GEOLOGY AND MINERALOGY.

1. *An Occurrence of Anorthite and Epidote* (communicated).—In a large series of specimens collected at Phippsburg, Maine, by T. F. Lamb of Portland, these two minerals occur under unusual circumstances. The mass of the material consists of cinnamon garnet, with occasional green pyroxene, similar to the well-known occurrences at Raymond, Maine, and elsewhere, the rock itself being evidently a highly metamorphosed contact limestone. Occasionally there is imbedded in the masses of garnet a dark gray mineral, nearly black, in brilliant plates, in nowise suggesting epidote. This however, it proved to be, after partial analysis by Dr. W. F. Hillebrand, and optical examination by Mr. J. S. Diller. The anorthite, also verified optically by Mr. Diller, and by partial analysis by Mr. George Steiger, is associated sometimes with the epidote, and sometimes in coarse crystals, only with the garnet. The analyses are as follows:

	Epidote.	Anorthite.
SiO_2	38·54	45·62
Al_2O_3	28·39	35·29
Fe_2O_3	6·89	
FeO	·50	
CaO	24·12	17·31
MgO	trace	
Ignition	2·26	
	100·70	98·22

On first inspection I supposed the epidote to be axinite, which is said to occur at the Phippsburg locality, and which in this case it somewhat resembles. F. W. CLARKE.

2. *A new locality of true Emeralds* (communicated).—In July, 1894, a new locality of true emeralds was discovered, by Mr. J.

L. Rorison, miner of mica, and Mr. D. A. Bowman, on the Rorison property near Bakersville, Mitchell County, N. C. Here, at an elevation of five thousand feet a. t., on Big Crab-Tree Mountain, occurs a vein of pegmatite some five feet wide, with well-defined walls, in mica schist. This vein carries a variety of minerals besides its component quartz and feldspar, among these being garnets; translucent, reddish, and black tourmalines, the latter abundant in slender crystals; white, yellow, and pale-green beryls; and the emeralds. These latter are chiefly small, 1 to 10^{mm} wide by 5 to 25^{mm} long, but some have been found two or three times larger than the larger size named. They are perfect hexagonal prisms, generally well terminated, and are clear and of good color, with some promise for gems. They very strikingly resemble the Norwegian emeralds from Arendal.

One vein outcrops for perhaps a hundred yards, with a north to south strike. The results thus far obtained are only from about five feet depth of working, so that much more may be looked for as the vein is developed.

The locality is fourteen miles south of Bakersville, and about the same distance from Mitchell's Peak, a little north of the crest of the Blue Ridge. It is some fifty miles west of the emerald locality at Stony Point, Alexander County, N. C., described by William Hidden in 1881 in a pamphlet privately printed at New York, and in the Transactions of the New York Academy of Sciences, 1882, pp. 101–105, as also by the writer in "Gems and Precious Stones of North America," New York, 1888, p. 91.

I am indebted to Messrs. Rorison and Bowman for the information contained in this paper and for the privilege of examining the specimens found by them. GEORGE F. KUNZ.

3. *The Physical Geology and Geography of Great Britain, by the late Sir Andrew C. Ramsay*, 6th edition edited by HORACE B. WOODWARD, pp. 1–421 (Edward Stanford), London, 1894.—This simple account of English geology prepared in 1863, originally as a course of lectures to workingmen, after having passed through five editions and now revised to express the more modern views of geology still retains the charm which came from the personal enthusiasm of its author, a prominent figure in English geology a generation ago.

4. *The Story of our Planet*, by T. G. BONNEY, pp. 1–535 (The Cassell Publishing Co.)—The author of this treatise has attempted, as he says in his preface, to tell the story of our planet in fairly plain words and has framed the book on a plan similar to that adopted by Sir C. Lyell in his great work "The Principles of Geology," the last edition of which was published twenty-one years ago. Some of the more difficult problems of the science have been left out of discussion, and particular attention has been given to some subjects, in which his personal interests have been concerned. Among these latter are the physical geography of Britain in the earlier part of the Triassic,—the affects and former extent of glaciers and the history and age of certain crystalline

rocks. The book is illustrated and is a thoroughly readable book for general students interested in the scientific discussions of the day.

III. Botany.

1. *Flora of Mount Desert Island, Maine. A Preliminary Catalogue of the plants growing on Mount Desert and the adjacent Islands*; by Edward L. Rand and John H. Redfield. Cambridge: John Wilson & Son. 1894.—The territory covered by this catalogue possesses no special botanical interest except that which attaches to its proximity to the sea, and to the retention of some of the characteristic glacial plants. But these two features have attracted the attention of a group of assiduous explorers who now embody in this convenient and pleasing volume some of the results of their studies.

With the exception of the Fungi and some other Cryptogams, the catalogue is considered by the authors to represent fairly the existing knowledge regarding the species in their limits. The authors have had the assistance of collaborators who have worked up special genera, and they have made extensive use of local notes of a trustworthy character contributed by many observers. To add to the value of the handbook, an interesting article by Prof. W. M. Davis, on the geology of the region, has been given. This article is remarkable for its vigorous and attractive style.

At the outset, the authors declare their position with respect to proposed changes in nomenclature. After expressing the belief in which all must share, that a catalogue ought to be made as useful as possible to all who employ it, the joint authors waive certain personal preferences and adopt substantially the names as given in Gray's Manual. They then state with great force their reasons for not accepting the so-called Rochester and Madison codes. These reasons are essentially two: (1) these codes do not in themselves possess elements of permanency, and (2) they disregard the principle that *ex post facto* legislation is inherently wrong. As a clear and judicial charge to the jury of botanists who have not yet prejudged the case, the communication made by the authors of the catalogue may be cordially commended.

G. L. G.

2. *Researches in regard to the respiration of Muscineæ.*—B. Jönsson (Comptes rendus, 20 Aug., 1894).—The following is a summary of the results. In mosses there is a wide range of variation as regards the intensity of respiration and chlorophylline assimilation, and this variation depends largely on the content of water. Specimens of the same species taken from a very wet place emitted more gas than did those selected from dry places. Reddish color diminishes both respiration and the activity of assimilation. G. L. G.

3. *On the Constitution of the Atmosphere* (Comptes rendus, 20 Aug., 1894). — T. L. Phipson adds further suggestions to his

earlier one that the primitive vegetation was essentially anaërobic, gradually adapting itself to the changing conditions by which the amount of oxygen in the atmosphere was augmented and heat diminished, and becoming thus partly aërobic. Looking at cells, he traces their course from primitive vegetal forms of an aërobic type up to the animal cell which is strictly aërobic. The most interesting fact in the paper is quoted from an earlier communication, by which it appears that the confined atmosphere, in which a plant of *Convolvulus arvensis* grew, contained, after three months, a larger percentage of oxygen than is found in our atmosphere. G. L. G.

IV. Astronomy and Mathematics.

1. *The Collected Mathematical papers of Henry John Stephen Smith*, edited by J. W. L. Glaisher, with a mathematical introduction by the editor, biographical sketches, and a portrait. Two vols., 4°, pp. xcv, 603 and vii, 719. Clarendon press, Oxford, 1894.—These volumes contain 47 papers published by Prof. Smith, and one memoir on the Theta and Omega Functions not before published. All but three or four of the papers have appeared in the publications of learned societies or in the scientific journals and therefore could be consulted by those who had access to large libraries. But to all others they were as a whole practically inaccessible. The volumes are designed as a memorial, and in the character of the work presented and in this form of publication they constitute a magnificent and most worthy memorial of a remarkable man.

Professor Smith's earliest work was in pure Geometry, but very soon he was attracted to the theory of numbers, and his six reports on that subject made to the British Association are well known to mathematicians. In following years he became interested in elliptic functions. The longest paper in the second of these volumes, that on the Theta and Omega functions, grew out of a request to him from Prof. Glaisher that he would write an introduction to the volume of Tables of the Theta Functions, which had been computed by Prof. Glaisher in connection with a Committee of the British Association. For some unexplained reason these tables have not yet been given to the public. H. A. N.

2. *Cordoba Durchmusterung Atlas containing the positions and brightness of all the fixed stars down to the 10·0 magnitude for the mean equinox of 1875·0 in the belt of the heavens comprised between 22 and 42 degrees of southern declination;* to accompany vols. xvi and xvii of results of the Argentine National Observatory, published by the Observatory, 1893. Also vol. xvii of Results.—These twelve maps with the Argelander and Schönfeld maps cover the whole heavens down to 42° southern declination. This Durchmusterung and Atlas formed part of Dr. Gould's plan of work in going to Cordoba, but was deferred by him in order to carry out his meridian circle observations. It

has been undertaken by his successor Director Thorne. The maps are much more crowded with stars as Mr. Thorne observed stars down to the 10th magnitude. Vol. xvi was distributed some months ago, and now comes vol. xvii completing the catalogue of the zone. H. A. N.

V. Miscellaneous Scientific Intelligence.

1. *Popular lectures and addresses*, by Sir William Thomson (Baron Kelvin), in three volumes, Vol. II, *Geology and general Physics*, pp. 1–599 (Macmillan & Co.) 1894.—This is the final (published) volume of the valuable series of opinions, publically expressed on numerous cases of general interest involving the laws of pure science in the realms of physics, astronomy, geology and kindred branches, by this clear and calm judge of modern science. Some of the more important subjects upon which decisions are given in the present volume are : The doctrine of Uniformity in Geology; the Annual loss of Heat from the Earth; Geological time; the Origin and amount of Plutonic Energy; the Meteoric theory of the Sun's heat; on the Physical Condition of the Earth; the internal condition of the Earth, as to temperature, fluidity, and rigidity; Polar ice-caps and their influence in changing sea levels; on the origin of motive power, and natural sources of energy, the dissipation of energy, etc. There are also numerous addresses, résumés of opinions of others and of progress of science. The articles have been published in various places, and were originally delivered at various times ranging from 1856 to 1893, but lose nothing of their value by republication. In their present form they become accessible to the general student of science as a body of valuable scientific decisions which will stand until a more exhaustive analysis of the facts shall be made.

2. *The International Geological Congress* held its sixth meeting at Zurich from August 29th to September 3d, under the presidency of Professor Renevier, with an attendance of over 220 members. A large number of valuable papers were read of both general and local importance. A report on the state of progress of the geological map of Europe was made by Dr. Hauchecorne of Berlin. Six of the forty-nine projected sheets are now ready, including those for the northwest part of Europe, northern Germany, parts of France, Belgium, Poland, etc. The map is being published by Dietrich Reimer, Berlin.

Michel Levy, in an address before the Congress, proposed that some general system of classification of rocks be adopted by petrographers and suggested that it be founded primarily upon *texture* and secondarily upon the essential *constituent minerals.* A commission was appointed to consider the proposition and to revise the present classification and nomenclature of rocks.

M. E. de Margerie, Secretary of the Commission on Bibliography announced that the "Catalogue of Geological Bibliographies" prepared by the Commission and now in press will be sent gratuitously to all members of the last and of the present Congress.

The guide book, prepared by the local *comité d'organisation* of the Congress, forms an admirable geological description of the important features of the Swiss Jura and Alps. It is a volume of 306 pages entitled "*Livret-guide géologique dans le Jura et les Alpes de la Suisse*," with numerous woodcuts and thirteen colored maps, illustrating the itineraries of the eleven excursions planned for the members, and was prepared by several of the ablest Swiss geologists. This guide book, together with a beautiful new geological map of Switzerland, on a scale of 1 : 500,000, brings before geologists the latest detailed scientific interpretation of this always interesting region of the Alps.

The next meeting of the Congress, the seventh, will be held in 1897 at St. Petersburg. Arrangements are being made for a particularly interesting meeting in Russia, excursions are planned to cross Russia and the Urals into Siberia, and one to the Caucasus and the Caspian Sea. The Czar has expressed his interest in the Congress by inviting it to meet in St. Petersburg, and by subscribing liberally toward defraying the expenses of the Congress at its Russian meeting.

3. *Chloride of mercury batteries.*—Mr. D. H. Fitch of Cazenovia, N. Y., wishes attention called to the fact that he made use of the chlorides of mercury as the active agents in chemical batteries prior to the date of Helmholtz's description cited in Professor Carhart's article in this Journal.* Mr. Fitch took out a United States patent for a battery constructed on this principle, dated Sept. 16, 1879, the application for which was filed Sept. 9, 1878, entitled No. 219,631, Galvanic Batteries, Derick H. Fitch.

L'or a Minas Geraes (Brézil), by Paul Ferrand, Vol. I, pp. 159, Ouro Preto, 1894.

Minnesota, Geological and Natural History Survey, Vol. III.

The Lower Silurian Ostracoda of Minnesota, by E. O. Ulrich, pp. 629–693. 1894.

The Lower Silurian Trilobites of Minnesota, by John M. Clark, pp. 694–759. 1894.

The Animal as a Machine and a Prime Motor, and the laws of Energetics, by R. H. Thurston, pp. 1–97 (John Wiley & Sons). 1894.

Congrès géologiques international, Livret-guide géologique dans le Jura et les Alpes de la Suisse. (Comité d'Organisation, VI Session, Zurich), pp. 1–306. 89 figures, i–xiii plates. 1894.

Arkansas, Annual Report of the Geological Survey for 1892, Vol. II, *The Tertiary Geology of Southern Arkansas*, by G. D. Harris, pp. 1–207. 1894.

Miscellaneous Reports, pp. 1–349. 1894:

F. W. Simonds and T. C. Hopkins: The Geology of Benton County.
J. C. Branner: Elevations in the State of Arkansas.
J. C. Branner: Observations on erosion above Little Rock.
J. C. Branner: Magnetic observations.
F. A. Sampson: The Mollusca of Arkansas.
C. H. Bollman: The Myriopoda of Arkansas.
Seth E. Meech: The Fishes of Arkansas.
C. E. Siebenthal: The Geology of Dallas County.
J. C. Branner: Bibliography of the Geology of Arkansas.

* A one-volt standard cell. This Journal, vol. xlvi, p. 60.

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[THIRD SERIES.]

Art. LXI.—*Inversion of Temperatures in the 26·68 day Solar Magnetic Period*;* by Frank H. Bigelow.

The Epoch and use of the Ephemeris.—In previous abstracts, containing some of the results of my research into the relations between solar magnetism and meteorological phenomena, no complete account has been given of the formation of the Epoch and general use of the Ephemeris. A brief statement, however, interposed at this place, may be of service to some who are interested in this subject. The Ephemeris depends chiefly on the European Stations, Greenwich, Paris, Pola, Prague, Vienna, Pawlowsk, and Tiflis, the mean geographical position of the group being, longitude 17° 7′ east, and latitude 48° 37′ north. Each of these stations reports 24 observations of the three components of magnetic force every day, and the mean of these values, therefore, is equivalent to an ordinate on the scale of abscissas at noon of the station. Certain periodic changes were found in the system of deflecting forces that emerged from the daily residuals, of which one type was peculiarly conspicuous. The first day following this principal change was called number one of the new period, and from such dates the mean epoch for the year 1887 was computed, namely June 12·22, being very near the middle of the last quarter of the century. Strictly this applies to the position at longitude $1^h\ 8^m\ 28^s$ east, but not thinking the data of astronomical accuracy, I have in my work taken the epoch as practically Greenwich mean time, the correction being −0·05 day, if applied.

* Communicated by permission of the Chief of the Weather Bureau.

The meteorological observations of the U. S. Weather Bureau are now made at 8 A. M. and 8 P. M. 75th meridian mean time, and as it is generally agreed that the arithmetical mean of these values is nearly equal to that derived from hourly observations, this has been used in reducing the variations from day to day. In some of the years, if necessary, the mean of the maximum and minimum readings is taken as the mean for the day. In every case this mean corresponds to a noon observation at the station, as with European stations, and therefore a correction for longitude is required for the epoch of the ephemeris. I have preferred to retain the Greenwich epoch throughout the computations, and then move the comparison magnetic curve to the right by the amount of such correction. It has been found that the variations of the meteorological elements synchronize closely with the fluctuations of the magnetic curve in the extreme northwestern states, Manitoba, North and South Dakota, and Montana. If the temperature changes are transferred to millimeter paper, so that one centimeter is equivalent to a day, then for this region there is only a small correction to the epoch of the corresponding magnetic curve. If we could have our observations at a proper origin in British Columbia, no correction would be needed, and such an origin is 115° W. longitude, 55° N. latitude. This seems to be physically determined by the peculiar meteorological conditions of North America, namely, the latitude of the high pressure belt, and the winter accession to the same from the Arctic regions, which passes near this origin; the neighborhood of the pole of maximum cold and maximum magnetic intensity; the nearness to the magnetic pole in Boothea Island; all of which in combination cause this region to be a special theatre of formation of the high and low areas that are the agencies causing many of the weather variations of the United States. Passing to the south and east of this origin one can follow the changes produced by the temperature waves, by simply moving the magnetic curve to the right a number of days equal to the time of progress from the origin eastward. In practice, the calendar dates have been written along the top of the sheet and underneath them the dates of the magnetic ephemeris. Beginning at the day with its fraction which starts a new period, a line is drawn down the sheet so that it passes through the same phase for each district of the country. This was always determined by matching the magnetic curve to the temperature curve. Hence the same phases may be collected together by counting this line as the beginning of a period in every case. The difference between this line and the straight lines drawn from the ephemeris date gives the time consumed in the eastward drift. Since in this way the longitude from Greenwich has not entered, the final result as plotted on a curve will match the mean magnetic curve by moving the latter about eight hours to the right.

Since the epoch is that of the mean ordinate corresponding with noon, the real beginning of the magnetic curve is twelve hours earlier. There is this practical advantage in retaining the ephemeris on the noon ordinate, namely, that in following the fractional part of the dates, this ordinate may oscillate between the one and the ninety-nine hundredths of a day, and yet without changing the name of the day when it exceeds fifty hundredths. Therefore in tabulating data through many periods the integer date of the day can be always taken and the fraction neglected, since it is clear that the oscillation due to fractions of a day will soon balance themselves. The convenience of this device in practical work is very evident.

There are some plausible reasons for adopting the *115° meridian west longitude as the prime meteorological meridian for the United States.* Near it is the junction of the high polar circuit with the midlatitude circuit; the low pressure belt is thus chiefly interrupted by temperature waves at this point; near it is the greatest range in the temperature intensities; from it most conveniently can be computed the rate of the eastward march; the weather conditions originating on this stage of the meteorological field are propagated with such other variations as are due to the relaxation and disintegration of the same across the United States; the convenience of a meridian for meteorological reductions and the use of the ephemeris; the simple practical correction, half a day, from European to American phenomena. One point should be carefully remembered by meteorologists. It is necessary to distinguish between the phenomena of the pure ether and of ponderable matter. Magnetic forces are due to ether stresses alone, and hence those produced by the solar field are cosmical, and act instantaneously as well as simultaneously over the whole earth; when this ether energy is absorbed by the gases of the atmosphere, the forces are converted into those having their seat in ponderable matter, and hence the time factor due to convection or conduction must not be disregarded. Now the polar magnetic field chiefly concentrates in British America, and this combined with the general movements of the air causes the resulting temperature effects to be felt in other places only as the motion of the air allows them to spread. Hence at other stations, as in the east of the United States, the time discrepancy between the variations of the magnetic field and the temperature changes differ by three or four days. It is necessary to add to the epoch of the ephemeris this number to bring the synchronism approximately to view.

The temperatures of the United States have been plotted on long rolls, as described in my paper of January (Astron. and Astro-Physics), 1894, for more than 30 periods beginning 1892, Jan. 18·06, and continuing to date, and including the sixteen districts into which the synopsis of temperatures was subdivided, the Yuma district not participating in these changes. The time of the eastward movement from the origin, to the mean geographical position of the district to which the last station included in the group gives the name, is as follows in days and tenths of a day, for three different series of months, in each of which the rate is approximately the same. It will be necessary to say something more regarding the winter and the summer circuits of the movement, in a later section of this paper.

Eastward movement of the Temperature Waves of the United States from the position, Long. 115° W. Lat. 55° N.

Name of District.	Mean Longitude.	Mean Latitude.	December, January, February, March.	April, May, June, July, August.	September, October, November.
1. Roseburg	122° 33′	46° 42′	0·1	0·1	0·1
2. Calgary	107 43	50 46	0·3	0·3	0·2
3. Salt Lake City,	109 7	44 59	0·8	0·7	0·5
4. Fort Buford ..	99 42	45 8	1·1	1·1	0·7
5. Sioux City	96 20	39 43	1·4	1·6	1·0
6. Tucson	103 29	37 24	1·7	2·0	1·2
7. Corpus Christi,	95 13	31 34	1·8	2·3	1·5
8. Saint Louis ...	91 40	41 42	2·1	2·6	1·9
9. Duluth	87 8	44 41	2·2	2·9	2·0
10. Saugeen	81 51	46 37	2·4	3·2	2·7
11. Port Huron ..	80 44	42 24	2·6	3·5	2·9
12. Pittsburg	84 43	37 55	2·7	3·6	3·1
13. New Orleans ..	87 15	31 14	2·7	3·7	3·3
14. Key West	79 41	32 32	2·8	3·8	3·4
15. Washington ..	73 43	40 58	2·9	3·9	3·5
16. Northfield	67 51	45 58	2·9	3·9	3·5

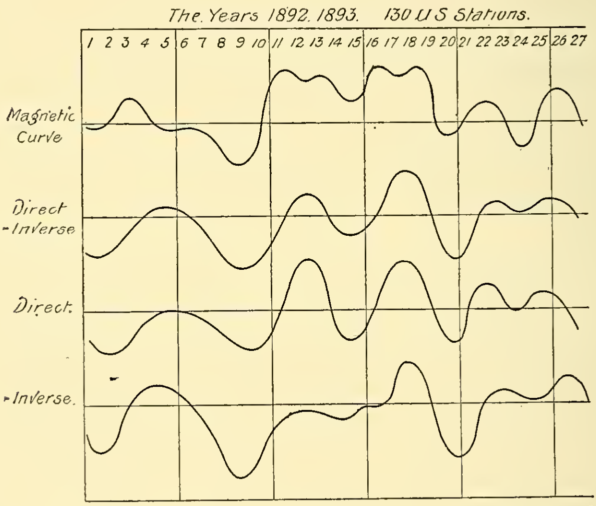
Inversion of Temperatures.—In accordance with the method established for reducing all temperature variations to the origin, and using the rates of eastward movement as given in the preceding table, a series of periods, thirty in number, from Jan. 18·06, 1892, to Dec. 11·74, 1893, inclusive, have been thus treated. One hundred and thirty stations, arranged in sixteen groups, were taken and the mean of the 8 A. M. and 8 A. M. tabulated. These groups were arranged in four divisions:

I. Roseburg, Calgary, Salt Lake City, Fort Buford.
II. Sioux City, Tucson, Corpus Christi, Saint Louis.
III. Duluth, Saugeen, Port Huron, Pittsburg.
IV. New Orleans, Key West, Washington, Northfield.

The mean temperature of each division for each day was taken out; then the mean temperature for the period from these means, and also the mean temperature from the middle of one period to the middle of the next; from these last means were interpolated values for each day; finally the differences between these two sets of numbers gives the daily departure of temperature. In this way the annual changes of temperature, due to the motion of the sun in latitude were to a considerable extent eliminated. The final sum of these residuals for each day is entered in the accompanying table. It will be observed that they are divided into two nearly equal parts which was accomplished as follows: The residuals of each period were plotted on half centimeter paper, and the line of variation of temperature drawn through them. These curves were carefully compared with the mean magnetic curve, which represents the intensity of the solar field, by superposition, when it was easily seen that certain periods agreed with the magnetic curve in its direct position, and others with the same curve inverted on its long axis. The magnetic curve is transferred to transparent celluloid, so that such comparisons are very easily performed.

The consideration of these curves disclosed some conditions, which are inherent in this type of work. They are the final effect of a number of causes. (1) The temperature gradients produced by the equatorial field, together with the wind currents by which heat is transported from station to station; (2) The annual change of the sun in latitude; (3) The rotation of the sun on its axis carrying the polar magnetic field. The result of these variations is to cause the formations of the individual curves corresponding to the solar rotation to be quite loosely constructed. The phases may fall a little to one side of the mean date, the amplitude of the crests is not uniformly built up, the mean elevation of the curve changes in an irregular manner, and the inversion of the curve may fall somewhere within the period. The magnetic curve itself is one of rapid variation, and hence it is difficult for it to persist steadily under all these sources of disturbance, so that the tendency of the residuals to cut themselves down algebraically must be admitted. The mean curve can be found only by using an extensive series of data, and ascribing to the small surviving residuals a larger degree of importance than at first sight they might seem to justify. These have been regarded as true relative numbers, and the final residuals have been restored to their proper magnitude, which can easily be concluded from the tabulations, by use of an appropriate factor. The residuals are thus to be considered as relative numbers, rather than absolute values in themselves, the magnitude of the single curves, without regard to the phase times, controlling the amplitude of the crests. It must be remarked that nothing less than a very accurate determination of the period of rotation of the sun, would permit the survival of any residuals in such an irregular curve. Hence by as much as there remain residuals, which being derived from very different sources yet produce the same curve, the argument in favor of the existence of the system of forces in nature corresponding to them is greatly strengthened.

Temperature Variations in the 2668 day Period showing direct & inverse changes



Since the labor of constructing such elaborate tabulations is very great, especially in extending the same over a series of years, resort was had to a shorter process for the years 1878–1891. It had been observed that the temperature variations of the Dakota Stations were the least distorted from the fundamental curve, doubtless due to the continental location, the amplitudes being large and the phases steady, and hence five stations, Fort Buford, Bismarck, St. Vincent, Moorhead and Huron, were employed for this purpose. By a similar method, allowing one day for the reduction to the origin, the following table and curves were constructed. In the case of each system of curves the plotting is moved 8 hours to the left to allow for the longitude on the Ephemeris not yet taken into the count, the rule covering all cases being, "For any station correct the epoch and succeeding dates of the Ephemeris by adding the longitude from Greenwich and the time of eastward movement from the American origin."

Residual Variations in the direct and inverse types.

