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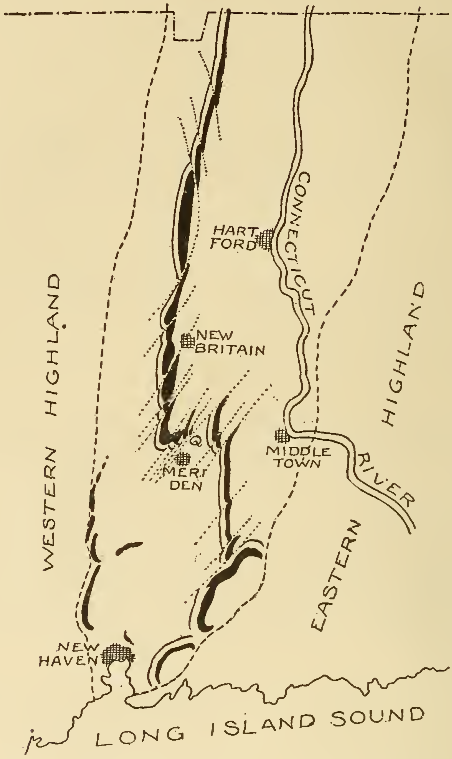
Art. I.—*The Quarries in the Lava Beds at Meriden, Conn.;* by William M. Davis.

Summary.—Three quarries in the Triassic (Newark) formation near Meriden, showing the vesicular upper surface of one lava bed under the dense basal portion of a later flow, and a number of fractures dislocating the double flow. Relation of these features to the geological structure of the district.

The present condition of the quarries in the trap ridge near Meriden, Conn., affords so fine an exhibition of the two lava beds of which the ridge is composed and of the fractures by which the beds are faulted, that the following account of their local and general relations is here placed on record.

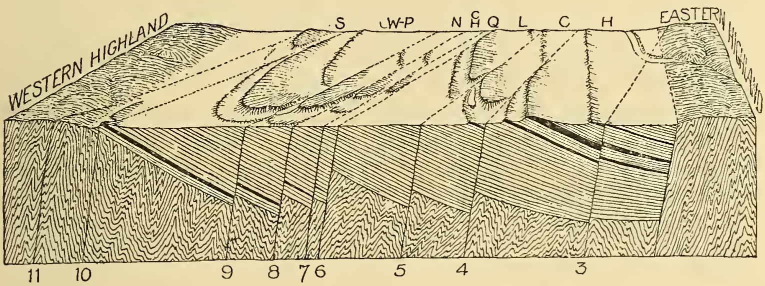
The general location of the quarry ridge is a mile north of Meriden, at the point marked Q in the adjoining sketch map (fig. 1) of central Connecticut; broken lines indicating the boundary of the Triassic formation against the crystalline highlands on the east and west. It thus appears that the quarry ridge is topographically the smallest eastern member of the Hanging Hills group and therefore belongs to the long series of ridges that extends from Saltonstall or Pond ridge, close to Long Island sound east of New Haven, northward into Massachusetts as far as Mts. Tom and Holyoke. The interpretation of the structure of the district here advocated shows, further, that all these ridges are the outcropping edges of a great extrusive lava sheet, once horizontal and continuous; now tilted, dislocated and denuded. Some of the dislocations of the region are indicated in fig. 1 by oblique dotted lines.

1.



The more local relations of the quarry ridge are exhibited in diagrammatic fashion in fig. 2, looking north. Here a piece of country, stretching from the western crystalline highland across the Triassic sandstones and the trap ridges, to the eastern highland, is roughly figured in perspective; the front face of the figure showing a vertical section of the faulted Triassic formation unconformably overlying an eroded foundation of crystallines. Much detail is omitted, and as is usual in the construction of generalized diagrams of this kind, a greater degree of definiteness and certainty is given at various points than would be allowed in a verbal statement. The structure of the crystalline rocks is wholly diagrammatic. The drawing nevertheless has a value in placing the reader quickly in possession of a number of important structural features. The district is shown to be divided into "blocks" or "slabs," by a system of faults, here running obliquely with much regularity about northeast-southwest. Each block, whether wide or narrow, contains representatives of the normal sequence of sedimentary and igneous beds; the most important of the latter being the "main trap sheet,"—the greatest lava flow of the region—which always stands up as a dominating topographic element. The name locally given to the ridge formed in each block by the main sheet is here extended to the block itself; the initials of the name of each block standing over the northern margin of the diagram.* The faults are numbered

2.



beneath the diagram; two important faults occur southeast of the area here included, and the count therefore begins at "3." All the faults here shown, except the last one, have the upheaved side on the east, and hade steep to the downthrow, as far as determined. Two examples of small uplift on the west are known, one being number 11 and the other occurring a little north of the district here portrayed. In addition to the strong ridge of the heavy main sheet, there are in each block two smaller ridges, one in front of the outcropping face of the main ridge, the other behind its back slope; and hence called by Percival in his Survey of Connecticut some sixty years ago the *anterior* and *posterior* ridges. As all these ridges are but the topographic expressions of three extrusive lava sheets, the terms *anterior*, *main* and *posterior*, may be used in a chronological as well as a topographical sense. Near the left front margin of the diagram, the northern terminal members of the West Rock and Gaylord mountain range are seen; their whole length being indicated on fig. 1, north of New Haven. These ridges are formed on an intrusive trap sheet, apparently tilted, dislocated and denuded in the very manner that prevails with

* The initials on the upper margin of figure 2 are as follows: H., Higby; C., Chauncey; L., Lamentation; Q., Quarry; C. H., Cat-Hole; N., Notch; W. P., West Peak; S., Short.

the extrusive sheets; but in the present paper the intrusive sheet need not be further considered.*

It is manifest from figure 2 that the true stratigraphic sequence of the formation can be detected only by moving obliquely to the strike within the boundaries of a single "block;" but this is by no means manifest on the ground, for the fault lines by which the blocks are bounded cannot be seen except in rare instances and for very short distances. Hence it is important that the field evidence on which the existence of the faults is based should be carefully argued. An essential postulate in this argument is the extrusive origin of the three lava sheets, above mentioned: for extrusive sheets may, in spite of their igneous origin, be treated as if they were normal members of the stratified sedimentary series; and of all this series the lava sheets are of the greatest value in field work, on account of their strong outcrops. It is therefore of prime importance that the postulate as to the extrusive origin of the sheets should be carefully tested. Both these points,—extrusive origin of lava sheets, and existence of oblique faults, may be well studied in the Meriden district; and no single locality offers so large a variety of features for examination as the Quarry ridge in its present excellent condition of deep dissection. The district has become especially familiar to me on

* Some of my earlier articles seem to have given the impression that I regarded East Rock, New Haven, as belonging with the extrusive sheets of which Saltonstall and Totoket mountains are typical examples, and not with the intrusive sheets, of which West Rock and Gaylord's mountain are the type. Nothing has been further from my intention. My first summer's work on the Trias, in 1882, convinced me of the intrusive nature of East Rock, on the back slope of which "a very strongly baked granitic sandstone is found within a few feet of fine compact trap." (On the Relation of the Triassic Traps and Sandstones of the eastern United States, Bulletin Museum Comp. Zoöl., vii, 1883, 268.) Saltonstall ridge was regarded at the same time as an extrusive sheet, and contrasted with the intrusives, "such as East Rock and the Palisades" (ibid, 269). Specific account of the evidence on which the intrusive nature of East Rock was argued is given in the essay by Mr. Whittle and myself, entitled "The Intrusive and Extrusive Triassic Trap Sheets of the Connecticut Valley" (Bulletin M. C. Z., xvii, 1889, 105).

Another point in which my interpretations have been misunderstood concerns Mt. Carmel and the associated large dikes of the Blue Hills, southwest of Wallingford. I have been quoted as calling these dikes "buried volcanoes," but on the other hand I have regarded them as the underground necks of volcanoes from which some of the extrusive sheets were poured out. As such they are monuments of "lost volcanoes," but they are by no means "buried volcanoes." (See Bull. Geol. Soc. America, ii, 1891, 420–421; also, The Lost Volcanoes of Connecticut, Pop. Sci. Monthly, Dec., 1891, 226.) Having sometimes been taken to task for not considering the flows of Saltonstall, Totoket and the other ridges farther north to be intrusive sheets, it is now a little amusing to be called to account for not considering the undoubtable intrusive sill of the Palisades in New Jersey to be an extrusive sheet, and this on no other evidence than its great extent roughly conformable with the bedding. (See Lyman's recent Report on the "New Red" of Bucks and Montgomery Cos., Penna., in Final Report, 1895, iii, 2621.)

account of the use of it for a number of years past as one of the stopping places for a week or two of our summer course in geology: thus the ground has been carefully and repeatedly explored by teachers and scholars, and the explanations suggested to account for its structure have been subjected to close scrutiny. A brief account may be given of the evidence on which the extrusive origin of the three lava sheets rests.

In all three sheets, the upper surface is vesicular where exposed near the base of the back slope. This makes a striking contrast with the dense upper surface of the East Rock and West Rock sheets, and at once raises a strong presumption in favor of extrusion. Not satisfied, however, with this alone, careful search has been made for critical contacts and structures in the sheets of the separate blocks.

In the Higby block, the lower part of the anterior sheet consists in part of volcanic ash and lava blocks; at the upper surface of the sheet numerous detached fragments of vesicular trap have been found in the sandstone. The main sheet also is immediately overlain by a sandstone containing many fragments of vesicular trap. No evidence for the posterior sheet has been found.

In Chauncey block, the anterior sheet has a bed of ash and lava blocks at its base; and its upper vesicular surface is covered with sandstone containing many trap fragments, well shown when the reservoir was in process of construction in the anterior valley. A gulley on the back slope of the main sheet discloses an overlying stratum of sandstone holding amygdaloidal trap. A railroad cut at the southern end of the posterior sheet exhibits the usual "mixture" of vesicular trap fragments in the sandstone, as if a clinkery field of "*aa*"—in the Hawaiian sense—had been buried by a deposit of sand and mud: the fresh-cut rock here exposed several years ago frequently revealed minutely stratified sediments in the open vesicles of the trap, both in the loose fragments and in the back of the sheet itself; and the stratification of these little deposits was always parallel to that of the adjacent sandstones and shales.

In Lamentation block, the base of the anterior sheet contains the heavy bed of ash and lava blocks that has in recent years become well known to the people of Meriden, but unfortunately under the name of "the volcano." There is no evidence of any vent or local eruption to be found. The back of this sheet has the usual "mixture," and among the basal beds of the overlying sandstone there is a stratum of tuff-like nature. The back of the main sheet at its northern end is cut by Spruce brook so as to expose the sandstone where it filled the spaces among a confusion of vesicular fragments. The posterior sheet does not here give decisive evidence of its origin.

The Quarry block will be described in detail below.

In Cat-hole block, the anterior sheet is opened in a small quarry near its base, where a ropy flow-structure is exposed. The vesicular upper surface of this sheet is well seen, but no actual contacts are found. The main and the posterior sheets in this block have afforded no evidence as to their manner of origin.

In Notch mountain block, a water-worn fragment of vesicular trap has been found in the sandstone about a foot above the very scoriaceous upper surface of the anterior sheet. The main and posterior sheets afford no evidence.

In West Peak and Short mountain blocks, no exposures of upper contacts have been found.

Other blocks north and south of the Meriden district afford repeated instances of "mixture" at the upper contact: for example in the gorge of Farmington river at Tariffville.* It should be understood, however, that while the lines of upper contact—sandstone on lava sheet—must measure many miles in total length, it is only here and there that they are exposed to sight, and then for but a few feet. To the geologist not familiar with these small but significant exposures, the sufficiency of the evidence of extrusion in the several blocks may be doubted, such is the prepossession in favor of "dikes" and "intrusions" when dealing with igneous rocks. The sufficiency of the evidence in one block to prove the extrusion of sheets in neighboring blocks, where no contacts are found, may be seriously questioned, so naturally is suspicion aroused when stratigraphic continuity is broken: but after repeated observation on the ground I believe that, taken altogether, the evidence of extrusion of the anterior, main, and posterior sheets is overwhelming and incontrovertible.

When the lava beds are once clearly recognized as extrusive, they may be used with any other members of the rock series in stratigraphic studies. The systematic repetition of the anterior, main, and posterior ridges in orderly succession over and over again, naturally suggests faulting: a line passing by the northern end of one set of the three ridges will, if continued to the southwest, pass by the southern end of the set in the next block: the lines of this kind also mark the termination on one side or the other of various minor ridges of sandstone on conglomerate: the same lines lead to the occasional

* See an article by Professor W. North Rice, this Journal, xxxii, 1886, 430–433. Also, The Intrusive and Extrusive Triassic Trap Sheets of the Connecticut Valley, by Davis and Whittle, in Bull. Museum Comp. Zoöl., xvi, 1889, 99–136.

changes of dip, these changes always departing from the rule of the monocline in such a way as to indicate a dragging pull from the neighboring fault: finally, it is upon these lines that occasional "dikes" of brecciated structure are found, agreeing in strike and dip with the expected attitude of normal fault planes. All these features occur so repeatedly and systematically that the faulting cannot be doubted for a moment when the facts become familiar. One after another of the ridges of lava, sandstone, or conglomerate that continue without interruption across a block will submissively end as they reach the invisible oblique line of a fault. Examples of this submission are so numerous and so systematic that the faulting of the blocks may be considered as conclusively proved as the extrusion of the lava beds.*

For those to whom it seems questionable to use lava beds as if they were sedimentary strata, a reassuring confirmation of the occurrence of faults may be found in the repetition of two beds of fossiliferous black shale, one in the anterior and the other in the posterior valley adjoining the ridges of the main lava sheet. Here the more customary stratigraphic argument for faulting, re-enforced by paleontological support, leads to the same conclusion as that already reached, but less definitely to my mind, for the beds of black shale are topographically weak, and are so seldom exposed that they prove only the occurrence but not the location of the faults by which they are dislocated.†

It is only when the facts and conclusions here briefly outlined are familiar that the Meriden quarries gain their full value. They are then seen to be not only serviceable as excel-

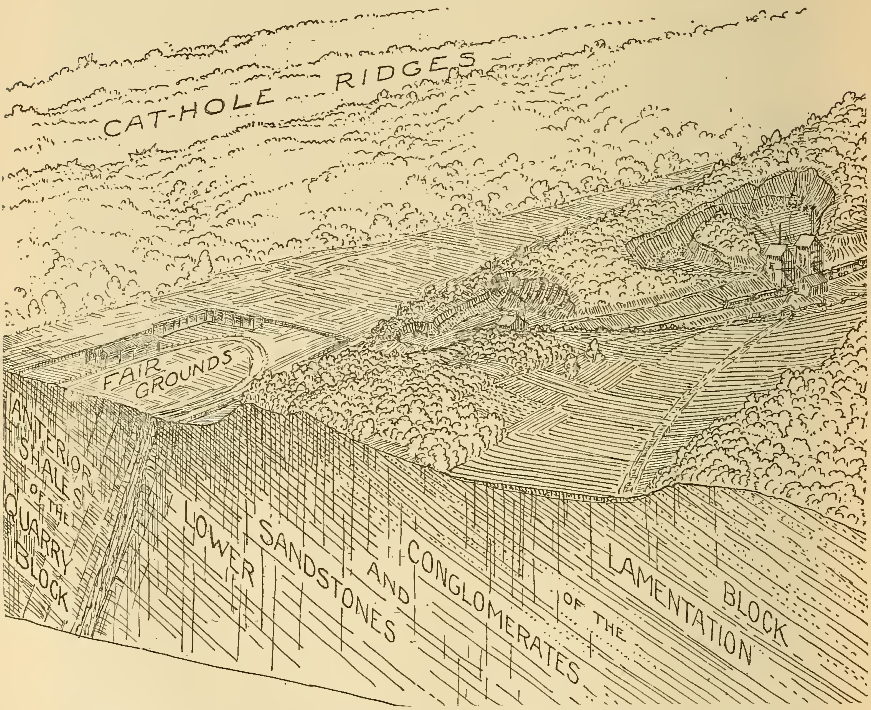
* Details concerning the faults in the Meriden district may be found in "The Faults in the Triassic Formation near Meriden, Connecticut." Bull. Mus. Comp. Zoöl., xvi, 1889, 61–86.

† Further details on this subject are given in "Two belts of fossiliferous black shale in the Triassic Formation of Connecticut," Davis and Loper, Bull. Geol. Soc. Amer., ii, 1891, 415–430.

It is well known that observations which are convincing to one geologist may not appeal forcibly to another. This was illustrated by an incident during the excursion made by many members of the International Geological Congress of 1891 from Washington to the West. On reaching Salt Lake, a recent fault along the base of the Wasatch mountains was argued from the visible topographic dislocation of the alluvial fans and glacial moraines at the foot of the range; but the European geologists of the party were so unaccustomed to arguments based on topographic form that with hardly an exception they refused to credit the conclusion as to recent faulting that had been reached by the geologists of our western surveys. It was only after repeated examples of faulted fans and moraines had been seen during two days of local excursions that a limited acceptance was allowed for what seemed to many of us as a very clear case. With this in mind, the evidence of faulting in the Connecticut Trias, as supplied by the ordinary stratigraphic and paleontological arguments from the black shales, has been a welcome addition to the evidence derived from the lava beds: not, however, so much for its effect on my own belief—for the argument based on the lava beds seems to me conclusive alone—as for the effect it might have on others to whom the lava beds may not seem to be altogether orthodox members of the sedimentary series.

lent local illustrations of faulted lava beds, but also as typical examples of structures on whose recognition the interpretation of the Triassic structure of the Connecticut valley depends. The locality has been a favorite with me for a number of years, always yielding new facts on repeated visits. During an excursion made in company with a number of geologists at the close of the meeting of the American Association in Springfield, September, 1895, the lesson of the quarries was found to be so much enlarged by their extension in the past three or four years, that I made another visit there a few weeks later just before the opening of our college year, so as to have leisure to examine them in detail. It is from notes taken on the latter visit that the following description is written.

3.



The quarries are opened in the southern quarter of a mile of the Quarry ridge, which extends thence northward for about a mile. The oldest quarry is at the end of the ridge; the others were opened in 1890. They are worked by Messrs. John S. Lane & Son, for railroad ballast and road metal; the rock being crushed alongside of a branch of the Consolidated railroad, by which it is hauled away. Some 800,000 tons have been sold in the last five years. In the rough sketch here given, the lower and inner part of the quarries is occupied by what I shall call the lower bed: the upper and outer part by the upper bed. The surface of separation between the two beds may be traced without much difficulty; it is now very clearly shown at several places, but its distinctness varies with the condition of the quarry. Followed around the various faces of the quarry, this surface may be traced with more or less continuity for six or eight hundred feet; and if all loose stuff were cleaned away, a length of a thousand feet might probably be measured. I have attempted to show the contact in fig. 3 by a line that breaks the shading at the back of the quarries.

The deepest part of the lower flow now exposed is in the back of the southern one of the new quarries, where it is seen for about forty feet beneath its surface. Here it is of a bluish gray color, fine-grained and dense, rarely vesicular. Nearer its surface it becomes red or purplish, with an increasing proportion of vesicles. The red color does not seem to depend on the weathering of to-day, for it is fully developed deep in the quarries and in massive, unjointed rock: it should therefore be ascribed to weathering immediately subsequent to eruption, or to underground alteration. The color is often so strong near the upper surface that this part of the trap might easily be mistaken for baked sandstone. The largest regularly shaped vesicles in the upper part of the flow are nearly an inch in diameter; in the most vesicular rock the originally empty spaces must have occupied at least a third of the entire volume. Besides the spheroidal vesicles, now filled chiefly with calcite and chlorite, there are occasional irregular cavities, up to six inches in diameter, more or less completely filled with crystalline minerals, chiefly calcite. Mr. Chapman, foreman of the quarry, assured me that these contain water when first opened in fresh broken rock. With all these secondary minerals, however, this account has little to do.

The lower bed nowhere exhibits any distinct columnar structure, but has on the other hand a tendency to split into slabs four or five feet thick, along weathered joints parallel to its surface. The scoriaceous surface of the flow is occasionally stripped bare: thus at present there is, in the old quarry near its southern end, an area measuring about sixty by ten or fifteen feet, where its rolling form is well exposed. It is a typical example of the Hawaiian "pahoehoe." The adjacent swells of the surface measure three to six feet across, and their vertical relief may reach a foot or more.

The upper bed, as far as exposed in the quarries, is unlike the lower in many respects. The color of its deeper joint planes, where not affected by weathering, is dark steel-gray, greenish or bluish; the fresh broken rock is dark gray or greenish, without any of the bright reds or purples of the lower flow. The texture is dense throughout, vesicles and cavities being very unusual: but by following the quarry ridge to the northeast about a third of a mile, one may find the ordinary vesicular structure of the upper part of the bed there exposed on its back slope. The density of the upper bed in the quarry is particularly noticeable where it rests directly upon the rolling surface of the strongly colored and highly vesicular lower bed. At the point in the old quarry where the surface of the lower bed is best exposed, the dense, dark lava of the upper bed fits closely into all the inequalities, the two beds being sometimes so closely welded together that weathering has not loosened them along the surface of contact, and hand specimens can be broken off showing the two kinds of lava: but as a general rule a weathered seam or parting follows the contact. The columnar jointing of the upper bed is fairly well developed at many parts of the quarries, but it nowhere produces columns of notable regularity. Near the base of the upper bed, the rough joint columns are of small dimensions: half a foot to a foot in diameter. Some fifteen or twenty feet above the base the columns are often two, three or four feet in diameter. The weathered joints in the rocks near the surface of the ridge are yellowish in the upper bed, but brownish in the under bed. The former is hard enough for use as road metal to the very top of the quarry, but the latter is weak and rotten where it has been weathered. The stripping of the ridge in preparation for further quarrying exposes many well-glaciated rock surfaces.