Direct Temperatures.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1892 Jan. 18·06	− 3·9	+ 3·6	+ 1·8	+4·8	+7·2	+1·6	+ 0·3	+ 1·6	+ 4·3	+ 4·3	+ 4·8	+8·4	+ 6·5	+ 4·3
Feb. 13·74	−11·3	− 3·8	− 2·4	−2·2	−0·5	+1·0	+ 2·4	+ 3·6	+ 3·1	+ 2·0	− 1·1	−0·5	+ 1·5	+ 0·8
Apr. 7·10	− 6·7	− 4·4	− 1·5	−1·6	−4·3	−2·9	− 0·9	+ 2·8	+ 1·9	− 0·4	− 0·6	−0·1	− 0·8	− 1·3
May 3·78	− 3·0	− 3·6	− 2·2	−2·5	−4·9	−2·3	− 1·0	+ 1·6	− 1·4	− 1·9	− 2·0	+2·1	+ 0·2	− 6·3
Nov. 6·54	− 8·8	− 5·9	− 3·1	+2·5	+6·8	+3·9	+ 3·9	+ 5·6	+ 2·6	− 1·0	− 0·8	−1·6	− 2·7	− 8·3
1893 Jan. 25·58	+ 6·4	+ 3·8	− 0·5	+1·7	−1·1	−9·1	−10·7	−14·5	− 1·0	− 3·3	−13·4	−8·8	+ 4·4	+ 4·1
Feb. 21·26	+ 2·9	+ 1·8	− 0·6	+2·1	+0·6	−1·2	+ 0·9	+ 1·1	− 9·4	−10·9	− 5·1	−1·0	+ 7·1	+ 9·5
Apr. 15·62	− 0·4	− 2·4	− 6·0	−5·5	−5·3	−2·6	+ 0·1	− 0·5	− 1·5	− 0·8	− 0·1	−1·0	− 1·9	− 3·3
July 4·66	+ 0·4	− 2·9	− 1·9	+0·2	+1·7	+2·4	+ 1·9	+ 2·8	− 0·2	− 0·3	− 1·7	−1·7	+ 0·7	+ 1·7
Sept. 22·70	− 5·2	− 6·8	− 5·4	−3·7	−3·6	+2·1	+ 2·0	+ 1·1	− 1·0	− 0·6	− 0·4	+1·4	+ 1·3	+ 3·6
Oct. 19·38	+ 2·0	+ 4·4	+ 5·6	+0·2	+0·2	0·0	− 0·8	− 4·2	− 7·3	− 6·9	0·0	+6·3	+ 3·0	− 4·2
Nov. 15·06	+ 5·1	− 1·1	− 5·5	−2·1	+4·2	+4·8	− 4·1	−11·0	− 8·9	− 1·5	+ 5·1	+5·8	+ 6·7	+ 1·9
Direct ...	−22·5	−17·3	−21·7	−6·1	−1·2	−2·3	− 6·0	−10·0	−18·3	−21·3	−14·6	+9·3	+26·2	+ 2·5

Direct Temperatures.

	15	16	17	18	19	20	21	22	23	24	25	26	27
1892 Jan. 18·06	+ 1·4	− 0·6	− 0·4	+ 3·5	+ 2·8	− 0·5	− 2·8	− 0·3	− 6·3	− 4·0	+ 3·3	− 1·1	− 10·5
Feb. 13·74	− 3·8	− 0·6	+ 2·7	+ 5·5	+ 5·1	+ 5·9	−14·3	+ 7·6	+ 6·7	− 3·0	− 3·0	+ 4·9	− 0·8
Apr. 7·10	− 3·4	− 1·3	+ 3·4	+ 5·1	+ 2·6	− 1·7	− 1·0	+ 4·4	+ 2·8	+ 1·9	+ 1·9	− 0·7	− 1·2
May 3·78	− 8·2	− 8·4	− 6·3	− 1·8	+ 0·3	− 1·7	− 2·4	− 1·6	+ 0·5	+ 0·5	+ 2·8	+ 2·2	− 1·5
Nov. 6·54	− 7·3	− 3·9	− 2·4	− 2·2	− 1·5	− 2·6	− 0·6	+ 2·6	+ 4·0	+ 5·5	+ 3·0	+ 1·5	+ 6·7
1893 Jan. 25·58	− 1·0	+ 2·1	+ 6·8	+ 9·8	+ 0·1	− 0·9	− 2·0	+ 2·4	+ 1·8	− 1·2	+ 2·1	+ 3·5	+ 4·8
Feb. 21·26	+ 9·4	+ 9·8	+ 5·7	+ 4·9	+ 0·7	− 9·6	−11·6	− 9·4	−10·0	− 8·9	− 1·7	+ 0·4	+ 1·7
Apr. 15·62	− 3·0	− 2·8	− 0·7	− 1·1	− 2·0	− 1·4	+ 1·7	+ 4·5	+ 6·6	+ 3·0	+ 2·1	+ 3·4	+ 1·7
July 4·66	+ 1·7	+ 0·6	+ 1·4	+ 3·6	+ 1·3	− 0·2	+ 0·3	+ 0·4	+ 0·4	− 0·1	− 1·7	− 0·4	+ 1·6
Sept. 22·70	+ 5·5	+ 4·8	+ 4·4	+ 3·6	− 0·5	− 3·4	− 5·4	− 4·4	− 1·1	− 0·1	+ 0·9	+ 1·1	+ 1·9
Oct. 19·38	− 2·8	+ 0·2	+ 2·8	+ 5·6	+ 4·7	+ 4·2	+ 4·3	+ 4·4	+ 3·3	+ 1·2	− 1·4	− 5·8	− 1·3
Nov. 15·06	− 5·8	− 9·8	− 6·3	− 9·8	− 1·1	+ 0·9	− 4·0	+ 1·0	+ 5·5	+ 1·5	− 1·7	− 2·7	− 12·2
Direct ...	−17·3	− 9·9	+10·7	+26·9	+12·5	−11·0	−19·2	+11·6	+ 7·6	− 1·4	+ 6·5	+ 6·3	− 9·1

Inverse Temperatures.

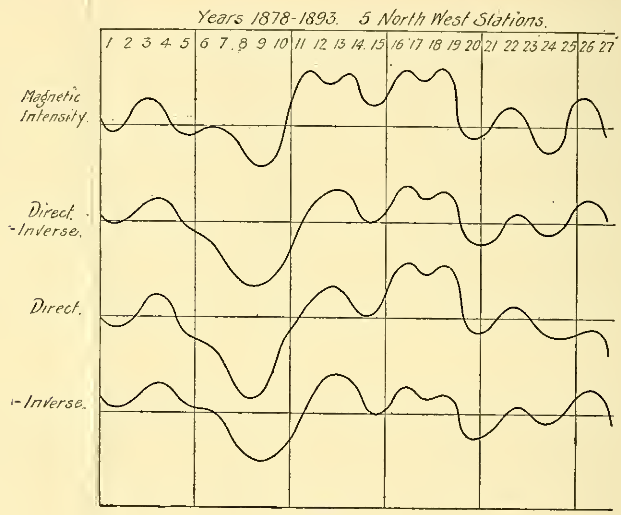
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1892 Mch. 11·42	− 4·3	− 6·6	− 9·2	−10·4	−11·5	−8·4	− 9·0	− 9·0	+ 3·6	− 2·0	− 0·6	+1·5	+ 3·4	−0·8
May 30·46	− 2·3	− 0·7	+ 0·2	+ 0·8	− 0·5	+1·1	+ 3·6	+ 3·4	+ 4·6	+ 7·5	+ 8·4	+5·8	+ 4·9	+5·3
June 26·14	+ 0·4	− 0·7	− 0·9	− 0·8	− 3·0	−3·5	− 3·0	− 1·1	− 0·8	+ 0·3	− 1·9	0·0	+ 1·4	+2·5
July 22·84	+ 4·2	+ 3·4	+ 3·2	+ 0·9	− 3·1	−2·6	− 1·6	− 1·4	− 0·1	+ 0·6	+ 0·7	+1·0	+ 2·3	+2·6
Aug. 18·50	− 1·4	− 1·0	− 0·1	0·0	+ 0·2	+0·4	+ 0·8	+ 2·2	+ 2·0	− 0·8	− 3·2	−1·9	+ 1·3	+2·1
Sept. 14·18	+ 1·4	+ 7·5	+ 6·9	+ 6·7	+ 7·1	+9·5	+10·6	+ 9·8	+ 8·3	+ 6·2	+ 2·8	+4·5	+ 2·5	+2·2
Oct. 10·86	+ 3·0	+ 5·5	+ 2·5	+ 1·0	+ 4·5	+2·0	0·0	0·0	0·0	− 0·5	− 3·6	−5·5	− 6·0	−4·7
Dec. 3·22	+ 8·0	+ 6·1	+ 2·4	− 1·3	− 2·9	−3·6	− 0·6	+ 3·3	+ 5·9	+ 5·7	+ 4·6	+2·1	+ 3·1	+0·9
Dec. 29·90	+ 7·9	+ 2·6	+ 1·0	+ 2·8	+ 1·9	+1·6	+ 1·5	+ 2·0	− 1·1	− 3·9	− 2·2	−5·5	− 6·7	−7·1
1893 Mch. 19·94	+ 0·5	+ 4·4	− 0·6	− 5·2	− 5·7	−6·1	− 4·1	+ 1·3	+ 6·3	+ 7·0	+ 1·5	+3·9	+ 7·9	+5·7
May 12·30	+ 0·5	− 1·1	+ 0·5	+ 3·1	+ 5·7	+4·4	+ 3·3	+ 0·2	− 4·1	− 2·9	− 3·8	−5·7	− 5·4	−3·4
June 7·98	− 0·4	+ 2·9	+ 3·3	+ 2·6	+ 0·3	−1·5	+ 0·5	− 2·7	+ 4·2	+ 3·5	− 0·4	−2·1	− 1·8	+0·4
July 31·34	+ 1·8	+ 2·6	+ 0·6	+ 0·2	+ 1·4	+2·2	+ 1·7	+ 2·5	+ 0·6	− 3·4	− 3·3	−0·5	− 0·5	−0·8
Aug. 27·02	− 3·5	− 3·1	− 1·9	− 3·7	− 1·7	−0·2	+ 1·3	+ 1·2	+ 0·9	+ 0·6	+ 1·9	+2·2	+ 1·6	+3·3
Dec. 11·74	− 6·5	+ 3·8	− 0·5	− 4·7	− 0·7	+0·8	− 3·1	+ 0·6	+ 8·6	+13·1	+12·6	+6·9	− 2·6	+0·9
Inverse ...	+ 9·3	+25·6	+ 7·4	− 8·0	− 7·5	−3·9	+ 1·9	+17·7	+38·9	+31·0	+13·5	+6·7	+ 5·4	+9·1
D−I	−31·8	−42·9	−29·1	+ 1·9	+ 6·3	+1·6	− 7·9	−27·7	−57·2	−52·3	−28·1	+2·6	+20·8	−6·6

Inverse Temperatures.

	15	16	17	18	19	20	21	22	23	24	25	26	27
1892 Mch. 11·42	− 0·9	− 0·4	+ 2·4	+ 1·4	+ 7·1	+ 7·9	+ 7·1	+ 8·6	+ 7·1	+ 4·6	+ 6·7	+ 1·2	− 4·4
May 30·46	+ 4·7	+ 3·5	+ 2·9	+ 3·7	+ 5·1	+ 4·9	+ 4·5	+ 1·6	− 0·1	− 1·9	− 1·5	− 0·4	+ 0·6
June 26·14	+ 1·6	+ 1·5	+ 0·2	− 2·9	− 1·8	− 1·3	+ 0·6	+ 0·5	+ 1·1	+ 1·5	− 7·1	+ 3·3	+ 3·8
July 22·84	+ 3·5	+ 2·0	+ 1·1	− 2·0	+ 0·2	− 0·8	− 1·7	− 1·7	− 3·0	− 3·2	− 1·8	− 1·3	− 1·6
Aug. 18·50	− 0·1	− 3·2	− 3·1	− 3·5	− 0·6	+ 1·1	+ 1·2	+ 0·8	− 3·1	− 1·7	− 2·2	− 3·4	− 3·0
Sept. 14·18	− 0·6	+ 1·2	+ 2·2	− 0·2	− 2·5	− 1·4	+ 0·3	− 1·1	− 4·6	− 3·3	− 2·2	+ 0·2	+ 2·4
Oct. 10·86	− 1·8	− 2·3	− 0·9	+ 0·6	+ 1·0	+ 2·7	+ 1·6	− 2·6	− 2·7	+ 2·4	+ 3·3	− 0·3	− 5·5
Dec. 3·22	− 4·1	− 6·5	− 7·2	−10·4	− 8·6	− 7·3	− 5·8	− 9·2	− 7·4	− 1·1	+ 4·9	+ 8·8	+ 10·5
Dec. 29·90	− 8·8	− 6·8	− 2·7	− 2·8	− 2·7	+ 2·2	+ 4·4	+ 8·5	+10·2	+ 10·8	+ 8·0	− 0·4	+ 3·2
1893 Mch. 19·94	÷ 2·5	+ 4·6	+ 8·1	+ 2·2	− 0·3	+ 1·0	+ 4·3	+ 5·6	− 2·3	− 6·5	− 4·9	− 2·7	− 1·1
May 12·30	− 2·2	− 0·2	− 0·3	− 0·2	+ 1·2	+ 1·9	+ 0·6	− 2·3	− 1·9	+ 0·4	+ 1·8	+ 1·3	− 0·6
June 7·98	− 0·7	− 1·4	− 2·3	− 0·3	− 0·3	− 0·1	− 0·6	− 0·9	− 0·7	+ 1·3	+ 1·3	+ 2·4	+ 1·7
July 31·34	− 0·9	− 0·7	− 0·7	− 0·3	+ 0·4	+ 1·6	+ 2·3	+ 2·5	+ 1·7	+ 1·9	+ 1·6	+ 0·1	− 3·5
Aug. 27·02	+ 4·2	+ 6·7	+ 4·9	0·0	− 0·2	+ 2·0	+ 4·6	+ 0·9	+ 1·5	+ 1·3	− 0·7	− 1·9	− 5·6
Dec. 11·74	+ 7·1	+ 3·0	− 4·3	− 5·8	− 1·3	+ 4·1	+ 6·3	+ 2·3	− 2·7	− 4·4	−10·9	− 12·2	− 9·9
Inverse ...	+ 4·7	+ 1·0	+ 0·2	−20·5	− 1·3	+18·5	+29·7	+13·5	− 6·9	− 1·4	− 3·7	− 5·3	− 13·0
D−I	−22·0	−10·9	+10·5	+47·4	+15·8	−29·5	−48·9	− 1·9	+14·5	0·0	+ 10·2	+ 11·6	+ 3·9

In each diagram the first curve is the solar magnetic intensity, the second the direct temperatures minus the inverse temperatures, the third the direct and the fourth minus the inverse temperatures by themselves. The inverse residuals have all the signs changed so as to bring out the conformity to the eye. The factors used for the successive curves to reduce to the magnetic amplitude is 1, 1, $\frac{1}{2}$, $\frac{1}{10}$, $\frac{1}{5}$, $\frac{1}{15}$ respectively.

Temperature Variations in the 26.68 day Period showing the Direct & Inverse Types.



A few words only, on these remarkable curves are needed. There can be no collusion between the magnetic and the temperature variations, because the magnetic curve depends exclusively upon European observations, there being none available in America; the magnetic curve was published before work on the temperatures was commenced; the argument is estopped that the change of temperature as a meteorological phenomenon is what affected and was observed in the magnetic field. On plotting all the curves from year to year it is easy to match the magnetic curve yearly and the result shows that the solar rotation period is very exact, since there is no tendency to sidle, in about 220 revolutions of the sun. This result carries with it the conclusions, that the sun has a nucleus in which the permanent magnetism resides; that the period of rotation corresponds to the solar equatorial belt and not to the sun spot belts in latitudes ±12°; that the corona is at least in part a magnetic phenomenon, since from it was first deduced the fact

Direct and Inverse Temperature Variations. 5 Northwestern Stations, 1878–1893.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Sum.	D.	D + I.
Direct Temperatures.																														
1878	−9	−7	−3	−3	−4	−24	−30	−14	2	14	20	6	−14	−8	−20	−16	4	0	2	−14	−3	9	−5	−23	−36	−10	11	311	−142	−332
1879	5	7	14	19	1	10	−18	−5	−27	18	1	−4	3	−28	−20	16	7	26	51	14	−19	−50	−36	−18	1	11	−16	444	−9	−34
1880	7	18	5	−8	2	−13	−26	−31	−12	−9	−15	12	18	29	10	9	47	19	−12	−23	−24	−22	2	−31	−45	−6	48	503	+50	−48
1881	−6	−1	6	13	15	−1	−31	−6	−20	−16	−15	4	16	3	7	9	19	32	28	−3	−14	14	19	−27	−39	21	37	402	−51	−84
1882	4	7	11	18	15	−20	−65	−60	−79	−29	−14	−30	18	−13	28	47	29	17	30	3	−14	20	−16	−30	−32	−6	8	663	+210	+30
1883	−29	−5	23	33	17	32	22	−2	−20	−25	−23	−3	−4	15	−8	5	24	0	−11	−7	24	21	−7	−15	20	24	−4	423	−30	−116
1884	9	−17	−30	16	28	−5	−12	−24	−63	−36	−8	37	15	5	5	24	36	11	28	27	12	11	13	10	19	2	22	525	+72	+82
1885	−18	−3	0	8	−21	−43	−47	−64	−83	−60	−53	−36	−30	−21	−34	4	−1	27	53	29	46	74	58	51	26	7	30	927	+474	+543
1886	14	13	20	39	13	9	23	−2	−30	−9	12	18	16	27	24	14	23	9	10	−14	−27	−19	−2	6	−27	−23	−15	458	+5	+132
1887	−28	3	19	21	4	−15	−32	−15	−17	−32	−11	1	14	31	−24	−13	−2	29	50	14	−2	5	25	19	14	19	−16	505	+52	+187
1888	−5	0	8	−5	−9	7	0	11	−9	9	15	22	35	7	−16	−13	−7	1	−9	−11	−17	−18	−2	0	5	27	9	277	−176	+207
1889	22	15	7	8	−28	−9	10	−22	−54	−22	−4	20	12	21	8	13	12	17	22	−17	19	−19	−15	−2	−16	−5	−24	439	−14	+24
1890	6	−5	−20	−4	0	−2	−1	−11	−21	−20	8	11	17	3	2	−6	−10	−16	−17	−23	−19	−13	−14	5	14	17	21	206	−247	−111
1891	−16	−22	−56	−17	−1	−3	−24	−1	7	−11	−20	−23	21	27	16	27	33	29	7	−14	−16	−19	−18	−6	−10	3	−9	456	+3	−10
1892	−39	−5	−20	−3	−4	4	2	9	13	7	16	25	15	4	0	6	13	2	5	−5	−5	10	12	5	6	11	−6	237	−216	−361
1893	6	−5	−26	−24	−28	−22	−23	−40	−46	−38	−32	−19	−5	−17	10	−8	18	12	8	12	−7	4	17	9	15	11	12	474	+21	−88
Sum	−77	−7	−42	111	−56	−95	−272	−277	−459	−259	−125	41	147	85	−7	118	245	215	245	−32	−66	9	31	−47	−85	103	108	453		
Inverse Temperatures.																														
1878	0	15	7	19	13	4	3	2	1	−4	−1	−5	−6	−6	−11	−11	−14	−8	1	8	17	14	9	15	20	−2	−11	227	−190	....
1879	−25	−51	−31	−8	12	−6	19	13	26	37	6	17	24	−6	−9	5	−4	−9	2	14	12	4	3	20	22	15	17	417	−25	....
1880	4	31	36	22	19	19	25	25	8	−2	−3	−5	−8	8	−2	−15	−15	−15	−18	−6	2	3	15	3	−6	−9	−20	344	−98	....
1881	35	23	4	−12	−10	12	8	10	3	23	8	−27	−28	−43	−27	−7	16	0	−20	15	14	−4	−17	−1	−10	16	28	409	−33	....
1882	−2	10	16	−6	−23	−23	−6	3	9	5	12	−9	−12	2	18	13	9	−5	−5	−15	−6	−3	−5	4	−9	−11	−11	262	−180	....
1883	−1	−8	−9	−7	−1	−11	−1	−3	−13	−10	0	−17	−25	−36	−36	−6	−6	14	27	25	27	18	6	16	−15	−14	−4	356	−86	....
1884	−17	−17	−20	−31	−29	−24	−9	−1	22	17	2	−9	−9	−21	−26	0	10	32	24	24	27	24	3	27	−2	−14	−11	452	+10	....
1885	11	18	26	42	15	2	7	11	23	29	12	−5	−43	−48	−28	−3	−7	13	25	−17	−16	−7	−1	−10	−26	−43	−23	511	+69	....
1886	−4	8	28	17	14	30	7	19	24	9	−33	−36	−44	−25	9	11	2	−10	−44	−22	−32	−12	−12	−35	−45	−9	28	569	+127	....
1887	−1	−1	−43	−72	−73	−26	−4	22	32	34	22	9	−47	−30	51	45	−6	10	6	26	23	−13	−8	8	2	−23	−40	577	+135	....
1888	−41	−63	−32	−43	−40	−45	−33	−23	25	34	64	33	37	32	43	13	−1	2	3	18	31	31	34	−10	24	−13	−57	825	+383	....
1889	−18	−13	7	−7	23	4	−31	−3	19	36	38	35	43	6	−1	5	−16	−14	−9	−21	−14	21	4	10	41	42	25	480	+38	....
1890	27	10	12	−19	−7	7	29	50	20	12	−24	−33	−2	−11	−3	−39	−19	−40	−51	−34	−7	−21	−2	4	16	46	33	578	+136	....
1891	−6	−30	−49	−26	2	0	14	22	12	−6	11	−10	−20	−13	0	1	−40	−10	−5	10	42	40	−5	5	15	2	−33	429	−13	....
1892	15	20	0	−6	−3	−10	−12	0	11	20	9	22	13	9	16	−10	−6	−14	−10	7	11	−1	1	20	27	−1	−10	297	−145	....
1893	−16	−6	9	17	23	18	4	10	24	23	16	3	0	3	5	10	2	3	10	12	10	−12	−25	−13	−21	−19	−29	333	−109	....
Sum	−39	−56	−39	−120	−65	−27	20	157	246	255	139	−57	−127	−179	−1	12	−95	−51	−64	44	141	82	0	63	−15	−37	−122	442		
D–I	−38	49	−3	231	9	−68	−292	−434	−705	−514	−264	98	274	264	−6	106	340	266	309	−76	−207	−73	31	−110	−70	140	230			

of the existence of a system of magnetic poles and heterogeneous distribution. Furthermore the cosmical region between the sun and the earth must be filled with a magnetic radiation as distinct from the electromagnetic field, a fact of profound significance in considering the relations of electricity and magnetism to the constitution of the ether. The meteorological system is under the direct influence of this solar field, and shows itself primarily in the temperatures of the polar regions, and secondarily in the circulations of the air dependent upon them. Other phenomena of this polar field are the solar magnetic storms, the earth currents, and the aurora which is properly the visible vibration of this magnetic radiation in passing through the atmosphere, in variable intensities.

Variations of the Meteorological and the Magnetic Elements in the Annual and the Sun Spot periods.

An extensive compilation of material has been worked out to determine whether the synchronous variations of meteorological and magnetic elements extend to long periods, such as the annual, due to the orbital motion of the earth, and the eleven year period, of which the sun spot frequencies is characteristic. The results are briefly mentioned, as a complete description of the process is not suitable to this paper.

An arbitrary scale was constructed on semi-transparent celluloid, the size of the daily weather map, on which the lines of latitude and longitude are drawn, as well as certain curves more or less parallel to and others perpendicular to the High Pressure Belt of the United States. By means of these meteorological coördinates, the positions of the estimated centers of all the Highs and Lows, as well as the axis of the clearly defined waves (see previous paper) were read off for the years 1882–1893 inclusive. These were separated into northern and southern groups, which were treated independently. The coördinates were condensed and tabulated so as to be collected by years and by magnetic periods, the object being to learn whether such mean coördinates show any variations in the latitude. The accompanying map shows the resulting positions of the mean North and South High, and North and South Low Pressures, respectively, and also the axis of the advancing wave. The North Low and the South High lines are recognized as the axes of Ferrel's Low Pressure belt, which forms a portion of the polar circuit, and the Mid latitude high pressure belt which forms the tropical circuit. The North High track is the average position of the Highs traveling along the polar circuit; the South Low is that of the average position of formation or occurrence of cyclones in the Southern United States. To these are added the Colorado-Superior, the Texas-Michigan, the Florida-Nova Scotia, and the Mexican branches. On the same map are placed the average position of the wave fronts from the origin, in the annual mean eastward march. The North High and the South Low tracks are in reality abnormal outgrowths of the atmospheric circulation.

The question is, do these tracks in general move in latitude during the sun spot period? The result is that the North Low and the South High belts vary in latitude directly with the solar intensity, being further north at the maximum, and further south at the minimum of the period; while the North High and the South Low belts vary inversely, that is are further south during the maximum of sun spots. This means that an increase of solar magnetic intensity generates the cyclones further south, and causes the anticyclones from the polar circulation to travel to the south. Precisely the same remarks hold true in the annual period.

The Table of Relative Variations in the Meteorological and Magnetic Systems gives the final results of an extensive computation, many details of which will here be omitted. "Movement in Latitude" refers to the average geographical latitude

Table of Relative Variations in the Meteorological and Magnetic Systems.