The various original features of the two masses thus described accord so perfectly with what occurs in modern volcanic districts, and the secondary features result so naturally from the long lapse of time that the rocks have existed, that "a double-bedded lava-flow" seems to be a well warranted name for the whole structure. The most significant features of the structure appear over so large a quarry face, and maintain throughout so constant a relation that no reasonable doubt can remain as to their meaning. In order to enforce the general recognition of a conclusion so well supported, I have replaced the ordinary term "trap sheets" with the more suggestive term "lava beds," in the title of this article, and hope that the latter term may come into common use.

The absence of stratified deposits between the two lava beds may be variously explained. The first bed may have filled the shallow waters of the estuary into which it flowed, so that its surface was exposed to the air; then before the gradual depression that long prevailed in the region succeeded in submerging the lava surface, the second bed may have been poured out on the first. If the top of the first bed did not reach the surface of the estuary waters, it must be supposed that the second flow occurred before a perceptible deposit of sediment had time to form. The probabilities seem in favor of the first supposition: for the close study that has been given to many good contact specimens by Mr. Whittle failed to detect any trace of stratified deposits between the two lavas: but on the other hand, a few grains of quartz were found, not derivable from the lava and perhaps best explained as wind-born sand.

The difficulty of recognizing the double structure of the "trap sheet" on the weathered, drift-covered, and wooded surface of the Quarry ridge prepares the observer not to expect manifest exhibition of double-bedded structure in the adjacent ridges of Cat-hole and Notch mountain blocks: but on the back of Notch mountain there are good indications that an upper flow occurs above the greater mass of the sheet.*

The lava beds no longer lie horizontal as they must have at the time of their extrusion, but dip to the east-southeast at an angle of fifteen or twenty degrees. This is shown by the slope of the vesicular portion of the under bed; the slope is so manifest that it is well known to the quarrymen. The sandstones of the district have a similar dip, thus confirming the idea that the lava beds were essentially level when they were poured out, and that they were afterwards tilted along with the whole mass of the formation. Indeed on this point there can be no doubt with regard to the extrusive sheets; but whether the intrusive sheets of West and East rocks, near New Haven, were driven between the sandstone beds before or after tilting is not definitely settled. The opinion that they were intruded after the tilting of the stratified beds is generally accepted; but the general accordance of their dislocations with those of the extrusive sheets in the Meriden district strongly suggests that both the intrusive and the extrusive sheets took their place in the bedded rocks before the tilting and faulting occurred.

The evidence of faulting, both on a small and a large scale, is remarkably distinct in the Meriden quarries and their immediate surroundings. Within the quarries there are several fissures, of breadth varying up to five or more feet, filled with fractured rock, now more or less weathered. The greater part

* Bulletin Museum Comp. Zoöl., xvii, 1889, 81.

of the filling is of trap fragments; but the space between the angular blocks of trap is generally filled with a matrix of sandstone or sandy shale; not fragments of bedded sandstone and shale, but a recomposed mass, presumably derived in the form of sandy or muddy powder from the grinding of overlying sandstones and shales at the time of faulting. All the ordinary features of fault structure may here be studied to good advantage.*

The amount of movement on the fault lines reaches fifteen or twenty feet in the best examples now exposed; this being on the little hill of rock left standing between the two northern quarries, where the vesicular surface of the lower lava bed is dropped by nearly twenty feet on the northwest side of the fault. This dislocation is very clearly exhibited at present. Several smaller examples of measurable throw occur in various parts of the quarries. The trend of the fractures varies from about north-northeast to northeast, the latter direction being that of a little swampy water course that obliquely terminates the quarry ridge on the south. The rock exposures nearest to this little valley are the weathered breccias on the margin of the southern quarry, and there is every reason to think that the valley itself is nothing but the topographic expression of a broad band of fractured rock, produced by a strong fault. The distribution of ledges and ridges in the neighborhood gives full support to this idea. Just across the little valley is the northern end of a ridge of conglomeratic sandstone, whose strike would carry its strata directly into the lava beds. Although the lavas were poured out previous to the deposition of the overlying fragmental beds and although the pebbles of the conglomeratic beds give evidence of rather active currents, no trap fragments are to be found among the pebbles; and this increases the presumption that the two masses—the lava beds and the conglomeratic sandstones—do not lie in their original relative positions, but have been brought into their present relation by faulting. Adopting provisionally the general course of the little valley as the trend of the dislocation separating the two dissimilar ridges, and walking northeast or southwest, abundant confirmation of this idea is found. The sandstone ridges, coming northward towards the line of the supposed fault, end on reaching it in the submissive manner already described; and at a distance of several miles to the northeast, the northern ends of the anterior, main and posterior sheets of the Lamentation block are similarly truncated. The uplift of the fault is then seen to be on the eastern side, and its movement approaches two thousand

* Details are given in the article on "The Faults in the Triassic Formation near Meriden," already referred to.

feet; this being the great fault of the region, numbered 6 on fig. 2. The entire structural arrangement of the district is soon found to accord with the clue suggested by the quarries; thus enhancing their value as a place for beginning the study of the region.

The best approach to the quarries is by an old road leading north from the highway just east of the Fair Grounds. The observer then follows the ridge of conglomeratic sandstone above referred to for a little distance before the quarry ridge comes in sight. With the expectation that a strong topographic feature would suggest, he naturally looks forward to the continuation of the ridge for some distance. Hence there is always an element of surprise when dark rocks in the old quarry first rise into view a few hundred feet to the north in line with the strike of the conglomerates. The chief problem of the region—the relation of the lava beds to the sedimentaries—is thus brought vividly to mind; and before returning from the quarries the problem may be advanced far toward solution.

Harvard University, October, 1895.

Art. II.—*Note on Globular Lightning;* by O. C. Marsh.

A great deal has been written recently on the various forms of lightning, and the subject itself has so much scientific interest, that it may be worth while to place on record an observation of my own on globular lightning, made years ago, in which the main facts are different from any I have seen described.

On Tuesday, July 23, 1878, I was on board a large yacht at anchor in the harbor of Southampton, England. About two o'clock in the afternoon, when we were about to sail, a violent thunder storm came up from the west, and as it passed over Southampton, several bolts descended, one of which, as I afterwards learned, struck a church. As the first drops of rain came down on the yacht, I was standing in the after companion way, looking forward, when my attention was attracted by a bright light apparently near the upper part of the foremast. When I first saw it distinctly, it was about half-mast high, and was falling slowly and directly toward the deck. This light was a ball of fire, a delicate rose-pink in color, pear-shaped in form, with the large end below, and appeared to be four or five inches in diameter and six or eight in length.

When it struck the deck, about forty feet from where I was standing, there was a loud explosion, and it was some minutes before it could be ascertained what damage had resulted. The mate, who was near the mainmast, about twenty-five feet from where I stood, was knocked down, but soon recovered. The same bolt, or part of it, also passed in front of the foremast, down a windsail ventilator, into the galley, where it knocked a large tin pan from the hands of a cook, and upset things generally in the culinary department, but injured no one seriously. Of the crew, some were on deck and some below, but none were really harmed, although a few were badly demoralized. A strong ozone-like odor was observed immediately after the explosion, and this remained perceptible for some time.

The officer in command of the yacht, Captain Matthews, who was forward at the time, and escaped without injury, stated that just after the stroke, he saw "streaks of lightning running around on deck like snakes." I was myself only dazed for a moment by the explosion, and saw distinctly that the deck forward was illuminated with a bright confused light. The owner of the yacht, George Peabody Russell, and his other guests, had gone below when the storm began, and suffered no harm, except possibly from fright, as they were still further away from the stroke.

As soon as the storm had passed, I made careful notes of the whole occurrence, with drawings and measurements, as I was much interested in the subject, and it was the first instance of the kind I had seen at close quarters. An inspection showed that the vessel itself had sustained no material damage, and not even permanent marks were left on the deck where the ball of fire exploded. A number of other yachts were at anchor quite near our vessel at the time, among them the white "Sunbeam" just home from her well-known voyage, but we saw no indications that any of these had been struck. I had no time to inquire, as immediately after the storm we sailed on a cruise to the eastward.*

Yale University, New Haven, Conn., December 4, 1895.

*Those interested in the rarer forms of lightning will find many observations recorded in "Nature," especially during the last fifteen years.

ART. III.—*The Form of Isolated Submarine Peaks;* by G. W. LITTLEHALES, U. S. Hydrographic Office.

THEORETICALLY the form of an isolated submarine peak would be that of a solid of revolution in which the crushing strength of any section is equal to the combined weight of the portion of the formation above that section and of the superincumbent body of water. Let y denote the radius of any section, and x its distance from the top of the formation. Let K denote the coëfficient of crushing strength of the material composing the formation; δ, the weight of a unit of its volume; and δ', the weight of a unit of volume of sea-water.

Assuming that the top of the formation just reaches to the surface of the ocean,

$\pi\delta\int y^2 dx =$ the weight of the formation above any section whose distance from the top is x,

$2\pi\delta'\int y.\,x.\,dy =$ the pressure of the water upon the formation above any section whose distance from the top is x,

$\pi K y^2 =$ the strength of any section to resist crushing.

Then

$$\pi\delta\int y^2 dx + 2\pi\delta'\int y.\,x.\,dy = \pi K y^2 + C \qquad (1)$$

in which C is a constant representing the excess of crushing strength in any section above what is necessary to withstand the pressure caused by the weight of the formation and the weight of the superincumbent body of water.

By differentiation, equation (1) becomes

$$\pi\delta y^2.\,dx + 2\pi\delta' y.\,x.\,dy = 2\pi K.\,dy$$

or

$$\frac{\delta}{2}\,\frac{dx}{(K - \delta' x)} = \frac{dy}{y}$$

or

$$\frac{\delta}{2\delta'}\,\frac{dx}{\left(\frac{K}{\delta'} - x\right)} = \frac{dy}{y} \qquad (2)$$

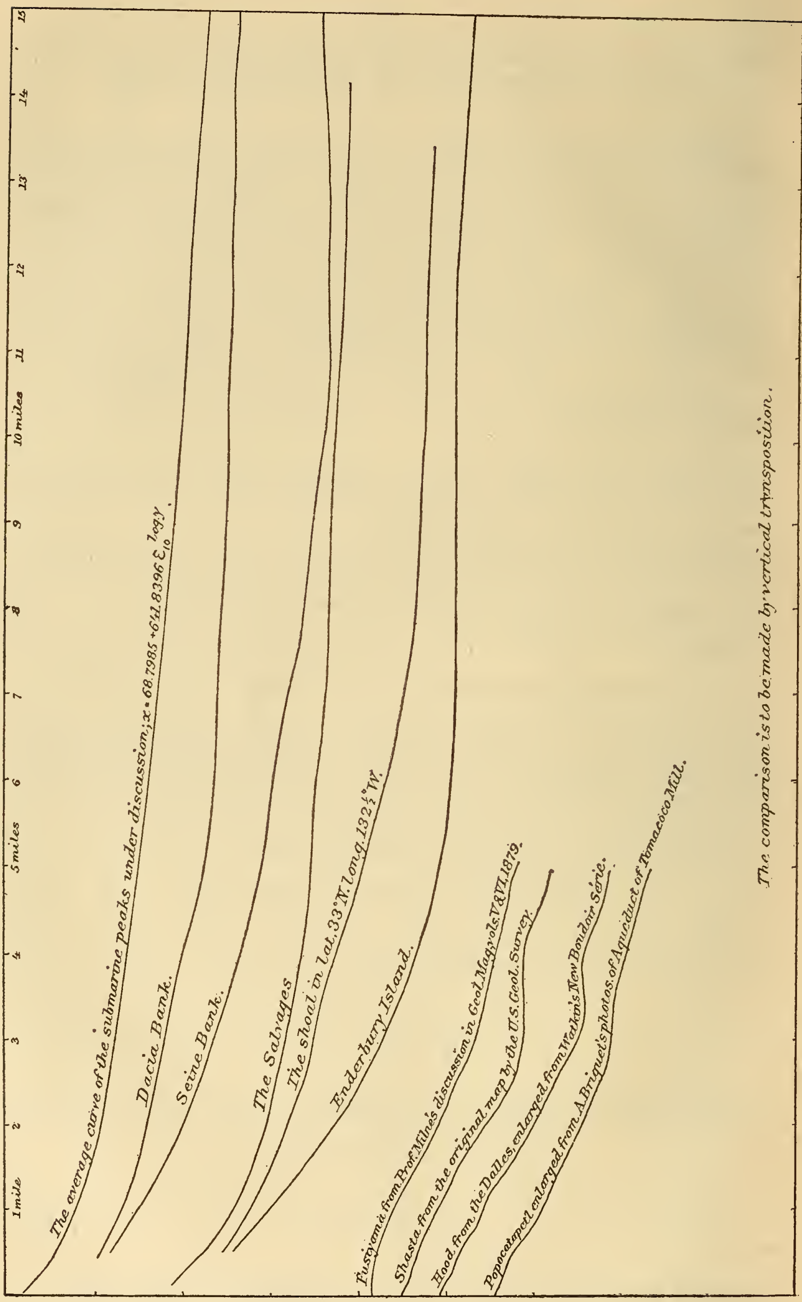
By integration, equation (2) becomes

$$\frac{\delta}{2\delta'}\log\left(x - \frac{K}{\delta'}\right) = \log y$$

or

$$x = \frac{K}{\delta'} + \varepsilon^{\frac{2\delta'}{\delta}\log y} \qquad (3)$$

in which ε is the base of the Naperian system of logarithms.



Each division = 1000 fathoms.

This equation has been used in the generalized form, $x = A + B\varepsilon^{\log y}$, to find from the observed bathymetric data in relation to Dacia Bank in latitude 31°–10′ N. and longitude 13°–40′ W., Seine Bank in latitude 33°–50′ N. and longitude 14°–20′ W., The Salvages in latitude 30°–05′ N. and longitude 15°–55′ W., Enderbury Island in latitude 3°–10′ S. and longitude 171°–10′ W., and the shoal in the North Pacific ocean in latitude 32°–55′ N. and longitude 132°–30′ W., the equation to their average form.

For this purpose the values of y, expressed in nautical miles, and x, in fathoms, were inserted in the above equation and a conditional equation was formed for each of the submarine formations. From these conditional equations normal equations were found by the Method of Least Squares, which gave the values of the constants A and B. The resulting equation is

$$x = +68{\cdot}7985 + 641{\cdot}8396\ \varepsilon^{\log y},$$

and the corresponding curve is shown in the accompanying diagram together with others which have been plotted from measured data for purposes of comparison.

This investigation has an important bearing upon the intervals at which deep-sea soundings should be taken in searching for probable shoals in the open ocean and in developing the character of the bottom of the sea. It shows that isolated formations occupying comparatively limited areas at the bottom can and do occur in deep water, and we are able to assign at once the maximum interval that should obtain between deep-sea soundings taken in the above-mentioned operations. The minimum radius at the bottom which a dangerous shoal can have must vary directly with the depth, but on the average, in the deep sea, it may be stated as 10 miles. An interval of 10 miles coupled with an interval of 2 miles would be sufficient for general development, and would prove with certainty the existence or absence of any formation rising close to the surface. Of all the possible ways in which a 10-mile interval could lie with reference to a submerged peak, that which would be most advantageous for a prompt discovery of its existence is the condition in which one end of the interval is at the bottom of the slope and the other near the apex, and that which would be least advantageous is the condition in which the interval is bisected by the position of the apex. In the latter case, there would be nearly equal soundings at both ends, but the soundings at the ends of the adjacent 2-mile intervals would immediately disclose the slopes.

ART. IV.—*On the Double Fluorides of Cæsium and Zirconium*; by H. L. WELLS and H. W. FOOTE.

IN connection with his comprehensive work on zirconofluorides, Marignac* has investigated the double fluorides of zirconium with ammonium, sodium and potassium, and since the corresponding cæsium salts have never been investigated, we have undertaken a study of them.

The following table gives Marignac's ammonium and potassium salts, together with those which we have prepared with cæsium:

3 : 1 Type.	2 : 1 Type.	1 : 1 Type.	2 : 3 Type.
$3NH_4F . ZrF_4$	$2NH_4F . ZrF_4$	....	....
$3KF . ZrF_4$	$2KF . ZrF_4$	$KF . ZrF_4 . H_2O$	....
....	$2CsF . ZrF_4$	$CsF . ZrF_4 . H_2O$	$2CsF . 3ZrF_4 . 2H_2O$

The analogy between two types of cæsium and potassium salts is complete, while one type varies in each series. No evidence has been found that cæsium, in this case, forms a greater variety of compounds than potassium.

The symmetrical arrangement of the vacancies in the table, where no salts have been discovered, indicates that alkaline fluorides of lower molecular weight combine with a relatively smaller number of molecules of zirconium fluoride, while those of higher molecular weight combine with a greater number of such molecules.

The 2 : 1 type is the only one occurring in all three series. This is the common and usually the only type of double halogen salts formed by tetravalent elements, hence its occurrence in all cases was to be expected. The single sodium salt described by Marignac, $5NaF . 2ZrF_4$, does not correspond to any of the compounds in the above table, but it is to be noticed that the composition corresponding to this formula varies but little from that required for $2NaF . ZrF_4$. Although Marignac's work on this salt was, as usual, very thorough and careful, it seems possible that his products may have been the 2 : 1 salt containing a small amount of some impurity, possibly a 3 : 1 compound.

Marignac described the salts $Mn_2ZrF_8 . 6H_2O$, $Cd_2ZrF_8 . 6H_2O$, $Zn_2ZrF_8 . 12H_2O$ and $Cu_2ZrF_8 . 12H_2O$, all of which correspond to a 4 : 1 type which has not been obtained with the alkali-metals. This type and those given in the preceding table make five varieties of zirconofluorides, one of which has been discovered in the present investigation.

* Ann. Chim. Phys., III, lx, 257.

The materials used for the preparation of the cæsium salts under consideration were carefully purified by ourselves. Hydrofluoric acid was made from perfectly pure fluor-spar and sulphuric acid, using a platinum still and redistilling the product. Cæsium carbonate, purified by the method described by one of us,* was used in preparing the fluoride. Zircon was used as the source of zirconium. The crude hydroxide was conveniently obtained by fusing the finely pulverized mineral with four parts of sodium carbonate, treating the resulting mass with hydrochloric acid, evaporating with an excess of sulphuric acid until the latter fumed, taking up with water, filtering and precipitating with ammonia. For purifying the zirconia, the method of Mitchell which has been advocated by Baskerville† was found convenient. This consists in dissolving the zirconium hydroxide in hydrochloric acid, nearly neutralizing with ammonia, adding a strong solution of sulphur dioxide and boiling. The precipitate, which, from the results of Venable and Baskerville,‡ appears to be a basic zirconium sulphite, can readily be washed free from iron.

The double salts were prepared by mixing solutions of the two fluorides in widely varying proportions, in the presence of more or less hydrofluoric acid, evaporating to the proper point and cooling.

When cæsium fluoride is in excess, even with very small amounts of zirconium fluoride, the salt $2CsF . ZrF_4$ is formed. It crystallizes in rather large, simple hexagonal plates, showing negative double refraction, and it can be recrystallized unchanged from water.

When a larger proportion of zirconium fluoride is used, the salt $CsF . ZrF_4 . H_2O$ is obtained. This forms monoclinic crystals elongated in the direction of the *b* axis, and with faces which are usually too rough for accurate measurement. This salt also can be recrystallized unchanged from water.

With a large excess of zirconium fluoride extremely small, difficultly soluble crystals of the salt $2CsF . 3ZrF_4 . 2H_2O$ are produced. The small crystals have a slight action upon polarized light, but their form could not be made out. It does not recrystallize from water in a pure condition, the product being mixed with the 1 : 1 salt.

To determine cæsium and zirconium, the fluorides were converted into sulphates, then zirconium was separated from cæsium by the use of ammonia, and zirconium oxide and cæsium sulphate were finally weighed. In order to determine fluorine a separate portion was dissolved in water, zirconium hydroxide was precipitated with ammonia, sodium carbonate

* This Journal, xlvi, 188. † Jour. Am. Chem. Soc., xvi, 475.
‡ Jour. Am. Chem. Soc., xvii, 448.

was added in slight excess to the filtrate and all the ammonia was removed by evaporation. To the hot solution calcium nitrate was added, and the resulting precipitate, after ignition, was cautiously treated with dilute formic acid until, after evaporation on the water-bath, a further addition of the acid produced no effervescence. The calcium fluoride finally remaining after a final evaporation was washed, ignited and weighed. The results of the fluorine determinations were invariably somewhat low.

The substitution of formic acid for the acetic acid usually used in removing calcium carbonate from the fluoride was suggested by the greater volatility of the first acid and the solubility of its calcium salt. We have found the modification to be an improvement as far as convenience is concerned, but we are not yet prepared to say that it is more accurate than the old method.

Water was determined by heating the substance in a boat behind a layer of dry sodium carbonate in a combustion-tube, and collecting and weighing it in a calcium chloride tube.

The following analyses of separate crops were made:

	$2CsF.ZrF_4$			
	A.	B.	C.	Calculated.
Cæsium	56·41	----	55·51	56·60
Zirconium	18·94	19·30	19·16	19·15
Fluorine	22·73	22·75	----	24·25
Water	1·63	0·98	0·97	

The small amount of water found in the analyses was evidently mechanically included, for, under the microscope, bubbles of mother-liquor could be occasionally seen within the crystals.

	$CsF.ZrF_4.H_2O$		
	A.	B.	Calculated.
Cæsium	----	38·44	39·58
Zirconium	27·19	27·11	26·79
Fluorine	27·24	27·52	28·27
Water	6·27	5·20	5·36

	$2CsF.3ZrF_4.2H_2O$		
	A.	B.	Calculated.
Cæsium	32·03	30·56	31·74
Zirconium	32·45	33·48	32·22
Fluorine	31·09	30·43	31·74
Water	4·40	3·96	4·30

Sheffield Scientific School,
New Haven, Conn., July, 1895.

ART. V.—*Section of the Cretaceous at El Paso, Texas*;* by T. W. STANTON and T. WAYLAND VAUGHAN.

THE detailed section of the Cretaceous of the Texas region here described is of interest because it is the most western of the outlying areas of the Texas Cretaceous as yet described, being 600 miles south of west from Denison, and 530 miles north of west from Austin.†

Although the details of the El Paso section have not hitherto been published, many references‡ have been made to it in the literature, and collections of fossils have been made there by Mr. R. T. Hill and Dr. E. A. Mearns, U. S. A. Mr. Hill's collection is at the Johns Hopkins University, and that of Dr. Mearns is deposited in the U. S. National Museum.

The section§ here described was made in Mexico and New Mexico near the Initial Monument of the Mexican Boundary Survey, about three miles west of the city. The lowest part of it is exposed in the cutting of the Southern Pacific railroad on the west bank of the Rio Grande, where it cuts the pass through the mountains. The section extends from here to the top of the hill across the arroyo southeast of the Initial Monument of the Boundary Survey. The rocks are greatly faulted, folded and disturbed by igneous intrusions, so to obtain the sequence and thickness of the beds it was necessary to establish horizons and measure between them where we could find them. Therefore, the highest beds of the section are not at the southeastern end of the exposures that we examined, but just north of a line joining the initial and second monuments of the Boundary Survey, where the rocks abut against a mass of hornblende porphyrite which is intruded through them. The downthrows of the faults are usually to the west.

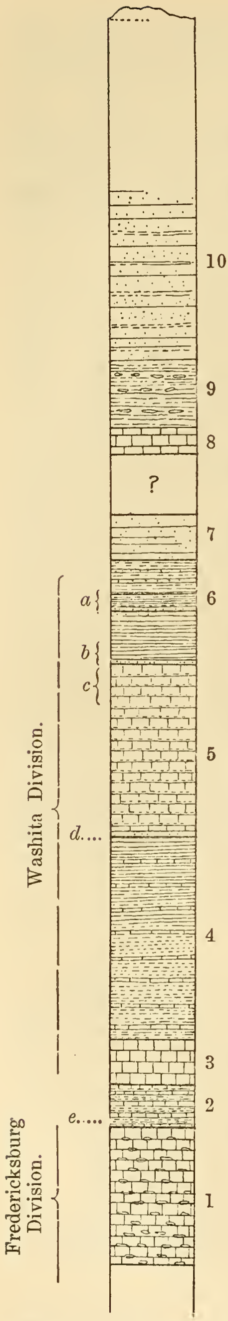
The following is a description of the section beginning with the highest bed:

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

† Gabb in vol. ii of the Paleontology, Geol. Survey of California, pp. 257–276, 1869, describes a collection of fossils made by Rémond from Sierra de las Conchas, near Arevichi, Sonora, Mexico. He recognized their resemblance to the Cretaceous fossils of Texas. Mr. R. T. Hill says concerning these fossils, in this Journal, vol. xlv, p. 313, April, 1893, "The fossils are the characteristic fauna of the latest or Washita division of the Comanche Series, and resemble the variations seen at El Paso and Juarez and throughout the northern littoral of the latest beds of the Comanche Series."

‡ R. T. Hill: Bull. Geol. Soc. of America, vol. ii, pp. 517 and 518, May, 1891; this Journal, vol. xlv, p. 312, April, 1893; Bull. Geol. Soc. America, vol. v, p. 332, March, 1894; this Journal, vol. l, p. 233, September, 1895. T. W. Stanton: In notes on a collection of fossils from near Belvidere, Kansas, published in R. T. Hill's "Outlying Areas of the Comanche Series in Kansas, Oklahoma, and New Mexico," this Journal, vol. l, p 218, Sept., 1895.

§ The description of the Denison Section published by R. T. Hill, Bull. Geol. Soc. of America, vol. v, pp. 303–304, and plate 13. March, 1894, should be consulted, while reading the description here presented.



Columnar Section of Cretaceous near Initial Monument of Mexican Boundary Survey, on west side of the Rio Grande from El Paso, Texas.
Scale $\frac{9}{10}$ in. = 100 ft.

10. Sandstone, white, yellow, or brownish, with shale beds .... 200 ft. ±
9. Clay shales, with bands of limestone nodules, containing great numbers of a large Exogyra .... 40 ft.
8. Hard limestone with the same species of Exogyra in the top .... 15 ft.
7. Sandstone, white or brown, 30 ft. +
6. Upper part of the bed, clay shales alternating with brown sandy flags.

   Brown sandy calcareous layers at base, containing *Gryphæa washitaensis* Hill and *Nodosaria texana* in great abundance.

   The *G. washitaensis* is confined to base. 30 ft. above the base, *Ostrea subovata. Ostrea quadriplicata* Shum. very abundant between 30 and 40 ft. 40 ft. above base zone of *Kingena wacoensis* ..... 60 ft.
5. Flaggy argillaceous limestone, with shale partings. Layer of sandy flags at base. In the sandy flags, *Cyprimeria.* In the limestone bands *Schlœnbachia leonensis*, *Gryphæa washitaensis*, *Protocardia*, *Trigonia emoryi.* The zone of *G. washitaensis* is at the top .... 100 ft.
4. Clay shales, with indurated calcareous bands. No fossils were found .... 125 ft.
3. Ledges of hard limestone. Fossils not numerous; at the base, there is a considerable number of an undetermined species of *Gryphæa*, *Gryphæa tucumcarii*, *Neithea*, and *Schlœnbachia* .... 25 ft.

a. *Kingena wacoensis*, *Ostrea quadriplicata*, *Ostrea subovata.* *b.* *Gryphæa washitaensis* and *Nodosaria texana.* *c.* *Gryphæa washitaensis.* *d.* Sandy layer with *Cyprimeria.* *e.* Sandy layer.

2. Alternations of clay and soft argillaceous limestone ledges. Fossils: *Exogyra texana, Gryphæa tucumcarii, Gryphæa forniculata, Schlœnbachia peruviana,* 2 other species of *Schlœnbachia*, and a large *Neithea*, 24 ft.
1. Argillaceous limestone, in thick ledges, weathering into nodular limestone, the nodules surrounded by clay. Fossils: *Protocardia texana, Tylostoma pedernalis, Trochus, Turritella, Exogyra texana*, an Anchuroid genus, 2 sp. of Echinoids, *Pleuromya knowltoni, Requienia*, etc.......................
11 feet from the top *Ostrea subovata* (?)........... 79 ft.

Total thickness.................... 698 ft.±

The following is a list of species from the various beds:

No. 9 of Section.

Exogyra sp. A large species related to *E. ponderosa* Roemer.

No. 6 of Section.

Nodosaria texana Conrad.
Terebratula (Kingena) wacoensis Roemer.
Ostrea subovata Shumard. Typical examples of the species.
Ostrea quadriplicata Shumard.
Gryphæa washitaensis Hill.
Neithea texana (Roemer).
Gervilliopsis invaginata White ?
Plicatula incongrua Conrad.
Modiola sp.
Trigonia emoryi Conrad.
Cardium (Protocardia) multistriatum Shumard ?
Turritella sp. Related to *T. planilateris* Conrad.

No. 5 of Section.

Pyrina parryi Hall.
Enallaster texanus (Roemer).
Epiaster elegans (Shumard).
Gryphæa washitaensis Hill.
Neithea texana (Roemer).
Lima n. sp.
Lima wacoensis Roemer ?
Modiola sp.
Cardium (Protocardia) texanum Conrad.
Turritella seriatim-granulata Roemer ?
Aporrhais ? —— Distinct from those in No. 1.
Natica ?
Schlœnbachia leonensis (Conrad).

No. 3 of Section.

The fauna of No. 3 is essentially the same as that of No. 2, though the fossils are less numerous and not so well preserved. *Gryphœa forniculata* White, *Neithea texana* Roemer, *Schlœnbachia belknapi* Marcou, and a few other forms were recognized.

No fossils were seen in No. 4.

No. 2 of Section.

Enallaster texanus (Roemer).
Holectypus planatus Roemer.
Gryphæa tucumcarii Marcou.
Gryphæa forniculata White.
Exogyra texana Roemer.—Most of the specimens belong to a rather robust variety described by Conrad under the name *Exogyra fragosa.*
Plicatula incongrua Conrad.
Neithea texana (Roemer).
Pinna comancheana Cragin.
Trigonia emoryi Conrad? Imperfect specimens that seem to be referable to this species.
Cardium (Protocardia) texanum Conrad.
Pholadomya sancti-sabæ (Roemer)?
Pleuromya knowltoni Hill?—Large specimens that probably belong to this species.
Tylostoma? sp.
Turritella seriatim-granulata Roemer?
Schlœnbachia peruviana von Buch.
Schlœnbachia belknapi Marcou.
Schlœnbachia sp.

No. 1 of Section.

Diplopodia texanum (Roemer).
Enallaster texanus (Roemer).
Ostrea subovata Shumard? A single specimen doubtfully referred to this species.
Exogyra texana Roemer.
Lima sp.
Neithea texana (Roemer).
Requienia texana (Roemer)? A large specimen probably of this species.
Cardium (Protocardia) texanum Conrad.
Pleuromya knowltoni Hill.
Neritina n. sp.
Tylostoma pedernalis (Roemer).
Turritella sp.
Aporrhais? Casts of two species.

Notes on the Fauna.

Taking the fauna of the section as a whole, its essential identity with that of the noted Tucumcari region in New Mexico and of other localities on the western and northern borders of the Lower Cretaceous area is at once apparent. The following list of species reported from Tucumcari is compiled by Mr. R. T. Hill in a recent paper:*

Turbinolia texana Conrad.
Ostrea marshi Sowerby (=O. subovata Shumard).
Ostrea quadriplicata Shumard.
Gryphæa dilatata, var. tucumcarii Marcou.
Gryphæa pitcheri Morton.
Exogyra texana Roemer.
Plicatula sp.
Neithea occidentalis Conrad.
Trigonia emoryi Conrad.
Protocardia multistriata (Shumard).
Protocardia texana Conrad.
Cytherea leonensis Conrad.
Pinna comancheana Cragin.
Cardita belviderensis Cragin.
Tapes belviderensis Cragin.
Roudairia (?) quadrans Cragin.
Cyprimeria sp.
Turritella seriatim-granulata Roemer.
Turritella marnochi White?
Ammonites leonensis Conrad.

These species, according to Mr. Hill, come from sandy and shaly beds below the supposed Dakota sandstone with a total thickness of 115 feet.

In the El Paso section, although there are one or two species that range from Nos. 1 to 6 inclusive, there are at least three well marked paleontological zones, each characterized by peculiar species that have been found useful as guide fossils in other parts of the Texan Lower Cretaceous area. Thus the fossils from No. 6 indicate a horizon in the upper part of the Washita corresponding to the Denison beds, that portion of the Washita in the Denison section that overlies the restricted Fort Worth limestone.

No. 5 contains *Schlœnbachia leonensis* and *Epiaster elegans*, which are regarded as the most characteristic species of the Fort Worth limestone.

* Outlying Areas of the Comanche Series in Kansas, Oklahoma and New Mexico, this Journal, III, vol. 1, p. 230, Sept., 1895.

Nos. 1, 2 and 3 may be grouped together as the lowest of the three zones, which shows a commingling of fossils that elsewhere occur in the lowest Washita and in the Fredericksburg, with a few that range down into the Trinity division.

In north Texas the same species of Ammonites occur in the Kiamitia and Duck Creek (the Preston beds) at the base of the Washita and in the Goodland limestone, which belongs in the Fredericksburg. *Gryphæa forniculata* is a Kiamitia species. *Exogyra texana* is most abundant in the lower part of the Fredericksburg, though it ranges beyond both the lower and the upper limits of that division. The Echinoids also occur in both the Fredericksburg and the Washita. *Requienia texana*, *Pleuromya knowltoni* and *Tylostoma pedernalis* are other forms that suggest a lower horizon than the Washita.

The evidence of the fossils taken altogether is in favor of the view that a part of the Fredericksburg is represented here and that it grades into the basal Washita so imperceptibly that no palæontologic line can here be drawn between them. The Caprina limestone and its characteristic fauna, which in Central Texas, south of the Brazos river, usually affords such a distinct plane of separation, is absent here, as it is in north Texas and in all the outlying Lower Cretaceous areas of Kansas, Oklahoma and New Mexico.*

ART. VI.—*On the Epidote from Huntington, Mass., and the Optical Properties of Epidote;* by E. H. FORBES.

IN the fall of 1892, Mr. W. L. Angell of Huntington, Mass., brought several crystals to the Mineralogical Laboratory of the Sheffield Scientific School for determination. They resembled zoisite in color and general appearance, but upon examination proved to be epidote. Their light color and the absence of the usual green of epidote indicated a low iron percentage and suggested a chemical and optical investigation.

Abundant material was furnished by Mr. Angell, upon whose farm the mineral occurs, and some was also collected by Profs. S. L. Penfield and L. V. Pirsson, who visited the locality and found the epidote occurring in a seam in gneiss associated with quartz, biotite, albite and calcite. When the crystals project into cavities, they have a dark gray color and are clear and transparent, but when imbedded in the matrix they are much lighter in tone and less transparent, due undoubtedly to crushing, as the crystals are permeated by cracks and some are bent.

* See this Journal, September, 1895, p. 234.

Carefully selected crystals were taken for the analysis, which was made in duplicate according to the usual methods. The ferrous iron was determined as described by Pratt.* The results are given below, together with the specific gravity determinations, which were made upon a chemical balance:

Specific gravity.. 3·341 3·379 3·389 Average..3·367

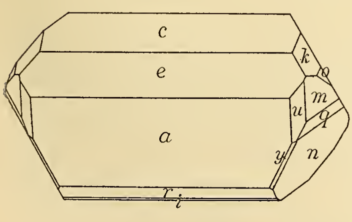
			Average.		Ratio.	
SiO_2	38·20	37·78	37·99		·633	6·00
Al_2O_3	29·00	30·06	29·53	·286 }	·321	3·04
Fe_2O_3	5·63	5·71	5·67	·035 }		
FeO	0·54	0·52	0·53	·007 }		
MnO	0·21	0·21	0·21	·003 }	·436	4·13
CaO	23·82	23·87	23·85	·426 }		
H_2O	2·05	2·03	2·04		·113	1·07
Total	99·45	100·18	99·82			

The above ratios approximate closely to 6, 3, 4, 1, which, regarding the water as coming from hydroxyl, gives the usually accepted formula $H_2Ca_4Al_6Si_6O_{26}$ or $Ca_2(AlOH)Al_2Si_3O_{12}$, in which the calcium has been partly replaced by ferrous, and aluminium by ferric, iron. The analysis is interesting as showing a remarkably low iron percentage for epidote.

The crystals, as is common with epidotes, show a prismatic development parallel to the *b* axis and some of the largest ones measured over 30mm in length and 15mm in diameter. They are usually simple, but some are twinned parallel to 100.

Although the faces of the crystals were brilliant, yet the reflections of the signal on the goniometer were usually poor as the planes were commonly vicinal, which rendered the measurements somewhat uncertain. Some of the faces in the ortho-diagonal zone were deeply striated, so that there was a continuous series of reflections of the signal. Upon a suite of crystals which was measured, the following forms were identified:

a, 100	*u*, 210	*r*, $\bar{1}01$	*n*, $\bar{1}11$
c, 001	*e*, 101	*k*, 012	*q*, $\bar{2}21$
m, 110	*i*, $\bar{1}02$	*o*, 011	*y*, $\bar{2}11$



All of these were found upon a single crystal, as shown in the figure.

On the simpler crystals the forms *a*, *c*, *e*, *r* and *n* were prominent and developed about like fig. 5, page 517, 6th edition of Dana's Mineralogy.

* This Journal, xlviii, p. 149, 1894.

The following is a list of some of the measured angles compared with the calculated ones derived from the axes of N. von Kokscharow Jr.*

$$a : b : c = 1{\cdot}57874 : 1 : 1{\cdot}80362\ ;\ \beta = 64°\ 36'\ 50''$$

	Measured.	Calculated.		Measured.	Calculated.
$c \wedge a$, $001 \wedge 100$	$= 64°\ 31'$	$64°\ 36'\ 50''$	$c \wedge r$, $001 \wedge \bar{1}01$	$= 63°\ 31'$	$62°\ 42'$
$a \wedge m$, $100 \wedge 110$	$= 54\ 34$	$54\ 59\ 54$	$c \wedge k$, $001 \wedge 012$	$= 38\ 29$	$39\ 10$
$c \wedge e$, $001 \wedge 101$	$= 34\ 43$	$34\ 42\ 52$	$c \wedge m$, $001 \wedge 110$	$= 75\ \ 4$	$75\ 45$
$c \wedge o$, $001 \wedge 011$	$= 58\ 32$	$58\ 27\ 45$	$c \wedge n$, $001 \wedge \bar{1}11$	$= 75\ 11$	$75\ 11$
$a \wedge e$, $100 \wedge 101$	$= 29\ 48$	$29\ 54$	$c \wedge q$, $001 \wedge \bar{2}21$	$= 89\ 32$	$89\ 42$
$c \wedge i$, $001 \wedge \bar{1}02$	$= 34\ 00$	$34\ 21$			

Each of the above is the mean of at least three separate measurements, and their agreement is very satisfactory.

The optical investigations were made upon a single large crystal twinned about 100 and measured to make sure of the orientation. A section parallel to the clinopinacoid showed a slight zonal structure, and the central, or clearest portion, gave the following extinction: $\mathfrak{a} \wedge c$ red, Li $= 1°\ 51'$; yellow, Na, $2°\ 9'$; green, Tl, $2°\ 12'$, and for white light with the Bertrand ocular $2°\ 47'$, all inclined to the c axis in the *obtuse* angle β. The extinctions were measured on either side of the twinning plane and the above are half of the recorded angles. The value with the Bertrand ocular is considerably higher than the others, due undoubtedly to the influence of the blue and violet of white light. The Untersulzbach epidote with about 14 per cent of Fe_2O_3, gives, according to Klein,† $\mathfrak{a} \wedge c$ for red $2°\ 56'$ and for green, $2°\ 26'$, but on the opposite side of the c axis, that is, in the *acute* angle β.

For the indices of refraction one prism was cut with a face parallel to 010 and its edge, as near as possible, parallel to the $\mathfrak{a}$ axis, from which, by placing 010 perpendicular to the rays coming from the collimator, α for yellow, Na $= 1{\cdot}714$ and $\gamma = 1{\cdot}724$ were determined. By minimum deviation α was also found to be $1{\cdot}714$. By means of a second prism parallel to the b axis, β was found to be $1{\cdot}716$. As the crystal under examination had a zonal structure, the results have only a relative value, as they would be slightly different in another part of the crystal.

The low double refraction $\gamma - \alpha = 0{\cdot}010$ is below that of any recorded epidote.

From plates cut at right angles to $\mathfrak{a}$ and $\mathfrak{c}$ the axial angles were determined by measuring in α-mono-bromnaphthalene (n, Na, $= 1{\cdot}6577$) on a large Fuess axial-angle apparatus. From the plate at right angles to $\mathfrak{a}$, $2H_o = 94°\ 33'$ for yellow Na, and from the second plate $2H_a = 93°\ 25'$ were measured. From these values $2V_o = 90°\ 32'$, $2V_a = 89°\ 28'$ and $\beta = 1{\cdot}7144$ were

* Materialen zur Mineralogie Russlands, viii, p. 44. † Jahrb. f. Min., 1874, p. 1.

obtained. In this crystal, $\mathfrak{a}$ instead of being, as is usual, the acute becomes the *obtuse* bisectrix and the optical character is therefore positive.

The dispersion was distinctly inclined. In the section at right angles to $\mathfrak{c}$, the color to the right of each hyperbola was violet and to the left red, but they were more diffused in one than in the other. The dispersion $\rho < \upsilon$ was shown by the following measurements: $2H_a$ red, Li = 93° 10′, $2H_a$ yellow, Na = 93° 25′, $2H_a$ green, Tl = 93° 51′, but over the axis $\mathfrak{a}$ the dispersion was $\rho > \upsilon$, as in other epidotes.