	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	
Movement in Latitude	----	----	----	----	+ 9	+ 7	+ 24	+ 5	+ 5	− 18	+ 1	− 4	− 15	+ 7	− 3	+ 11	× 1
Movement in Longitude	----	----	----	----	+ 53	− 5	+ 9	+ 5	+ 21	− 22	− 8	+ 15	− 31	− 2	− 2	− 38	I × ½
Temperature Amplitudes	− 332	− 34	− 48	− 84	+ 30	− 116	+ 82	+ 543	+ 132	+ 187	+ 207	+ 24	− 111	− 10	− 361	− 88	× $\frac{1}{20}$
Mean Annual Temperatures	−2·51	−1·19	−1·27	−1·31	−1·26	+0·36	−0·08	+1·38	+1·38	+0·52	+0·75	−0·95	−1·33	−0·63	+0·23	+0·99	I × 10
Reduced to same Amplitude	----	----	----	----	9	7	24	5	5	− 18	1	− 4	− 15	7	− 3	11	
	----	----	----	----	27	− 3	5	3	11	− 11	− 4	8	− 16	− 1	− 1	− 19	
	− 16	− 2	− 3	− 4	2	− 6	4	27	7	9	10	1	− 6	− 1	− 18	− 4	
	− 25	− 12	− 13	− 13	− 13	4	0	14	14	5	8	− 10	− 13	− 7	2	10	
Mean of Relative Numbers	− 21	− 7	− 8	− 9	+ 6	0	+ 8	+ 12	+ 9	− 4	+ 4	− 2	− 13	0	− 5	− 1	
Magnetic Intensity	− 21	− 11	0	+ 3	+ 24	+ 12	+ 14	+ 10	+ 5	− 14	− 8	− 18	− 36	----	----	----	
Sun Spot Numbers	− 18	− 17	− 4	+ 7	+ 10	+ 12	+ 12	+ 6	− 7	− 14	− 17	− 17	− 17	− 2	+ 17	+ 22	

that the four mean tracks, North Low and High, South Low and High, occupy from year to year. The North High and the South Low move in opposite directions to the North Low and South High, the latter moving north with increasing intensity of the magnetic system. The units are 3 miles in latitude, and the range in the sun spot period is about 120 miles. "Movement in Longitude" indicates the variation on the mean eastward drift of the meteorological conditions, taken year by year, and the numbers are here given with the signs inverted. This shows that the increase in eastward movement is for the years of decrease in the magnetic intensity. The physical interpretation of these inversions is at hand, but cannot be explained in this abstract. The unit is 1·37 miles, and the change in movement ranges about 50 miles per day; that is in years when the magnetic intensity of the sun increases, the normal tracks move northward, and the eastward circulation slows down.

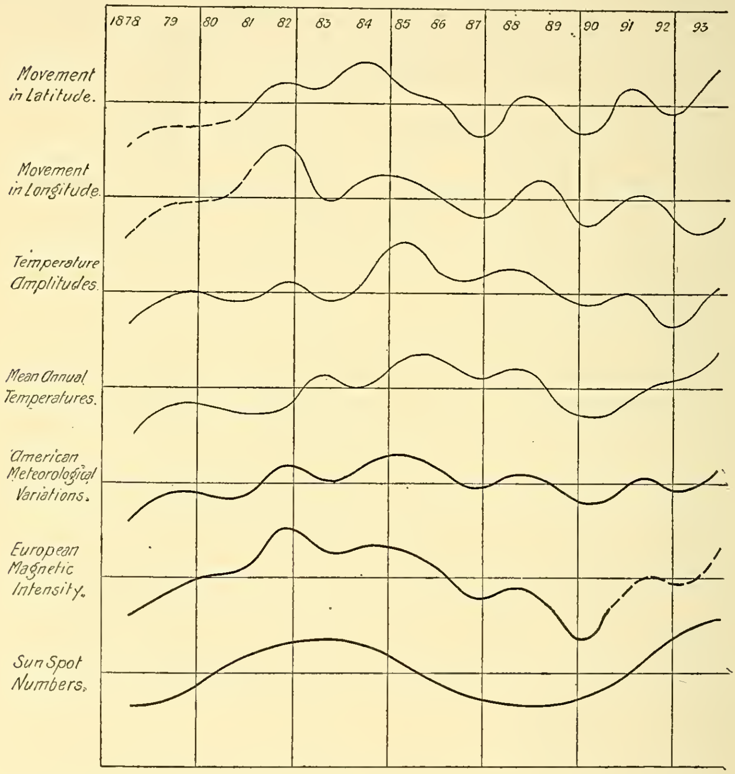
"Temperature Amplitudes" relates to the changes in temperature in the 26·68 day periods from year to year. By summing the residuals, already explained, without regard to signs, the amplitudes are obtained, and the sum of these for each year is entered in the table. They are only relative numbers but show the annual changes. The "mean annual temperatures" are derived from 80 Weather Bureau Stations, the annual temperatures being tabulated, summed and the residuals entered, these being the surviving residuals for each year. They are however entered with the opposite signs, and express the fact that the years of an increase of solar magnetic intensity are those of colder temperature in the United States, the explanation of the phenomenon being in harmony with the theory of anticyclonic and cyclonic circulations which I have briefly described in an earlier paper. (Astron. and Astro-Phys., Jan., 1894).

All of these sets of numbers may be treated as merely relative values of one fundamental impulse, namely the solar magnetic field, and hence can be reduced to the same amplitude, the mean of the last relative numbers being a closer representation of the average system than either of these sets alone. It should be noted that on plotting in a diagram, the four sets clearly agree among each other in producing the same curve, even to minute details, the years 1883, 1884, near the crest alone showing some uncertainty in the curves.

"Magnetic Intensity" gives the annual variations of the European magnetic field, as derived for five or more stations, the data referring to the horizontal component, $\sigma = 0{\cdot}000084$ C. G. S., and the unit being the sixth decimal. The sun spot numbers are taken from the Jahrbuch der Astronomie und

Geophysik, III, 1892, with extension to latest observations. These numbers are variations on the mean sun spot number 40, multiplied by the factor $\frac{1}{2}$. The accompanying diagram,

Relative Variations: the American Meteorological the European Magnetic, and the Sun Spots, 1878-1893



plotted on the scale $0{\cdot}5^{mm}$ = unit, gives the comparison of the changes in the American Meteorological System, the European Magnetic Field, and the visible surface of the Sun. The conclusion seems unavoidable that we are here dealing with different portions of a great cosmical system, emanating from the sun and influencing the entire northern hemisphere of the earth, by means of the polar magnetic field. Similar computations for the changes in the meteorological system, its movement in latitude and longitude, and its mean and amplitude temperatures, have been executed for the annual, and the 26·68 day periods, with results in agreement with this important thesis.

The next step in the progress of this investigation is to determine the physical function for the transformation of the energy of the solar magnetic fields, the electromagnetic and the magnetic, into the equivalent heat-energy that exhibits itself in temperature changes. There are many difficulties in the way of this step, but it is hoped that they can be overcome before long.

Formation of Anticyclonic and Cyclonic Circulations.

One of the most remarkable facts regarding the development of the theories of the origin of the Anticyclones and Cyclones of Middle Latitudes, is the excessive weight ascribed to the cyclones. This is perhaps due to a popular interest in the system of winds accompanying Low Areas of Pressure, and to a supposed resemblance between these and the general circulation of the air. Vertical convection currents are said to be the primary source of the movement, and some have seen in the High Areas only the pericyclonic overflow ring, as if these were secondaries to the Lows.

The real order of events in nature may, however, be summarized as follows: The Equatorial Field generates a tropical High pressure, and a sub-polar Low pressure belt, by its distribution of temperature. The continents rearrange these belts so that in winter the small polar circuit surrounding the Icelandic permanent Low, supersedes and predominates, while in summer the great mid-latitude circuit regains its supremacy. Therefore in winter the circulation of the polar circuit is more rapid, being smaller in diameter, the supply comes across the North American Polar regions, and but little from the Pacific; in the summer the slower eastward march in the wider circuit sets in, with the supply from the Pacific. In both cases the movement of air masses is dominated by the varying intensities of the polar magnetic field from the sun, by which the densities of the contents of the unit volume is changed. High Pressure areas are the primary products of these sources of energy, being in part whirled up by the general circulation, and in part the result of reducing the polar absorption by diminution of the cosmical energy on certain dates. Between two successive areas of greater density lies an area of smaller density, where absorption of magnetic radiation has been more vigorous. Under the force of gravity the adjacent sides of the denser areas are drawn together, and meet abruptly along the axis of the low section, in the so-called "trough." The characteristics are that southern warmer air reinforces the high pressure outflow, and transports its charge of aqueous vapor in the current; this meets the colder sheet from the north, in a calm area or one of variable winds, the vapor contents being cooled by mixture with the lower temperatures and therefore precipitated; at the same time with the counter flow, right hand deflecting forces generate a couple of gyration (See U. S. daily weather maps, Tuesday, March 27, and April 7, 1894, for illustration), which develops somewhere along the axis of encounter a cyclonic whirl, due almost exclusively to horizontal transportation, the vertical movement being a subordinate action; indeed the rapid whirling is a symptom of the lack of vertical motion, the escape of the air at the top of the vertex in the general eastward current being a source of loss of gyratory energy; rainfall accompanies a low area on the side chiefly of greatest cold, or where the oceanic supply can first meet with colder air, and is not a cause of it; tornadoes, thunder storms, the thin band of rain and other phenomena, are secondaries to the counter flow from the two high sheets, are located along the axis, and derive their power from the force of gravity acting on the primary denser high area masses. The synchronism of the magnetic curve is evidently, from day to day, the efficient governor in the succession, this changing in type with the inversion of the system. The difference between the North American and the Siberian systems is a marked increase in the number of cyclones in North America, which cannot be accounted for by geographical conditions. The presence of the magnetic polar system on the American continents is, however, a sufficient source of differentiation. The peculiar system of feeders in the United States is due to the existence of long troughs between successive High areas, along the axis of which the cyclones move eastward and northward; while the Siberian High area, thrown up by the general circulation, is not broken into smaller masses by the magnetic variable intensities. The interplay about the "origin" is that of the discharge of the polar High belt across the Low belt, the tendency of the Pacific High to join the Polar High, the drift of the High areas east, partly along the Low belt, and partly into the southern High, and also between them as if in doubt which system to join. The interplay of these several systems adds to the complexity of the weather of the United States, and renders the art of forecasting very difficult to acquire.

Much light is, however, thrown upon these problems, by the possession of the true solar period of rotation, the form of the intensity curve, and the fact of its sudden reversal at certain times. This has occurred recently, on Dec. 3, 1893, Jan. 21, 1894. Attending these reversals are stagnations of movement, the transition from the polar to the midlatitude circulation, the passage from one hemisphere of the sun to the other, and apparently some action within the solar nucleus which is not yet understood. For if the periods of direct and inverse temperatures are collected in a table, marked D and I respectively, it is seen that there is a peculiar sequence among them in relation to the sun spot curve. The D and I periods interchange position in the table along with the sun spot variations, the I type following the curve directly, and the D type inversely. What this signifies in solar physics it is not yet possible to say, though it probably has to do with the nature of so-called positive and negative magnetism. Such material needs perfecting to reach its final form, but the clue here presented is so suggestive that it is published as it stands at this time.

DISTRIBUTION OF THE TYPES D AND I IN A SUN SPOT PERIOD.

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1878 ..	**D**	I	I	I	I	**D**	**D**	I	**D**	**D**	**D**	I	**D**	**D**
1879 ..	I	I	**D**	I	I	I	**D**	I	**D**	**D**	**D**	**D**	**D**	**D**
1880 ..	**D**	**D**	**D**	I	I	I	I	**D**	I	**D**	**D**	**D**	I	
1881 ..	**D**	**D**	I	I	I	I	**D**	**D**	**D**	I	I	I	**D**	I
1882 ..	**D**	**D**	**D**	**D**	**D**	I	I	I	I	I	I	I	I	**D**
1883 ..	**D**	**D**	**D**	**D**	**D**	I	I	I	I	**D**	I	I	I	
1884 ..	**D**	**D**	**D**	**D**	**D**	I	I	I	I	**D**	**D**	**D**	**D**	I
1885 ..	**D**	**D**	**D**	**D**	**D**	I	I	I	I	I	I	**D**	**D**	I
1886 ..	I	**D**	I	**D**	**D**	I	**D**	**D**	**D**	**D**	**D**	I	I	
1887 ..	I	I	**D**	I	I	I	**D**	I	I	**D**	**D**	**D**	**D**	I
1888 ..	I	I	I	I	I	I	I	**D**	**D**	**D**	**D**	**D**	**D**	I
1889 ..	I	**D**	I	I	**D**	**D**	**D**	**D**	**D**	**D**	I	I	I	
1890 ..	I	I	**D**	**D**	I	I	I	I	**D**	**D**	**D**	I	**D**	I
1891 ..	I	I	I	I	I	**D**	**D**	**D**	I	I	I	I	**D**	**D**
1892 ..	**D**	**D**	I	**D**	**D**	I	I	I	I	I	I	**D**	I	I
1893 ..	**D**	**D**	I	**D**	I	I	**D**	I	I	**D**	**D**	**D**	I	

Sun Spot Curve.

Temperatures direct **D**, inverted I.

ART. LXII. *Remarks on Colloidal Silver*; by C. BARUS.

1. IN the absence of Dr. E. A. Schneider I wish to say that there does not seem to be any real issue between the recent note of Mr. Carey Lea* and our own work.† It was our endeavor to arrive at new data relative to colloids in general, and colloidal silver was chosen merely as a promising subject for attack. We showed at length that colloidal silver possesses properties which can be explained with reference to the analogous behavior of suspended sediments. Differences neces-

* Carey Lea: this Journal: October, 1894.

† Barus u. Schneider: Ostwald's Zeitschrift: viii, p. 278, 1891; Wied. Annalen, xlviii, p. 327, 1893. Full references to the above and other allied physical questions are there given.

sarily remained as a result of differences in the size of particles in the two cases, the silver being much more finely comminuted. For this reason we can not admit that Mr. Lea's recent experiment is decisive. A similar test had already been made by Prange* and it was repeated by us with the remark that the Tyndall experiment is no valid criterion unless precise statements are made as to the size of particles which just appreciably interfere with optical clearness. In other words the dimensions below which Tyndall's experiment practically fails are here vitally in question, and data for these have not been forthcoming.

Suppose a solid is dropped into an excess of its solvent. In order that the system may become a solution, the disaggregation must at least reach the molecule. In electrolytes it may even go further as is evidenced by Arrhenius's celebrated factor 2. But, under other circumstances, may not the separation stop short *before* the molecule is reached; or conversely, when a precipitate is being formed out of individual molecules, may not the process of growth be arrested in virtue of an equilibrium of forces when the particles formed consist of 2, 10, 100 or even 1000 molecules? To answer affirmatively is to find a home for the family of colloidals, and they will more nearly resemble solutions in proportion as the particles are smaller. Certainly the beam of light is no longer an available criterion, for the whole phenomenon is mapped out on a scale which is small even in comparison with the wave length of light.

2. About a year and a half ago I incidentally made an experiment in connection with certain meteorological questions, which has a precise bearing on the point here at issue. In the endeavor to pass compressed air through a wet porous porcelain septum into water, I was struck by the magnitude of the pressures necessary. Supposing I waited long enough to insure the transpiration of liquid, no flow of gas through the septum occurred for pressure excesses of even above 100 lbs., excepting at isolated points which were obviously the seat of fissures. Now let T be the surface tension of water in dynes per linear centimeter, α the angle of capillarity, r the mean radius of the pores of the septum, and x the pressure of the gas in atmospheres. Then (very nearly) $10^6 x\pi r^2 = 2\pi r T\cos\alpha$, or

$$r = 2T\cos\alpha / 10^6 x$$

If therefore in the above experiment, $x = 8$ atm., $T = 71$ (Everett's tables, p. 50), $\cos\alpha = 1$ (say, for the superior limit is in question),

$$r = 18 \times 10^{-6} \text{ cm},$$

* Prange: Rec. des Trav. chim. des Pays. Bas, ix, p. 125.

nearly, making the diameter ($2r$) of the pores smaller than the wave length of violet light. Schneider showed however that colloidal silver passes readily through such a septum whereas the alcoholic precipitate fails to do so. The particles are therefore respectively smaller and larger than the diameter* given. If 10^{-8} cm be taken as the order of molecular dimensions, the size in question is at least 1000 times as large, showing the aggregates to consist of the enormous number of 10^9 molecules, at least. There is thus an abundance of room for particles containing (say) 100 molecules to the aggregate, and forming suspensions in water (colloids) in their general aspects hardly distinguishable from true solutions.

It is interesting to ask how great a pressure would force the water out of a septum just large enough to let the particles of the size in question (5×10^{-8} cm) pass. It would take several thousand atmospheres, and it is therefore quite impossible to test finer septa like animal membrane to the extent in question. Nevertheless if the attempt be made to *grade* porous clay septa, prepared by successive vitrifications, by the method given, I dare say that a range of mean diameters of pores could be obtained, sufficient to answer many outstanding dimensional questions† in relation to the colloidal state; but one should be prepared to exert pressures as high as 100 atmospheres.

2. There is another point of view from which colloidal silver invites treatment, this time in the solid state. Dr. Schneider and I interpreted the high degree of insulation which we detected in Carey Lea's metallic mirrors as an instance of the allied behavior of non-coherent metallic matter, in general. Wöhler (quoted by Wernicke) showed this some 50 years ago; but our references were chiefly directed to the recent work of Auerbach ‡ and of Ed. Branly § the latter of whom in particular proved that non-conduction ceased when an electric spark was passed through the column of powder. One therefore readily calls to mind the startling results recently obtained by Oliver Lodge ‖ with his "coherer," and the question is pertinently asked whether solid colloidal silver, swept by a train of electric surges will begin to show increased electric conduction, as it does for instance under the influence of heat.

* By the hydrodynamic method particles smaller then 2×10^{-6} were measured, supposing the method vouched for. Ostwald's Zts., l. c.

† I may here call to mind the allied geological fact that hot water will pass through porous rock in virtue of capillarity, in the face of enormous withstanding steam pressures.

‡ Auerbach: Wied. Ann., xxviii, p. 604, 1886.

§ Branly: Phil. Mag., (5), xxxiv, p. 530, 1892.

‖ Lodge: Nature, vol. l, p. 136, 1894.

Oberbeck's* electric work, undertaken in a different direction with a view of showing the occurrence of an allotropic state in Carey Lea's silver has quite failed to convince us. We see no reason for withdrawing the views which we originally expressed (l. c.)

3. At the close of our experiments † we suggested that a field of great promise would be found in the metallic optics of colloidal silver. Work of this kind has since been taken up with success by Wernicke.‡ The change of phase observed on the reflection of light from thin metallic laminæ enclosed between clear media, with the front plate of greater refractive index, is either an acceleration or a retardation, according as the metal is intrinsically coherent or non-coherent. The method is remarkably sensitive and applicable to metallic films so thin as to be quite invisible to the eye. Tested in this way colloidal silver according to Wernicke§ takes rank with bodies which in their ultimate nature are an aggregate of individual particles, however small they may be, or however perfect the mirroring surface which an even distribution may produce. It is this method which is to be looked to for decisive results, not only for silver but for other colloids.

4. Of the two interpretations which may be given of Carey Lea's brilliant discovery, the one originally advocated by Dr. Schneider and myself is to me intensely the more interesting. As an aggregate of excessively fine suspended particles, colloidal silver introduces a whole series of fascinating physical problems, subject to forces which as to their nature are almost tangible. Even in an ordinary case of sedimentation if I write

Muddy water + acid = acidulated water + mud,

the latter body being precipitated, I have a chemical equation in embryo,—an equation‖ which so far as can now be discerned lacks stochiometric precision, but which in its general character is undoubtedly a double decomposition. If the actuating forces be traced, they must lead by slow gradations up to affinity.

Washington, October, 1894.

* Oberbeck: Wied. Ann., xlvi, p. 265, 1892; xlvii, p. 353, 1892;
† Barus u Schneider: Wied. Ann, xlviii, p. 336, 1893.
‡ Wernicke: Wied. Ann., li, p. 448, 1894; lii, p. 515, 1894.
§ Wernicke: l. c. p. 523.
‖ In the same way I picture to myself, the remarkable physical effects produced by traces of foreign admixtures in metallurgy.

ART. LXIII.—*The Duration of Niagara Falls;* by J. W. SPENCER.

[Read before the meeting of the American Association for the Advancement of Science, Aug. 20, 1894.]

CONTENTS:

1. *Conjectures as to the Age of the Falls.*

ABOUT the year 1760, Sir William Johnson acquired possession of Niagara Falls, and from that time its recession impressed itself upon the few observers, so that when Andrew Ellicott made the first survey of the chasm, shortly before 1790, he was informed that the cataract had receded twenty feet in thirty years; whereupon he concluded that its age was 55,440 years.* Bakewell's estimate, in 1830, reduced its duration to about 12,000 years.† According to Lyell, in 1841,‡ the Falls was about 35,000 years old, and this conjecture was generally accepted until a few years ago. The first steps taken towards the determination of the age of the falls were those to ascertain the rate of actual recession. In 1842, Prof. James Hall triangulated the cataracts;§ in 1875,‖ the Lake Survey; in 1886,¶ Prof. R. S. Woodward; and in 1890,** Mr. Aug. S. Kibbe repeated the measurements. In 1819,†† the International Commission surveyed the river, and showed that the apex of the cataract was very acute, yet it does not appear that the measurements could be compared with the later surveys made for the determination of the rate of reces-

* "Journal of William Maclay," Appletons, 1890.
† Cited in "Travels in North America in 1841," by Sir Charles Lyell, vol. ix, p. 27.
‡ The same.
§ "Natural History of New York," Part IV, vol. iv, p. 184.
‖ Lake Survey Chart.
¶ Report of the meeting of the Am. As. Ad. Sc. in Science, Sept., 1886.
** 7th Rept. Com. State Res. Niag., 1891.
†† Printed by the U. S. Lighthouse Board.

sion. The four surveys naturally give data for superseding the earlier estimates, and if the mean rate of retreat of the falls during 48 years, be taken, its age would appear to be 9,000 years. The conjectures of the older geologists have been set aside by recent writers who have endeavored to reduce the age to 7,000 years by using the maximum rate of measured recession. Substituting a measured rate of retreat for one purely assumed was a step in the right direction, but without knowing it, the later writers were farther astray than the earlier, for they neglected to take into account the changing episodes of the river, which was not known to the earliest observers. Only one other geologist besides myself has called attention to the *varying* forces which have made the Niagara *cañon*,—and this is Mr. G. K. Gilbert,* by whom and the writer the principal phenomena affecting the history of the river have been discovered. The last question which had to be determined before a computation of the age of the falls could be undertaken was the approximate amount of work accomplished by the river during each of the episodes in its history. This I was able to estimate last fall.

2. *Modern Topography.*

For distance of 19 miles from Lake Erie (573 feet above tide), the Niagara peninsula is a plain, with slight undulations, rising from 15 to 30 or 40 feet above the lake. But three features are notable: (*a*) a drift ridge trending westward from the falls and surmounted by a beach (L, fig. 8) rising to 114 feet above the lake, with a knob 30 feet higher, at Drummondville; (*b*) at the outlet of Lake Erie, the river cuts through an escarpment of Devonian limestone, which there rises to about 30 feet; and (*c*) at a point about a mile north of the site of the falls there is another limestone ridge here named William Johnson's ridge in honor of the first settler (*e*, *e*, fig. 1) with an elevation of 40 or 50 feet. Between these two rocky ridges is the Tonawanda basin. From the northern margin of the plain, the escarpment suddenly descends about 240 feet to a lower plain which extends eight miles to the shores of Lake Ontario (247 feet above the sea). Upon leaving Lake Erie the river channel is only a quarter of a mile wide but reaches a depth of 48 feet. After passing the Devonian escarpment, the river is broad, even a mile and a half above the fall, with a depth of from 1 to 16 feet. The cañon is about 36,500 feet

* Mr. Gilbert writes thus: "You are aware that I am everywhere quoted as estimating the age of the river (Niagara) as about 7,000 years. It was partly to dispel this impression that I wrote . . . . In point of fact I have made no estimate and my opinion, so far as I have one, is that the age of the river is much greater than 7,000 years."

long and varies from 900 to 1400 feet in width (see fig. 1 and sections). After the river issues from the gorge its width is about a half a mile, and the depth reaches to 96 feet, or 94 feet below the surface of Lake Ontario. In the cañon, three quarters of a mile below the site of the falls, the river has a depth of 189 feet, at a point where the surface is about 105 feet above the lower lake. That the upper part of the walls of the cañon are vertical should be emphasized.

3. *Geology of the District.*

The geology of the district is too well known to need description, but the measurements had not been made which could be used in determining the varying character of the work performed by the river; accordingly I made the following sections and those illustrated in figures 3, 6, 7, 8, 9, 10, 11.

	At Falls.		Whirlpool		Devil's Hole.		N. Cath. Col.		End of Gorge.	
	Feet thick.	Ft. ab've L. Ont.	Feet thick	Ft. ab've L. Ont.	Feet thick.	Ft. ab've L. Ont.	Feet thick.	Ft. ab've L. Ont.	Feet thick.	Ft. ab've L. Ont.
Pleistocene in depressions and on ridges	160	440	40*	340	----	----	----	----	----	----
Niagara limestone	55	280	65	300	30	340	35 †	340	15 †	340
Crest of Falls	----	270	----	----	60 †	----	40	----	25	
Niagara shale	60	225	65	235	----	250	60	265	75	300
Clinton limestone	15–20	165	20	270	----	----	20	205	15	225
Bands of shale, limestone and sandstone at base	20–15	----	----	15–20	----	----	20	----	20	
Surface of river	----	110								
Medina shale	25	----	25	----	----	----	----	----	20	
sandstone‡	5–10	100	8	105	----	----	----	----	5	170
shale	30	----	30	----	----	----	----	----	25	
sandstone	20	60	20	60	----	----	----	----	20	140
shale to lake level	40	----	40	----	----	----	----	----	120	

The plain between the escarpment and Lake Ontario is underlaid by a great thickness of Medina shales thinly covered with drift and lacustrine deposits. The flat country, between the head of the rapids above the falls and the Devonian escarpment near Lake Erie is underlaid by shaly rocks of Onondaga age. The southward dip of the strata from the end of the gorge to the Devil's hole (9,700 feet distant, at the mouth of Bloody run) is 40 feet; thence to the whirlpool

* Drift on west side, rocks on east side of gorge.

† The upper figures relate to rocks in river terrace; the lower in walls of gorge.

‡ Both the Medina sandstone and shales vary in thickness.

(8,500 feet) 26 feet; and from there to the falls (15,000 feet in a direct line) only 10 feet, or almost horizontal.