The pleochroism was quite striking, being in sections about 0·5mm thick for rays vibrating parallel to $\mathfrak{b}$ a lavender or pale plum-color, but parallel to $\mathfrak{a}$ and $\mathfrak{c}$ almost colorless, the former showing a slight tinge of lavender and the latter of green.

By a comparison of the analysis of the Huntington with those of other epidotes, it was found that the light-colored one from Zillerthal in Tyrol, analyzed by Laspeyres,* was almost identical in chemical composition, as shown by the following:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	H_2O	Insol.	Total
Huntington,	37·99	29·53	5·67	0·53	0·21	23·85	2·04	---	99·82
Zillerthal,	38·46	28·59	5·76	0·53	---	24·60	1·92	0·42	100·28

These analyses are, moreover, the lowest in iron percentages of any recorded epidotes. As no optical investigation of the crystals from Zillerthal has been published, one was made, for sake of comparison, upon a specimen in the Brush collection. The material used was a fragmentary crystal about 10mm in diameter, decidedly zonal and of a pale red color on the exterior, but pale green in the interior. The crystallographic orientation was determined by measurement of the angle 100 ∧ 001 and the cleavage parallel to 001. On a clinopinacoid section the extinction, measured with the Bertrand ocular, was found to be $\mathfrak{a} \wedge c$ = 0° 30′ in the acute angle β for the interior green portion of the crystal, but for the exterior, or reddish part, it was about 0° 30′ in the obtuse angle β.

Prisms were cut, as in the Huntington mineral, with their edges in the inner green portion and the following indices of refraction determined: For yellow, Na, $\alpha = 1·720$, $\beta = 1·7245$, $\gamma = 1·7344$, $\gamma - \alpha = 0·0144$. From a plate parallel to 100 the value of $2H_o$, yellow Na, was found to be 96° 40′. (n, Na. for α-mono-bromnaphthalene being 1·6572) and from which 2Va, Na was found to be 87° 46′.

The pleochroism was very similar to that of the Huntington epidote. For sections about 0·5mm thick $\mathfrak{b}$ plum color, $\mathfrak{a}$ and $\mathfrak{c}$ alike and nearly colorless in the interior greenish part, while in the exterior reddish envelope $\mathfrak{a}$ was pale green and $\mathfrak{c}$ pale rose.

*Zeitschrift für Krystallographie und Mineralogie, iii, p. 562, 1879.

For further comparison an iron determination was made, with the following results: Fe_2O_3 = 6·97, FeO = ·89 per cent, using as far as possible the green interior portion of the crystal, but owing to the scarcity of the material, some of the red part was also included. If only the green interior part had been used, these results would probably have been a trifle higher, but they are higher than those given by Laspeyres, whose analysis was made on carefully selected pale yellow crystals.

The following table, containing the results already given, together with the optical determinations on epidote from Untersulzbach in Tyrol by Klein,* will show the changes in the optical properties resulting from variations in the percentages of ferric iron:

Locality.	Fe_2O_3	Indices of refraction for yellow. α	β	γ	$\gamma-\alpha$	2Va, Na measured over a.
Untersulzbach,	14·0	1·7305	1·7540	1·7677r	0·0372	73° 39′
Zillerthal,	6·97	1·720	1·7245	1·7344y	0·0144	87 46
Huntington,	5·67	1·714	1·716	1·724y	0·010	90 32

With a decrease in the percentage of iron, the indices of refraction and the strength of the double refraction decrease, while the axial angle measured over a increases, so that in the Huntington epidote c becomes the acute bisectrix and the crystal is positive with $\rho<\upsilon$ while most epidotes are negative with $\rho>\upsilon$.

In this connection the results of Ramsay† are of interest, who studied the zonal character of epidotes and determined the strength of the double refraction, $\gamma-\alpha$, in light and dark portions of crystals from different localities. He found that the light portions, containing presumably less iron than the dark, had the lowest double refraction, but gave no determinations as low as the ones given in this article for Zillerthal and Huntington. Some of his determinations are as follows:

Locality.	Dark. $\gamma-\alpha$.	Light. $\gamma-\alpha$.
Sulzbach	0·050	0·049
Zöptau	0·046	0·038
Arendal	0·054	0·050
Haddam	0·037	0·034
Brosso	0·023	0·017

In conclusion I wish to express my indebtedness to Prof. S. L. Penfield for valuable advice and assistance during the progress of this investigation.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, June, 1895.

* Zeitschrift für Krystallographie und Mineralogie, iii, p. 562, 1879.
† Jahrb. f. Min., 1893, i, p. 111.

ART. VII.—*The Iodometric Determination of Selenious and Selenic Acids;* by F. A. GOOCH and A. W. PEIRCE.

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

IT has been shown in a recent paper from this laboratory* that the simple contact of solutions of selenious acid, potassium iodide, and hydrochloric acid according to the recommendation of Muthman and Schaefer† is not enough to effect the liberation of the theoretical amount of iodine when the assumption is made that the selenium of the selenious acid is all reduced to the elementary condition. On the other hand, it was found that the yield of iodine is complete when such mixtures are submitted to distillation under well-defined conditions. It is necessary, however, to estimate not only the iodine which passes to the distillate, but that which is retained in small proportion in the residue, and, though this method of proceeding yields closely accurate analytical results and is by no means difficult, it is obvious that a process so contrived that the reduction of the selenious acid should be registered entirely in the residue would possess the advantage in point of convenience. We have made the attempt, therefore, to apply in this case a principle of action laid down in a method elaborated in this laboratory for the estimation of chlorates.‡ When a solution of arsenic acid containing potassium iodide and sulphuric acid is boiled under defined conditions§ the arsenic acid is reduced to arsenious acid with liberation of iodine. When the arsenic acid is in excess the whole of the iodine is evolved and the arsenious acid produced is its exact measure. Upon making the solution alkaline with acid potassium carbonate, the arsenious acid may be re-oxidized by standard iodine, and the amount of iodine thus used will be the exact equivalent of that set free in the reduction-process. If, however, any other substance more easily reducible than arsenic acid is present, such substance should, naturally, take its part in liberating iodine from the iodide and the reduction of the arsenic acid should be correspondingly less. This was found to be the case when a mixture containing a chlorate, arsenic acid, potassium iodide, and sulphuric acid was boiled under regulated conditions, so that, with a knowledge of the amount of iodide employed and the determination of the quantity of

* Gooch and Reynolds, this Journal, l, 254.
† Ber. d. Chem. Gesell., xxvi, 1008.
‡ Gooch and Smith, this Journal, xlii, 220.
§ Gooch and Browning, this Journal, xxxix, 188.

iodine necessary to reoxidize the arsenious acid produced, the data were at hand for calculating the amount of chlorate present in the mixture. It was our hope (which proved to be well-founded, as the sequel shows) that selenious acid would behave like a chlorate under similar conditions.

Pure selenium dioxide was prepared by oxidizing presumably pure selenium in strong nitric acid, evaporating the solution to dryness, dissolving the residue in water, treating the solution with barium hydroxide until precipitation ceased, filtering, evaporating the filtrate to dryness, subliming the selenium dioxide from the residue, and resubliming that product in a current of dry oxygen (which we found to be vastly more convenient and effective than dry air) until it was perfectly white and crystalline. From the oxide thus made a standard aqueous solution was prepared, from which portions were measured and (for the sake of greater accuracy) weighed for use in the experiments to be detailed. To each weighed portion of the selenious acid, contained in an Erlenmeyer flask of 300 cm^3 capacity, was added a weighed amount of potassium iodide (somewhat in excess of that theoretically required) prepared in solution of convenient strength and tested as to its reducing power upon arsenic acid under the conditions of the experiments; a solution containing about 2 grm. of pure di-hydrogen potassium arseniate was introduced; and, finally, 20 cm^3 of sulphuric acid of half-strength. Protected from ordinary mechanical loss by a trap (consisting of a two-bulbed drying tube cut short and hung loosely with the wide end downward in the mouth of the flask) and from violent ebullition by the introduction of a few bits of porcelain, the liquid was boiled until the volume decreased according to indicating marks on the flask from 100 cm^3 or more to 35 cm^3—concentration to about this lower limit having been found to be necessary to the completion of the reaction. The residue was cooled, the acid was nearly neutralized with potassium hydroxide, acid potassium carbonate was added until it was present to the amount of 20 cm^3 of its saturated solution in excess of the quantity needed to complete neutralization, and, after the addition of starch, standard iodine was introduced until the starch-blue appeared. The iodine introduced measured the arsenious acid (and so the quantity of iodine set free by the arsenic acid), and the difference between it and the iodine originally present in the form of the iodide represents the amount set free by the selenious acid.

The following table comprises the details and results of a series of determinations made in the manner outlined :

Se = 79·1, O = 16

Initial volume. cm^3.	Final volume. cm^3.	H_2SO_4 half-strength. cm^3.	Di-hydrogen-potassium arseniate. grm.	KI taken. grm.	SeO_2 taken. grm.	SeO_2 found. grm	Error. grm.
100	35	20	2	1·3277	0·1280	0·1275	0·0005 –
"	"	"	"	1·0429	0·0998	0 0994	0·0004 –
"	"	"	"	1·0887	0·1024	0·1028	0·0004 +
"	"	"	"	1·0405	0·1036	0·1028	0·0008 –
"	"	"	"	1·0721	0·1030	0·1029	0·0001 –
"	"	"	"	0·9958	0·1273	0·1272	0 0001 –
125	"	"	"	2·0828	0·1997	0·2000	0·0003 +
"	"	"	"	2·2272	0·2110	0·2113	0·0003 +
"	"	"	"	2·1535	0·2067	0·2069	0·0002 +
150	40	"	"	2·6554	0·2560	0·2549	0·0011 –
175	35	"	"	3·2428	0·3110	0·3118	0·0008 +
"	35	"	"	3·2428	0·3085	0·3083	0·0002 –

Obviously the reduction of selenious acid by this method is regular and accurate.

When similar treatment was applied to selenic acid it became apparent that the arsenic acid attacked and destroyed the iodide before the selenic acid had been completely reduced. It is plain, therefore, that the selenic acid must be reduced to the condition of selenious acid before its estimation by the iodide method can be attempted. Ordinarily the simplest mode of reducing selenic acid is by boiling it in solution with hydrochloric acid of definite strength,* but in this case the presence of hydrochloric acid is precluded on account of the consequent volatilization of arsenious chloride during the process of concentration in the subsequent treatment with the iodide. It has been shown, however, in a recent paper from this laboratory† that selenic acid is easily and completely reduced to selenious acid by potassium bromide and sulphuric acid under defined conditions. Moreover, arsenious bromide is not volatilized appreciably under the conditions. We made the attempt, therefore, to effect the iodometric determination of selenic acid by first reducing it to selenious acid by the bromide process and then treating the residue with arsenic acid and potassium iodide in the manner described.

Selenic acid was prepared in standard solution by treating a known weight of pure resublimed selenium dioxide by a strong solution of potassium permanganate, in presence of a moderate amount of sulphuric acid, until the purple color was distinctly visible, dissolving the precipitated oxide of manganese by oxalic acid, again adding permanganate until the final color of faintly visible pink was permanent for a half-hour or more, and diluting to a fixed volume. Portions of the solution of selenic acid were measured into counterpoised Erlenmeyer flasks of 300 cm^3

* Gooch and Evans, this Journal, l. 400.
† Gooch and Scoville, this Journal, l. 402.

capacity and weighed, 1 grm. of potassium bromide was added, and sulphuric acid in such quantity that the total amount of the free acid should correspond to 20 cm³ of the acid of half-strength. The solution possessing a volume of 60 cm³ to 100 cm³ was boiled until the clear, colorless solution left when the bromine vanished began to color again. Experience showed that the reappearance of the brownish color is very easily seen and that it is not safe to conclude that all free bromine has been eliminated, under the conditions of dilution and proportion, until this stage of concentration—which corresponds to a volume of about 35 cm³—has been reached; but the distillation should not be pushed beyond the point at which the returning color is noted. When this condition was reached the solution was cooled, and treated exactly in the manner described for the reduction of selenious acid. The neutralization by acid potassium carbonate, after the final boiling, generally occasioned the precipitation of manganous carbonate, but the precipitate did not interfere in the slightest with the titration which followed.

The following table comprises the determinations which were made to test the accuracy of the iodometric determination of selenic acid by the combined processes of reduction.

SeO_2 taken as H_2SeO_4. grm.	KI used in second reduction. grm.	SeO_2 found. grm.	Error grm.
0·0378	0·6306	0·0380	0·0002 +
0·0378	0·5643	0·0374	0·0004 —
0·0516	0·7136	0·0517	0·0001 +
0·0503	0·7302	0·0508	0·0005 +
0·0541	0·6671	0·0544	0·0003 +
0·1007	1·3277	0·1011	0·0004 +
0·1008	1·3277	0·1011	0·0003 +
0·1007	1·2082	0·1005	0·0002 —
0·1007	1·1684	0·1016	0·0009 +
0·1007	1·0522	0·0999	0·0008 —
0·1009	1·2679	0·1005	0·0004 —
0·1031	1·1119	0·1032	0·0001 +
0·1870	1·8720	0·1879	0·0009 +
0·2014	1·9915	0·2020	0·0006 +
0·2016	2·0745	0·2025	0·0009 +
0·2059	1·8687	0·2064	0·0005 +

It is plain, therefore, that selenic acid may be determined iodometrically with accuracy by first reducing it to the condition of selenious acid by treatment with potassium bromide in presence of sulphuric acid, in the manner described, and then completing the reduction to the elementary condition by the treatment with potassium iodide and potassium arseniate.

Art. VIII.—*On the Interaction of Chromic and Arsenious Acids;* by Philip E. Browning.

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

Kessler* has shown that arsenious acid may be determined by treating it, in the presence of hydrochloric acid, with an excess of a chromate solution of known strength, by which treatment the arsenious acid is oxidized and the chromic acid reduced. The excess of the chromic acid is then determined by the addition of a ferrous salt of known strength until a drop taken from the solution gives a blue color with a ferricyanide. Chromic acid is then added again until the blue color disappears. The amount of the chromate originally used less the excess determined by the ferrous salt gives the amount of the chromate used for the oxidation, from which may be calculated the amount of arsenious acid originally present. Despite the use of a ferrous salt and the numerous steps involved in the manipulation, Kessler claims very satisfactory results for his method. The object of this paper is to give the results of some experiments in which Kessler's reaction was used for the reverse process, the arsenious acid being used in excess, according to the reaction:

$$4CrO_3 + 3As_2O_3 + (X)As_2O_3 = 2Cr_2O_3 + 3As_2O_5 + (X)As_2O_3$$

For the work, a solution of potassium dichromate was made, the standard of which was determined by evaporating definite portions measured from a burette into previously weighed and counterpoised crucibles, heating just to the melting point, and weighing after cooling. A decinormal solution of arsenious acid was made in the usual manner, as was also a decinormal iodine solution which was standardized frequently in course of the work against the arsenious acid. The method of manipulation was as follows: Definite portions of the chromate solution were measured from a burette into counterpoised flasks and weighed, as a check on the burette reading, about 10 cm^3 of dilute hydrochloric or sulphuric acid (1–4) added, and a carefully measured amount of the arsenious acid solution—care being taken to have an excess of the amount necessary for the reaction. After a few moments the reduction seemed complete, the solution having taken on the bluish green color characteristic of the chromium salts. The application of heat was found to be unnecessary, the reaction going on quickly

* Pogg. Anal., xcv, 204, 1855.

and completely, as it seemed, in the cold. The solution was then treated with acid potassium or sodium carbonate (about 5 grm.) in excess. At this point a precipitate formed unless Rochelle salts had been added, as was sometimes the case, to prevent it. To the alkaline solution iodine was added until a yellow tinge showed it to be in excess, and the solution was allowed to stand, with frequent shaking, about one-half hour, at the end of which time the excess of the arsenious acid was thoroughly acted upon. In order to test the permanency of the iodine color in alkaline solution, two experiments were made, in the first of which 5 grm. of acid sodium carbonate were dissolved in about 100 cm^3 of water, and in the second the amount of acid generally used (10 cm^3) was neutralized with the acid carbonate and an excess added, the amount of water present being about the same as in the first experiment. Starch and a drop of iodine solution were then added. No bleaching effect was apparent during two hours. Several experiments, made without allowing the solution to stand, with the excess of iodine seemed to show that the excess of the arsenious acid had not been completely oxidized by the iodine. As this took place mainly in those experiments in which the precipitate had not been held up by Rochelle salts, I am inclined to attribute it to the holding of the arsenious acid by the precipitate. After this point in the process had been reached, the excess of iodine was destroyed by the addition of arsenious acid, starch was added and the blue color obtained with iodine. Knowing the amount of arsenious acid originally added together with the second amount, used to bleach the excess of iodine, also the total amount of iodine employed and its value in terms of arsenious acid, we are in position to determine the amount of arsenious acid used for the reduction ; and, by referring to the reaction given above we can calculate the amount of chromic acid originally present. The use of Rochelle salts had a disadvantage, however, which should be mentioned. If the precipitate is held up, the solution takes on a dark green color which makes the starch iodide reaction difficult to detect. The presence of the precipitate, except for the apparent holding of some arsenious acid—a source of error which seems to be largely obviated by the standing with the excess of iodine—causes no inconvenience, being itself of a very light green color and leaving the solution almost colorless. I have tried filtering with no gain in convenience, since the precipitate is of a gelatinous character and filters very slowly, so that the filtration and thorough washing lengthen the process very materially.

The results follow in the table :

	CrO_3 taken. grm.	CrO_3 found. grm.	Error. grm.	Remarks.
1	0·1001	0·1004	0·0003 +	
2	0·1005	0·1004	0·0001 —	The iodine acted 20 minutes
3	0·1006	0·1007	0·0001 +	" " "
4	0·1004	0·1011	0·0007 +	" " "
5	0·1009	0·1009	0·0000	" " 2 hours
6	0·1002	0·1003	0·0001 +	" " "
7	0·1011	0·1004	0·0007	Rochelle salts used
8	0·1007	0·1007	0·0000	" "
9	0·0401	0·0395	0·0006 —	
10	0·0402	0·0388	0·0014 —	0·5 grm. ferric alum present
11	0·1001	0·1018	0·1017 +	
12	0·1009	0·1007	0·0002 —	
13	0·1007	0·1011	0·0004 +	1 grm. ferric alum present
14	0·1005	0·1017	0·0012 +	
15	0·1004	0·1010	0·0006 +	
16	0·1000	0·1032	0·0032 +	Rochelle salts used
17	0·1005	0·1006	0·0001 +	1 grm. ferric alum present.

In three of the above experiments the process was carried through in the presence of a ferric salt with fairly successful results. The presence of the brown precipitate, however, makes the end reaction rather difficult to determine. If, however, the precipitate be allowed to settle after each addition of iodine, the color can be detected very readily in the supernatant liquid.

Among volumetric processes of great delicacy this process naturally does not find its place. It is, however, interesting to know to what degree the reaction may be depended upon for analytical purposes.

ART. IX. — *Note on the Analysis of Contrast-Colors by viewing, through a reflecting tube, a graded series of gray discs, or rings, on colored surfaces ;* by ALFRED M. MAYER.

PROFESSOR ROOD in his "Modern Chromatics" (N. Y., 1879), p. 185, *et seq.*, describes a series of experiments he made on the change which a color undergoes when darkened. He gives a table of results on seventeen colors. These colors were obtained as intense, saturated and brilliant as possible and were painted on discs of card-board. Each of these discs was placed on the rotator in combination with a disc of black, so that the color could be gradually darkened by exposing more and more of the black disc on the surface of the colored one. He found that the effect of mixing black with some of these colors was merely to darken them. The effect of mixing black with others of the colors was not merely to darken these colors but also to change their hues.

On page 261 of "Modern Chromatics," Rood writes: "By preparing with Indian ink a series of slips of gray paper, ranging from pure white to black, an interesting series of observations can be made on the conditions most favorable for the production of strong contrast-colors. The strongest contrast will be produced in the case of red, orange and yellow, when the gray slip is a little darker than the color on which it is placed, the reverse being true of green, blue, violet and purple; in every case the contrast is weaker if the gray slip is much lighter or much darker than the ground."

The particular gray which gives the strongest contrast-color effect on a given colored ground can only be determined experimentally by observing a graded series of gray surfaces placed on the colored ground. In this manner I obtained the grays used in "Studies of the Phenomena of Simultaneous Contrast-color," etc., this Journal, July, 1893. These grays, however, were not selected by the unaided eye but by viewing the gray surfaces through my reflecting tube, which doubles the saturation and brilliancy of the contrast-color.* This increase in the saturation and brilliancy of the contrast-color renders the selection of the proper gray easy and definite.

The fact that the mixing of black optically with a color either merely darkens it, or changes its hue at the same time it darkens it, taken in connection with the fact that different depths of gray are required to give the maximum contrast-color effect on different colored surfaces, seems to me to offer,

* This Journal, July, 1893, p. 7 et seq.

in certain cases, a means of analyzing a composite contrast-color. Suppose that a small gray disc, or ring, when placed on a colored ground gives a contrast-color which is composite, like purple, and that the same depth of gray gives the maximum contrast-color effect for each component color of the purple; then, as we view in succession the gray discs of a graded series, the contrast-color of these discs should merely become darker and darker, as each component of the contrast-color is similarly affected as we view darker and darker grays. This, to my vision, is the case when the graded gray discs are viewed on a pure green ground. But if the maximum contrast-color effect for one of the component colors is given by a gray differing much in depth from the gray giving the maximum contrast-color effect for the other component, then the contrast-color should change both in its darkness and in its hue as we view in succession the darker and darker grays on the colored ground. This is what takes place in the case of viewing the graded series of gray discs on a violet ground; where the greenish-yellow given by the lighter shades of gray, become yellowish-green on viewing discs of deeper gray; the yellow component diminishing and the green component increasing till we reach a gray containing 80 per cent of black.