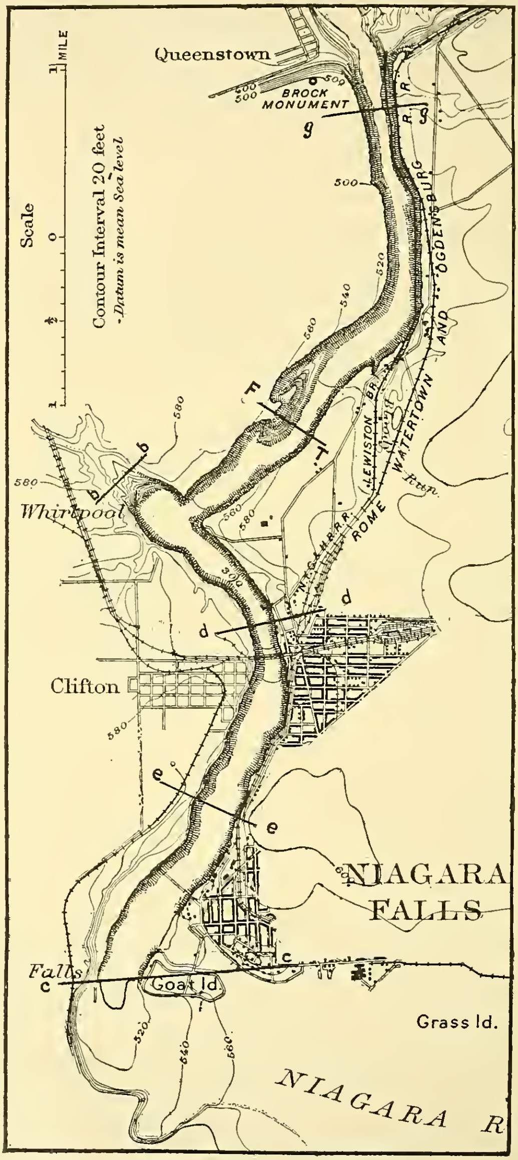


FIG. 1.—Map of the Niagara *Cañon* (U. S. Lake and Topographic surveys) showing its variable width and the position of the cross sections.

4. *Ancient Topography and Basement.*

In the numerous writings upon the Niagara river one ancient topographic featnre has been overlooked and another exaggerated into importance which it does not possess. The ancient drainage of the Erie basin was not by way of the Niagara but by a channel forty miles to the west.* Even at the end of the Lake Erie the borings show old channels deeper than the floor of the river across the Devonian escarpments.† The feature overlooked is the Tonawanda valley, a mile and a half in width, extending from the rapids above the falls to the Johnson ridge. Its basement is 80 or 90 feet below the northern barrier of Johnson's ridge. The rocky subsurface of Goat Island was part of the ancient floor (see fig. 11). This depression is part of the ancient Tonawanda basin, which is now filed with drift (see fig. 8). The gorge through Johnson's ridge is modern with vertical walls, but half a mile to the west it falls away and the wells reveal the continuation of the Tonawanda depression extending northward. It is again made known by a well half a mile west of the whirlpool (*w*, fig. 3), in the line of the extension of the St. David's valley. This forms an embayment one and a half miles wide and only three-quarters of a mile deep in the face of the Niagara escarpment. The modern river is simply crossing a portion of the old Tonawanda basin in the vicinity of the falls, and consequently it has here much less rock to excavate than through and north of Johnson's ridge.

The other feature is the imaginary whirlpool—St. David's valley, supposed to have been the old course of the river.

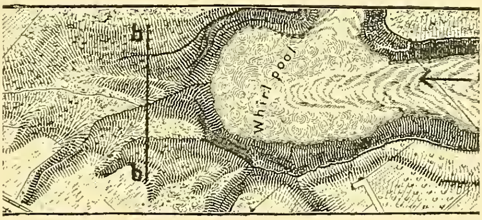


Fig. 2.—Map of the whirlpool ravine; *bb*, position of section (fig. 3).

Above and below the whirlpool alike, the gorge is of recent date as may be seen by the vertical walls shown in the several sections. The whirlpool ravine has sloping V-shaped bound-

* "Origin of the Basins of the Great Lakes," Q. J. G. S. Lond., vol. xlvi, p. 523, 1890, and "Notes on the Origin and History of the Great Lakes," Proc. A. A. A. S., vol. xxvii, 1888.

† "The Life History of Niagara," by Julius Pohlman, Trans. Am. Inst. Min. Eng.

aries in its higher portion, which is an antique structure. The depression is so obstructed with drift, that gives rise to landslides that the old topography is much obscured. Yet a little stream has removed the fallen earth and exposed a natural section of Clinton limestones, which cross the valley at an elevation of 115 feet above the surface of the whirlpool, or 160 feet above Lake Ontario, with Niagara shales showing for at least 20 feet higher. Thus the rocky barrier across the ravine is not less than 240 feet above the bottom of the cañon in the whirlpool. This barrier in the ravine is illustrated in fig. 3, which should be compared with figures 9 and 10, in order to appreciate the insignificance of the whirlpool ravine.*

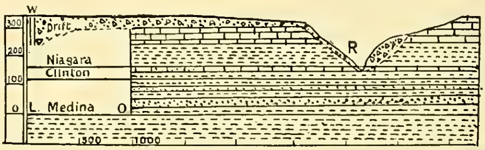


FIG. 3.—Section across the whirlpool ravine, located at *bb*, fig. 2; W, well; R, stream.

The form of the whirlpool cauldron requires explanation. At Mr. Shepherd's house, a short distance west of the whirlpool, there is a well 90 feet deep without reaching rock (*w*, fig. 3) and this shows the absence of Niagara limestones to a depth of more than 50 feet below the surface rocks of the western wall of the whirlpool. At that point the limestones rise 40 feet higher on the eastern side of the river than on the western, but the depression was leveled up with drift. Thus it appears that at this point the Niagara river took possession of the eastern side of a drift-filled valley (Tonawanda—St. David's), and the whirlpool ravine was a little tributary to it. When the falls had receded to the whirlpool and penetrated the rocky barrier, the currents were able to remove the filling of the buried ravine, and this gave rise to the form of the cauldron, which deepened its basin to lower levels by the currents of the river acting upon the underlying soft shales, with the landslides obscuring the older features. It is evident that there was no preglacial Niagara river.

The Niagara river crossed the broad shallow depression of the Tonawanda drainage, at the falls and that adjacent to the whirlpool on a basement of drift, but elsewhere generally on hard limestones. Out of both of these materials, terraces were carved thus marking the old river level, before it sunk within the chasm.

* In Rept. of meeting of Am. As. Ad. Sc. in Science, Sept., 1886, it is noted that Prof E. W. Claypole found rocks in the ravine, without giving any details in explanation. Since this paper has been in type, Prof. James Hall informed me that Prof. J. W. Powell and himself had also seen the occurrence of the rocks, but no notice has been printed. The error has been even recently repeated by a writer in "Nature."

5. *Discharge of the Niagara River.*

The corps of Engineers U. S. A., made the measurements of the outflow of the Great Lakes between June 27th and Sept. 17th, 1868.* That of Lake Huron was 216,435 cubic feet per second; and of Lake Erie for the first part of the season, 304,307 cubic feet, and 258,586 feet for the second part. From these figures, I have taken the maximum proportional discharge (as the volume is variable) of Lake Erie, which is found to gather $\frac{3}{11}$ of the total drainage of the Niagara River but the mean discharge is less than $\frac{3}{14}$. This is an important factor in the following computations.

6. *Modern Recession of the Falls.*

The four surveys illustrated in figure 4, show the modern recession of the horseshoe cataract. During 48 years, 275,400 square feet fell away. The mean width of the adjacent portions of the gorge (as opposite Goat Island) is 1,350 feet. Thus the mean recession would be 4·175 feet a year. The American falls have undermined 32,900 square feet of rock which gives a mean rate of 0·64 foot a year. But the rate is not uniform. In 1819, the crest of the Canadian fall was very acute, it had

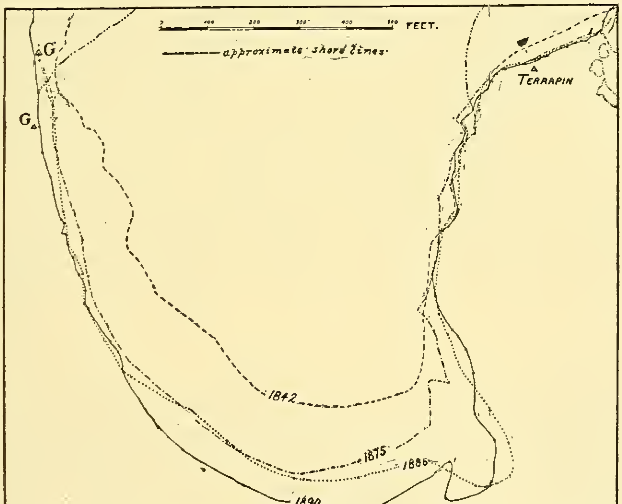


Fig. 4.—The four surveys of the Canadian Falls showing the retreat of the cataract (in which some inaccuracies are apparent). (Kibbe).

become quite obtuse in 1842, acute in 1886, but it was broadening out again in 1890; thus there are cycles of slow and rapid retreat.

* Report of Chief of Engineers for 1869, p. 582.

The measured recession has probably obtained, since the cataract cut its way through Johnson's ridge, for beneath the Tonawanda basin the limestones have a thickness of only 45–55 feet as the upper 90 feet had been removed in pre-Pleistocene times. The capping limestone in Johnson's ridge was 140 feet thick. To the north the thickness was reduced. Along those portions of the chasm where the limestone is heavier and the gorge narrower than in the pre-glacial depression, the stronger arches must have arrested the maximum rate of retreat, and on this account, I have reduced the measured mean rate of recession by an estimated amount of ten per cent, or to 3·75 feet a year for the recession of the falls from the end of the cañon to Johnson's ridge, under conditions of the modern discharge and descent. The mean descent of the river was from the plain now at 340 feet above Lake Ontario; but whilst passing the rapids of Johnson's ridge, 25 feet must be added to the declivity of the river. After the basin behind the ridge was reached, the water plain was reduced to about 320 feet including 50 feet of descent above the falls in the form of rapids. The surface of the country has been deformed since the commencement of the cataract by a northward terrestrial uplift to the extent of 12 or 15 feet divided throughout the length of the gorge where, as seen in the cañon, the character of the different strata is remarkably uniform except in the described depressions, across Johnson's ridge, and at the end of the chasm where the capping limestones were much thinner but partly compensated for by the greater prominence of the hard Clinton and Medina layers.

The following computations are based upon the mean rate of recession modified by the variations in the descent of the waters and their changing volumes, which have been discovered in the geological investigations of the Great Lakes.

7. *Sketch of the Lake History and the Nativity of the Falls.*

This outline is taken from the chapters on the Lake History noted at the foot of the page.* At the commencement of the Lacustrine epoch, Warren water covered most of the Lake region, and Forest Beach was its last strand. Afterwards the waters sank 150 feet, thereby dismembering Warren water into Algonquin Lake (confining it to the basins of Superior, Michi-

* "The Iroquois Beach, a chapter in the History of Lake Ontario," Trans. Roy. Soc. Can. 1889, p. 132. "Deformation of the Iroquois Beach and Birth of Lake Ontario," this Jour., vol. xl, p. 443. 1890. "Deformation of Algonquin Beach and Birth of Lake Huron, Id.," vol. xli, p. 12, 1891. "High Level Beaches in the region of the Great Lakes and their Deformation." Id., p. 201. "Deformation of the Lundy Beach and the Birth of Lake Erie," Id., vol. xlvii, p. 207, 1894. All by J. W. Spencer. "The History of Niagara River," by G. K. Gilbert, Six. Rep. Com. State Res. N. Y., 1891.

gan and Huron) with an outlet by way of the Ottawa valley, and Lundy Lake (occupying the Erie basin and) extending into the Ontario valley. These two bodies of water appear to have had a common level as if connected in some way across the Ontario basin, but their northeastern extensions are not known and involve unsettled questions that do not effect the history of Niagara. Again the waters were lowered so that the Niagara River emptied the overflow of the Erie basin, without a fall into the Ontario valley. This condition did not last long, for the waters sank to a level (Iroquois Beach) of 300 feet below the Lundy (and also Algonquin) plain and the falls commenced their descent with the waters of the Erie basin alone. The subsidence was accompanied by slight pauses, but waters remained for a long time at the level of the Iroquois beach, which is now about 135 feet above Lake Ontario at the end of the gorge. Again the waters subsided to the level about 80 feet beneath the present level of the head of Lake Ontario and thereby lengthened the river to 12 miles beyond the end of the chasm. At this time the descent of the river after passing the rapids at Johnson's ridge was 420 feet. By the continued northeastern terrestrial elevation the waters of the Huron basin were turned from the Ottawa drainage into the Erie basin, whose northeastern rim was elevated so as to flood the lake. Later, the waters at the head of Lake Ontario were raised 80 feet to the present level. This differential movement was at zero at the head of Lake Erie; 2·5 feet per mile in the Niagara district; 4 feet northeast of Lake Huron, and 5 feet per mile at the outlet of Lake Ontario.

At the nativity of the Niagara River, there was no fall. A little later in the Iroquois episode the falls were very much like the modern American cataract both in height and volume, but afterwards it increased in magnitude and went through the changes noted later.

8. *Laws of Erosion.*

When erosion is considered from a theoretical point of view and the whole energy of the water is supposed to be expressed in the erosion, it varies as the mass of the water into the square of the velocity (wv^2). Hence for a given river increase of the amount of its water or increase of the velocity along its course should be expressed by greater erosion. But erosion is not the only expression of the theoretical value of the energy of the river. Again it is well known that the more rapid the descent of the stream the more the erosive effects are expended on the floor of the channel, in deepening and forming U-shaped valleys or gorges. On the other hand, the reduction in the slope causes the channel to become broader—a principle which has an important bearing in this study. While the observations are imperfect owing to the variable conditions of erosion, still the attempt to ascertain the duration of the different episodes is the only natural sequence to the measurements of the modern recession of the falls, and it gives approximate results, for without considering the changing episodes the rate of recession is of no geological interest. But this study may lead to further detailed investigations.

8. *Episodes of the River and the Duration of each—Age of the Falls.*

First Episode.—From the history of the lakes and the river, we learn that the early falls cascaded from the brow of the escarpment to the level of the Iroquois beach 200 feet below, with the Erie drainage only $\frac{3}{11}$ of the total discharge of the upper lakes). There is no indication that the Erie rainfall was greater at that time than now. The length of the chasm excavated during the first .episode is found in the data fur-

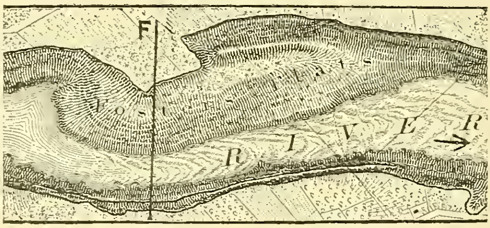


Fig. 5.—Map of the gorge at Foster's flats; F, location of the cross section fig. 6.

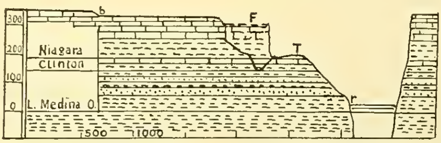


Fig. 6.—Section of the george at Foster's flats (FT, fig. 1). Platform (F) of the old river floor projecting into the cañon. Its section is shown in broken shading but with ravines descending from both sides of it. T, rock terrace surmounted by huge blocks of Niagara limestones; *b*, original river terrace; *r*, surface of river; L. O., surface of Lake Ontario. Bottom of river about 80 feet below the surface of the lake.

nished by the study of Foster's flats. Their location is shown at F, figure 1, and the structures are further illustrated in figures 5 and 6.

The terrace (T) represents the former level of the river (about 190 feet above Lake Ontario). It is the only feature of the kind in the cañon. It is about 50–60 feet above the Iroquois level to which the river descended. Thus the slope of the earlier and smaller streams was about half as great again as the modern river over the rapids at this locality. The youthful river was broad and shallow, like and of about the same magnitude as the modern American channel and falls, acting evenly over the whole breadth and receding at about the same rate. The remnant of the platform shows how far the fall had receded before the physical change which threw the current to the eastern side of the channel. This change could be effected by increasing the height of the falls which would favor the deepening of the chasm at the expense of the width, especially as the lower rocks are mostly shale. This change of breadth from a wide and shallow to a narrow and deep channel is shown along the lower part of the cañon and is illustrated by the contracted channel at the bottom of the cañon in a section just above the end of the gorge (fig. 7).

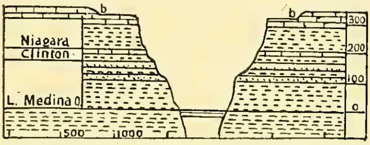


FIG. 7.—Section half a mile from the end of the cañon (*gg* fig. 1); *bb*, terraces of river at the original level; L. O., level of Lake Ontario; bottom of river about 80 feet below the surface of Lake Ontario.

As the changing conditions were gradual, I have placed the close of the first episode at the time when the falls had reached the foot of the terrace (B fig. 8), which is 11,000 feet from the end of the chasm. Varying the rate of recession for the different conditions of height and volume, acting under a general uniformity, the time needed to excavate the immature cañon as far as Foster's terrace is found to be 17,200 years.

Second Episode.—The subsiding of the waters at the end of the first episode, which concentrated the stream upon the side of the channel amounted to 220 feet, thus increasing the descent of the water to 420 feet, with the lake receding twelve miles, and adding this length of shaly rocks to be removed. The increased descent gave rise to new cascades over the hard Clinton limestones (*c* and *d*, fig. 8) and Medina sandstones (*h*, fig. 8) at the end of the cañon, after the shales between it and the lake had been somewhat reduced in height. A modern repetition of three such cascades over the same series of rocks may be seen along the Genesee River near Rochester. Under this condition the upper cascade receded by itself past Foster's ter-

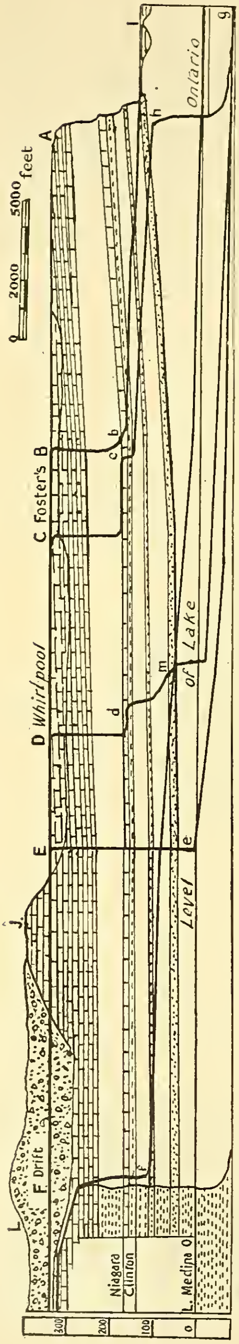


Fig. 8.—Longitudinal section showing the retreat of the falls and the geological structure. A, brow of escarpment and original site of falls; I, Iroquois beach and level of that water; B *b* I, chasm at the end of the first episode; C *c h g*, falls retreating in three cascades, but from *h* to *g* the slope was extended over a distance of 12 miles beyond the escarpment; D *d m g*, position of cataracts at the end of the second episode; E *e g*, development of gorge at the end of the third episode; F, present site of falls, and F *m g*, the modern cañon; *g*, level of the lowest stage of water in the river history; L, Lundy beach capping the drift; J, Johnson's ridge. Broken shading about whirlpool shows occurrence of drift on west bank only with rock on the eastern; block shading represents limestone; dotted, sandstone; broken lines and unshaded portion, shales. Bottom of river 80 feet below present surface of Lake Ontario, as shown in figure.

race, a distance of 3,000 feet. Thus closed the first stage of the second episode. After passing Foster's flats the chasm shows the effects of a greatly increased force, for the gorge is again widened with the terrace below washed away. As no change in the total height occurred about this time, the magnitude of the erosion indicates an increased discharge, which was produced by the turning of the waters of the Huron basin and adding them to the Niagara drainage. The effects of the greatly increased volume of the water were to widen the chasm and cut away part of Foster's platform, but leaving enough to tell the history. The upper falls were not joined by the more rapidly retreating lower cascades until after the whirlpool was passed, for the evidence of the upper water-level is left in the deposits of river gravels at an elevation of 190 feet on the northern side of the whirlpool ravine, which would not have been the case if the river were at a lower level after cascading over one united falls. Just above the whirlpool, the chasm becomes narrow, and here I close the second stage of this episode of three cascades. The length of this section of the gorge (from C to D fig. 8) is 7,000 feet. By considering the proportional amount of work accomplished during the elongation of the chasm, the deepening of the gorge left at the close of the first episode, and its extension 12 miles lakeward (the mean depth of shales removed from eight miles was 180 feet, and from four miles, 60 feet), and applying the laws of erosion, I have found that the first stage required 6,000 years and the second 4,000 years; or the duration of the second episode was 10,000 years.*

Third Episode.—The narrowest portion of the gorge extends from the whirlpool for a distance of 4,000 feet as is shown in figure 9 and on the map in fig. 1. The various sections (figs. 6, 7, 9, 10, 11) should be compared.

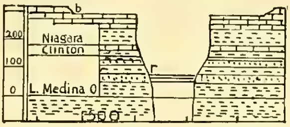


FIG. 9.—Section across the narrows just north of the railway bridges (*dd*, fig. 1) *b*, original bank of the river; *r*, surface of the river; L. O., level of lake; floor of cañon 80 feet below lake level.

This is the site of the whirlpool rapids. My explanation of this narrow chasm, without any increased thickness of the limestone capping over the shaly bed is that the whole force of the falls descending 420 feet was concentrated in one cataract with a rapid of an additional height of 25 feet descending in front of Johnson's ridge. Thus the force engaged in undermining the limestones was exhausted in the recession of the falls by deepening the gorge in place of broadening it, a process more strongly brought out by contrast with the sections of the cañon, immediately above (fig. 10) and below (fig. 6) which are half as wide again. Such result is in accordance with the common observations that increased declivity causes the channels to be deepened, and decreased slope accelerates the widening of the channel as is shown in the section near the end of the gorge (fig. 7). The computation of the time of the retreat of the falls across this section is a simple problem, as the fall of water amounted to 420 feet in place of 320 of the present day, and the volume was the same. Under these conditions the duration of this episode was 800 years.

Fourth Episode.—This is characterized by the rising of the waters in the Ontario basin so as to bring the lake to the pres-

* One method considers only the recession of the upper one of the retreating falls (descending 150) feet during the two stages of this episode. Owing to the prevalence of limestones in the upper section, the computation would appear to be an under estimate. Another process is based upon the excavation of the new portions of the chasm to the full depth of 420 feet, and adding to the components the time required to deepen the gorge of the first episode and extend the cañon to the lake—the amount of work being considered in terms compared with the full depth of excavation in the chasm.

ent level, 320 feet below the rapids above the falls. The commencement of the work of this epoch was taken where the cañon suddenly became broad at the head of the whirlpool rapids, a phenomena explained by the force of the river being vertically diminished and latterly increased—the converse to the conditions of those of the third episode. At first the rocks

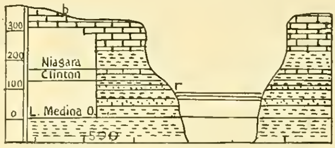


Fig. 10.—Section across the gorge at Johnson's ridge (*ee*, fig. 1); L. O, level of Lake Ontario; *r*, surface of river; *b*, original bank of river; bottom of river 80 feet below surface of the lake.

in Johnson's ridge offered great resistance on account of the increased thickness of limestones, nevertheless the lateral erosion gained the ascendancy over the vertical. The section through Johnson's ridge is 5,500 feet long, and with the laws of erosion the time necessary for the falls to retreat through it would be about 1,500 years—thus would end the first stage of the last episode. The last stage is the modern, or that since the cataract reached the Tonawanda basin south of Johnson's

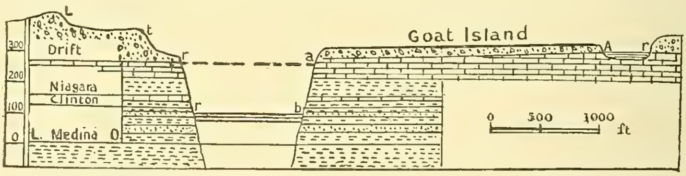


Fig 11.—Section across gorge 1,000 feet north of the Horseshoe falls (*cc*, fig. 1 L, Lundy beach to the west; *t*, terrace with sandy face; *ra*, surface of river at crest of falls; *rs*, ditto below falls: *Ar*, ditto of American falls; L. O., level of Lake Ontario. Bottom 80 feet below lake surface.

ridge, whose rocky floor, generally speaking, is about 80–90 feet lower than that on the ridge (see fig. 8); yet the cañon just north of the ridge is only 250 feet wider than through that barrier. The drift filling the basin offered but little resistance to the recession of the falls and accordingly the rate of retreat has been comparatively rapid along this section of the river, which is 6,000 feet long. Consequently its age is about 1,500 years. Thus the duration of the fourth epoch has been 3,000 years.

Age of Falls.—Allowing 1,000 years for the duration of the river before the advent of the falls,—for that its commencement was not characterized by a cascade is shown by the terraces on the edge of the escarpment and at the deserted mouth of the infant river,—and adding the duration of the four episodes, which have been calculated at 31,000 years, the age of Niagara River would be 32,000 years; and the date that the Huron drainage turned from the Ottawa valley to the Niagara was 7,800 years ago. In order to reduce the errors in reading the means of erosive effects, the component stages have been taken to as great a degree of accuracy as practicable. In the changes of level, the error would suggest itself to me as on the side of shortening the time; and there is no evidence that a much greater rate of recession than now has occurred other than that already made use of; also I have used the maximum discharge of Lake Erie. Consequently I am led to conclude that the present study has set forth the history and has compensated for possible over-estimates in degrees of hardness, and fairly represented the age of the falls, which is very near that of Lyell's conjecture. There is considerable cumulative evidence adduced from the history of the lakes to strengthen confidence in the methods pursued in this investigation. Let us see.