The experiments on which the foregoing statements are founded were made as follows: A series of grays were selected varying in depth from No. 1, containing 25 per cent of black to No. 15, containing 95 per cent of black. From these gray papers were cut discs of 1^{cm} in diameter which were pasted in order, from 1 to 15, on seven different colored surfaces. These discs were viewed, in succession, through a reflecting glass tube, having an interior diameter of $1{\cdot}9^{cm}$ and a length of $15{\cdot}5^{cm}$. This tube is coated on its outside surface with black Japan-varnish, which coating does away with the reflection from the outside surface of the tube and leaves alone the brilliant reflection from the interior surface. If a gray disc is placed on a colored ground and viewed through this tube it appears surrounded by two contrast-color rings produced by the reflection of the gray disc from the interior surface of the tube. These rings appear to have about double the saturation and brilliancy of color of the gray disc as seen without the aid of the reflecting tube.

Viewing the fifteen gray discs on a green ground* the contrast color given to the discs is purple, or a mixture of red and violet-blue. As you view, in order of their number, the

*The colored grounds used in these experiments were the colored papers of Milton Bradley Co., Springfield, Mass.

gray discs, there is, to my vision, no decided change in hue, but only a deeper shading of the purple as you view deeper and deeper grays. Now the maximum red of the purple contrast-color is given by gray No. 8 on a cyan-blue ground, while the maximum violet-blue of the purple is given by disc No. 8 on a yellow ground, therefore the hue of each component is equally affected, as the purple is mixed with more and more black. To test further whether the darkening of the purple causes a change in its hue, I obtained on the rotator a purple similar to that seen by viewing disc No. 5 on the green ground, and changed its illumination by rotating the plane of the discs, on the rotator, away from the incident light. I also darkened the purple by adding black on the rotator. In neither experiment, to my vision, did the purple change its hue; it was only darkened.

Viewing in succession the gray discs on a violet surface, numbers 1, 2, 3 and 4 appear greenish-yellow. No. 5 appears as much green as yellow; No. 6 appears yellowish-green. The following discs in order of their number appear greener and greener till No. 13 appears of a dark green almost devoid of yellow. Here you have an analysis of the contrast-color by viewing through the reflecting tube the gray discs on a violet ground, for the maximum contrast-color of the yellow component of the greenish-yellow is given by disc No. 4 on a blue ground, while the maximum contrast-color of the green component is given by disc No. 11 on a purple ground.

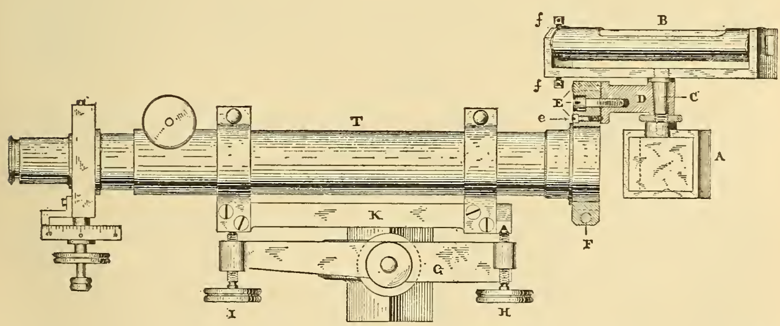
In this matter of color perception the personality of the observer enters as a very important factor; especially when the observer has reached an age when he knows that his color sense must be somewhat deadened and he does not know how much remains of the good perception of color which he once possessed. I therefore do not hesitate to say that I may be somewhat in error in my observations and in the deductions made from them. It may be that the whole matter of this note will turn out to be nothing more than the effect of mixing a color with black, as in Rood's experiments; though to my vision this is not so.

ART. X.—*A Very Simple and Accurate Cathetometer*; by F. L. O. WADSWORTH. (With Plate I.)

OF the various standard physical instruments which are usually found in a student's laboratory, the cathetometer may justly be considered as one of the most instructive and valuable, both because of the many principles involved in its adjustment, and because of the number of measurements which may be made with it. Unfortunately good cathetometers (and it is never good policy to use poor instruments for the purposes of instruction), are so expensive, as made at present, that one or at most two are all that one laboratory can afford. For this reason it may perhaps be of interest to briefly describe a form of cathetometer recently designed by the writer which costs less than one-tenth as much as the best German or English instruments, but which has shown itself in use to be quite as accurate and in some respects even more convenient of manipulation than the latter.

In the new arrangement, the general method of comparison, now employed in nearly all of the most accurate linear measurements, is followed: i. e., the images of the observed points and of the lines on a standard bar, placed parallel with the length to be measured, are brought in succession into the field of an observing telescope or microscope, and their relative position determined by means of a micrometer or some equivalent arrangement. In previous forms of cathetometer this has been

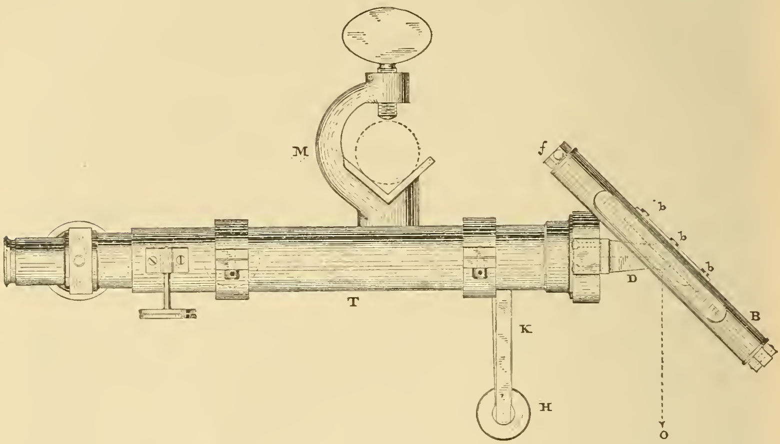
1.



done by rotating the observing telescope itself on a long heavy-vertical axis; in the new form, all of these heavy rotating parts are dispensed with, the observing telescope is fixed in position and the images of the object and scale brought successively into the field by means of a light silvered mirror mounted on a vertical axis just in front of the objective. A sensitive level attached to the upper end of this axis enables the latter to be set accurately vertical, this adjustment being made as in an ordinary cathetometer.

The complete arrangement is shown in elevation in fig. 1 and in plan in fig. 2. **A**, fig. 1, is the mirror frame and **B** is the level, mounted at the lower and upper end respectively of the short conical axis **C**. The boss **D** in which this axis turns

2.



is attached by means of a geometrical clamp at **E** to a split cap which slips over the end of the observing telescope **T** and is clamped thereon by means of the screw **F**. This much really constitutes all of the essential parts of the new cathetometer, the telescope mounting itself, consisting of the two **L**-shaped bars **K**, **G** and the adjusting screws **H**, **I**, being merely accessory to the convenient adjustment of the axis **C** to verticality. An ordinary open **V**-clamp **M** attached to the lower bar **G** enables the whole arrangement to be clamped to any convenient support; such, for example, as the upright of a heavy retort stand, or an iron wall bracket or even a stiff well-secured water or gas pipe on the wall of the laboratory. If a retort stand or other support with adjusting screws in its base is used, the adjustable support **G**, **K**, etc., on the telescope itself may be dispensed with and the clamp **M** attached directly to the telescope tube as in Plate I, which shows the cathetometer in use.

In the use of the instrument the mirror is first adjusted until it is parallel to the axis of rotation **C** and perpendicular to the optical axis of the telescope **T**. These two adjustments are made simultaneously in the same manner as described in a previous article in this Journal,* i. e. by bringing the reflected image of the cross wires into coincidence with the wires themselves, revolving the mirror through 180° and correcting one-half of the resulting vertical displacement by means of the adjusting screws b, b, b, against the heads of which the mirror rests, and the other half by means of the screw e, which forms part of the geometrical clamp **E**. The level is then adjusted until it is perpendicular to the axis of rotation by means of the screws f, f, in the usual manner.

Last the telescope is set at the height of the object to be measured and clamped in position and the axis **C** adjusted to verticality by the screws **I** and **H** (or the leveling screws in the base of this support), the level being placed first parallel to the telescope tube and then at right angles to it.† The first of these adjustments is made once for all, the second is tested at the beginning of each day's work, and the third only is necessary at each setting of the telescope.

It is important to notice that a small error in leveling has the same effect in this new form as in the ordinary form, i. e. the error is not doubled by reflection from the mirror, because the telescope and the latter move together, so far as any movement in a vertical plane is concerned. Let us consider the effect of a small error in leveling, first in the vertical plane parallel to the axis of the telescope; second, in the vertical plane at right angles to that axis. Let θ be the angle which the line of sight to the object makes with the first plane considered and α the angle which the axis of rotation c makes with the vertical in that plane. Then if ε denote the difference in reading produced by this inclination from the vertical, and r the distance of the object from the axis of rotation, we have evidently

$$\varepsilon = r \sin \alpha \cos \theta$$

and for the difference produced by an inclination α' in a plane at right angles to this

$$\varepsilon' = r \sin \alpha' \sin \theta$$

and for the corresponding errors in comparison of object and scale

$$\Delta = \varepsilon - \varepsilon_{\prime} = r \sin \alpha (\cos \theta - \cos \theta_1) \qquad (1)$$

$$\Delta' = \varepsilon' - \varepsilon_{\prime}' = r \sin \alpha' (\sin \theta - \sin \theta_1) \qquad (2)$$

* A Simple Method of Determining the Eccentricity of a Graduated Circle with only one vernier, F. L. O. Wadsworth, this Journal, May, 1894, vol. xlvii, p. 373.

† The mounting shown in figs. 1 and 2 is especially convenient in performing this last operation, as the screws **H**, **I**, and the third pivot point bear respectively in a slot, plane, and conical hole at the three vertices of a right angled triangle, and the motion of either screw, therefore, affects the position of the axis **C** only in the vertical plane passing through that screw and the pivot point.

In the new form of instrument the best position for the object and the comparison scale is about 90° from the axis of the telescope or in the direction, *o*, fig. 2. If we suppose the object and scale 15° from one another, and symmetrically placed on the two sides of the 90° position, we have for θ and θ_1 respectively $90°\pm 7\frac{1}{2}°$ or $97\frac{1}{2}°$ and $82\frac{1}{2}°$. Hence,

$$\varDelta = 0{\cdot}26\, r \sin \alpha \simeq \cdot \tfrac{1}{4} r\alpha \qquad (3)$$

and

$$\varDelta' = 0 \qquad (4)$$

The general equations (1) and (2) show that care in leveling is only necessary in the vertical plane perpendicular to the line of sight, i. e. in the new form the plane parallel to the axis of the telescope; in the usual form *the plane at right angles to that axis.* Hence if the greatest accuracy is to be attained with the ordinary cathetometer the usual telescope level should be placed at *right angles* to its customary position (or perhaps better still, a second level added in that position), so as to at once call attention to any error of adjustment in that plane. It is strange that this rather important fact should have been overlooked in previous designs.

The actual magnitude of the error in measurement, due to an error in leveling, is, however, always small, unless either the distance of the object from the telescope is considerable, or the difference between the angles θ and θ_1 is larger than 60°. If $\alpha = 5''$ and $\theta - \theta_1 = 15°$ as in (3), the error, $\varDelta$, for objects distant $\frac{1}{2}$ M. from the axis of rotation, would be about $\cdot 003^{mm}$ or about the limit of accuracy of setting with the best cathetometers under the best conditions.

With a good level sensitive to $5''$ per division (the best cathetometer levels are from two to three times as sensitive as this), there is no difficulty in setting by reversal to within less than $\frac{1}{5}$ div. or $1''$, reducing the error under the above conditions to about $\frac{1}{2000}^{mm}$.

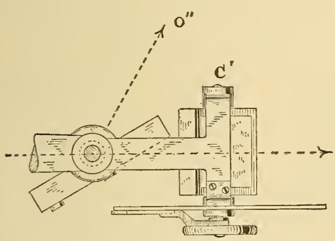
This shows that we may very considerably increase the angular difference $\theta - \theta_1$, without introducing any appreciable error. For when this difference is 60° the value of $\varDelta$ is only twice the above values or about $\cdot 001^{mm}$ in the last case, a quantity quite negligible in comparison with the errors of setting. This indicates another method of using this new form of instrument to good advantage, i. e., the method of superposition of object and comparison scale. To accomplish this the mirror **A** is half silvered and the scale is viewed directly through the unsilvered half in the direction o' (see fig. 3) the object being at the same time seen by reflection from the silvered half in the direction o''.* In this case we may make the measure-

* The mirror should be half silvered horizontally, i. e. the line of separation of the silvered from the unsilvered portion should be parallel to the axis of rotation, both because the maximum resolution is required in a vertical direction and because, as will be seen later, this management is the better adapted to the use of certain forms of micrometer.

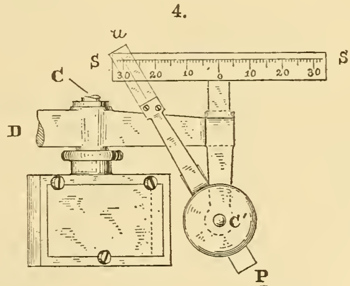
ment either by determining the distance between the image of the point and the image of the nearest mm. division on the scale with an ordinary form of micrometer; or better, by bringing these two images into coincidence by means of a Rochon double image micrometer, an opthalometer or a parallel-plate micrometer. The second method of coincidence has the decided advantages both of greater rapidity, only one setting and reading being necessary instead of two, and of greater accuracy for the same reason, since any error, due to a change in position of any part of the apparatus in the interval between two settings, is thus avoided. This last advantage fully balances the disadvantage of the greater effect of a given error of leveling on account of the greater angular distance between scale and object. One additional cause of error is introduced, i. e., that due to a want of parallelism between the mirror **A** and the axis of rotation **C**; but since this should not exceed a fraction of a second, if the first adjustment has been properly made, its effect is negligible.

Of the various instrumental means for obtaining coincidence perhaps the simplest and most convenient, as well as one of the most accurate, is the parallel plate micrometer first invented by Clausen and quite recently reinvented and much improved by Poynting,* who was the first to adopt it for cathetometric

3.



4.



measurements. Figs. 3 and 4 show in plan and elevation a form of this micrometer modified slightly from that described by Poynting to better adapt it to this particular instrument. It consists simply of a plate of plane-parallel glass, **P**, rotating on an axis **C**′ at right angles to the axis **C** and carried in a fork which is a prolongation of the boss **D** shown in the preceding figures.

The rotation of the plate on its axis shifts the ray from *o*′, which passes through it, and hence also the image of the scale, by an amount Δ which may easily be shown to be

* Phil. Trans., vol. clxxxii, 1891, A, p. 588. See also "On a Parallel Plate Double Image Micrometer," Monthly Not. of the Royal Astron. Soc., vol. lii, No. 8, 1892, p. 556.

$$\varDelta = t \sin \varphi . \left[1 - \frac{\cos \varphi}{\sqrt{n^2 - \sin^2 \varphi}} \right].$$

φ being the angle of rotation measured from the position in which the plate is normal to the ray. This expression may be written:

$$\varDelta = \cdot \frac{n-1}{n.} t \operatorname{tang} \varphi . \left\{ \left(1 - \frac{\cos \varphi}{\sqrt{n^2 - \sin^2 \varphi}} \right) \frac{. n \cos \varphi}{n-1} \right\}. \quad (1)$$

$$= \frac{n-1}{n.} t \operatorname{tang} \varphi . f(\varphi)$$

The quantity in brackets or $f(\varphi)$ may be shown to be very nearly unity for all values of φ between 0 and 30°. In order to determine its exact value we may develop it into a series as Poynting does, but since this series is only rapidly convergent for low values of φ, it is on the whole better to compute it directly from (1), which is in a form well adapted to logarithmic computation. I have calculated the values of $f(\varphi)$ for values of φ from 5° to 30° and for two values of n, viz: $n = 1·5$ and $n = 1·55$, about the mean indices of the glass most likely to be used for this purpose. These values are given in the following tables:

Table I.

$n = 1·5 \quad n-1/n = \frac{1}{3} = 0·3333.$

ϕ	$\frac{n-1}{n}$ tang ϕ	$f(\phi)=$	$1+\delta$*	$rs =$ tang a tang ϕ	$rs-\delta$
5°	·02916	1·00044=	1+·00044	+·0011	+·00066
10°	·05878	1·00162=	+·00162	+·0021	+·00049
15°	·08932	1·00333	+·00333	+·0033	·00000
20°	·12132	1·00528	+·00528	+·0045	—·00078
25°	·15544	1·00681	+·00681	+·0057	—·00111
30°	·19245	1·00708	+·00708	+·00708	+·0000

Table II.

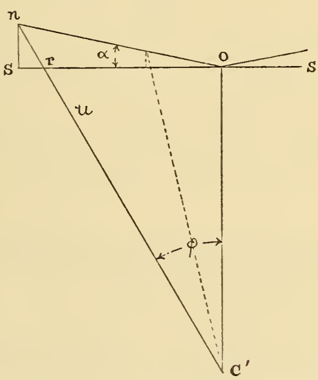
$n = 1·55 \quad \frac{n-1}{n} = ·35484$

ϕ	$\frac{n-1}{n}$ tang ϕ	$f(\phi)$	$1+\delta$
5°	·03104	1·00024	1+·00024
10°	·06257	1·00085	+·00085
15°	·09508	1·00162	+·00162
20°	·12915	1·00216	+·00216
25°	·16547	1·00188	+·00188
30°	·20487	1·00002	+·00002

* [In a similar table given by Poynting, the sign of δ is erroneously written negative (probably a typographical error), and there is also a small error in the value of δ for $\phi = 10°$, which is however unimportant since δ itself is so very small for this angle.]

An inspection of these two tables shows that in the case of glass of the higher refractive index ($n = 1{\cdot}55$), the maximum value of δ is only 0·2 per cent of $f(\varphi)$, and since the maximum shifting of the image need never exceed 1^{mm} (if comparison is made on a mm. scale), the corresponding correction to the tangent value is only $\frac{1}{500}^{mm}$ and may be disregarded. In this case we may read off the value of $\varDelta$ directly on a straight scale *s s* by means of a pointer, *u*, which consists of a thin plate of glass or mica on which is ruled a fine radial line. The distance *ro* from *o*, to the point of intersection of this line with the longitudinal line *s s* on the scale, equals $c'o$ tang φ and hence is directly proportional to $\varDelta$. If we make $c'o$ equal to $17\frac{3}{4}\ t$ in mm., then each mm. on the scale *s s* corresponds to a shifting of the image through $\frac{1}{50}^{mm}$. For an angle of 30° $\varDelta \simeq \frac{1}{5}\,t.$, hence for a shifting of 1^{mm} corresponding to this angle, the plate **P** must be 5^{mm} thick, and the distance $c'o$ therefore about 89^{mm} as laid off in fig. 5. The scale *s s* of fig. 4 is grad-

5.



uated in 2^{mm} intervals so that such intervals correspond to $\frac{1}{25}^{mm}$, but it is easy to set and read the position of the pointer to $\frac{1}{10}$ div. or $\frac{1}{250}^{mm}$.

In the case of glass of refractive index 1·5 the proportionality between the scale readings obtained in this manner and the value of $\varDelta$ is not so exact, the error amounting in case of an angle of 30° to nearly $\frac{3}{4}$ of 1 per cent or to nearly $0{\cdot}01^{mm}$. This is a quantity too large to be neglected. Poynting suggests a very ingenious system of link work, whereby the readings on the scale may be made directly proportional to $\varDelta$ for all values of φ; but this, as he himself recognizes, is hardly practicable on account of mechanical difficulties. We may, however, obtain the desired result very much more simply. An inspection of the values of δ in Table I will show that they are roughly proportional to tang φ. If we draw a line, no (fig. 5), inclined at a small angle α, in each direction from o, to the longitudinal line on the scale $s\,s$, and read in each case to the intersection of this line with the radial line u on the pointer; we increase the scale reading by an amount $sr = os$ tang α tang φ, and the new scale reading is therefore

$$os \simeq c'o \text{ tang } \varphi . [1 + \text{tang } \alpha \text{ tang } \varphi]$$

Hence we have only to make tang α tang $\varphi = \delta$, in order to make os the new scale reading directly proportional to Δ as before. To find the inclination α of the line n, o, to the axis of graduation we have only to put

$$\text{tang } \alpha \text{ tang } \varphi = \delta$$

for some particular value of φ. Suppose we do this for $\varphi = 30°$. Then we find

$$\text{tang } \alpha = \frac{\cdot 0071}{\cdot 577} \text{ or } \alpha = 42'$$

Using this value of α to calculate the values of the scale correction, rs, at other points we find the values given in the 5th column of Table I. As will be seen, they differ on the average from the corresponding values of δ by less than $\frac{1}{20}$ per cent; or only about $0{\cdot}0008^{mm}$ at the maximum for $\varphi = 25°$. By this simple method, therefore, the necessity for making any correction to the scale reading, even in the most accurate work, is entirely avoided.