9. *Confirmation of the Age of the Falls by the Phenomena of Terrestrial Movements.*

In the deformatory elevation of the Niagara district, the Johnson ridge was raised 24 feet above the Chicago divide, between the Michigan and Mississippi waters, and did cause a rise of the waters in the lakes to the point of overflowing, but the ridge was incised by the retreating falls in time to prevent the change of the lake drainage. By the simplest case of division we have seen that Johnson's ridge was completely cut through only about 1,500 years ago. Allowing two or three feet of water to have been on the Chicago divide (covered with silt) and as much more for error, we find that the differential elevation of the Niagara district becomes a local absolute uplift of about 1·25 feet a century. The equivalent rate of elevation northeast of Lake Huron is 2 feet and at the outlet of Lake Ontario 2·5 feet a century. This average is that of episodes of activity and repose during 1,500 years. Applying the time ratio to the amounts of deformation we shall obtain the results given below in a form for comparison.

The rise of the Algonquin beach of the Huron basin, between the present outlet of the lake and the former outlet at Lake Nipissing, amounts to 660 feet,* about 560† of which

* Elevation south of and adjacent to Lake Nipissing determined by Mr. F. B. Taylor.

† The waters of both Lundy and Algonquin lakes were lowered about 100 feet before the beginning of the Niagara river; this being apparent and local, produced by a pre-Iroquois uplift of about half a foot per mile, thus raising the northeastern extensions of the beaches.

have been raised up since the birth of Niagara Falls. Of this latter amount about 130 feet have been lifted since the waters were turned into the Niagara drainage. Again we get some proportions.

The ratios of the deformation of the Lundy and Iroquois beaches are about the same, and we have the Lundy beach differentially raised 160 feet in the Niagara district, and the Iroquois beach deformed to 370 feet near the outlet of Lake Ontario (compared with the level at the head of the lake) since the close of the Iroquois episode. And here there are data for comparison. These figures have been mostly taken from the papers already cited. Compiling the results derived from all these data, it appears that:

A. The time which has elapsed since the Iroquois episode, or the end of the first episode of the falls is :		
(1) From the computations given	13,800	years.
(2) From the date of deformation recorded in the Iroquois beach*	14,800	"
(3) From the deformation recorded in the Lundy beach†	12,800	"
Mean result	13,800	"
B. (1) Computed time since the Huron waters turned into the Niagara	7,800	"
(2) From the proportional deformation of the Algonquin (N.E.) outlet compared with the computed age of the river‡	7,400	"
(3) From the proportional deformation of the Algonquin uplift§	6,500	"
Mean result	7,233	"
C. (1) Computed age of Niagara river	32,000	"
(2) From the rate of deformation of Algonquin beach since the commencement of Niagara river‖	28,000	"
Mean result	30,000	"

These computations were originally made not to seek for favorable evidence but to discover discrepancies, for I did not expect that the date had been correlated with sufficient accuracy; but the several results agreeing so closely in spite of the unavoidable inaccuracies, seem to me to comfirm the general correctness of the determinations of the phenomena and the methods of computation.

* A differential rise of 370 feet at the outlet of Lake Ontario divided by 2·5 feet a century.

† A rise of 160 feet in the Niagara district divided by 1·25 feet a century.

‡ $\frac{130}{560}$ of 32,000 years.

§ $\frac{13}{56}$ of 28,000 (see next note).

‖ Rise of 660 feet in the Algonquin beach less 100 feet before the birth of the Niagara at the rate of 2 feet a century.

10. *Relationship of the Falls to Geological Time.*

All attempts to reduce geological time to terms of years are most difficult, but the Niagara river seemed to be an easy chronometer to read, and yet we see that utterances even this year are vastly farther from the mark than those made fifty years ago—the clock had not kept mean time throughout its existence. After this attempt at regulating the chronometer, investigators will doubtless carry the determinations to greater accuracy, but for the present I can offer this geological compensation. The Niagara seems a stepping stone back to the ice age. What is the connection between the river and the Pleistocene phenomena?

The Lake epoch is an after or late phase of the Glacial, and Niagara came into existence long subsequent to the commencement of the lakes. If we take the differential elevation of the deserted beaches, and treat them as absolute uplifts in the Niagara district, with the mean rate of rise in the earlier portion of the lake epoch as in the later, then the appearance of Warren water in the Erie basin was about 60 per cent* longer ago than the age of Niagara river; or about 50,000 years ago. The earlier rate of deformation was not greater than that during the Niagara episode as shown by the deformation of the beaches but it may have been slower, so that from 50,000 to 60,000 years ago Warren water covered more or less of the Erie basin. Before the birth of Niagara river, by several thousand years, there was open water extending from the Erie basin far into the Ontario and all the upper lakes were open water with a strait at Nippissing, but the northeastern limits are not known, and although they do not affect the age of Niagara, yet they leave an open question as to the end of the ice age, in case of those who do not regard the advent of the lakes as its termination. Certainly, if not before the Iroquois episode, at its close the ice age had ended so far as the whole lake region and St. Lawrence valley is concerned; and the end of the Iroquois episode was about 14,000 years ago. To attempt to place the end of the ice age at either 50,000 or 14,000 years ago, or between, would be to base the conclusions upon opinions and conjectures not so far settled by the incompletely written history of the lakes, whose age in terms of the falls may be inferred. The determination of the end of the ice age will be in terms of the lake history.

* The beaches show an elevation in the Niagara district (accompanied by deformation) amounting to 940 feet above tide, of which 573 feet have been raised since the birth of the Niagara river.

11. *End of the Falls.*

As has already been noted, the falls was in danger of being ended by the turning of the waters into the Mississippi, when the cut through the Johnson ridge was effected. With the present rate of calculated terrestrial uplift in the Niagara district, and the rate of recession of the falls continued, or even doubled, before the cataract shall have reached the Devonian escarpment at Buffalo, that limestone barrier shall have been raised so high as to turn the waters of the upper lakes into the Mississippi drainage by way of Chicago. (An elevation of 60 feet at the outlet of Lake Erie would bring the rocky floor of the channel as high as the Chicago divide, and an elevation of 70 feet would completely divert the drainage. This would require 5,000 or 6,000 years at the estimated rate of terrestrial elevation. It would be a repetition of the phenomena of the turning of the drainage of the upper lakes from the Ottawa valley, into the Erie basin.

12. *Conclusions.*

The computation of the age of the Niagara river,—based upon the measured rate of recession during 48 years; upon the changing descent of the river from 200 to 420 feet and back to 320 feet; and upon the variable discharge of water from that of the Erie basin only, during three-fourths of the life of the river, to afterwards that of all the upper lakes,—leads to the conclusion that the Niagara Falls are 31,000 years old and the river of 32,000 years duration; also that the Huron drainage turned from the Ottawa river into Lake Erie less than 8,000 years ago. Lastly, if the rate of terrestrial deformation continues as it appears to have done, then in about 5,000 years the life of Niagara Falls will cease, by the turning of the waters into the Mississippi. These computations are confirmed by the rate and amount of differential elevation recorded in the deserted beaches. It is further roughly estimated that the lake epoch commenced 50,000 or 60,000 years ago, and there was open water long before the birth of Niagara in even the Ontario basin, and that under no circumstances could there have been any obstruction to the Ontario basin, if even then, later than the end of the Iroquois episode which has been found to have ended 14,000 years ago.

Art. LXIV.—*Resonance Analysis of Alternating Currents;* by M. I. Pupin, Ph.D., Columbia College. Part II.

Additional evidences proving the correctness of its indications referred to in the last paragraph will be found among the results of the following experiments.

IV.—*Location of the Origin of Upper Harmonics.*

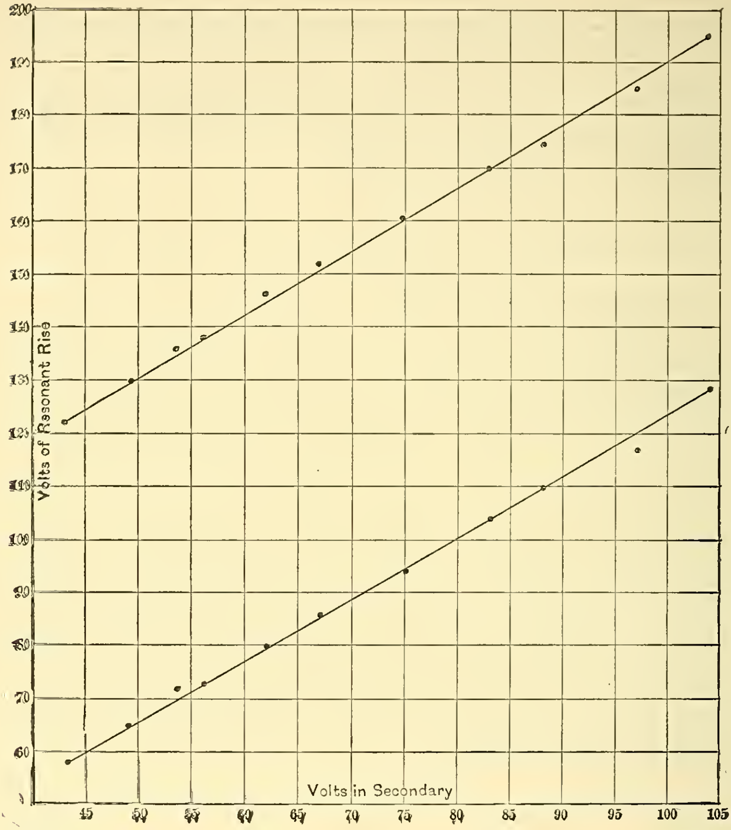
A. Experiments with alternator of smooth core armature.

1*st Series.*—The first set of experiments in this direction was performed with the 10 H. P. Fort Wayne 8 pole alternator with smooth core armature and the Stanley 5 K. W. transformer (closed magnetic circuit). The secondary circuit carried no load and a Cardew voltmeter indicated the secondary voltage. The current which excited the field of the alternator was gradually increased. The secondary voltage measured the strength of this excitation. The air core transformer with the resonator was inserted into the primary circuit as indicated in fig. 1^b. The resonant rise of potential, recorded by the multicellular voltmeter e', was carefully determined at every excitation for the fundemental frequency and for the first odd harmonic. Higher harmonics were present but very faint. The results are given in Table IV and plotted in fig. 5. The initial voltage in the resonant circuit was small, just perceptible in the multicellular voltmeter.

Table IV.

Secondary voltage.	Resonant rise in volts due to the fundamental.	Resonant rise in volts due to the first odd harmonic.
43	122	58
48	130	65
53·5	136	72
56	138	73
62	146	80·5
66·75	152	86
75	160	94
83	170	104
88	175	110
97	185	117
104	195	128·5

5.



The curves in fig. 5 were plotted from this table by taking the readings of the first column for the abscissæ and the corresponding readings of the second and third columns for ordinates. The upper curve corresponds to the fundamental and the lower curve to the harmonic. *The two curves are two straight lines parallel to each other*, which means *that the fundamental and the harmonic increase at the same rate from nearly one third excitation to full excitation of the alternator.* This result was not expected, but its correctness was verified beyond all reasonable doubt.

The same series of experiments was extended to lower excitations of the alternator, but, since I had no low reading alternating current voltmeter, the excitation was measured by measuring the exciting field current. This current was 10 amperes at full excitation and the series of experiments extended down to 1·5 amperes, hence to nearly one seventh of the full excitation. To bring the readings of the resonant rises of potential within the scale of the multicellular voltmeter at these low excitations the number of turns in the air-core transformer was suitably increased. *Within all these limits of excitation both the fundamental and the harmonic increased at the same rate and proportionally to the magnetization of the transformer core.* This magnetization extended between about 600 and 4000 C.G.S. lines of force per square centimeter.

2d Series.—To determine whether the presence of the harmonic was due to the action of the transformer or to that of the alternator the transformer was disconnected from the alternator and two series of incandescent lamps, connected in parallel, were substituted in its place. Each series consisted of 13 twenty-four candle power lamps. The resonator with its air-core transformer remained in circuit as before. First one series of lamps was placed in circuit. The rise due to the fundamental was stronger than in the preceding experiments, but that due to the harmonic was exceedingly faint. When both series of lamps were thrown in the harmonic appeared a trifle stronger but still very weak. Hence the inference, that the harmonic was due almost exclusively to the action of the transformer.

It should be observed here that the alternator armature, though well laminated, runs fairly hot in a short time, hence it must be the seat of a decidedly strong hysteretic action. On the other hand the transformer does not heat nearly as much as the alternator armature and yet its action produces the harmonic. This certainly seems to speak strongly against the view that harmonics are due to hysteresis. Other evidences against this view will be given below.

3d Series.—A series of experiments with open magnetic circuit transformers of induction coil type in place of the lamps showed the harmonic much stronger than the lamps did, but considerably weaker than the experiments with the transformer with closed magnetic circuit. Accurate numerical comparisons between the two types of transformers in this respect was not attempted. It sufficed to establish that, *closed magnetic circuit transformers distort the primary current considerably more than transformers with open magnetic circuits under equal degrees of magnetization;* on the other hand, in the first case the distortion is confined almost entirely to the primary circuit when the secondary is closed by a non-self-inductive resistance, whereas in the second case it is felt in the secondary circuit also, though considerably less than in the primary.

The general conclusions of this group of experiments may be summed up as follows:

I. *A ferric self-inductance in circuit with an alternator which gives a simple harmonic electromotive force distorts the current by introducing higher odd harmonics, principally the harmonic of three times the frequency of the fundamental.*

II. *This harmonic* (and in all probability all other harmonics) *increases at the same rate as the fundamental when the excitation increases, the rate of increase being up to 4000 C. G. S. lines of force per sq. centim proportional to the intensity of magnetic induction.*

III. *When this ferric inductance is a transformer then the distortion appears in the induced secondary electromotive force, if the transformer has an open magnetic circuit, it does not appear there (to any extent worth considering) if the magnetic circuit is a closed one.*

IV. *A practically simple harmonic electromotive force is produced by alternators with smooth core armatures when symmetrically wound, even if the machine is worked at considerable degrees of magnetization of the armature core.*

B. *Experiments with alternator of slotted core armature type.*

The machine employed in these experiments was the 1 H. P. alternator mentioned above. It is a 16 pole machine with slotted armature core. It gives at full excitation and the speed at which it was usually run in these experiments about 1500 volts.* The transformer connected with it was of induction coil type with a cylindrical iron core made up of very carefully insulated fine iron wire. The same series of experiments were performed as under group (A). *The first series* in this group gave exactly the same results as the corresponding series in group (A). The excitation varied from one-seventh of the full to full excitation; the amplitude of the fundamental and the first odd harmonic† varied at the same rate during the whole interval, so that a parallel pair of straight lines like those in fig. 5 could be plotted in this case also. *The second series* resulted in the conclusion that *the harmonic was very strong and due*, in a very large measure, *to the action of the armature and not to that of the transformer* as in the other case, although the transformer, also, contributed a distinct but

* A more complete description of this machine and the transformer will be found in this Journal, June, 1893, p. 510, etc. Owing to an accident which somewhat impaired the insulation of the armature the machine was run last year at low excitation and hence low voltage although the speed was then considerably higher.

† The second odd harmonic, that is the harmonic whose frequency is five times that of the fundamental was there but weak.

comparatively small share to the strength of the harmonic. *The third series* showed that the harmonic appears in the secondary of an open magnetic circuit transformer although considerably weaker, but does not appear there to any appreciable extent when the magnetic circuit of the transformer is a closed one.

To the four conclusions given at the end of the series of experiments under group A the following additional conclusions may, therefore, be added:

V. *An alternator with slotted core armature produces a complex harmonic electromotive force in which the upper harmonic of three times the frequency of the fundamental is generally by far the strongest.*

VI. *The amplitudes of the fundamental and the harmonic increase at the same rate with the increase of excitation; this rate is within the limits of magnetization mentioned above proportional to the excitation, that is to say, proportional to the magnetization of the armature.*

VII. *A ferric inductance in circuit with a slotted iron core armature introduces no new harmonics. It strengthens those already existing in the electromotive force, that is odd harmonics, especially the first odd harmonic.*

The same conclusions will evidently hold true for alternators of ordinary types whose armature is made up of coils wound on iron cores which are bolted to a cylindrical iron drum common to all of them.

High degrees of magnetization of the transformer core produce a strong deformation of the primary current wave. With inductions of over 12000 C. G. S. lines of force per sq. cm. it is possible to make the amplitude of the 1st odd harmonic even greater than the amplitude of the fundamental. It is evident, therefore, that the parallelism of the lines in fig. 5 ceases as soon as the magnetization curve of the transformer core begins to approach the knee. Experiments relating to this point will be described in the near future. The experiments described in this paper were limited to conditions met with in the operation of commercial alternating current apparatus.

V. *Effect of the load upon the harmonics.*

It is a well known fact that the distortion of the primary current disappears gradually with the increase of the secondary load, that is when the external part of the secondary circuit is a non-self-inductive resistance. The question arises now, what becomes of the harmonics which produce the distortion of the primary current when the secondary current increases. The following experiments seem to answer this question definitely:

The arrangement of circuits was that given in fig. 1[b]. The secondary circuit of the large 5 K. W. transformer contained an electrolyte resistance and the secondary current was measured by means of a Siemens electro-dynamo-meter. For every particular value of the secondary current the resonant rises of potential due to the harmonic and the fundamental were carefully determined by means of the multicellular voltmeter. Table V contains the observations relating to the harmonic of three times the frequency of the fundamental; Table VI relates to the fundamental (130 P. P. S.) The apparatus employed were the large alternator and the 5 K. W. transformer.

TABLE V.

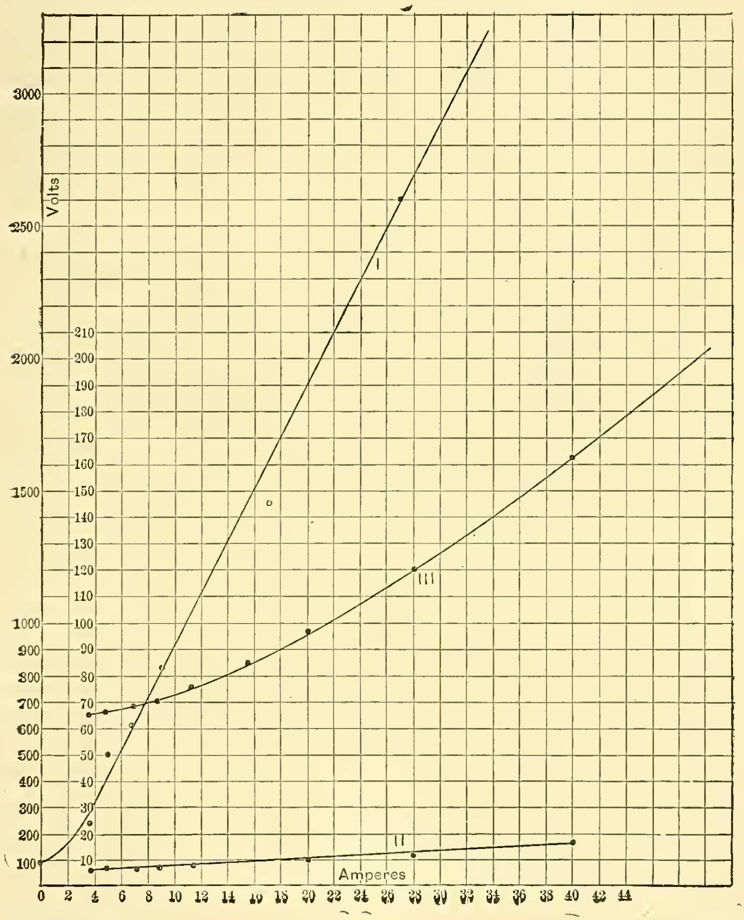
Secondary current in amperes.	Resonant rise of the harmonic in volts.
0	65
3·6	65
4·8	66
6·9	68
8·5	70
11·5	76
15·7	85
20	97
28	120
40	162·5
56	202

TABLE VI.

Secondary current in amperes.	Resonant rise of the fundamental in volts. (Observed.)	Auxiliary resistance in the resonator in ohms.	Resonant rise of the fundamental in volts. (Calculated.)
0	80	0	80
3·6	240	0	240
5·0	122	50	503
6·7	150	50	613
9·0	200	50	825
17·3	200	100	1,450
27·0	185	210	2,613
44·0	155	410	4,127
56·0	160	510	5,100

Table VI requires explanation. When the secondary current was over 3·6 amperes the resonant rise of the fundamental was too high for the voltmeter employed and also too risky for the condenser. An auxiliary resistance had to be introduced into the resonator to bring the resonant rise down to the limits of the voltmeter. These auxiliary resistances are given in the third column. The readings that would have been obtained without these auxiliary resistances were then calculated, roughly, as follows: According to theory which was verified

6.



by experiments described in the beginning of this paper the resonant rise multiplied by the resistance of the resonator is within certain limits mentioned above independent of these resistances. The resistance of the resonator coils was 16 ohms. Hence, if, for instance, x denote the rise which would have been obtained without auxiliary resistance in the resonator when the secondary current was 5 ampères, then since with an auxiliary resistance of 50 ohms the resonant rise was 122 volts we have with a rough approximation,

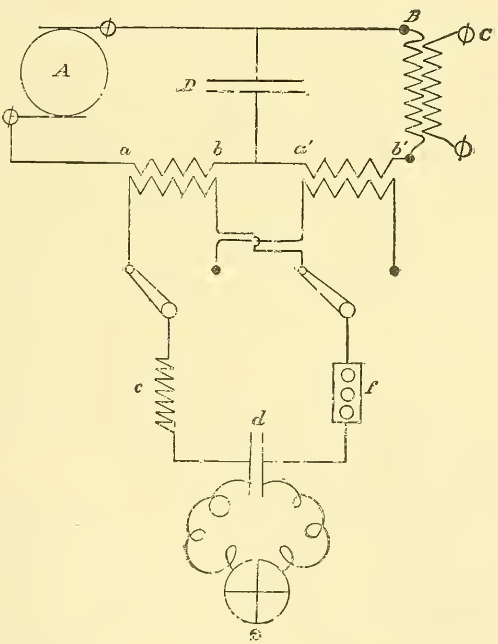
$$x = \frac{122 \times 66}{16} = 503 \text{ volts.}$$

In this manner the figures of the fourth column were obtained. They are only very rough approximations, but still they give a fair idea of the ratio of the fundamental to the upper harmonic at various loads. Curves I and II, fig. 6, were plotted from these data. The secondary ampères were taken for the abscissæ and the corresponding resonant rises in volts for the ordinates. Curve III represents Curve II plotted on a different scale for the volts of the resonant rise of potential. These are given in the right hand vertical column of the diagram. This curve gives a better picture of the gradual *apparent* increase of the harmonic. An inspection of I and II shows clearly how much more rapidly the fundamental increases than the harmonic. *In reality the increase is even more rapid;* for according to Table V it appears as if the strength of the harmonic increased with the secondary current, only much less rapidly than the fundamental. For instance, at open secondary the voltmeter indicated 65 volts for the resonant rise of the fundamental; and at 56 ampères in the secondary this rise was indicated by 202 volts. *But it must be noted that in the first case the voltmeter needle went from practically zero at no resonance, to 62 when resonance was reached; whereas in the second case it went from 135 volts at no resonance to 202 volts when resonance was reached, so that the real resonant rise was practically the same in both cases.* Similarly for all other loads in the secondary. It follows, therefore, that if the harmonic increased at all with the increase of the load this increase was much smaller than appears at first sight from the data of Table V. The more important conclusion, however, which follows from this experiment and which I wish to point out more particularly is that *the harmonic which manifests itself in the distortion of the primary current when there is no load in the secondary is present at all loads, if not stronger, then certainly with about the same strength. At full load this harmonic could not possibly be detected by Joubert's method of sliding contact; it is so exceedingly small in comparison to the fundamental.*

This persistence of harmonics at all loads even when completely hidden by the fundamental wave holds true also when their origin can be traced to the action of the armature of the generator as in the case of the machine with slotted iron core armature. *In all cases their strength depends upon the mean intensity of magnetization of the magnetic circuits to which they owe their origin and upon nothing else.*

Another somewhat more difficult but very instructive way of proving the persistence of the harmonics is represented in fig. 7. In circuit with the primary of the large machine and transformer described above are two equal air-core transformers, *a b* and *a′ b′*. By means of a double switch either one of the two can be made a part of the resonator circuit, *c d f*. A number of condensers, D, in series, are connected across primary circuit as indicated. The two air-core transformers, *a b* and *a′ b′*, will be equivalent when the resonator voltmeter *e* gives the same indications, no matter which one of the two transformers be connected to the resonator. This balanced arrangement having been obtained, the balance will be disturbed as soon as the condenser D is plugged in, and it will be

7.



disturbed in a great variety of ways, according to the capacity plugged in. But when the transformer B is of closed magnetic circuit type, then the resonator indications remain practically the same as long as the resonator is switched on the air-core transformer *a′ b′*, no matter what capacity is plugged in the condenser D. When the resonator is switched on the air-core transformer, *a b*, then its indications will be different for every particular capacity in D. In fact the circuit A, *a*, *b*, D, A, can be treated as an entirely separate circuit from the circuit A, *a′ b′*, B, A.

This statement needs practically no modification in order to cover that case also in which the self-inductance of the primary of B is diminished by putting a non-self-inductive load on the secondary. This utter disagreement between theory and experiment deserves a closer discussion, but since its connection with the subject of this paper is only an indirect one I prefer to reserve it for some other time. That which has a direct bearing upon the present discussion is the method which the above mentioned relation offers for observing the variation of the harmonics with the load without the disturbing inductive effect of the large primary current. It is this: Connect the air-core transformer *a b* (and with it the resonator) in series with the condenser. Add to this series an auxiliary coil *c* (no iron core). By the combination, thus obtained, bridge the primary circuit, so that in place of the simple condenser bridge D given in fig. 7 there will be a bridge consisting of condenser D, the air-core transformer *a b* and the auxiliary inertia coil *c*. The secondary C being open, tune the circuit consisting of the alternator armature, the primary conductors up to the bridge, and the bridge, to any one of the harmonics. The tuning is done by means of varying the capacity of the condenser and the self-inductance of the auxiliary inertia coil. Then close the secondary circuit by means of an electrolyte resistance and vary the secondary current. It will be found that the harmonic diminishes only slightly with the increase of the secondary load. As an example I give the following: The circuit just mentioned was tuned to the harmonic of five times the frequency of the fundamental, that is 650 p. p. s. At no load the resonator indicated a rise of 108 volts, at overload (56 ampères) the rise was 94 volts. But this drop was in all probability caused by armature reaction.