The exact constant of the scale reading for any particular value of the index, differing from those given above, may be either calculated from the above formula or determined experimentally.

In order to always make the value of a 1^{mm} scale division correspond to some convenient fractional part of a mm. the support for the scale is made adjustable in height so that the value of $c'o$ may be always made equal to $\frac{n-1}{n} \cdot \frac{t}{a}$ where a is the fractional value desired. One advantage which the rotating plate has over the ordinary eye-piece micrometer, is that its constant remains the same for all distances of the scale from the telescope.*

The above form of parallel plate micrometer may also be advantageously substituted for the eye-piece micrometer in the first instrument described. In this case it should be placed

* The great practical advantage of this form of micrometer over the ordinary form is its much greater simplicity and cheapness. For these reasons it would have been adopted in all of the above instruments had it not happened that we already had on hand a number of micrometer eye-pieces which were available for this purpose.

between the objective and the reflecting mirror **A** or else mounted on the mirror frame itself so as to rotate with it. The last position enables the same instrument to be used either in the method of comparison or in the method of coincidence, but it is objectionable both on account of the increased weight of the moving parts and because of the liability of disturbing the adjustment of the axis or mirror while manipulating the micrometer. It is therefore better to place the rotating plate in the first position indicated and adapt it to either method of use if desired, by making it cover only one-half the field of the telescope, that half of course which is opposite the unsilvered half of the mirror when the coincidence method is used, and opposite the silvered half when the comparison method is employed.

In closing I wish to express my thanks to Messrs. Francis and Kathan, the mechanicians of the laboratory, for the care exercised in the mechanical execution of these designs.

University of Chicago, September, 1895.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Determination of Argon.*—By the use of an elaborate apparatus, Schlœsing Jr. has carefully determined the amount of argon in the air. The arrangement was such that the atmospheric "nitrogen" was gradually supplied to the apparatus where it circulated over heated magnesium and copper oxide and through drying apparatus, and the last traces of nitrogen were finally removed by sparking with oxygen. The method was tested by mixing the purest obtainable argon with chemical nitrogen in the same proportion in which they exist in the air and subjecting the mixture to analysis. These tests gave excellent results but showed a slight loss of argon. The author concludes that 100 volumes of atmospheric nitrogen and argon contain 1·183 volumes of argon, while air as a whole contains 0·935 per cent by volume. He believes that these numbers are correct within $\frac{1}{100}$ of their value.—*Compt. Rend.*, cxxi, 525.

In a subsequent article the above-mentioned author describes a continuation of his experiments. Repeated tests of the method invariably showed a loss of argon amounting, on the average, to about 0·7 per cent. This loss is not satisfactorily explained, but the possibility is suggested that argon may have some slight action upon hot metallic magnesium. The author gives the results of a number of analyses, as follows:

	Argon in 100 volumes, of atmospheric nitrogen.	of air containing 79·04 of nitrogen.
Air taken in Paris at about 10 m. above the ground, Sept. 25	1·185	0·9369
" 26	1·183	0·9349
" 30	1·185	0·9367
Oct. 1	1·180	0·9325
" 4	1·185	0·9363
Air taken in Normandy on a hill 305 m. high	1·182	0·9343
Air taken at a height of 300 m. on the Eiffel Tower	1·180	0·9328
Air taken in an iron mine	1·183	0·9534

The above results are not corrected for a supposed constant loss in analysis of about 0·7 per cent. Making this correction, the average results for normal air become 1·192 and 0·941. The variations in the results are within the limits of experimental error, and it must be concluded that argon, like oxygen and nitrogen, in the air is practically constant in amount.—*Compt. Rend.*, cxxi, 604. H. L. W.

2. *A study of Graphite occurring in Pegmatite.* — Having previously shown that all other forms of carbon are converted into graphite at the ordinary pressure by a sufficient rise of temperature, and further that all the graphites produced by crystallization from molten metals possess the property of sprouting when heated after the addition of a little nitric acid, while, on the contrary, graphites produced by simple transformation by heat or by volatilization in the electric arc do not sprout when so treated, MOISSAN has now examined, in this way, a graphite occurring in a pegmatite rock. This graphite was found to sprout, and the author believes that it must have been formed in a manner similar to that produced from molten metals, and that it existed before the pegmatite was formed. Continuing this research, the author has examined a number of other natural graphites from various parts of the world, and finds that a part of them sprout while the others do not. He concludes that the first class seem to have been produced by the action of molten baths, especially of metallic baths, while the second class were evidently formed by the action of an elevated temperature upon any variety of amorphous carbon.—*Compt. Rend.*, cxxi, 538, 542.

H. L. W.

3. *The Volumetric Determination of Cyanogen.*—The method of Liebig is carried out by adding a standard solution of silver nitrate to that of the alkaline cyanide in which cyanogen is to be determined, until a permanent precipitate of silver cyanide appears. One atom of silver corresponds to two cyanogens. DENIGÈS has now modified this well-known method so as to greatly improve the delicacy of the end-reaction and to widen

the applicability of the process. He finds that if a small amount of an iodide is present in an ammoniacal solution of a cyanide, silver iodide appears at the end of the reaction, although the method, in its original form, cannot be used in the presence of ammonia. He shows that the amount of silver solution used is rigorously proportional to the cyanogen present, even when considerable amounts of caustic alkalies, varying amounts of ammonia, etc., are present. He recommends the following method for alkaline cyanides: Weigh out one gram, dissolve in water, making a volume of one liter, take 100 c.c. of the filtered liquid, add 10 c.c. of ammonia solution, and about ten drops of a 20 per cent. solution of potassium iodide, and run in decinormal silver nitrate solution until a permanent precipitate appears. When sulphides are present, 10 c.c. of a 10 per cent. solution of zinc sulphate and a few drops of a basic lead acetate solution are added to the liquid before it is made up to a liter. The author proposes the use of a standard solution of potassium cyanide for the determination of silver by titration, the end of the reaction being determined by the disappearance, in an ammoniacal solution, of a slight precipitate of silver iodide. He considers this method preferable to Volhardt's thiocyanate method, but the greater instability of potassium cyanide solutions is evidently not in its favor.—*Ann. Chim. Phys.*, VII, vi, 381. H. L. W.

4. *The Emission of Light during Crystallization.*—Instances of this phenomenon have long been known, and H. Rose, who studied the subject, concluded that it was due to a change from an amorphous to a crystalline condition. He believed, for example, that vitreous arsenious acid when dissolved in hydrochloric acid gave light when it crystallized, while the porcelain-like form of the substance, dissolved in the same way, failed to give the phenomenon. This view, that the amorphous or crystalline nature of a substance could in any way affect the nature of a solution of that substance, is not in harmony with the modern ideas concerning solutions. Bandrowski has now shown, as was to be expected, that both kinds of arsenious acid produce the same results under like conditions. He finds the result, in the case of arsenious acid, to depend upon the presence of hydrochloric acid, as no emission of light occurs when the crystallization takes place from water or from alkaline solutions. The author made a series of experiments by dissolving 15 g. of arsenious oxide in 150 c.c. of hydrochloric acid, gradually varying the strength of the acid. He found that with very weak and very strong acid no light was emitted upon cooling to crystallization, and that the maximum effect was produced when the acid contained from 16·5 to 18 per cent. of hydrogen chloride. The phenomenon is described as very brilliant when observed in darkness, sometimes furnishing sufficient light for telling the time by a watch. The light appears in the form of innumerable bright sparks which are accompanied by a peculiar sound, and the whole phenomenon is suggestive of an electric discharge.

Bandrowski has also made a study of the emission of light from mixtures of potassium and sodium sulphates when they crystallize, the circumstance having been originally observed by Rose. Curiously enough, neither of the single sulphates gives the phenomenon, and the author concludes that the formation of a double salt, $2K_2SO_4 . Na_2SO_4$ is the necessary condition. He promises further results in this interesting field.—*Zeitschr. Physikal. Chem.*, xvii, 234. H. L. W.

5. *The Preparation and Properties of Titanium.*—MOISSAN has succeeded in preparing titanium, in a purer state than it has heretofore been known, by reducing the oxide with carbon in his electric furnace. With a current of 100 amperes and 50 volts, a fused or crystallized oxide of an indigo-blue color is obtained. With 300 or 350 amperes and 70 volts a perfectly fused mass of a bronze-yellow color, the nitride, Ti_2N_2, of Friedel and Guerin, is produced. At still higher temperatures the nitride is decomposed, so that with a current of 1,200 amperes and 70 volts, either the carbide, TiC, or titanium itself is obtained, according as to whether carbon is in excess or not, and these products are entirely free from nitrogen. The titanium was obtained in a fused condition, but Moissan states that it is the most refractory body that he has as yet obtained in his electric furnace, being more infusible than vanadium, and still more so than chromium, tungsten, molybdenum and zirconium. The purest titanium obtained in this way contained about 2 per cent. of carbon, bnt was practically free from other impurities. The fused titanium forms a brittle mass, harder than quartz, showing a brilliant, white fracture. Its density is 4·87. When heated, it combines with chlorine and oxygen with incandesence, and with nitrogen with some elevation of temperature. Nitric and hydrochloric acids attack it slowly even when hot, while aqua regia and sulphuric acid dissolve it much more readily. When titianium is heated in the electric furnace with boron and silicon, there are formed borides and silicides, either fused or crystallized, which are as hard as diamond.—*Bull. Soc. Chim.*, III, xiii, 959. H. L. W.

6. *Practical Proofs of Chemical Laws ;* by VAUGHAN CORNISH, 12mo, pp. 92. London and New York, 1895. (Longmans, Green & Co.)—This small text-book gives a series of experiments by which students may verify certain fundamental laws of chemistry, including conservation of mass, definite proportions, equivalent proportions and multiple proportions. The experiments are well devised and, for the most part, satisfactorily described and explained. Results obtained by students, showing a good degree of accuracy, are given throughout the book, and the author states that these pupils were mostly between twelve and eighteen years of age. Such young pupils would probably gain some knowledge of quantitative analytical processes by pursuing such a course, but it seems doubtful if most beginners would fully realize its significance, especially since chemical equations and formulæ are excluded on the ground that they are inadmissible in an exami-

nation of the facts upon which the atomic and molecular theory is based. Teachers of chemistry will undoubtedly find the book useful in furnishing suggestive problems for quantitative work.

H. L. W.

7. *Anleitung zur Molekulargewichtsbestimmung*, von Dr. G. Fuchs, 8vo, pp. 41, Leipzig, 1895. (Engelmann. Price M 1.20.)—This little book deals with the boiling-point and freezing-point methods for determining molecular weights, which have been elaborated by Professor Beckmann. Coming as it does from the pen of one of Beckmann's pupils and from his own laboratory, it may be considered an authoritative work upon the subject. The historical and theoretical bearings of the subject are clearly outlined, but the book is especially intended for use as a laboratory manual for students who are making molecular-weight determinations by the methods under consideration. The operations are well described and illustrated by figures, and the necessary formulæ and tables for making calculations are given and clearly explained. H. L. W.

8. *A Laboratory Manual of Organic Chemistry;* by Lassar Cohn. Translated by Alexander Smith, 12mo, pp. 403. (Macmillan & Co., $2.25.)—This work is a compendium of laboratory methods used in organic chemistry. The first part, dealing with the general methods, contains chapters on baths, crystallization, decolorizing of liquids, distillation, drying solids and liquids, extraction, filtration, determination of melting-points, determination of molecular weights, sealed tubes, and sublimation. The second part, devoted to special methods, embraces chapters on condensation, preparation of diazo bodies, preparation of esters, fusion with caustic alkalies, preparation of halogen compounds, preparation of nitro derivatives, oxidation, reduction, preparation of salts, saponification, preparation of sulphuric acids, and remarks on organic analysis. The methods are illustrated by numerous examples taken from chemical literature, and the great number of references indicates that a vast amount of reading was necessary for the compilation of the book. The work of the translator is very satisfactory. A number of changes in arrangement and additions have been made, with the author's sanction, and another improvement over the German edition is the use of smaller type for matters of subordinate interest. The work has been very favorably received in Germany, where it quickly reached a second edition. It is undoubtedly a very important aid to the investigator in organic chemistry, and the present translation will doubtless find extensive use among English-speaking students.

H. L. W.

9. *Organic Chemistry, The Fatty Compounds*, by R. Lloyd Whiteley, 12mo, pp. 290. London, 1895. (Longmans, Green & Co.)—The author aims to give students an intelligible and connected account of the theory of the subject, and also to provide them with such information as shall enable them to gain a prac-

tical acquaintance with it. The second purpose has evidently been more successfully carried out than the first. To a beginner in the laboratory the book would be of much practical aid, as the details for the preparation of compounds are clearly and copiously given, but as a guide to the systematic study of the paraffine compounds and their chemical structure and behavior the usefulness of this volume seems doubtful. W. T. H. H.

10. *Histoire de la Philosophie Atomistique, par* LÉOPOLD MABILLEAU, 8vo, pp. 560. Paris, 1895. (Imprimerie Nationale.)—As the title indicates, this work is a history of the various forms of atomic philosophy, and it includes discussions of Hindu and Grecian systems, as well as the theories of the Arabs and alchemists and finally modern atomistic philosophy and the atomic theories of science. The work has been crowned by the French Academy of moral and political science and is evidently a notable philosophical production. The part devoted to scientific theories occupies but a small portion of the book, and while this subject is well presented from a historical standpoint, it offers little that is novel to well-informed chemists and physicists. H. L. W.

11. *Modern Copper Smelting*, by EDWARD DYER PETERS, JR. Seventh edition, 8vo, pp. 642. New York, 1895. (The Scientific Publishing Co.)—The popularity of Dr. Peters' work on the metallurgy of copper is shown by the fact that it has gone through seven editions since 1887. The work has been the recognized authority upon the subject, both from the theoretical and practical points of view, since its first appearance. The new edition has been re-written and greatly enlarged, bringing the subject up to date and describing the prevailing practice in all parts of the world. The number of working-drawings has been largely increased, and much new matter of a very important nature has been added. In this connection the chapters upon the Bessmerizing of copper mattes, the electrolytic refining of copper and on pyritic smelting deserve special mention and commendation. The author uses the term "pyritic smelting," not in the sense of smelting with sulphides in the old-fashioned way to produce matte, but, as he defines it, "the fusion of sulphide ores by the heat generated by their own oxidation, and without the aid of extraneous heat such as carbonaceous fuel, etc.," a blast-furnace operation which has lately become an accomplished fact in several different localities. H. L. W.

12. *Comparison of the light-emission power of bodies at high temperatures.*—An important research by Mr. CHAS. E. ST. JOHN, late holder of the John Tyndall scholarship of Harvard University, has just been published. This research was conducted under Professor Warburg in Berlin, and led to an interesting method of comparing the light-emissive power of different bodies. The question has an immediate practical bearing in relation to the Auer burner and the Welsbach burner, the light of which is produced by the vivid incandescence of the various oxides of the rare earths zirkonium, yttrium, lanthanum, etc.—in the Bunsen

burner. Mr. St. John shows that the method of coating an incandescent platinum wire with the various oxides, the light-emissions of which are to be examined, leads to inaccurate results at high temperatures. He was led to examine also the mooted question whether the light of the above burners is rich in phosphorescent and fluorescent rays. Various methods which he employed, however, showed that these rays were very slight. The most important part of the research relates to the use of what may be termed the oven method of testing the light-emission. In this method the two bodies whose emissive power is to be determined are placed in an oven the temperature of which was raised 1100°–1200° C., a range of temperature which was determined by the pyrometer of Holborn and Wien. Two pieces of platinum foil were suspended side by side in this oven and the observation of their incandescence was made through a suitably placed window, by means of a Glan's spectrophotometer. A Triplex lamp served as the standard light. When one piece of foil was coated with the oxides it appeared brighter than the uncoated piece. If one piece of foil was inclined to the wall of the oven so that the reflected rays were sent through the window the two pieces of foil could be made to appear of the same intensity. The sum of the direct and reflected light is then for both pieces of foil equal. The uncoated piece must reflect just as much more light than the coated as it is deficient in the amount of direct light it can transmit. This is in accordance with Kirchhoff's law that in a heated space a bundle of rays made up of direct and reflected rays from a surface shows the same peculiarities that a bundle of rays from a dark hot body would show. Mr. St. John utilized this idea by bringing a porcelain cylinder into the neighborhood of the pieces of foil. The bare platinum could then be quickly distinguished from the surrounding hot walls and appeared darker than the coated platinum. As soon as the rod took the temperature of the oven the field of view appeared uniformly bright.

The spectrophotometer was adjusted for light of a determined wave length, and the image of one of the two bodies was thrown on the slit. The porcelain rod was then placed in the furnace, the light was observed; by means of a piece of plane parallel glass, the image of the other body was brought into the field. The porcelain rod acts to cut off the reflected light. Mr. St. John gives the following table:

$$\lambda = 0{\cdot}515$$

	Platinum.	Magnesium oxide.	Zirkonium oxide.	Erbium oxide.	Lanthanum oxide.
According to the electrical method of glowing platinum	1·00	1·26	1·81	1·70	1·88
According to the oven method	1·00	3·81	4·04	3·35	2·27

The inaccuracy of the electrical method is clearly shown. The results of Mr. St. John show that the Kirchhoff's law leads to a practical method of measuring in an oven the light-emission of bodies at high temperatures.—*Ann. der Physik und Chemie*, No. 11, 1895, pp. 433–450. J. T.

13. *Method of proof of the law of radiation of an absolutely dark body.*—W. WIEN and O. LUMMER, who had apparently been working independently upon the problem upon which St. John was also working (Ann. der Physik und Chemie, No. 11, 1895, p. 433), state the conditions which should be fulfilled in making observations according to Kirchhoff's law, and for the measure of radiation according to Stefan's law. They suggest that two pieces of thin platinum foil brought to incandescence by an electric current be placed near each other. One is provided with a slit through which the other is viewed. The inner appears much brighter than the outer. The temperature can be determined by the increase of resistance of the platinum. The arrangement can be used also as a bolometer, the radiation to be measured being sent through the slit and both pieces of platinum foil thus heated. In this way a result is obtained which is independent of the individual peculiarities of the absorbing and emitting surfaces, and the absolute radiation can be measured more correctly than by previous methods.—*Ann. der Physik und Chemie,* No. 11, 1895, pp. 451–456. J. T.

14. *Plasticity of Ice*, by O. MÜGGE.—In corroboration of the results of McConnell (Proc. Roy. Soc., xlviii, p. 259, 1890; and xlix, p. 323, 1891), experiments are made upon the bending of small bars of ice, held horizontally, supported at the ends, and loaded at the middle. If such a bar, or crystal, is so cut that the optical axis is perpendicular to the length, the load causes considerable bending; but a rod having the optical axis horizontal shows no appreciable bending under these conditions. This agrees with the supposition that the crystals consist of thin laminæ, formed of a flexible but almost inextensible substance, the interspaces being filled with a separating medium which is sufficiently viscous to retard the mutual gliding of the plates. Ice, in this respect, resembles $KMnCl_3 . 2aq.$, where the deformation results, similarly, from a motion of translation of the component laminæ, retarded by viscous matter in the interspaces, The experiments seem to show that this motion of translation takes place with equal facility in all directions parallel to the end surfaces; and, within the limits of — 3° C. and — 16° C., the extent of the motion, for a given load, appears to be independent of temperature. (Nach. G. Wiss. Göttingen, pp. 173–174, 1895.)—*Phys. Soc. Abstracts,* Nov., 1895.

15. *Ueber den Magnetismus der Planeten von* ERNST LEYST. 118 pp. 4to. St. Petersburg, 1894. (Repertorium der Meteorologie herausgegeben von der K. Akad. der Wissenschaften.)—The author has exhaustively examined the photographic records of the magnetographs at St. Petersburg, and later at Pawlowsk between 1873 and 1889, to see if it is possible to trace any systematic effect produced on the terrestrial magnetic elements by the other planets of the solar system. In this paper the author deals at great length with the declination records, and somewhat less fully with those of horizontal force. Three methods are em-

ployed:—(1st) The mean declination for the day at which the inferior or superior conjunction in the case of the inferior planets, or conjunction or opposite in the case of superior planets, takes place is compared with the mean declination for neighboring days or for the month. (2d) By means of the mean value of the secular change for the period 1873–1885 the value of the declination for the time of conjunction, etc., is compared with the actual value. (3d) The value of the diurnal range at conjunction, etc., is compared with the mean value. Although the differences obtained are excessively small, amounting as they do to only a fraction of a minute of arc, and large as is the probable error, the author considers that the numbers obtained point to the planets being so highly magnetized that they are capable of affecting the magnetism of the earth to an extent which is recognizable with the magnetographs now in use.—*Phys. Soc. Abstracts,* Nov., 1895.

16. *Molecules and the Molecular Theory of Matter*, by A. D. RISTEEN. 223 pp. Boston and London, 1895. (Ginn & Company.)—This popular and yet scientific presentation of the accepted molecular theory of matter with reference to solids, liquids and gases, will aid many to gain a clear idea of a difficult subject and one which has not been written out before in connected form. The language is for the most part simple and the illustrations numerous and helpful. The volume is based upon a lecture delivered a year since and the same form of address has been maintained in the expanded work; it may be questioned whether this is an advantage.

17. *School Physics: a new text-book for high schools and academies*, by ELROY M. AVERY. 608 pp. New York and Chicago. (Sheldon & Company.)—This new edition of Avery's Physics is commendably fresh in matter, introducing many new topics and new applications of physical principles. At the same time, it retains the good features of earlier editions, conspicuously clearness of style and arrangement, and liberality of illustrations and of exercises and problems. In the hands of a good teacher, properly equipped as to laboratory apparatus, it should produce excellent results.

II. GEOLOGY AND MINERALOGY.

1. *Reconnaissance of the Gold Fields of the Southern Appalachians;* by GEORGE F. BECKER, Ann. Rep. U. S. Geol. Surv. 1894–5, Part III. (Abstract prepared by the author.)—This report is based on field work done in 1894. Besides due reference to the results obtained by earlier observers in the same field, it also contains a digest of the literature dealing with the gold deposits of the maritime provinces and the Green mountains, the purpose being to present in one paper the most noteworthy facts concerning the occurrence of gold on the entire eastern side of the continent. In the northern portion of this region gold has been found in important quantities in Nova Scotia, and a considerable

amount of the metal has been obtained in the Chaudière district at the northern end of the Green mountains. In the South a belt of gold-bearing country passes through Virginia from the neighborhood of Washington, a second more important belt stretches through North Carolina past Charlotte into South Carolina; an auriferous area occurs in the heart of North Carolina at the South mountains, and still another belt crosses northern Georgia extending into Alabama. Field studies were made only of the deposits in Georgia and the Carolinas.

The first discovery of gold in the South seems to have been due to Ponce de Leon in 1513 and some curious notes on the early reports are set down. The first discovery which drew the attention of the present population to the gold resources was at the Reed mine, North Carolina, in 1799 and no "gold fever" occurred until 1830. The total production of the South up to the end of last year is estimated by the Mint authorities at above 45 million dollars. This does not represent a very large annual yield, but then it also represents only a small annual effort. In the palmy days of the Comstock about 10 miles of galleries were driven each year. It is doubtful whether all the galleries run during the century in the southern gold mines would aggregate 10 miles.

The rocks of the Georgian belt are mainly gneisses and gneissoid schists, believed by the geologists of the survey to be Archaean from evidence occurring farther westward. They are intersected by granite dikes supposed to be Algonkian. In the South mountain area the rocks are similar to those in Georgia. In the Carolinian belt granite is not absent, but the main mass of the country is composed of metamorphosed sedimentaries and volcanics. These last belong to the series studied by the late George H. Williams and with the sedimentaries are supposed to be Algonkian. To the northward the continuation of the volcanics is known to be pre-Cambrian.

All the rocks associated with gold in place have been subjected to profound dynamical action excepting a portion of the dikes. Almost all the country has acquired slaty cleavage, which strikes in a direction about parallel with the general trend of the Appalachians. In some areas the dip is westerly and in some easterly. It is suggested that these two groups of cleavages do not indicate forces of different directions but may be the conjugate cleavages due to a force of nearly constant direction as indicated in the author's theory of slate.*

Subsequent to the genesis of the cleavage a wide spread dislocation took place under the action of forces not coinciding in direction with that to which the cleavage is due. This fresh disturbance opened the fissures now occupied by quartz, and the direction of faulting, in all instances observed, was normal. In a large proportion of cases the effect was to split the rocks approximately along their cleavage. In the South mountain area, however, the strike of the schists is abnormal and the astonishingly regular vein-fissures cut sharply across the cleavage.

* Bull. Geol. Soc. Amer., iv, 1893, pp. 13–90.

Since the deposition of ore there has been no disturbance at all comparable to those which preceded this deposition. The associated dikes too are little disturbed. The greater part of the gold is certainly Paleozoic or older, for the Newark sandstones contain transported gold. There is no known disturbance in the Paleozoic which would answer in intensity or vulcanicity to those mentioned. These facts and such evidence as is available concerning the age of the ancient eruptives point to the Algonkian as the age of gold deposition. The slaty cleavages are older than the quartz veins and they are mechanically equivalent to distributed orogenic dislocations. Thus they indicate that as far back as the Algonkian a range or ranges existed which belonged to the Appalachian system. It will not be surprising if the tendency to mountain-building along this trend, which has manifested itself in the Pleistocene, should be detected even in the Archaean.

The report contains a long list of "gangue minerals" with localities and literary references. No less than sixty of these minerals are recorded, including, however, the sulphides as well as the earthy salts. The propriety of using the term gangue to include those metallic minerals which are not ores of the metal sought is open to question, but the term is very convenient and, when discrimination is requisite, it is easy to specify earthy gangue or metallic gangue. The conclusion reached from study of the ores is that "the gold ores of the South are quartzose deposits with very subordinate admixtures of carbonates in which pyrite is always present, while chalcopyrite is common, and galena, mispickel, and zincblende are by no means rare. The long list of other minerals found in the veins is unimportant, excepting in so far as it assists in elucidating the genesis of the ores." The gold ores of the South are thus substantially like those of most auriferous regions.

The quartz veins of the southern Appalachians have been regarded by several previous observers as beds contemporaneous with the rocks, but W. B. Rogers early pointed out that the conformity between the veins and the rock laminæ is only approximate. This important observation is fully borne out, and it appears that the structure with which the quartz is often approximately conformable is not bedding at all, but slaty cleavage. Almost everywhere the veins occasionally break across from one parting to some parallel one, and in most cases angular fragments of slaty wall rock occur imbedded in the quartz. Many of the deposits are not solid veins but zones of small lenticular veinlets separated by thin sheets of slate. For these the term *stringer-lead* is proposed, since they do not answer to the definition of a vein, which is "the filling of a fissure." No evidence of replacement was detected in these deposits, which seem to occupy only openings due to fracture. In many cases, however, the slate is impregnated with auriferous sulphurets for some inches from the quartz.

In the Carolina belt, particularly among the ancient volcanics of that region, impregnations occur which correspond closely to the Norwegian Fahlbands. The most profitable mine of the South, (the Haile in South Carolina) is on such an impregnation.

The placers of the South are of two well marked types accompanied by intermediate gradations. Ordinary auriferous stream gravels occur, but somewhat more frequent are masses of rock in place which are intersected by innumerable gold-bearing quartz seams, sometimes no thicker than paper, and which have subsequently been decomposed to a great depth. The term *saprolite* is proposed and employed as a general name for thoroughly decomposed, earthy, but untransported rock. Such a word is much needed and the only term ever proposed quite corresponding to it is "geest," which for good reasons has failed to find acceptance. Between the saprolitic placers and the stream gravels there are naturally transitions. Other things being equal, the water-worn gold is of greater value per pennyweight than the gold of the saprolite. The refining effect of running water was known to Oviedo and even to Pliny. One nugget of 8 pounds 5 ounces and another of 10 pounds have been discovered during the present year at the Crawford mine, North Carolina.

The report contains, in addition to the systematic portion, descriptive notes of the principal districts, and a bibliography of the subject, and it concludes with a review of the northern deposits, particularly those of Nova Scotia. It appears that these two are probably Algonkian and in most of the details of occurrence they resemble those of the South.

It is probable, therefore, that near the end of the Algonkian a set of chemical and physical conditions prevailed from Newfoundland to Alabama favorable to the deposition of auriferous quartz, and similar to the conditions which existed in the Sierra Nevada of California about the beginning of the Cretaceous.

2. *Geological Survey of New Jersey.*—The Annual Report for 1894 was received in November, 1895, and contains three parts, in all 303 pages, plates i–xi, one figure and a large colored geological map. Part I is the Report of Progress on the Surface Geology by ROLLIN D. SALISBURY, and nearly completes, with what has already appeared, the work on the northern half of the state. The author calls attention to the emphasized importance of the influence of stagnant ice upon the stratified drift of the valleys of the northern part of the state. Additional particulars are given regarding the Pensauken and Jamesburg formations. Accompanying the report are four map-sheets bound in with the text and a large colored geological map of the surface formation of the Valley of the Passaic, covering the area of topographic sheet 6. Part II is the Report on Artesian Wells in Southern New Jersey, by LEWIS WOOLMAN, in which the depths of the various formations are noted, the underground stratigraphy worked out, and numerous lists given of the fossils met with in the strata penetrated. Part III is C. C. VERMEULI's Report on Forestry in the northern part of the state, accompanied with a map showing the distribution of forests in the state. H. S. W.

3. *Geological Survey of the State of New York.*—The 13th annual report of the State Geologist for the year 1893 appears in two large volumes full of interesting material. Volume I, Geology, (pp. 1–597) contains four valuable papers on the Livonia salt shaft, based upon the investigations of JAMES HALL, D. D. LUTHER and J. M. CLARKE. A shaft, 12x22 feet, was sunk in Livonia, Livingston County, New York, penetrating from the Hamilton rocks outcropping at the surface, 1432 feet to the base of the salt group of the Silurian. Fossils and accurate measurements were preserved, so that the section serves to give an accurate record of the thickness of each member of the series, and of the exact position, succession and recurrence of the faunas for this portion of the geological scale. The record of the shaft and sequence of rocks was made by Mr. Luther, and the study and report upon the fossils by Mr. Clarke, and the whole furnishes an exceedingly valuable record for the study of the succession and modification of fossil faunas with passage of geological time.

The second part of this volume contains a number of reports prepared during the construction of the geological map under the supervision of the United States geological survey. These reports are as follows: On the Helderberg limestones, on the geology of Albany and Ulster Counties and on the geology of the Mohawk Valley, by N. H. DARTON; on the economic geology of Albany County, and on the geology of Ulster County, by F. L. NASON; on the geology of Essex County, by J. F. KEMP; of Clinton County, by H. P. CUSHING; on the general and economic geology of parts of St. Lawrence and Jefferson Counties, by C. F. SMYTH, Jr.; on the geology of Cattaraugus and Chautauqua Counties, by F. A. RANDALL; and of Chenango County, by J. M. CLARKE. Mr. Clarke also contributes a list of publications relating to the geology and paleontology of the State of New York from 1876–1893.

Volume ii, Paleontology, in addition to an extract from vol. viii, Part 2 of the Paleontology of New York on the Evolution of the genera of the Paleozoic Brachiopoda, contains a paper on Platycnemic Man in New York, by W. H. SHERZER; also a discussion of the different genera of Fenestellidæ, by GEO. B. SIMPSON; and, finally, Part II, An Introduction to the study of the Brachiopoda, intended as a hand-book for the use of students, by JAMES HALL, assisted by JOHN M. CLARKE. This last work completes a most valuable contribution to Paleontology, and furnishes the American student of stratigraphical geology with the means of precise and thorough work which were almost impossible without such a work on these indispensable indicators of the geological horizons of Paleozoic rocks. H. S. W.

4. *Mollusca and Crustacea of the Miocene Formation of New Jersey;* by R. P. WHITFIELD, Monograph XXVI, U. S. Geol. Survey, 1894, 4°, 193 pp., 24 pl.—This monograph, originally prepared for the New Jersey Survey, was finished by the author and transmitted for publication by the late Professor Cook in

1889, but was not published until 1894. The author has gathered from various sources information regarding all the then known species of the miocene formation of New Jersey. One hundred and four species are recognized; of these thirty-five species are reported from New Jersey only, and no very close representatives of living species are in the list. "No living forms," the author observes, "have been found in the New Jersey deposits that are not also known to occur in some of the more southern localities." A single species of *Discina* is the only representative of the Brachiopods, a fact in keeping with the almost complete absence of Brachiopods from the American Atlantic Tertiary. We observe, upon looking over the descriptions, that several species when compared with their more southern representatives, are of noticeably smaller size; as in the cases of *Ostrea percrassa*, *Arca centenaria*, *Astarte distans*, *Cardita granulata*, *Carditamera arata*, *Cardium craticuloides*, *Venus staminea*, *Fasciolaria sulcosa*, *Tritia bidentata*. This probably indicates that the locality was on the northern border of the geographical distribution of the fauna. It would be interesting, geologically, to know what relation the species which still live bear to living representatives in this respect. H. S. W.

5. *The Climates of the Geological past* and their relation to the evolution of the Sun; by EUG. DUBOIS, pp. 1–167, (Swan, Sonnenschein & Co.) London, 1895.—The author, whose remarkable report on *Pithecanthropus* has been already noticed in these pages, sets forth in this essay the hypothesis that the climatic changes, indicated by the geographical distribution of fossils upon the earth's surface, are due to changes in the heat radiated from the sun. Following Janssen, he assumes that differences of the stars, in color and spectra, indicate differences in their temperature, Thus, the stars which are rich in violet rays, like Sirius, are assumed to be at an extremely high temperature; yellow stars, like Capella, less hot; while those of red color, like Betelgeuze, are in the third stage of cooling. The numbers of the stars of each color is estimated, and the relation of the numbers is taken as an index of the relative duration of each stage; on this hypothesis the white stage is estimated to have continued 58.5%, the yellow stage 33.5% and the red stage 8% of the total luminous existence of each star. The sun, as one of the stars, is assumed to be in its yellow stage of evolution. The author's hypothesis is expressed in the following passage, viz: "Now, since from the sun's history we learn that, during the greater part of its existance as a white star, it was much hotter, and on passing relatively rapidly from the white to the yellow stage, it lost much of its heat, we see, on the other hand, that the heat received by the earth underwent the same changes, for after a very long period of warmth, a relatively rapid cooling set in, finally reaching the present condition—then we may assume that the period of the cooling down of the climates coincided with the transition from the white to the yellow stage, the period of rapid cooling of the

sun. The present thermal condition at the earth's surface was developed during the Tertiary period and was fully attained at the beginning of the Pleistocene period—a date, geologically speaking, so recent that the time which has since elapsed may perhaps be estimated as but one-fiftieth of the time which elapsed since the beginning of the Palæozoic age. We, therefore, may further conclude that our sun only comparatively recently entered its yellow stage, and we may, without committing a great error, consider that it has now passed $\frac{3}{5}$ of its life as a luminous and heating star and that it has still $\frac{2}{5}$ before it." In the course of the discussion the chief facts in evidence regarding variation in climate during geological time are brought together in concise and logical form, and are clearly stated. We think the author is incorrect in assuming that "the supposition of a formerly greater amount of carbonic acid in the atmosphere can now no longer be seriously discussed." H. S. W.

6. *Geological Biology*, an introduction to the geological history of organisms, by Henry S. Williams, pp. 395, figs. 1–150. New York, 1895. (Holt & Co.)—The problems of biology, regarded as specially geological in this treatise, are those concerning the history of organisms, their relations to time and varying conditions of environment, and the laws of the modification of characters and the acquirement of differences. As is stated in the preface, "it is evident upon reflection that the biologist proper, who deals alone with the organisms now living upon the earth, must rest with a theoretical interpretation of the laws of evolution. To the geologist the records of evolution are open for direct examination, and geological biology is a scientific treatment of the observed facts of evolution." With this idea in mind the author has put together in systematic form discussions of some of the chief problems desirable as preparation for serious work in paleontological investigation. The general subjects elaborated are the geological time-scale, its divisions, its nomenclature and the principles of its formation, and estimates of the length of geological time; fossils and their interpretation; geographical distribution; the species; the organism; principles of classification, etc.

In the treatment of special topics, such as the modification, acquirement, plasticity and permanency of characters, typical series and groups of organisms are selected for detailed examination, in order to illustrate the exact meaning of the principles involved. The book, as a whole, is a much needed introduction to the study of the history of organisms for the specialist, and is an enunciation of general principles for those looking for a comprehensive statement of the chief facts in the case. It covers a field heretofore covered by historical geology, which in the rapid differentiation of sciences bids fair to take a place of its own as organic, in contrast to inorganic, geology.

7. *Mikroskopische Physiographie der massigen Gesteine von* H. Rosenbusch. 3d ed. enlarged and revised, 8vo, first half, pp. 552. Stuttgart, 1895.—The great impulse which the science of

petrology has received in the last ten years is nowhere more clearly to be perceived than in the increased size of this new edition of Prof. Rosenbusch's well known work over that published in 1887. And this increase marks well the incessant activity of the author in the coördination of the vast mass of material which has been published since that date.

It is needless to say that the appearance of this work will be greeted with the keenest interest by all petrographers. No one has held a more commanding position in this branch of science than the author, and no one has exerted a greater influence in its development through his pupils, especially in this country, from which they have been largely drawn.

It would, therefore, be a matter of interest to present a full review of its contents, but in the brief limits of this notice of its appearance it is only possible to say that the work is kept strictly within the limits set in the former editions, that is, to the microscopical physiography of the igneous rocks; general petrology and chemical and geological relations being confined by brief mention within the smallest possible limits, while the author's views are often hinted at rather than actually expressed.

The ideas which the author has advanced during recent years upon the classification and relationships of igneous rocks in various brief publications are here affirmed and their influence is everywhere observable upon the subject-matter of the work. The course laid down in the past is here steadily pursued to a logical conclusion.

In his preface the author states that he still retains the division of the extrusive rocks into two groups dependent on geological age, though it is clear from his remarks that he would prefer to do away with it.

The present half of the work comprises the plutonic rocks ("*tiefengesteine*") and the "dike rocks" ("*ganggesteine*"). Among the latter, as must be expected, we find a considerable number of new types and names expressed.

We note with regret that the author has felt obliged to confine the work so strictly within the limits mentioned above. Analyses of the types described would have added greatly to the convenience and value of the work. We trust that the author may see his way in the future to supplement this work by one dealing with the many phases of petrology, either wanting or all too briefly expressed in this volume. Its appearance would certainly be received with the greatest interest by all workers in this branch of science. L. V. P.

8. *The Rubies of Burma and Associated Minerals—their Mode of Occurrence, Origin and Metamorphoses.* A Contribution to the History of Corundum. By C. Barrington Brown and J. W. Judd.—An abstract of the paper bearing this title is given in a recent number (No. 345) of the Proceedings of the Royal Society. It details the investigations carried on in the field under the auspices of the government by Mr. Barrington Brown and also the results of a petrological and mineralogical examina-

tion by Prof. J. W. Judd of the specimens collected. The following pages are quoted from the source named :

"The famous ruby district of Upper Burma was almost unknown to Europeans before the annexation of the country by the British. It is situated about 90 miles N.N.E. of Mandalay, and about 11 miles E. of the military post of Thebayetkin, on the Irrawaddy. The tract, so far as explored, is about 26 miles long and 12 broad, and lies at elevations varying from 4,000 to 5,500 feet above the sea-level. The principal mining center in this district is Mogok, and the present workings for rubies extend over an area of 45 square miles; old workings, however, being found over an area of 66 square miles. The principal mining operations are carried on in the three valleys of Mogok, Kathay, and Kyatpyen ; but there are some smaller outlying districts, in which mines were formerly worked, in the Injouk Valley, near Bernardmyo, at Wapudoung, 11 miles E. of Thebayetkin, and at Launzee, 8 miles S.W. of Kyatpyen. There is also a small tract of ruby-bearing rocks (crystalline limestone) at Sagyin, 24 miles N. of Mandalay; and it is asserted by the natives that two other limestone hills, 15 miles N. of Sagyin, have yielded rubies; while old ruby workings were found in making the railway at Kauksay, 30 miles S. of Mandalay. It is also probable that ruby-bearing limestones, and the alluvial earths derived from them, may be found in portions of the adjoining Shan States. Indeed, at a point about 25 miles southward from Mogok, in the Shan State of Mainglôn, Dr. F. Noetling, of the Geological Survey of India, has found that rubies have been obtained from the alluvium of a stream that flows from the mountains that lie considerably to the S.E. of the Mogok District.

The rubellite (red tourmaline) of the same district was found by Mr. Barrington Brown not to occur in association with the rubies, but to come from certain gneisses and schistose rocks. The locality which yields this gem, so highly prized by the Chinese, is Nyoungouk, 10 miles S.E. of Mogok ; the alluvium which yields the rubellite appears never to contain rubies and spinels. Black tourmaline (schorl) has been extensively worked, as shown by Dr. F. Noetling, in the Shan State of Mainglôn, not far from the rubellite locality.

In the mountainous tract which includes the ruby districts, the general trend of the hill ranges is from east to west. The bottom of the Mogok Valley, in which the principal workings are situated, lies at a height of 4,100 ft. above the sea; while the loftiest mountains of the range to the north and east are the Chenedoung Peak, 7,362 ft., and the Taungnee Peak, 7,775 ft. above the sea-level. The alluvia of the valleys of Mogok, Kathay and Kyatpyen are formed by streams flowing southwards from this mountain chain; while those of the valleys of Injouk and Kabein are deposited by streams flowing in the opposite direction. The district, which is a somewhat malarious one, has an annual rainfall of about 80 inches; but in March, April, and May, the supply of water for mining operations is deficient.

The mountains are composed of various gneissic and granulitic rocks, occasionally passing into schists. Subordinate to the general mass of gneisses, often containing garnets, are certain peculiar varieties of foliated and massive rocks, including both acid and basic types, with limestone bands, often of a highly crystalline character. It was in these limestones that the rubies and spinels were found to be embedded, associated with graphite, phlogopite, pyrrhotite, and many other minerals. The sides of the hills are found to be shrouded in a deposit of hill-wash, often 50 ft. in thickness, composed of fragments, derived from the mountains, embedded in a clayey matrix. On the bottoms of the larger valleys there are extensive level deposits of alluvial matter, consisting of brown, sandy clay, resting on coarse gravels, which in turn cover other argillaceous beds. It is in these lower clay beds of the river alluvia, and in similar deposits formed in gullies in the hill-wash, that the rubies, spinels, and other gems of the district are found.