Whatever the ultimate meaning of the appearance and the persistence of the odd harmonics in an alternating current wave may be I am not quite prepared to state with any high degree of confidence. *One thing is certain and that is that they are at present at all loads with almost constant strength. Their presence is hidden by the fundamental wave at large loads, but when conditions favoring resonance with any one of them arise they will certainly come out and do all the mischief they can to the insulation.* The self-induction of a motor or that of a closed magnetic circuit transformer does not necessarily affect the conditions of their resonance. These conditions may depend in such circuits solely upon the self-induction of the alternator on the one hand and the self-induction and static capacity of the line on the other. According to the experiments just described the resonant current is then confined entirely to the alternator and the line, the di-electric forming a part of its circuit. These observations will be modified in the case of transformers with open magnetic circuits and their equivalents, that is, closed magnetic circuits possessing considerable magnetic leakage, especially when the conditions of the line favor resonance with the fundamental frequency, this frequency being low; such magnetic circuits possess much less magnetic sluggishness and can influence considerably the conditions of resonance with a low frequency.

VI. *Distortion of the secondary current.*

It was pointed out that the superposition of harmonics upon the fundamental wave was confined to the primary circuit when the secondary is closed by a non-self-inductive resistance, that is, if the transformer is of closed magnetic circuit type. With an open magnetic circuit transformer the deviation of the primary current wave from the simple harmonic form, due to action of the generator or the transformer or both, is felt more or less in the secondary circuit also. If, however, the secondary is closed by a ferric self-inductance then odd harmonics will appear in this circuit also in both types of transformers. *In fact, the secondary circuit should now, as far as the harmonics are concerned, be considered as a separate circuit, in which the secondary coil of the transformer and the ferric inductance in the secondary circuit play the same part as the armature of the alternator and the transformer in the primary circuit.*

The series of experiments which related to the origin and growth of harmonics in the secondary circuit was similar to the one described above, by means of which the so-called distortion of the primary current was studied. The results were similar. The presence of harmonics is due to the action of the ferric inductance; their strength increases proportionally to the intensity of magnetization of the iron in the ferric inductance. They seem to be entirely independent of hysteresis, that is, if by hysteresis the process be understood by means of which most of the heat is generated in a very finely laminated, well insulated and well annealed iron core, when such a core is subjected to rapid reversals of magnetism. I shall describe briefly an experiment bearing upon this point. The secondary circuit of the five K. W. transformer was closed by an electrolyte resistance, and a short cylindrical coil having about 120 turns coarse copper wire. A short cylindrical core made up of very fine (No. 26 B. and S.), and well annealed iron wire could be inserted into this coil. The core was 40^{cm} high and 5^{cm} in diameter. The wires were fairly well insulated from each other. A layer of fine copper wire surrounding this coil formed part of the resonator circuit. First, the secondary current was passed through the coil before the iron core was inserted. The resonator could detect no harmonic worth mentioning even when the current was increased almost to full load. But as soon as the iron core was introduced the odd harmonics appeared, especially the third harmonic; its strength increased proportionally to the current. Placing now another similar iron core on the top of the first and adjusting it in such a way that it allowed a small rocking motion the two cores could be set into violent vibration by the inductive attraction between them. This vibration manifested itself by a very loud note corresponding in pitch to the frequency of the alternator. The vibration could be diminished very much by pressing the top core against the lower core and against the table. The vibration produced no appreciable difference in the strength of the harmonic; if anything it seemed to make it stronger. Mechanical vibration produced by striking the cores produced no appreciable change in the harmonic. These experiments seem to me to render the theory which ascribes the origin of harmonics to the hysteretic action of iron completely untenable.

I do not think that the proper time has arrived yet for the formulation of a physical theory which will give a complete account of the peculiar behavior of iron, by means of which it superposes odd harmonics upon the wave of a simple harmonic current. The view which irresistibly suggests itself to my mind is simply this: Upper harmonics will be generated whenever more or less abrupt changes of the magnetic state in any part of the magnetic field through which an alternating current flows occur. A slotted core armature or an armature made up of coils with iron cores distributed over a drum common to all of them will introduce such changes. An alternating current induction motor, especially when it is not of a smooth core armature type, will also cause abrupt changes of magnetism and hence cause strong deviations of the feeding current from the simple harmonic form. But if this view be correct, then every complete cycle of magnetization to which iron is subjected when under the inductive action of a simple harmonic current must be accompanied by some abrupt changes in magnetism, and that, too, whether the mean magnetic intensity of the cycle be large or small. One thing seems certain and that is, that hysteresis, as commonly understood, will not account for these abrupt cyclic changes; for, if they really exist and are the cause of harmonics, they are certainly not affected by mechanical vibrations by which, as is well known, all hysteretic effects are influenced very much. But whatever the real theory underlying these upper harmonics may be, the bare fact which the engineers have to face is: *There is no cure against harmonics as long as the circuits contain iron.* Hence, construct lines in such a way that conditions favoring resonance with the frequency of the fundamental or with one of its odd upper harmonics will seldom occur, and whenever they do occur the resonant rise of potential should not be capable of producing any damage. *Avoid slotted armatures and armatures with projecting pole pieces and keep the magnetization down as much as possible.*

VII. *Analysis of rotary magnetic fields.*

Before closing this paper I will describe briefly the application of the resonance method of analysis to the study of the intensity fluctuations of a rotary magnetic field. The investigation was carried out by two students of the Electrical Department of Columbia College, at my suggestion, and will be published in the near future. The method, briefly stated, is this: A suitable number of turns of wire are subjected to the induction of a rotary magnetic field. These turns form part of a resonator. Whatever fluctuations there be in intensity of the rotary field they will be periodic, their period bearing a perfectly definite relation to the periodicity of the current which produces the rotary field. For instance, in a three-phase combination of alternating currents the intensity of the rotary field will, according to theory, show six maxima and six minima during each complete revolution, the maxima differing from the minima by about 14 per cent. A circuit, subject to the inductive action of such a field should have a periodic electromotive force induced in it whose frequency will be either three or six times the frequency of the fundamental, according to the shape of the curve of fluctuations. Similarly in a rotary magnetic field produced by a two-phase combination of alternating currents. If such electromotive forces were induced the resonator would detect them, and from the resonant rise of potential the extent of the fluctuations producing these electromotive forces could be estimated.

No electromotive forces of this type were detected in either a triphase or a two phase combination. Hence the inference: *Rotary magnetic fields produced by reasonably well constructed machines are not accompanied by fluctuations in their intensity.*

Electrical Engineering Laboratory,
School of Mines, Columbia College, New York, May 10, 1894.

ART. LXV.—*Distribution and Probable Age of the Fossil Shells in the Drumlins of the Boston Basin;* by W. O. CROSBY and HETTY O. BALLARD.

So long ago as during the Revolutionary war, Gen. Benjamin Lincoln noted that in digging a well 90 feet deep in the fort on Telegraph Hill, in Hull, many shells were found, the shells extending from near the top of the ground to the bottom of the well.* Seventy-five years ago it was recorded that fragments of clam shells had been found 40 feet below the surface at Jamaica Plain, and at the depth of 107 feet in digging the well at Fort Strong, which was built in 1814 on Noddle's Island, now East Boston.†

But the first observer to note the occurrence of shells in the natural sections of the drift hills in the vicinity of Boston was Dr. William Stimpson, who published in 1851 a list of the fourteen species named below, which he found in the sea-cliff at Winthrop Great Head, then a part of Chelsea:‡ *Balanus crenatus*, *Chrysodomus decemcostatus*, *Tritia trivitatta*, *Urosalpinx cinerea*, *Mya arenaria*, *Ensatella americana*, *Mactra solidissima*, *Venus mercenaria*, *Cyclocardia borealis*, *Astarte undata*, *Astarte castanea*, *Mytilus edulis*, *Modiola modiolus*, *Ostrea virginiana*. About twenty-five years ago, in digging a well in Fort Warren on George's Island, shells were found 100 feet below the surface and about 40 feet below the sea level.§ In 1888 Mr. W. W. Dodge added, doubtfully, three species—*Lacuna neritoidea*, *Tapes fluctuosa*, and *Cardium islandicum*—to Stimpson's list from the Great Head section;‖ and noted the occurrence of shells in Grover's Cliff on the northeast shore of Winthrop, nearly one and a half miles north of Great Head.¶

Stimpson believed that the shells were contemporaneous with the enclosing drift, and regarded them as evidence of a marine submergence within the Pleistocene or Quaternary period. This view appears to have been generally accepted, or at least not to have been questioned, until 1886, when Lewis

* Geographical Gazetteer of the Towns in the Commonwealth of Massachusetts, 1785, p. 56. (Only a small part of this work was published.)

† Outlines of the Mineralogy and Geology of Boston and its vicinity, with a geological map. By J. Freeman Dana, M.D., and Samuel L. Dana, M.D., 1818, p. 96.

‡ Proc. Boston Soc. Nat. Hist., vol. iv, p. 9.

§ Reported by Prof. W. H. Niles in the Proc. Boston Soc. Nat. Hist., vol. xii, 1869, pp. 244 and 364. In commenting on this discovery Mr. T. T. Bouvé read a letter from a gentleman in Hull noting similar facts known to him in his own vicinity (p. 364).

‖ This Journal, III, vol. xxxvi, p. 56.

¶ Proc. Boston Soc. Nat. Hist., vol. xxiv, p. 129.

showed* that the similar but more impressive occurrences in Great Britain, where shells are found in the till to a maximum height of 1350 feet above the sea, do not require a submergence of the land or any change of level; but rather that the shells and fragments of shells found on the mountains of Wales, etc. had simply been plowed up by the ice-sheet during its passage across the bed of the Irish Sea and incorporated with the normal drift. The shells are thus to be regarded as preglacial inhabitants of the Irish Sea, and they owe their present positions entirely to the agency of the ice-sheet.

Three years later, Upham applied this theory to the explanation of the shells in the till of the Boston Basin.† He examined many of the till sections in and about Boston Harbor, and proved that the distribution of the shells is very restricted, and that in no direction are they found far beyond the present limits of the harbor, adding seven new localities and four new species to what were known before. His tabulated list shows for the most prolific of the new localities, Peddock's Island, five species, as against eighteen then known for Great Head, Winthrop. Upham also pointed out more clearly than had been done before for this region the usual conditions of the occurrence of the shells, viz: in more or less fragmental forms in the entirely undisturbed, unmodified and unoxidized till. The shells are to be found, as a rule, only in deep sections, simply because they have been gradually removed from the superficial, oxidized till through the solvent action of meteoric waters.

In this Journal for February, 1894, Mr. R. E. Dodge has added four species—*Lunatia groenlandica*, *Scapharca transversa*, *Buccinum undatum*, and *Ilyanassa obsoleta*—to those previously found at Great Head, bringing the list for that locality up to twenty-two species, or twenty-five species for the entire Boston Basin,‡ six species only being known from points outside of Winthrop, three of which are included in the Winthrop list. Mr. Dodge was, apparently, not aware that one of the present writers§ had previously published a list of eleven species found in the drumlins of the Nantasket peninsula, this list including three of those named by him as new for Great Head, viz: *Ilyanassa obsoleta*, *Buccinum undatum*, and *Scapharca transversa*, and one other new species, *Crucibulum striatum*.

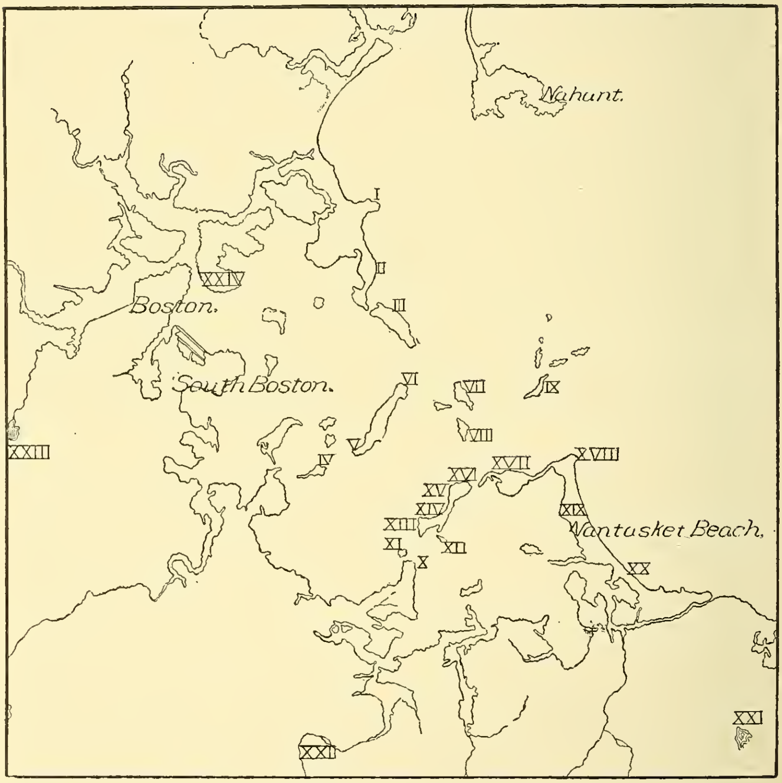
* Report of the British Association for Adv. of Sci., Birmingham, 1886, pp. 632–635; Am Naturalist, vol. xx, pp. 919–925, November, 1886; this Journal, III, vol. xxxii, pp. 433–438. December, 1886. Also, see American Geologist, vol. ii, pp. 371–379, December, 1888.

† Proc. Boston Soc. Nat Hist., vol. xxiv, pp. 127–141.

‡ Mr. Dodge has made these numbers 23 and 26, respectively, but this appears to be an error in addition.

§ Occasional Papers, Boston Soc. Nat. Hist., vol. iv, p. 142.

In connection with a systematic study of the geology of the Boston Basin, we have made a careful search for fossils in all the deep drift sections now accessible, more than doubling the number of localities and extending the list of species from twenty-six to forty-seven. Following is a list of the twenty-one new species which we have added to the drift fauna. *Cancer irroratus*, *Balanus balanoides*, *Fusus tornatus*, *Neptunea pygmæa*, *Sipho spitzbergensis*, *Buccinum cyaneum*, *Purpura lapillus*, *Anachis avara*, *Lunatia triseriata*, *Crepidula convexa*, *Crepidula plana*, *Crepidula fornicata*, *Zirfæa*



Map of Boston Harbor, showing the distribution of the fossiliferous drift sections.
Scale, 1 inch=4 miles.

I, Grover's Cliff; II, Winthrop Great Head; III, Deer Island; IV, Moon Island; V, West End of Long Island; VI, Long Island Head; VII, Lovell's Island; VIII, George's Island; IX, Great Brewster Island; X, Quincy Great Hill; XI, Nut Island; XII, Princess Head; XIII, XIV, XV, XVI, Peddock's Island; XVII, Telegraph Hill, Hull; XVIII, Point Allerton, Hull; XIX, Strawberry Hill, Hull; XX, Sagamore Head, Hull; XXI, well on James' Hill, Cohasset; XXII, well in Braintree; XXIII, well in Jamaica Plain; XXIV, well in East Boston.

crispata, *Siliqua squama* (?), *Mulinia lateralis*, *Saxicava norwegica* (?), *Cyprina islandica*, *Callista convexa*, *Anomia glabra*, *Pecten magellanicus*, *Astrangia danæ*.

In this Journal for March, 1894, Mr. Upham calls attention to the previously unpublished observations of Mr. Warren W. Herman, a zealous collector, who had found at Great Head the four new species subsequently published by Mr. Dodge, and one other—*Crepidula plana*. Mr. Herman, who has kindly placed his results at our disposal, has examined carefully only three sections—Great Head, Grover's Cliff and Telegraph Hill. He has found in all thirty-five species, eight of which have not been found by any other observers; viz: *Neptunea ventricosa*, *Sipho stimpsoni*, *Astyris lunata*, *Bela* (sp.), *Utriculus canaliculatus*, *Petricola pholadiformis*, *Macoma fragilis*, and *Argina pexata*. This brings the number of the drift species up to fifty-five.

The accompanying map shows the distribution of all the known fossiliferous sections, including the wells noted by early writers in Jamaica Plain, East Boston, and on George's Island, and two other wells to which our attention has been called, one in Braintree and the other in Cohasset. The map is intended especially to show the relations of the fossiliferous sections to the outlines of Boston Harbor; and it is apparent at a glance that the facts support the views of Lewis and Upham. If the shells are preglacial inhabitants of the Boston Basin which were scraped up by the ice-sheet and incorporated with the normal drift, they ought to be found, as they are, chiefly in the central and southern portions of the basin, and overlapping its southern but not its northern margin. The non-occurrence of shells in the numerous drumlin sections along the southern shore of the harbor is readily explained by the fact that the sections are all too shallow. In fact, it may be said that fossil shells are found at every point where recent erosion has cut through the buff till into the unoxidized or blue till, say to a depth of thirty feet or more. That the shells do actually exist in these seemingly barren drumlins, and others still farther south, is proved by the wells just referred to. The facts are as follows: Fragments of the round clam (*Venus mercenaria*) were found by Mr. Titus Burbank some years ago in digging a well near the summit of James Hill (a typical drumlin), northeast of Scituate Pond in Cohasset. The well is 45 feet deep; and the shells were observed only near the bottom.* Seven years ago Mr. Charles H. Custance of Braintree dug a well at the house of Ibrahim Morrison on a flat irregular drumlin between Braintree and East Braintree; total depth 49 feet—29 feet in "gravel and

* Occasional Papers, Boston Soc. Nat. Hist., vol. iv, p. 143.

boulders" and 20 feet in "blue clay" (blue till). In the blue clay he found a shell. Similar facts in many other wells along the South Shore have, doubtless, escaped intelligent observation and record.

The collections made by Mr. Herman and ourselves show that several localities, notably Grover's Cliff and the east and west ends of Peddock's Island, rival Great Head in the abundance and variety of the fossils. The nine most prolific localities are embraced in the accompanying table. The remaining localities have afforded the species indicated below: West end of Long Island, 33, 38, 43, 55; Long Island Head, 2, 38, 43, 47, 55; Lovell's Island and Nut Island, 38, 43, 55; George's Island, 11, 19, 38, 43, 55; Quincy Great Hill, 33, 38, 43, 44, 55; Princess Head, 33, 38, 55; Peddock's Island, 2d drumlin, 33, 38, 43, 53, 55; Peddock's Island, 3d drumlin, 38, 55; Strawberry Hill, 38, 43, 45, 47, 55.

Previous writers, including Upham and Dodge, have cited the occurrence of similar fossils in the drift, either unmodified or modified, at other points along this Coast from Brooklyn, N. Y., to the mouth of the Saguenay, and have noted that not a single certainly extinct species has been found; and it remains now to add that our studies in the Boston Basin have not changed this important generalization. Upham has also considered the climatic changes indicated by the general facies of our drift fauna. Southern forms prevail, including the round clam (*Venus mercenaria*) which is enormously more abundant than all the other forms taken together, although now of rare occurrence north of Cape Cod. A few forms, however, have a northward range far beyond this latitude; and, as Upham states, the intermingling of characteristic southern and northern forms in this assemblage of fossils from the till seems to be readily accounted for by the gradual refrigeration of the climate which culminated in the formation of the ice-sheet. The distinctly postglacial fossils dredged in the vicinity of Boston, of which Upham has reported fifty-one species,* are also mainly southern forms. The evidence thus appears to be fairly conclusive that in preglacial and again in immediately postglacial times the climate in this latitude was milder than at present.

The solution of the shells by meteoric waters is plainly indicated by the facts that they are generally wanting in the superficial, oxidized zone, and that such as are found in this zone are commonly more fragile and have an etched or half-dissolved aspect. Where the shells have wholly disappeared, their former presence may in some cases be safely inferred from the lumps and concretionary masses of till which are found chiefly in the

* Proc. Boston Soc. Nat. Hist., vol. xxv, pp. 305–316.

List of Species in the till of the Boston Basin.

Species.	Great Head.	Grover's Cliff.	E. end Peddock's Id.	W. end Peddock's Id.	Deer Island.	Moon Island.	Telegraph Hill.	Point Allerton.	Great Brewster Id.
1. *Cancer irroratus*, Say			×	×					
2. *Balanus balanoides*, Stimpson	×	×	×	×	×	×	×		
3. *Balanus crenatus*, Bruguiere	×		×	×				× ?	
4. *Bela* (sp.)	×								
5. *Chrysodomus decemcostatus*, Say	×			×					×
6. *Fusus tornatus*, Gould		×	×		×	×			×
7. *Sipho stimpsoni*, Morch	×						× ?		
8. *Sipho spitzbergensis*, Reeve	×		×	×	×				
9. *Neptunea ventricosa*, Gray	×						×		
10. *Neptunea pygmæa*, Gould		×			×		×		
11. *Buccinum undatum*, Linné	×	×			×			×	
12. *Buccinum cyaneum*, Bruguiere			×						
13. *Tritia trivittata*, Say	×	×	×	×		×	×	×	
14. *Ilyanassa obsoleta*, Say	×	×					×		
15. *Urosalpinx cinerea*, Say	×	×		×		×			
16. *Purpura lapillus*, Linné	×	×	×	×	×				
17. *Anachis avara*, Say	×		×				×		
18. *Astyris lunata*, Say		×							
19. *Lunatia heros*, Say	×	×	×	×	×		×		
20. *Lunatia triseriata*, Say			×	×	×				
21. *Lunatia groenlandica*, Moller	×								
22. *Lacuna neritoidea*, Gould (?)	×								
23. *Crepidula fornicata*, Linné	×	×	×	×	×	×			
24. *Crepidula plana*, Say		×					×		
25. *Crepidula convexa*, Say				×					
26. *Crucibulum striatum*, Say		×	×	×			×		
27. *Utriculus canaliculatus*, Say		×							
28. *Zirfæa crispata*, Linné		×							
29. *Ensatella americana*, Gould	×		×	×	×	×		×	
30. *Siliqua squama*, Blainville (?)			×						
31. *Saxicava arctica*, Linné			×						
32. *Saxicava norvegica*, Spengel (?)	×								
33. *Mya arenaria*, Linné	×	×	×	×	×	×	×		×
34. *Mactra solidissima*, Chemnitz	×	×	×		×				
35. *Mulinia lateralis*, Say				×		×			
36. *Macoma fragilis*, O. Fabr		×							
37. *Petricola pholadiformis*, Lamarck		×							
38. *Venus mercenaria*, Linné	×	×	×	×	×	×	×	×	×
39. *Callista convexa*, Say		×	×	×	×		×		
40. *Tapes fluctuosa*, Gould (?)	×								
41. *Cyprina islandica*, Linné		×							
42. *Cardium islandicum*, Linné (?)	×								
43. *Cyclocardia borealis*, Conrad	×	×	×	×	×	×	×	×	×
44. *Astarte castanea*, Say	×	×	×	×			×		
45. *Astarte undata*, Gould	×	×	×	×	×	×	×	×	×
46. *Argina pexata*, Say		×					×		
47. *Scapharca transversa*, Say	×	×	×	×	×	×	×	×	×
48. *Mytilus edulis*, Linné	×	× ?	×	×	×	×			
49. *Modiola modiolus*, Linné	×	×			×		×		
50. *Pecten magellanicus*, Conrad			×	×		×			
51. *Pecten islandicus*, Müller			×						
52. *Anomia glabra*, Verrill				×					
53. *Ostrea virginiana*, Lister	×	×		×	×	×			
54. *Astrangia danæ*, Agassiz		×	×						
55. *Cliona sulphurea*, Desor	×	×	×	×	×	×	×	×	×
	32	32	29	27	21	16	19	9	8

oxidized zone and are due to the very local cementation of the till by carbonate of lime, the most probable source of this cement being fossil shells which have vanished in this transformation. These masses of recent conglomerate or pebbly claystones range from a small fraction of an inch to several inches in diameter; are usually distinctly rounded in outline; and may occur loose in the till or attached to larger stones and bowlders. Although observed in several sections, they are especially noticeable in the buff till of Telegraph Hill; and one example from this section shows where broken the impression of a shell fragment, probably *Scapharca transversa*, with a minute portion of the original shell still remaining.

In part to the interstitial deposition of carbonate of lime from dissolved shells, but chiefly to the peroxidation of the iron oxide in the till, is due the setting or imperfect lithifaction of the buff till which causes the upper portions of the cliffs to present, usually, very precipitous or even vertical and overhanging profiles. That the buff till and the blue till are really contrasted in this respect is apparent from the fact that, no matter how high or how fresh the sea-cliff may be, the talus starts, as a rule, from near the junction of the two kinds of till, and the blue till can be seen *in situ* only where the slope is gullied.

The segregations of carbonate of lime are also found on the shells themselves, below the zone of most perfect oxidation of the till; the localities where this relation has been specially noted being Moon Island, the east and west ends of Peddock's Island, Deer Island, Point Allerton and Strawberry Hill. They occur almost exclusively on the larger and more massive shells, such as *Venus* and *Cyclocardia*; and are attached, as a rule, to the inner surfaces or the less salient portions of the shells, often filling the recesses of the hinge and the perforations made by the boring sponge — *Cliona sulphurea.* Occasionally, however, the shell fragments are almost entirely enveloped, forming the nuclei of concretions. In some cases, the segregations attached to the shells are protuberant and present the rounded outlines of normal concretions; but more commonly they have a worn or fragmentary character, as if they had suffered abrasion subsequent to segregation. These same shells frequently show glacial striæ; but in no instance, so far as we have observed, do the striæ cross the cemented material, although, on account of the rough and gritty character of the latter, one might well hesitate to speak positively on this point, but for the fact that prominent scratches are in some cases partly filled and covered by this natural concrete. This is an important point, since, in connection with the concretionary form of the segregations, it affords a conclusive answer to the view, which might otherwise appear tenable, that we have in these segregations remnants of a preglacial lithified matrix of the shells. In fact, the form and mode of occurrence are, in many cases, strongly suggestive of such an explanation ; and it is noteworthy that, although this adherent material is always of the same general nature and composition as the enclosing normal drift, it is also often much darker colored, varying from the usual gray tint of the till through dark brown to nearly black. Furthermore, the color is, in the thicker segregations, often noticeably darker in the portions lying nearest or in close contact with the shells. The blackness largely disappears on calcination, indicating that it is due to carbonaceous matter, the source of which, it appears probable, may be in the shell itself. This is one fact pointing to the conclusion that the shells, which are now white, opaque, more or less chalky, and as truly fossilized as many Tertiary shells, were recent in the fullest sense of the word at the time they were incorporated with the drift through the action of the ice-sheet; and it is in harmony with the fact that as yet no extinct species have been found in the drift.

Although the lithified matrix adhering to a small proportion of the drift shells must, in view of the foregoing observations, be regarded as of postglacial origin ; and the shells themselves are probably immediately preglacial inhabitants of Boston Harbor; one of the sections has afforded shells in an apparently preglacial matrix. While searching for shells on the west end of Peddock's Island, we found a rounded and distinctly glaciated fragment of a highly fossiliferous rock. It is a gray, seemingly unstratified, argillaceous and distinctly calcareous mass, $6\frac{1}{2}''$ long and $2''$ in greatest diameter, enclosing grains and more or less angular pebbles up to an inch in length of slate and other rocks, such as are common in the local drift. In fact, it looks exceedingly like a lithified portion of the drift, except that it is literally crowded with comminuted shells—the shell fragments ranging in size from mere specks to nearly an inch in diameter. When first found, the specimen was completely imbedded in the solid and entirely undisturbed gray till, one end projecting slightly from the side of a rain-washed gully about 15 feet above the beach and 25 feet below the top of the cliff. In digging it out, it was broken in two, and the aspect of the section is similar to that of the surface. That it is a true glacial erratic and reached the position where it was found through the agency of the ice-sheet we can not doubt. On a later visit to the section in company with Mr. T. A. Watson, he found another fragment of nearly the same size and shape and of very similar character save that the enclosed pebbles are larger and the shell fragments fewer.

Both specimens are distinctly glaciated, showing longitudinal scratches over almost their entire surfaces.

Concerning the origin and history of these specimens two views are suggested: (1) They are fragments of consolidated till, the product of an earlier ice-sheet, which was cemented by the segregation of carbonate of lime, perhaps locally where the enclosed shells were most abundant, during an interglacial period. (2) They represent a wholly preglacial and probably late Tertiary deposit, an uneroded remnant of which may even now underlie the water and drift deposits of Boston Harbor. This view is not, *a priori*, improbable, when we consider that Cretaceous and Tertiary strata fringe the southern coast of New England, appearing again in Marshfield, Mass., only twenty-five miles from Boston, and undoubtedly underlying a part, at least, of Massachusetts Bay, as indicated by the fragments of rock carrying characteristic Eocene fossils found by Upham in the drift of Cape Cod and described by the senior writer.* The Peddock's Island fragments include both Gasteropods and Lamellibranchs; but owing to the fragmentary character of the shells and the firmness of the matrix we have been unable to satisfactorily identify any of the species. We feel no hesitation, however, in saying that the general aspect of the shell fragments is strikingly similar to those found in the till and that they quite certainly embrace *Venus*, *Cyclocardia*, *Scapharca*, *Natica* and other species of the till. But the chief facts telling against the Tertiary age of these specimens are the comminution of the shells and the similarity of the calcareo-argillaceous matrix to the till, and especially to the cemented or concretionary masses of till. In view of all these considerations, we believe that these fossiliferous erratics, which agree, in color, with the gray rather than the buff till, should be correlated with the cemented portions of the till previously described. Among the various forms which the cemented till assumes, the most important distinction is between the globular, distinctly concretionary and uneroded forms and the worn and glaciated forms, the two specimens from the west end of Peddock's Island belonging to the second class. The uneroded globular forms are clearly of postglacial origin and may be regarded as still forming; but that the eroded forms, including the glaciated masses form Peddock's Island, are not truly preglacial is indicated, as already noted, by the comminution of the shells and the decidedly till-like character of the matrix. The only alternative, therefore, is to regard them as, in some sense, interglacial. When the ice-sheet first invaded this area, the shells on the bottom of Boston Harbor were reduced to fragments and became a part of the

* Proc. Boston Soc. Nat. Hist., vol. xx, pp. 136–140.

ground moraine or till. During a recession of the ice-sheet, the till was locally cemented or lithified by carbonate of lime derived from the shells through the solvent action of meteoric waters, the still undissolved shells thus becoming, in some cases, completely enclosed in a firm matrix. During the second advance of the ice-sheet the shells suffered further comminution, and the cemented or lithified portions of the till were more or less broken up and abraded or glaciated. The arenaceous character of the till must favor the solution and segregation of the carbonate of lime of the shells; and it does not appear probable that the very limited amount of lithified till antedating the close of the ice age of which we have evidence required for its formation a prolonged recession of the ice-sheet, or a period amounting to a true interglacial epoch. Our studies may be regarded as lending some support to the duality of the ice age; but it does not appear that during the vigorous discussion of this question now in progress any agreement has been reached as to how extensive or prolonged the recession of the ice-sheet must be to constitute an interglacial epoch in any given latitude. Important and repeated recessions of the ice-sheet are conceded by all glacialists, and the glaciation must have been intermittent in lower latitudes while continuous in higher latitudes. Thus the ice-cap which now covers a large part of Greenland is probably a remnant of the great sheet whose southern margin was a few thousands of years ago in the vicinity of New York and Cincinnati; and the age in which we live may eventually prove to be interglacial. It does not appear to us, however, that the facts presented in this paper indicate more than a brief or temporary recession of the ice-sheet from Boston Harbor; and certainly we have no evidence that preglacial conditions were reëstablished here or that any of the shells now found in the till date from an interglacial period.

A nearly complete series of the drift shells, representing all the known sections except the wells, and including the glaciated rock fragments from the west end of Peddock's Island, has been added to the collection illustrating the geology of the Boston Basin in the Museum of the Boston Society of Natural History. Mr. W. H. Dall of the U. S. Geological Survey, and Professor A. E. Verrill, of New Haven, have kindly identified some of the more doubtful species; but we feel that the drift fauna of the Boston Basin is still very incomplete, and especially that we have missed several species on account of the hopelessly fragmentary and abraded character of the material. In the collection of the shells we have received important assistance from Mr. T. A. Watson, and from Mr. H. D. Card, Mr. G. W. Stose, Miss Elvira Wood,

and Miss E. F. Fisher, students in the Geological Department of the Massachusetts Institute of Technology. We also take pleasure in acknowledging our great obligation to Mr. W. W. Herman for freely placing his extensive collection at our disposal. To his zeal as a collector we owe not only a goodly number of the new species recorded in this paper; but many other species in his collection are new for the localities in which he found them.

Art. LXVI.—*An Improved Form of Interrupter for Large Induction Coils;* by F. L. O. Wadsworth.

Every one who has had occasion to use a large induction coil knows the difficulty of keeping the contact breaker in good working order. Of the two forms of interrupter in common use, i. e., the spring contact form and the well known Foucault form, the latter is best suited for large coils, because the "break" may be made to take place under water or alcohol and the rapid oxidation of the contact surfaces is thereby much reduced. Even under the best conditions, however, it is difficult to secure uniformity of working for any length of time, and this, together with the necessity for frequent cleaning of the parts and renewal of the alcohol and mercury, renders the apparatus anything but satisfactory, when continued use with heavy currents is desired.

In the last number of this Journal Mr. St. John* describes a form of mercury contact interrupter similar to the ordinary Foucault form, except that the plungers are positively driven by means of cranks geared to a small electric motor, instead of by the more uncertain action of an electro magnet. This undoubtedly will give more positive and uniform results than are obtained either with the Foucault form or the ordinary spring contact form, but it seems to me to be considerably more complicated than need be for the purpose.

I am convinced from my own experience that mercury contacts are unsatisfactory if the best results are to be obtained with large induction coils. The electromotive force induced in the secondary circuit depends on the sharpness of the break in the primary, and this is lengthened considerably by the oscillation of the mercury surface and the formation, (on account of the low boiling point of the liquid), when the break occurs, of a considerable amount of conducting vapor.

* Wave Lengths of Electricity on Iron Wires. This Journal, vol. xlviii, p. 316, October, 1894.

For these last reasons, and also on account of the rapid oxidation of the surface, even when covered with alcohol, such contacts are entirely unsuitable when exact *equality* of the successive discharge intervals is of importance. Another objection to this form of interrupter, which becomes a serious one when work requiring concentrated attention on the part of the observer is under way, is the noisiness of its operation.

About four years ago I designed a form of interrupter for Prof. Michelson, which has been used ever since for the large induction coil employed to excite the Geissler tubes containing the vapor of the substance whose radiations are to be examined by means of the wave comparer.* The conditions which the interrupter is here required to fulfill are unusually severe. In the first place the action should be as noiseless as possible, in order to avoid distracting the attention of the observer. It must be constructed so that it will run constantly, often for some hours, without any attention or readjustment, even when the current in the primary is varied from zero to its maximum value (15 to 20 amperes), and finally in order to secure a perfectly steady source of light, the successive discharges should be as regular as possible, both as regards intensity and duration. For certain portions of the work it was also essential that the spark interval should be very uniform and considerably less than is usually obtained with a spring interrupter whose amplitude of swing is sufficient to enable it to be used with currents of any magnitude. It was also desirable that the number of breaks per second might be varied within considerable limits without interfering with the action of the interrupter, and that the observer might be able to readily start or stop the latter without leaving his seat.

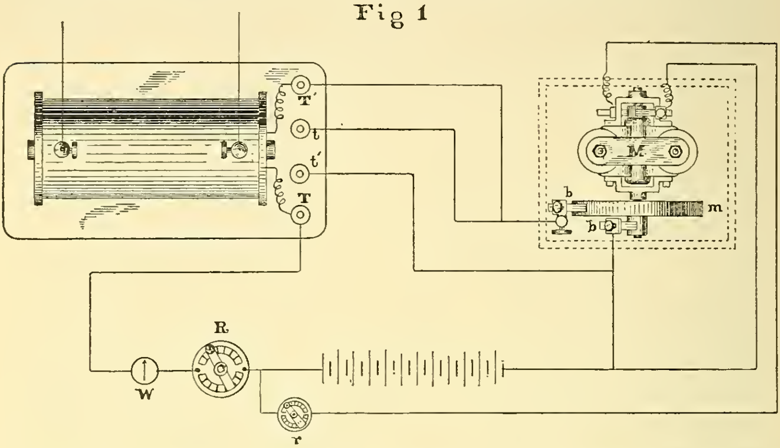
As all of these requirements have been satisfactorily met in the interrupter above referred to, and as it is, moreover, of very simple and inexpensive construction, it was thought that a brief description of it might be of interest to the spectroscopists and others who have had to use large coils for similar purposes.

It consists simply of a brass wheel about 6″ in diameter, with two insulating and two contact segments symmetrically placed in its circumference, and mounted directly on the shaft of a small electric motor making about 1200 revolutions per minute. Two copper brushes are arranged to bear, one on the hub of the wheel, the other on its circumference. A plan view of the arrangement, showing also the electric connections with the coil, is shown in fig. 1, where M is the motor (for an interrupter of this size a $\frac{1}{16}$ to $\frac{1}{12}$ H. P. motor is quite sufficient),

*See paper, Application of Interference Methods to Spectroscopic Measurements. II. A. A. Michelson. Phil. Magazine, vol. xxxiv, p. 280, Sept., 1892.

m, the revolving wheel; *bb*, the two contact brushes; TT, the terminals of the primary coil; *tt*, the terminals of the condenser; R, a rheostat for controlling the strength of the primary current; and *r*, one for controlling the speed of the

Fig 1

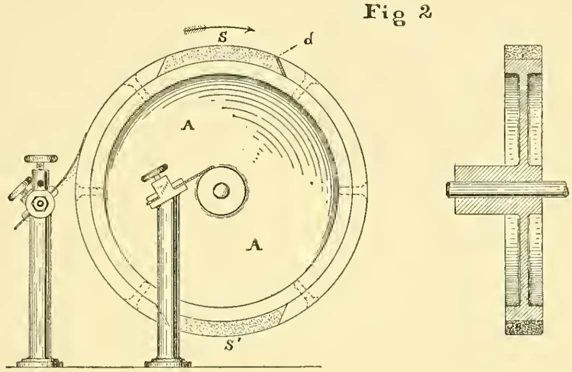


motor, which is supplied with current from the same batteries that feed the primary circuit. The current through the primary is broken each time one of the insulating segments on the circumference of the wheel passes under the contact brush *b;* the principle of its operation is therefore the same as that of the old toothed wheel interrupter. No novelty, therefore, can be claimed for it, except as regards the method of construction of the rotating wheel, but upon this depends almost entirely its successful operation, under the severe conditions of usage. In order that the action may be quiet, smooth and regular, it is of course necessary that the surfaces upon which the contact brushes slide, particularly the outer one, should be continuous, as regards outline; (i. e., not broken into teeth, as in the toothed wheel interrupter), and that they should be true at first, and remain so. The principal difficulty which had to be overcome was that of a rapid burning away of the material of which the insulating segments were made. It is unnecessary to record here in detail the various methods and materials which were at first employed in the attempt to secure a construction which would satisfactorily resist, without injury to itself, the heavy sparks of the "break." Hard rubber, vulcanite, vulcanized fibre, and even mica in its ordinary form rapidly burned or wore away. Finally cut slate segments were tried and have proved completely successful.*

* Porcelain segments would, perhaps, be even better, but the expense of making them (on account of the expense of making the necessary moulds, etc.) prohibited their use. The slate is a very satisfactory substitute and as it is easily worked the cost is comparatively trifling

To facilitate putting these segments in place and replacing them if accidentally broken, the construction shown in fig. 2 was adopted.

Fig 2



The hub, web, and flanged felloe of the brass wheel is cast in one piece and turned up true all over, so as to be perfectly balanced, even at high speeds. The insulating segments, *ss'*, each about 50° in length, are cut so as to fit the curve of the outer face and are beveled off at each end as shown. They are held in place by two brass or copper segments of the same thickness and each 130° long,* which are screwed down to the face of the wheel A A. A piece of sheet platinum, *d*, about $\frac{1}{2}^{mm}$ thick (giving a beveled edge about 1^{mm} wide) is placed between the slate and the brass at the side on which the "break" occurs.

When the surface is first built up in this manner, and afterwards, whenever a new segment is put in place (which is necessary only in case of an accident), the wheel is placed in the lathe and the outer surface ground perfectly true with a small revolving emery wheel or block of stick emery held in the tool post.

With a wheel of the construction just described, the wear, even with the heaviest currents, is inappreciable, on either the brass or the slate segments, it being confined almost entirely to the outer brush. By making this of spring copper and mounting it as shown in fig. 2, at a small angle to the surface, so that it springs into contact with the latter as it burns away, no attention is required until the brush is used up, when it is but the work of a moment to replace it by a new one; a

*The object of this relatively greater length of contact interval is to allow time, even at the highest speeds, for the current to rise to its full value in the primary circuit before the latter is broken.

stock of them being kept constantly on hand. With a mean* current (as indicated by a direct reading Weston ammeter (W, fig. 1) placed in the primary circuit) of 5 to 6 amperes, a brush usually lasts four or five or sometimes ten hours without being replaced. No other attention is required except to oil the bearings of the motor occasionally.

The only noise is that caused by the whirr of the revolving parts and the snap of the spark, and this is almost completely deadened by supporting the motor on rubber blocks and enclosing the whole arrangement in a small wooden box (indicated by the dotted lines in fig. 1).

The circumferential speed is so high, nearly two thousand feet per sec., that the break is extremely rapid and sharp. In the first instrument constructed the axis was vertical and the wheel was made to revolve under alcohol, but a short trial showed that this precaution was unnecessary.

If very heavy currents (15 or 20 amperes or higher) were continually used it would probably be found advantageous to place the contact-breaking brush between the poles of a powerful electromagnet (excited by the motor circuit). This would blow out the arc formed on breaking the circuit and thus greatly diminish the rate of burning away of the brush (see fig. 3). For ordinary work however neither this nor the use of a condenser is necessary although I have shown the latter connected to the interrupter in fig. 1.

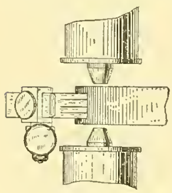


Fig 3

An alternating current dynamo properly wound is in many respects the most desirable means of exciting large coils, but on account of the expense of the dynamo itself and the cost of running it it is not often available. Even when it is there is one respect in which the action is inferior to that of an interrupter, viz: in the rapidity of the fall of electromotive force in the primary circuit. In this respect as well as in that of simplicity and cheapness the rotating wheel interrupter is superior to both the dynamo, and to all other forms of interrupters, and I do not think that any one who once gives it a fair trial will ever again use either a spring or mercury "break," for any but the very lightest work.

Addendum.—When this form of interrupter was first used it was noted that the spectrum of the spark at the "break" was very brilliant and pure and the possibility of using this spark as a source of radiation instead of an electric arc, suggested itself although not in any very definite form. This

* The maximum strength of current at the moment of breaking the circuit is, with the speed usually adopted, about twice the mean current as indicated above.

method has recently been developed by Prof. Michelson who in order to obtain spectra of difficultly volatile metals in vacuo, adopts the ingenious expedient of rotating the interrupter wheel in a Torricellian vacuum by means of a long shaft passing up through the mercury column.* A somewhat similar method has also been quite independently used for obtaining spectra of different metals in air by Messrs. Crew & Tatnall.†

It would seem to be a particularly promising one for the investigation of the infra red lines of the metals and alkali earths.

University of Chicago, October, 1894.

ART. LXVII.—*Post-Glacial Faults at St. John, N. B.;* By G. F. MATTHEW, D.Sc., F.R.S.C. (With Plate XI.)

NOWHERE, so far as the writer is aware, has there been put on record any account of disturbances in post-glacial times, of the rocks along the lines of faulting, in this North-eastern part of America. There are numerous places in all parts of this region where the removal of drift deposits allows of the inspection of the glaciated surfaces of the rocks, and had such faults been common it would seem highly probable that their presence would long ere this have been noticed. This thought induces the writer to give a brief sketch of the numerous small displacements, produced since the glacial period that have been observed in the rocks in and near St. John, N. B., Canada.

Numerous proofs of post-glacial disturbances of the earth's crust are visible in the slate rocks which form a large part of the rocky foundation on which St. John is built. These are true *post-glacial faults.* They are well shown along the hillside south of "The Valley" in that city. This valley is an east to west depression in the northern section of the thickly inhabited part of the town.

The rocks along the southern slope of this valley consist of the fine, dark-colored shales or slates of the Bretonian or Upper Division of the St. John Group; which by their fine grain and uniform texture, are well adapted to preserve the sharp grooves and striæ impressed upon them in glacial times, by the moving ice.

The faults visible along this hillside belong chiefly to a system having approximately a N.E. to S.W. course, and a hade of

* Univ. of Chicago, 1893–4. Results not yet published.
† Phil. Magazine, vol. xxxviii, p. 379, October, 1894.

from 60° to 80° to the S.E. But these faults are traversed by diagonal ones, some with a course approximately N. to S. and others E. to W. The principal movement of faulting in post-glacial times has been along the fault planes that have a N.E. to S.W. course.

The place where these faults were first observed was on the side of City Road, north of the City Hospital. Here a glaciated surface of slate about twelve feet wide has been exposed by the removal of the surface soil. There are nine faults visible here having a course nearly parallel to that of the street and a hade to the S.E. They vary in downthrow from one quarter of an inch to four inches, the downthrow being in all cases on the *north side.*

Beside these faults of the northeast and southwest system, two faults diagonal to these were seen, these have a course approximately N.E. to S.W. and the downthrow in both cases, though small, is on the *north side.*

On the steep hillside east of the end of Charles Street, numerous small faults of the N. E.–S.W. system were seen. In all these the downthrows were on the *north side.* Here the diagonal faults are of more importance as regards the downthrow that at the exposure on City Road; the hade of these faults is also less, being about 50°; the course of these is different from that of the diagonal faults at City Road being approximately E.–W. The downthrows here are on the *north side* of the diagonal faults and on the *north side* of the faults that have (approximately) a northeast to southwest course.

The best display of the S.E–N.W. post-glacial faults that has been observed is that on Rock street behind Fowler's Mill where a space of about one hundred and seventy feet of slate ledges has been laid bare. In this space sixty-one faults were observed which had been attended with displacement of the measures since their glaciation. In all of these faults, with one exception the *downthrow was on the north side*, and the hade of the faults was to the southwest. The sum of the displacement at these faults was five feet eight inches; the average throw for each fault being thus somewhat over one inch.

In one case only, a fault of half an inch had a downthrow on the *south side.* The diagonal faults which are not very conspicuous at this place, were not measured.

The heaviest throw seen at this place was five inches and very often an individual fault when traced along its course was found to vary in the amount of displacement. This was especially the case when the fault was complicated with a diagonal displacement, so that wedges of the slate would be raised above the general contour, or depressed below it; and occasionally a

EXPLANATION OF THE PLATE.

A ledge of clay-slate on City Road, St. John, N. B., Canada, showing a series of post-glacial faults. The view is taken looking southward up the hillside.

When exposed to the weather the sharp edge of the slate along the fault crumbles away from the effect of frost, and in the larger faults is only found perfect when the fault has been freshly exposed. In most of the faults here figured the projecting edge has thus suffered from exposure, except where they approach the covering of soil. The course of the glacial striæ is S. 15 E.

rhombic block could be observed, lifted above the surrounding slate.

At almost every place in the city and east and west of it, where the glaciated ledges of the slates of the St. John Group could be observed, some displacement was seen, though often very slight. At the N.E. corner of the Church of England burying-ground, east of the city, there is a ledge which shows two slight faults ($\frac{1}{4}$ inch each) with a downthrow *on the south*, eastward of Courtney Bay, at its head, the slates at the shore and on the road, have about a dozen faults with throws varying from one half an inch to an inch; these in almost all cases have the downthrow *on the north side.*

A fuller account of these faults will be given in the next Bulletin of the Natural History Society of New Brunswick, with some conjectures as to the causes which have produced them.

St. John, N. B., Canada, November 1, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the new Iodine Bases.*—Several additional salts of the new iodonium bases, discovered by V. Meyer and Hartmann,* have been described by these chemists. The nitrate $(C_6H_5)_2I.NO_3$, obtained by neutralizing a concentrated solution of the free base with strong nitric acid, appears as a white crystalline precipitate, readily soluble in hot water, from which it separates on cooling in small plates or spear-like crystals. It fuses at 153°–154°, to a clear liquid which soon begins to decompose and evolve gas; exploding if the quantity is considerable. The acid sulphate is produced by adding sulphuric acid in slight excess to a strong solution of the free base, and evaporating. The crystalline mass is dissolved in alcohol and on adding ether, the salt separates in colorless crystals reacting acid to litmus. The acetate is obtained by agitating iodobenzene with caustic soda and adding acetic acid. On filtering the warm solution, it deposits on cooling crystals of the acetate, which melt at 120°. One of the most interesting salts is the periodide, obtained by mixing the iodide of the base with an alcoholic solution of iodine and triturating. Combination at once takes place producing a brownish red precipitate, which yields, on crystallization from alcohol, dark red lustrous crystals having the composition $(C_2H_5)_2I.I.I_2$ and fusing at 138.° The sulphides are remarkably similar in appearance to the sulphides of lead, thallium and antimony. On mixing a solu-

* This Journal, III, xlvii, 399, May, 1894.

tion of the free base with ammonium sulphide, a bright orange-red precipitate is thrown down, very similar to antimony sulphide, and stable at 0.° At the ordinary temperature, however, it soon begins to decompose, evolving white clouds of vapor and yielding a mobile oil. Analysis shows it to be the trisulphide $(C_6H_5)_2I.S.S.S.I(C_6H_5)_2$, its decomposition products being iodobenzene and phenyl-trisulphide. The normal sulphide $(C_6H_5)_2I.S.I(C_6H_5)_2$ is precipitated from solutions of the base by sodium sulphide, as a bright yellow precipitate, decomposing at ordinary temperatures into iodobenzene and phenyl-sulphide. Several double chlorides, formed with the chlorides of mercury, gold and platinum are also described. The free base is reduced by sodium amalgam, one molecule decomposing into benzene, water and hydrogen iodide, the latter substance precipitating a second molecule of the base as insoluble iodide. The solution of the free base precipitates solutions of the salts of the heavy metals exactly as ammonia and the fixed alkali hydroxides do. The physiological action of the chloride has been studied by Gottlieb. It is found to be very poisonous, its mode of action combining the characteristics both of the salts of lead and thallium with those of ammonia and the ammonium bases.—*Ber. Berl. Chem. Ges.*, xxvii, 1592, July, 1894. G. F. B.

2. *On an Anomaly in the Density of Nitrogen.*—In a paper to the Royal Society, Rayleigh has called attention to an anomaly which he has encountered in his attempts to determine the density of nitrogen prepared by different methods. He had already established the fact that this gas, prepared by Lupton's method, i. e., by passing air mixed with ammonia through a red-hot tube containing copper, is lighter by about one thousandth part than nitrogen prepared in the usual manner, by passing air alone over the red-hot copper. Moreover he observed that on substituting oxygen for air in the former process, in which case the whole of the nitrogen instead of only about one-seventh part, comes from the ammonia, the discrepancy was increased to about one half per cent. In explanation of this condition of things, it might be assumed (1) on the one hand, that the heavier nitrogen contained admixed oxygen, or (2) that on the other the lighter specimens contained some gas lighter than nitrogen. The former hypothesis would seem to be negatived by the large quantity of oxygen required for the purpose as well as by the precautions taken to get rid of all of the oxygen, using various methods. The latter seems no less improbable, since the only gases involved are water-vapor, ammonia and hydrogen ; the two former being very readily removed, and the latter being certainly oxidized by the copper-oxide. Accordingly, further experiments were made, the nitrogen being prepared by the reduction of nitrogen monoxide or nitrogen dioxide, or by the ignition of ammonium nitrate, the gas obtained being in all cases passed over pure iron at a red heat, and carefully purified. In four experiments made on nitrogen prepared from NO by reduction with hot iron, the

mass of the gas contained in the globe used was 2·30143, 2·29890, 2·29816, 2·30182; the mean being 2·30008. Two experiments on nitrogen prepared by reducing N_2O by iron, gave 2·29869, 2·29940; the mean being 2·29904. Two experiments on nitrogen from ammonium nitrate, passed over hot iron, gave 2·29849, 2·29889; the mean being 2·29869. If now, we compare with these numbers, the values obtained from nitrogen prepared from the atmosphere, we find that in four experiments, the mass of the gas in the globe was 2·31017, 2·30986, 2·31003, 2·31007; the mean being 2·31003. Moreover, on removing the oxygen by placing air in a vessel containing a mixture of slaked lime and ferrous sulphate, the nitrogen gave the values 2·31024, 2·31010, 2·31028; mean 2·31020. Thus the result obtained from air in 1892 with hot copper 2·31026, that of 1893 by hot iron 2·31003, and that of 1894 by ferrous sulphate 2·31020 agree well together. It would, therefore, seem that the nitrogen prepared by the four chemical methods given is materially lighter than the nitrogen prepared from atmospheric air, the difference amounting to about 11 milligrams on the mass contained in the globe, or about one two-hundredth part of the whole. Moreover the lighter nitrogen did not become denser by standing for eight months. It was this anomaly in density that suggested to Rayleigh and Ramsay the possible presence in the air of some new constituent.*—*Proc. Roy. Soc.*, April, 1894; *Nature*, l, 157, June, 1894. G. F. B.

3. *On Carbon Boride.*—It has been shown by MOISSAN that when the electric arc is allowed to pass between two carbon electrodes agglomerated by means of a solution of boric acid and aluminum silicate, or when boron itself is placed in the electric arc, the carbon and boron unite to form carbon boride. It may be obtained in larger quantity by heating a mixture of 66 parts of amorphous boron and 12 parts of carbon made from sugar, in an electric furnace for six or seven minutes, by means of a current of 200–300 amperes and 70 volts. A black graphitoidal mass is obtained having a brilliant fracture. By treating this, first with fuming nitric acid and then with a mixture of nitric acid and potassium chlorate, the product is obtained in the form of a crystalline powder. Carbon boride may also be prepared by adding boron and carbon in excess to iron, and heating the whole in the electric furnace. Better results are obtained however by using copper or silver instead of iron; the crystals being better defined with the latter metal. Prepared in any of these ways carbon boride has the composition CB_6 and forms brilliant black crystals of sp. gr. 2·51. Chlorine attacks it below 1000°, but it is not affected by bromine, iodine or sulphur, at the softening point of glass, or by phosphorus or nitrogen at 1200°. Boiling acids do not act on it, nor do chromic acid, fuming nitric acid or concentrated iodic acid when heated with it in a sealed tube to 158°. At 500° no carbon dioxide is formed when the boride is heated in oxygen; but at 1000° it burns slowly and with more

* This Journal, III, xlviii, 345, October, 1894.

difficulty than the diamond. At a dull red heat potassium hydroxide attacks it, as also does a mixture of sodium and potassium carbonates. Though friable, carbon boride is hard and can be used to polish even the diamond, producing distinct facets.—*C. R.*, cxviii, 556, 1894. G. F. B.

4. *On the Carbides of Calcium, Barium and Strontium.*—By placing a mixture of 120 grams calcium oxide and 70 grams carbon in the crucible of the electric furnace and subjecting it to the action of a current of 350 amperes and 70 volts for 15 or 20 minutes, MOISSAN has obtained calcium carbide, the yield being from 120 to 150 grams. It has the composition CaC_2 and appears as a homogeneous black mass, distinctly crystalline and readily cleavable. The crystals are brilliant but opake and have a sp. gr. of 2·22. They are insoluble in all ordinary reagents, are not altered when heated in hydrogen or nitrogen at 1200°, or with silicon or boron at a bright red heat; neither sodium nor magnesium attacks it at the melting point of glass, nor does tin at a red heat or iron at a dull red; but at a higher temperature, an alloy of iron and calcium is formed which contains carbon. Dry chlorine does not attack it in the cold but at 245° it becomes incandescent and yields calcium and carbon chlorides. Bromine acts similarly at 350° and iodine at 305°. It burns in oxygen at a dull red heat, and in sulphur vapor at 500°. It rapidly decomposes water, developing heat and evolving almost pure acetylene. Fused chromic trioxide oxidizes calcium carbide, evolving carbon dioxide. Heated with absolute alcohol to 180° in sealed tubes it yields acetylene and calcium ethoxide.

Barium carbide is obtained by a similar reaction as a fused black brittle mass composed of large lamellar crystals, having a sp. gr. of 3·75 and a fusing point lower than the other carbides of this group. Strontium carbide has a lustrous crystalline fracture and a sp. gr. of 3·19. Both these carbides are decomposed by water, yielding the hydroxides and pure acetylene. Heated sufficiently in the gaseous hydracids, the carbide becomes incandescent. C_2Sr becomes incandescent in dry chlorine at 197 and C_2Ba at 140°—*C. R.*, cxviii, 501, 683, 1894. G. F. B.

5. *On the Size of the molecule of Mercurous chloride.*—The earlier determinations of vapor density in the case of mercurous chloride gave numbers agreeing with the formula HgCl. But since Odling showed that gold leaf immersed in the vapor became amalgamated, dissociation was inferred. V. MEYER and HARRIS now show that the gold leaf is instantly amalgamated in the vapor of mercurous chloride, but that it becomes pure gold again if allowed to remain in the vapor. Moreover by Meyer's method, the authors have determined the vapor density at the temperature of boiling sulphur (448°) and phosphorus pentasulphide (518°) and find their results to agree with the early ones in corresponding to the formula HgCl. A second series of experiments with a mixture of free mercury and mercuric chloride gave almost identical results. The bulb of the density apparatus was then made

of porous earthenware. A large amount of mercury vapor diffused through it when mercurous chloride was volatilized in it and was condensed on the surrounding glass vessel. Further when calomel is volatilized in a retort connected with a Sprengel pump, by which the pressure is reduced to about 30mm. the upper portion of the apparatus is covered with a layer of globules of mercury, a corresponding quantity of mercuric chloride being formed. Again pieces of caustic potash heated to the same temperature became covered with orange mercuric oxide when placed in the calomel vapor, and not black mercurous oxide. Hence the authors conclude that mercurous chloride is Hg_2Cl_2, the mercury in it not being univalent.—*Ber. Berl. Chem. Ges.*, xxvii, 1482, June, 1894. G. F. B.

6. *A Text-book of Inorganic Chemistry.* By G. S. Newth, F.I.C., F.C.S. 12mo, pp. xiv, 667. London and New York, 1894. (Longmans, Green & Co.)—The author has sought in this book to obviate many of the difficulties arising from the attempt to base a systematic course of elementary chemical instruction upon the periodic classification of the elements, by dividing it into three parts, the first of which is devoted to a brief sketch of the fundamental principles and theories of the science, the second to a study of the four typical elements hydrogen, oxygen, nitrogen and carbon, and the third to a systematic treatment of the elements according to the periodic law. The first part is especially worthy of notice since the more recent developments of the science in a physico-chemical direction are included in it, and are clearly though of course briefly, stated. Such subjects as the kinetic theory of gases, dissociation, electrolysis, critical temperature and pressure, osmotic pressure and thermo-chemistry, for example, are here included. The book is carefully written and appears fully up to date. The centigrade scale of temperatures is used exclusively and the metric system preferably; though we notice that the word "weight" for the most part is employed in the sense of "mass." G. F. B.

7. *An Elementary Chemistry.* By George Rantout White, A.M. 12mo, pp. xxx, 272. Boston, 1894 (Ginn & Company).—This book is a laboratory manual and is intended for beginners in chemistry. The first and second parts are devoted to experiments, the latter being the more advanced. The third part comprises the history and development of the laws and theories of chemistry. G. F. B.

8. *The mean density of the earth.*—Prof. Poynting's essay on the mean density of the earth has now been published. It contains a review of previous methods together with an account of the method of weighing by the ordinary balance which Prof. Poynting adopted. Newton in his Principia estimated that two spheres of the density of the earth, each a foot in diameter, would if separated by a quarter of an inch and left to their own attractions, take nearly a month to come into contact. Prof. Poynting points out that there is a mistake in the arithmetic, and that the

spheres would come into contact between five and six minutes. The mean density of the earth found by Professor Poynting is 5·49. Professor Boys result is 5·53.—*Nature*, Oct. 4, 1894, pp. 542–543. J. T.

9. *On the mean density of the earth.* (Communicated).—The last publication of the Philosophical Society of Washington, (Bulletin xii, 369–370 8 plates 7–10) gives a determination of the Mean Density of the Earth from two mountains in the Hawaiian Islands. Two distinct methods were used. In the case of Haleakala, astronomical latitudes were determined near the sea level on the north and south side of the mountain. These stations which were distant about 30 miles were connected by triangulation and by this means the deflection of the plumb line towards the mountain was ascertained. Contour lines for differences of elevation of 500 feet were established from the sea to the summit which is rather more than 10,000 feet high. Using these contours and a value of the mean density of the mountain derived both from determinations of the force of gravity and a study of the rock specimens, the attraction of the mountain was calculated. This compared with the total attraction of the earth gave an equation from which the earth's mean density was found.

In the case of Mauna Kea with an elevation of nearly 14,000 feet, contour lines could not be run, and the solution of the problem depends entirely on the determination of the differences of the force of gravity, combined with a value of the mountain density, from about 40 specimens of rock collected on both sides of the island between the lower and upper gravity stations.

Combining the results of both Mauna Kea and Haleakala a value of 5·35 was deduced for the mean density of the Earth.

At the end of the Bulletin is a table containing a list of all previous determinations which depend on pendulum or astronomical observations. The values given range from 4·67 to 6·77 and give a mean of 5·59.

The work in the Hawaiian Islands was done by Mr. E. D. Preston of the U. S. Coast and Geodetic Survey for the time being in the employ of the Hawaiian Government Survey.

10. *The source of friction electricity.*—C. Christiansen reviews the work of previous observers, and makes a number of experiments to ascertain the cause of frictional electricity. He arrives at the conclusion that it is to be sought in chemical separation or the relative turning of ions : and the action is analogous to that which takes place in electrolysis. Every atom has a charge which is positive or negative according as the atom acts as a *kation* or an *anion*. The author divides bodies into four classes. Class 1. Insulators or dielectrics. Bodies in which the ions are either fixed or can oscillate around their positions of equilibrium. Class 2. Metals in which the ions are either free or at least exchange their charges very easily. Class 3. Electrolytes in which the ions can move with more or less friction. Glass can be

included in this division. Class 4. Bodies analogous to water which include no ions or very few which permit movement. These can be called *hydrides.*—*Ann. der Physik und Chemie*, No. 11, 1894, pp. 401–431. J. T.

11. *Electrical conductivity of absolutely pure water.* — KOHLRAUSCH and HEYDEWEILER describe the processes by which they prepared and tested samples of pure water. They endeavored to find the true conductivity of water by extrapolation from previous experiments. The value thus obtained for the conductivity of absolutely pure water at 18° C. is $0{\cdot}036 \times 10^{-10}$. The amount of residual impurity was estimated at a few thousandths of a milligram per liter, which is 10,000 times less than the amount of air normally absorbed from the atmosphere.—*Ann. der Physik und Chemie*, No. 10, 1894, pp. 209–235. J. T.

12. *Self induction and capacity of coils.*—C. FROMME from magnetic experiments shows that bifilar wound coils possess a small capacity, so long as their resistance does not exceed 1000 ohms. At 2000 ohms the capacity begins to reach an appreciable amount. Chaperon's coils, however, so far as they were tested up to 3000 ohms were found free from capacity and self induction. These coils are unifilar. The direction of the winding changes with each layer.—*Ann. der Physik und Chemie*, No. 10, 1894, pp. 236–266. J. T.

13. *Spirals with compensated self induction.*—The difference of potential between neighboring turns in an ordinary coil is in general small, so that the capacity is small and is only noticeable with currents of high frequency. In order to obviate this capacity, TESLA recommends winding a wire B parallel to the first wire A and connecting the end of A with the beginning of B.—*Lum. Electr.*, li, pp. 432–433, 1894. J. T.

II. GEOLOGY AND MINERALOGY.

1. *A pre-Olenellus fauna:* "On the Cambrian Formation of the Eastern Salt Range." By Dr. FRITZ NOETLING, F.G.S. *Records of the Geological Survey of India*, Vol. xxvii, part 3, pp. 71–86, August, 1894.—From researches made in the palæozoic rocks of the Salt Range of India by the Geological Survey of that country, Dr. R. D. Oldham points out* what are the accepted divisions of the Cambrian rocks of that region and gives numerous lists of the fossil remains recognised up to date. In these lists such genera as *Olenellus*, *Hyolithes*, *Conocephalites and Neobolus* are recorded. There was however considerable confusion and mixture of horizons in the succession as known. Dr. Noetling has gone carefully into the natural succession of the Cambrian and newer palæozoic strata of the Eastern Salt Range. He separates the upper and middle portion of the Palæozoic from the lower and Cambrian portion.

* Manual of the Geology of India, Chapter V, p. 113 *et seq.*, Calcutta, 1893.

An historical sketch of the work done by Mr. Wynne, by the late Dr. Stoliczka, by Dr. Waagen of Vienna, by Dr. Warth, Mr. Middlemiss and Mr. Datta is then given. Dr. Noetling divides the Cambrian of the Eastern Salt Range of India into *four* groups which are in turn divisible into a number of zones or horizons. These four divisons of the Cambrian are as follows :

In descending order :

4. Bhaganwalla group, or Salt Range pseudomorph zone.
3. Jutana group, or Magnesian sandstone.
2. Khussak group, or Neobolus beds.
1. Khewra group, or Purple sandstone.

No fossil remains have yet been found in the Khewra group—but the Khussak group has yielded an interesting fauna divisible into *five* distinct zones at the top of which is the "*Olenellus zone*," so that there are four zones of fossiliferous strata below this Olenellus zone which may be termed pre-Olenellus zones.—These are the five zones of the Khussak group, in descending order :—

V. Olenellus zone.
IV. Neobolus zone.
III. Upper Annelid sandstone.
II. Zone of *Hyolithes Wynnei.*
I. Lower Annelid zone.

In the "Jutana Group"—above the Khussak group Dr. Noetling ascertained the following succession of strata in descending order :—

X. Upper Magnesian sandstone.
IX. " passage beds.
VIII. Middle Magnesian sandstone.
VII. Lower passage beds.
VI. " Magnesian sandstone.

In the Lower Magnesian sandstone, Dr. Noetling obtained a species of *Stenotheca* which he correlates with Billing's species: *Stenotheca rugosa*, *var. aspera* and an obscure *Lingulella.* That author has not attempted to make a critical examination of the fossil remains collected during the exploration but with the sanction of the Director of the Geol. Surv. of India these were sent to Dr. Waagen for determination. We are all anxious to hear the results of Dr. Waagen's observations inasmuch as a considerable proportion of the fauna is a pre-Olenellus fauna. Dr. Noetling is apparently satisfied to class all these sedimentary deposits under the term Cambrian without adopting any new term to include the pre-Olenellus fossils. H. M. A.

2. *The Mineral Industry, its Statistics, Technology and Trade for 1893;* Annual, Vol. II. Edited by R. P. Rothwell, 8°, xlii + 894 pp. Scientific Publishing Co., New York.—The compilation of this voluminous year-book is the result of the development of the annual statistical numbers of the *Engineering and Mining Journal.*

The volume under consideration contains a vast amount of statistics concerning the production and value of the mineral products of the world, as well as their movement in trade. It also embodies many special articles on the history and advancement of mineral industries, on the uses and occurrences of various products, on methods of mining and smelting, and so on, many of which are by specialists of the highest eminence in their several branches.

The book is of interest, not only to statisticians and those engaged in mining and the related industries, but also to those who desire to keep themselves informed on mining and metallurgical topics from a scientific point of view. H. L. W.

3. *Catalogue of Minerals.* GEORGE L. ENGLISH. 16th edition, 1894, pp. 124.—This catalogue is more than an illustrated price list of minerals. The classified list, with its alphabetical index, constituting 78 pages, presents in classified order the names of all the minerals and their varieties described in Dana's new "System of Mineralogy," 1892 edition, with the chemical formula, hardness and specific gravity of each. The catalogue will be useful to all mineral collectors who wish to keep up with the progress to the science.

III. BOTANY.

1. *Vegetable Resources of India.*—In the Kew Bulletin of Miscellaneous Information for September, 1894, is an abstract of Dr. GEORGE WATTS' recent memorandum on the resources of British India. The following notes are of general interest:

That part of British India treated of by Dr. Watt, comprises about 700,000,000 acres, on which lives a population of more than 220,000,000. The total acreage under *wheat* is over 20,000,000 acres. "In 1891–92, under exceptional circumstances of demand n Europe, Indian wheat was exported to the value of nearly 144 millions of rupees."

Tea.—It is well known that the indigenous tea plant has proved in India better than the acclimatized. The total acreage under tea is 334,845 acres.

The first commercial sale of Indian tea was in Calcutta more than fifty years ago. The exports in 1891–92 were 120,000,000 lbs. In the same year Ceylon exported about 70,000,000 lbs., and thus proves a formidable competitor.

Coffee.—It is believed that coffee has been cultivated in India for more than two centuries. The acreage is 125,000 acres:

Sugar.—Dr. Watts gives an interesting account of the fluctuations in the India sugar trade. There has been a steady decline of the export trade in refined sugar since 1845. The production of beet sugar in Europe has been: to close the markets which formerly received the refined sugar of India, and in the second place to "throw on the world large quantities as abnormally cheap cane sugar, which sought an outlet in India." The raw sugar in India, after making a correction for the foreign traffic, comes to 2,600,000 tons, or, say, 28 lbs. per head of the population.

Cinchona.—On the 31st of March, 1893, it was estimated that the matured plants on all of the plantations might be estimated at ten millions.

Indigo.—There are in India 2,762 factories and 6,032 vats, and these give employment to 356,675 persons during the working season irrespective of the agricultural labor to produce the plants. Last years' export of Indigo was 126,706 cwt.

Cotton.—It appears that the cultivation of cotton has not been developed on strictly scientific principles. It seems to Dr. Watts that selection of seed and the cultivation of specially selected plants might easily improve the Indian crop of any district by 50 per cent. The total area under cultivation is 9,000,000 acres.

Other Fibres.—Very little has been done in utilizing the remarkable fiber plants of native origin. The most promising possibilities appear in every direction. It is said that the fiber of Marsdenia tenacissima is far superior to Rhea. Its tensile strength is much greater than that of the finest hemp.

Cutch.—The process of boiling down the heart wood of Acacia catechu into a tanning extract, dates from remote antiquity. The modern methods of manufacture, though improved in many particulars are still far from economical. The export averages something over 2,200,000 cwt. annually.

Dr. Watts presents a most interesting account of the relations of Indian agriculture to the plants of other countries, pointing out that not far from 50 per cent of the prevalent cultivated and wild vegetation has been imported by India within historic times.

It is encouraging to note that various societies are coöperating with governmental departments in developing possibilities.

The August Bulletin of Miscellaneous Information from the Royal Gardens in Kew, contains a most interesting summary relating to *bananas* and *plantains.* The subject is dealt with very fully, especially with regard to the economic uses. A few of the statistics are here given :

During the year 1892, 13,000,000 of bunches of ripe bananas were imported into the United States. Each bunch usually consists of 80 to 200 bananas and weighs from 30 to 90 lbs.

Plantain meal, a food of great antiquity, has lately attracted considerable attention. It appears that some of the product has been made from unripe bananas. In all the samples, starch is more abundant than sugar. G. L. G.

2. *Grafting.*—M. Lucien Daniel (Revue générale de Botanique, 15 Sept. 1894) has published the results of interesting experiments in grafting herbaceous plants, especially different vegetables. His conclusions are as follows:

First, the flavor of vegetables can be made to vary by grafting them on vegetables of a different flavor.

Second, grafting flower pits at a suitable period retards the flowering of Cruciferæ. This delay enables us to suppress crossbreeding and consequently permits us to preserve varieties pure.

Third, seeds from a graft are better than those from the same plant ungrafted. Besides the immediate advantage which results from this, it may be possible for us in this way to regenerate and preserve varieties.

Fourth, herbaceous plants which are blanched cannot be grafted.

Fifth, from seeds produced from grafts new varieties can be created. G. L. G.

3. *Inflorescence in Descriptive Botany.* By M. F. Hy. (Revue gén. de Botanique, 15 Oct. 1894).—The author has introduced new terms descriptive of the multifarious forms of compound flower clusters. The terminology itself does not appear to possess any marked advantage over that which has been employed in more recent German treatises, but in the projections in a diagramatic form some curious relations are brought out which render the communication of considerable value.

The relations of inflorescence to the environment and to systematic affinities are not sufficiently dealt with. G. L. G.

4. *Researches on the Structure and affinities of Terebinthaceae.* By M. Jadin. (Annales des sciences naturelles, xix, I, 1894).—The following conclusions are reached: The stem in this Order is always characterized by canals of secretion developed in the liber. These canals are protected by enveloping fibers. This character is so marked that it should be taken as the most important character of the family. Second, there are no characters drawn from the anatomy of the stem by which the genera can be identified. Nevertheless in certain cases, such characters really aid when they are added to those of gross anatomy.

Third, the character drawn from the presence or absence of canals in the pith cannot always be taken as an important character. It however serves for certain cases.

Fourth, It does not appear that climate has any important influence on the development of the secreting canals in the pith. The following genera are excluded: *Ganophyllum*, Bl. *Filicium*, Thw. *Corynocarpus*, F. *Paiveusea* Welw. *Juliania*, Schlecht. All of these are excluded on account of anatomical peculiarities.

G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—The following is a list of the papers presented at the meeting of the National Academy held in New Haven, Oct. 30–Nov. 1:

William A. Rogers: An indirect experimental determination of the energy of obscure heat; Determination of the errors of the circles of an electrotype copy of Tycho Brahe's altitude azimuth instrument now in possession of the Smithsonian Institution.

Hubert A. Newton: The Winnebago County, Iowa, meteorites, and the meteor.

George W. Hill: Literal expression for the motion of the moon's perigee.

WILLIAM H. BREWER: Atmospheric dust and aqueous precipitation in Arctic regions.

SETH C. CHANDLER: Further researches on the polar motion.

THOMAS C. MENDENHALL: The relation of gravity to continental elevation; The legal units of electrical measure.

CHARLES S. HASTINGS: On derived equations in optics; On a method of eliminating secondary dispersion, using ordinary silicate glasses only.

THOMAS B. OSBORNE: The chemical nature of diastase.

CHARLES E. BEECHER: Some features in the development of brachiopods.

HENRY S. WILLIAMS: On the presence of Devonian fossils in strata of Carboniferous age.

JOHN S. BILLINGS: On the influence of insolation upon Culture Media, and of desiccation upon the vitality of the bacillus of typhoid, of the Colon bacillus, and of the Staphylococcus aureus.

WILLIAM L. ELKIN: Report on photographing meteors.

CHARLES A. WHITE: Biographical memoir of F. V. Hayden.

A. E. VERRILL: Geographical and bathymetrical distribution of the deep sea echinoderms, discovered off the American coast, north of Cape Hatteras.

A. A. MICHELSON: On the effect of pressure in broadening spectral lines.

JAMES HALL: Remarks upon the progress of work upon a handbook of the brachiopoda; Note upon the occurrence and distribution of the dictyospongidæ in the Devonian and Carboniferous formations.

S. P. LANGLEY: Infra red spectrum.

J. W. GIBBS: On a certain theorem in theoretical dynamics.

Boston Society of Natural History, Proceedings, vol. xxvi, Boston, 1894,—several interesting geological papers have appeared in the recently issued parts of this volume.

Parts II–III contain:

Facetted pebbles on Cape Cod, Mass, by W. M. Davis, pp. 166–175, with plates I–II.

Some typical Eskers of Southern New England, by J. B. Woodworth, pp. 197–220.

On the distribution of Earthquakes in the United States since the close of the Glacial Period, by N. S. Shaler, pp. 246–256.

The geographical development of alluvial river terraces, by R. E. Dodge, pp. 257–273.

The preglacial channel of the Genessee River, by A. W. Graham, pp. 359–369.

Occasional papers, IV.

Geology of the Boston Basin, by Wm. O. Crosby, vol. i, Part II, Hingham, pp. 179–288, with plates 6, 7 and 8. 1894.

Geotektonische Probleme; von A. Rothpletz, p. 175, fig. 107, plates 10 (E. Koch), Stuttgart, 1894.

Die Maschinellen Hilfsmittel du Chemischen Technik; von A. Parnicke, p. 320, fig. 327 (H. Bechhold). Frankfurt, 1894.

University of California, Bulletin of Dept. of Geology. Vol. I. Berkeley, 1894.

No. 5. The Lherzolite-Serpentine and Associated Rocks of the Potrero, San Francisco; by Charles Palache, pp. 161–179.

No. 6. On a rock from the vicinity of Berkeley, containing a new soda Amphibole; by Charles Palache, pp. 181–191, and two plates.

No. 7. The Geology of Angel Island; by F. Leslie Ransome (with a note on the Radiolarian chert from Angel Island, etc., by G. J. Hinde), pp. 193–240, plates 12–14.

OBITUARY.

WILLIAM TOPLEY, an active promoter of geology in Great Britain and for several years in charge of the Jermyn street office of the Geological Survey in London, died at the age of 53, on the 30th day of September.

INDEX TO VOLUME XLVIII.*

* This Index contains the general heads, BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS, and under each the titles of Articles referring thereto are mentioned.

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A TRIP TO EUROPE.

To our American Customers:

Mr. English is expected back in New York on November 24th, by the "Paris" from a trip to Europe. He has visited England and France as well as many remote regions in the east and south of Europe. As a result of this tour, we will have on sale probably about December 15th, *in time for Christmas trade*, some of the choicest European minerals we have offered for sale in many years.

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