Mining operations for the obtaining of rubies are carried on in Burma in four different ways. (1.) In the alluvia, "twinlones," square pits from 2 to 9 ft. across, ingeniously timbered with bamboo, are sunk to the ruby earth, the drainage of the pits and the removal of material being effected by baskets attached to balance poles, both made of bamboo. (2.) In the hill-wash long open trenches, called "hmyaudwins," are carried from the sides of a gully, and the earth is washed out by streams conveyed into the trenches by bamboo pipes. (3.) In the caves and fissures filled with earth which abound in the limestone rocks, regular mines—"loodwins"—are opened, and the productive ruby earth is followed for long distances by means of shafts and galleries. (4.) The limestones which contain the rubies are at one or two points quarried, and the gems are obtained by breaking up the rock masses.

The extensive rubellite mines at Nyoungouk are worked in a somewhat similar plan to the "hmyaudwins." Water is delivered by a number of bamboo pipes at the head of the almost vertically exposed faces of alluvium; and as the masses of the latter are loosened, the miners dash water upon them from shovel-shaped baskets, and are able to detect and pick out by hand the brilliantly colored stones exposed on the washed surfaces.

The petrology of this district of Upper Burma, in which the rubies, spinels, and rubellite occur, presents features of the greatest geological interest. In many respects the petrology of Burma exhibits close analogies with that of the corundiferous localities of Ceylon, the Salem district, and other portions of the Indian peninsula; but some of the phenomena presented by the rocks of the Burma ruby district do not appear to find a parallel in any of the gem-yielding tracts described by de Bournon and more recently by Lacroix.

The general mass of gneissic rocks composing the mountainous district in which the ruby localities are situated are of intermediate chemical composition, and consist of biotite-gneisses, biotite-granulites, and, more rarely, biotite schists—rocks in which hornblende is rare or altogether absent, but which, on the other hand, are often remarkably rich in garnets. Neither corundum nor spinel have been certainly detected in these rocks.

Interfoliated with these ordinary gneissic rocks, which form the great mass of the mountains, we find rocks of much more acid composition, including very coarse pegmatites and graphic granites, aplites and granulites (leptynite or Weiss-stein), granular quartzites, and orthoclase-epidote rocks. The orthoclase of these rocks frequently contains inclusions of fibrolite and other minerals, it often exhibits the "murchisonite" modification and partings, and is not unfrequently converted into "moonstone;" still more complete alterations of the orthoclase into epidote, muscovite, and kaolin being by no means uncommon. In the rubellite district of Nyoungouk these acid rocks contain pink and blue tourmaline (rubellite and indicolite), often beautifully zoned, and it is probably from rocks of this class that the fine gem rubellites are derived.

Of still greater interest are certain other subordinate rocks of basic and sometimes ultra-basic composition. These include the remarkable pyroxene-gneisses and pyroxene-granulites, which have in recent years been described as occurring in so many widely-scattered regions—such as Ceylon, Southern India, Central and Southern Europe, Norway and Sweden, Brittany, Spain, Algeria, Eastern, Western, and Southern Africa, the United States and Canada, Brazil, and New Caledonia. In these rocks the feldspars are for the most part basic ones, near to anorthite; the crystals almost always exhibit the phenomenon described by French petrographers as "quartz of corrosion," and the partial or complete transformation of these feldspars into scapolite ("wernéritisation") can frequently be traced. The ferro-magnesian silicates are represented by many varieties of augite (sahlite, diopside, and ægerine), of enstatite (bronzite and hypersthene), and more rarely of hornblende. Garnets are a frequent and abundant constituent in many of these rocks, which in their accessory minerals and their structures often exhibit many features of striking interest. By the gradual disappearance of the feldspars from these rocks, they pass into remarkable varieties of pyroxenites and amphibolites. The chief varieties of these rocks, which are now described from Burma, are the following: Augite-gneiss (with sahlite, green diopside, etc.), augite-granulites (very rich in garnet), enstatite-gneiss (with bronzite or hypersthene), enstatite-granulites (rich in garnet), scapolite-gneisses, scapolite-granulites, pyroxenites and amphibolites of many varieties, and lapis-lazuli (lazurite-diopside-epidote rock). Many of these rocks contain crystals of calcite scattered through them.

It is with these basic rocks, and more especially with the ultra-basic types last mentioned, that the remarkable crystalline limestones that contain the rubies and spinels are most intimately associated; indeed the passage of rocks consisting of various silicates with a few calcite crystals into masses principally composed of calcite, but with the silicate minerals and oxides dispersed through them, is of the most insensible kind. Some of the ruby-bearing limestones are highly micaceous ("cipollinos"), others are "calciphyres," in some of which the individual calcite crystals attain enormous dimensions. With the rubies and spinels are found a great number of oxides and silicates, both original and secondary, with much graphite and pyrrhotite.

In the gravels and clays of the district fine specimens of the minerals derived from the atmospheric degradation of the limestones and other rocks are found, sometimes broken and water-worn, at other times almost uninjured.

The study of the extensive series of minerals brought from the ruby mines of Burma is calculated to throw light upon many important scientific problems.

The association of minerals in the remarkable crystalline limestones of Burma is worthy of the most careful consideration. Corundum—in its various forms of ruby, sapphire, white sapphire, oriental amethyst, oriental topaz, etc.—is found associated with red, purple, brown, black and other spinels, the relative proportions of the minerals composed of aluminium oxide and of magnesium aluminate being very variable. The other minerals present in the crystalline limestones are zircon (rare); garnets (abundant in some places); a remarkable blue apatite; feldspars, of many species and varieties (including murchisonite, moonstone, sunstone, etc.), and in every stage of alteration; quartz (in many varieties, and exhibiting some remarkable peculiarities of crystallization); micas (phlogopite, fuchsite, with muscovite and other secondary and so-called hydromicas); hornblende and arfvedsonite; augite (sahlite, diopside, and ægyrine); enstatite (bronzite and hypersthene); wollastonite; lapis-lazuli; fibrolite; scapolite; with graphite and pyrrhotite. In addition to muscovite and other secondary micas, we find the following alteration products: Diaspore, margarite, and other clintonites, chlorites, vermiculites, and carbonates.

It is a noteworthy circumstance that none of the silicates combined with fluorine and boron compounds—such as topaz, tourmaline, chondrodite and humite, axinite, or datholite have been certainly detected in these limestones. Beryl (aquamarine) and danburite have been said to occur in the ruby earths, but there is reason for doubting the correctness of the statement. The limestone which, in the association of minerals found in it, most closely resembles the rock of Burma, is the remarkable white limestone of Orange County, N. Y., and Sussex County, N. J.; but in the American rock the corundum and spinels are associated with tourmalines and chondrodites.

In considering the question of the *origin* of the corundums and spinels of Burma, there are several very important facts to be borne in mind. The gems, when found *in situ*, always appear to occur in the limestone, and this limestone is of a very remarkable character. There are no facts which point to the conclusion that the limestone was originally of organic origin, but many circumstances suggest that it may have been formed by purely chemical processes going on at great depths within the earth's crust. The highly-crystalline calcareous rock, besides containing so many silicates and oxides, is associated in the most intimate manner with pyroxene-gneisses and granulites containing anorthite, and with various pyroxenites and amphibolites. The lime feldspars and lime-soda feldspars of these rocks show the greatest tendency to undergo change—passing into scapolites by the process known as "werneritisation," and eventually giving rise to the separation of calcium carbonate and hydrated aluminium silicates. That from the last-mentioned salts the hydrated oxides of aluminium (diaspore, gibbsite, bauxite, etc.) may be separated has been shown by the studies of Liebrich and others, while the conversion of these substances into the anhydrous aluminium oxide has been shown to take place by H. St. Claire Deville, Stanislas Meunier, and others.

Crystallized aluminium oxide (corundum) has now been formed by chemists by no less than 20 different processes, and in some cases, like those described by Senarmont, Weinschenk, Bruhns, and Friedel, the formation and crystallization of the substance has been effected at very moderate temperatures under pressure. By one or other of these or similar methods it is probable that the formation of the Burma corundum and spinel has been effected, the source of the minerals being the decomposition products of basic and easily-altered lime feldspars in the pyroxene-gneisses.

Of still greater interest than the question of the origin of the corundums and spinels are the problems connected with the remarkable changes that these minerals undergo in deep-seated rock masses. The rubies of Burma, when found *in situ* in the limestones, are usually seen to be enveloped in a mass of materials produced by the alteration of their superficial portions. Nearest to the unaltered gem is a zone of diaspore—the hydrated aluminium oxide—and this is found to pass insensibly into various hydrous aluminous silicates—margarites and other clintonites, vermiculites, muscovites, kaolinites, etc. While, in some instances, the corrosion of the rubies appears to have gone on in a seemingly irregular manner, in the majority of cases a very definite mode of metamorphosis may be detected by the study of the various examples. There are evidently certain planes of "chemical weakness" (analogous to the cleavage planes, gliding planes, and other directions of physical weakness) along which decomposition goes on most readily. The principal of these solution planes is the basal plane, and parallel to it we find the gems eaten away in a series of step-like surfaces. Other less pronounced planes of chemical weakness exist parallel to the prism faces. Unaltered corundum is, like quartz, destitute of true cleavage, and breaks with a perfectly conchoidal fracture. If, however, gliding planes and lamellar twinning be developed in corundum (like those so easily produced in the same way in calcite), parallel to the fundamental rhombohedron of the crystals, then these gliding planes become "solution planes," along which chemical action takes place most readily. Along the primary or secondary solution planes, hydration of the aluminium oxide takes place, and diaspore is formed, as shown by Lawrence Smith and Genth, and this unstable mineral enters into combination with silica and other oxides present to give rise to the numerous pseudomorphs of corundum, which are so well known to mineralogists.

There are certain crystals of corundum and spinel from Burma which present illustrations of corrosion of a very remarkable and interesting character. Commencing with the formation of naturally etched figures ("Verwitterungsfiguren"), the work of corrosion goes on till the whole crystal is broken up into an aggregate of simple forms—these being, in the case of the spinel, the octahedron, and, in the case of the corundum, a combination of the rhombohedron, basal plane, and prism.

It is interesting to note that the quartz, feldspars, and other minerals associated with the rubies and spinels of Burma, exhibit phenomena of external etching and internal chemical change similar to those we have been describing in the case of the gems. The study of the whole of the phenomena throws much new light on the remarkable changes which take place, at great depth in the earth's crust, in minerals which, at the surface, appear to be of a very stable character."—*Proc. Roy. Soc.*, No. 345.

9. *Brief notices of some recently described Minerals.*—ASCHARITE is a hydrous magnesium borate found in white lumps associated with boracite in the rock salt of Schmidtmannshall near Aschersleben. Specific gravity 1·85–1·95. The mean of three analyses gave:

$$B_2O_3\ 49{\cdot}2 \quad MgO\ 42{\cdot}8 \quad H_2O\ 8{\cdot}0 = 100.$$

Described by W. Feit, see *Zeitschr. Kryst.*, xxiv, 625, 1894.

CUPROIODARGYRITE is an iodide of copper and silver, $CuI . AgI$, described by H. Schulze from Huantajaya near Iquique, Peru, where it occurs as a decomposition product of stromeyerite. It is found as an incrustation or filling crevices in limestone. Color sulphur-yellow; translucent. An analysis gave:

$$I\ 57{\cdot}75 \quad Ag\ 25{\cdot}58 \quad Cu\ 15{\cdot}91 = 99{\cdot}24.$$

—*Zeitschr. Kryst.*, xxiv, 626, 1895.

HOEFERITE is a hydrated ferric silicate closely related to chloropal; it is described by F. Katzer from Kritz near Rakonitz, Bohemia. It is amorphous, either earthy, granular or scaly and of a bright green color; hardness 1–3; specific gravity 2·34. An analysis gave:

$$SiO_2\ 36{\cdot}14 \quad Fe_2O_3\ 45{\cdot}26 \quad Al_2O_3\ 1{\cdot}11 \quad \text{ignition}\ 18{\cdot}15 = 100{\cdot}66.$$

This yields the formula $2Fe_2O_3 . 4SiO_2 . 7H_2O$.—*Min. petr. Mitth.*, xiv, 519, 1895.

KAMAREZITE, described by K. Busz, is a hydrated copper sulphate from Laurion, Greece. It occurs in crystalline masses, showing minute tabular crystals. Hardness 3; specific gravity 3·98; color grass-green. An analysis gave:

SO_3 17·52 CuO 51·50 FeO 0·69 H_2O 30·29 = 100.

Formula calculated $(CuOH)_2\ SO_4 . Cu(OH)_2 + 6H_2O$. — *Jahrb. Min.*, i, 115, 1895.

LOSSENITE is another mineral from Laurion, Greece, for which the complex formula $2PbSO_4 . 3(FeOH)_3As_2O_8 + 12H_3O$ is deduced by L. Milch. It occurs in acute pyramidal crystals related to scorodite in form and of a brownish red color. An analysis gave:

A_2O_5	SO_3	PbO	Fe_2O_3	H_2O (comb.)	H_2O	SiO_2	$CaCO_3$
33·44	3·74	10·63	34·53	3·74	11·81	1·13	1·46=100·48.

—*Zeitschr. Kryst.*, xxiv, 100, 1894.

LEWISITE, described by E. Hussak and G. T. Prior, is a mineral from the cinnabar mine of Tripuhy, Ouro Preto, Brazil. It occurs in minute regular octahedrons of a honey-yellow to colophony-brown color. Hardness 5·5; specific gravity=4·95. The composition is expressed by the formula $5CaO . 2TiO_2 . 3Sb_2O_5$, which was deduced from the analysis:

Sb_2O_5	TiO_2	CaO	FeO	MnO	Na_2O
67·52	11·35	15·93	4·55	0·38	0·99=100·72.

—*Mineral Magazine*, xi, 80, 1895.

MAUZELIITE is another titano-antimonate of calcium related to lewisite and described a little earlier by H. Sjögren. It is also found in isometric octahedrons of a dark brown color. Hardness 6–6·5, specific gravity 5·11. The mean of two analysis by R. Mauzelius gave:

Sb_2O_5	TiO_2	PbO	FeO	MnO	CaO	MgO	K_2O	Na_2O	F	H_2O
59·25	7·93	6·79	0·79	1·27	17·97	0·11	0·22	2·70	[3·63]	0·87=101·53.

It occurs with svabite and calcite at Jakobsberg, Sweden.— *Geol. För. Förh.*, xvii, 313, 1895.

TILASITE is a mineral related to adelite but containing fluorine; it is described by H. Sjögren from Långban, Sweden. It is found in granular masses of a gray color and resinous luster. Specific gravity 3·28. The composition is $(CaF)\ MgAsO_4$ deduced from the analysis by Mauzelius:

As_2O_5	P_2O_5	FeO	MnO	CaO	MgO	Na_2O	H_2O	F	Cl
50·91	*tr.*	0·14	0·16	25·32	18·22	0·29	0·28	8·24	0·02=103·58.

—*Geol. För. Förh.*, xvii, 291, 1895.

ZIRKELITE is a rare zirconium mineral described by E. Hussak and G. T. Prior from the locality Jacupiranga in Brazil, which has afforded the new species baddeleyite (ZrO_2), also perovskite, etc. It occurs in regular octahedrons of a black color. Hardness 5·5; specific gravity 4·706. An analysis gave:

ZrO_2, TiO_2	FeO	CaO	MgO	ign.
79·79	6·64	11·61	0·49	1·02 = 99·55

—*Mineral Magazine*, xi, 86, 1895.

TIFFANYITE.—This name has been given by G. F. Kunz to a hydrocarbon assumed to be present in certain diamonds, which on this account, as it is believed, exhibit marked fluorescence and phosphorescence. These optical phenomena are shown to belong only to a limited number of diamonds and not to be as general as has been supposed.—*Trans. N. Y. Acad. Sci.*, xiv, 260, 1895.

III. BOTANY.

1. *Pleiotaxy in the androecium of Epidendrum cochleatum, L.*—Mr. Theodore L. Mead has sent to the Harvard Botanical museum, from Oviedo, Florida, a strong plant of this species, which exhibits an anomaly in the number of anthers. Most of the flowers are well-developed and, at first sight, would not attract attention as being at all different from the type. But Mr. Mead had observed that even the most nearly normal flowers on this plant have three anthers. In most of the flowers, the three pollinia are about equal in size, but the two lateral ones are a little distorted by the curvature of the column. The anther normally present in this group of orchids is of ordinary shape and size, and plainly belongs to the outer whorl. The two extra stamens, which flank it, appear, as far as examination has yet gone, to belong, as might be expected, to the same whorl. Altogether the case is interesting, although it is one of a class of monstrosities rather common in the orchid family. It does not appear that anyone previous to Mr. Mead has observed the present deviation from the normal number in any plants of this species, although Clos has made a note of the occurence of three fertile anthers in an unnamed species of *Epidendrum.*

Among other deviations in this genus may be mentioned the following recorded by Penzig, who states that Magnus has seen in this species trimerous peloria with labelliform petals, and also dimerous zygomorphic flowers having transverse sepals. *Epidendrum articulatum* has been observed with an inflorescence of the year before. Other species in this genus have also exhibited striking peculiarities in individual cases, but perhaps the deviations have not been more numerous than in allied genera. G. L. G.

2. *The Structure and Development of the Mosses and Ferns;* by DOUGLAS HOUGHTON CAMPBELL, pp. 544, 8°, fig. 266. (Macmillan & Co.)—This treatise on the Archegoniatæ has been admirably planned and executed by Prof. Campbell. We have had many books and monographs giving the details of the structure of the different orders of Archegoniatæ and not a small number of papers devoted to a consideration of their homologies and phyllogeny. We have not had, however, in recent years, a connected account of the subject by one who, while master of

details, was also able to show their general bearing without indulging in excessive speculation. The contributions of Prof. Campbell to the study of the development of higher cryptogams have been numerous and important. In the present work his large practical knowledge of the different orders and his wide reading have enabled him to give an admirable summary of the present state of our knowledge with regard to the group of plants which, perhaps, above all others, are most important from a phyllogenetic point of view. The book is by no means a mere summary, but includes a large number of original observations, the more important because they relate to imperfectly known species of this country, and the illustrations are refreshingly original and not the time-worn cuts which seemed destined to be copied in all books, even those by experts.

The proportions of the book are good, for the author has laid more stress on typical structures than on specific details. Hence we find about twice as many pages devoted to the Hepaticæ, in which there are several marked types of reproduction, as to the Musci, in which generic and specific differences are the prominent features. Furthermore, for purposes of phyllogenetic study, the Hepaticæ are, in the opinion of most modern writers, more significant than Musci. We think that Prof. Campbell did well not to offer a long introduction, but has made the subject clearer by first giving a condensed account of each order and then expanding the account of the suborders. If we congratulate Prof. Campbell on what he has given us, we can also thank him for what he has not given us. The terminology is simple and clear, and he has not attempted to force upon us a new series of names of different organs and structures to express what was sufficiently well expressed before. Nor has he indulged in hair-splitting theoretical discussions, the summary and conclusions being limited to ten pages. The book cannot be said to be easy reading; it is so full of facts that one must read slowly, and, in a short review, one can hardly refer to details. We have noticed but one statement which seems to us incorrect. On p. 40 it is said that *Ricciocarpus natans* fruits only when growing upon the earth. In eastern New England it fruits abundantly when floating. W. G. F.

3. *Phycotheca Boreali-Americana;* by F. S. Collins, Isaac Holden and W. A. Setchell.—We are glad to notice the appearance in rapid succession of the first three fascicles of this valuable collection of North American algæ. In form they resemble the fascicles of the Phycotheca Generalis of Hauck and Richter, each fascicle containing fifty species bound in folio. The specimens are in excellent condition and well mounted and the determinations of the species have been made with care and accuracy, the labels being clear and full. The algæ represented in the series include species from fresh water as well as marine and were collected in part in the West Indies and on the Pacific coast, although the larger part are from the Northeastern States, where the three botanists under whose supervision the Phyco-

theca is prepared, have made special studies of the flora. Among the many interesting species of this collection we may mention the numerous Cyanophyceæ, several of which had not been recorded previously in North America and which have formed the subject of Prof. Setchell's paper, Notes on some Cyanophyceæ of New England, in the October number of the Bulletin of the Torrey Botanical Club. The Chlorophyceæ, Phæophyceæ and Rhodophyceæ are represented by a number of interesting species. Among the West Indian forms are the rare and imperfectly known *Liagora decussata* Mout., collected in Jamaica by Miss Pease, and the curious *Hormothamnion enteromorphoides* Grunow, collected in Jamaica by Dr. Humphrey. The Phycotheca will prove an indispensable aid to phycologists, valuable not only from the excellence of the specimens but also from the careful determination of the species. W. G. F.

4. *An Introduction to the Study of Seaweeds:* by GEORGE MURRAY. Pp. 271, 8°, fig. 88, pl. 8. (Macmillan & Co.)—It is a long time since there has appeared any general introduction to the study of marine algæ, and the student has been forced to depend upon the common botanical text-books, in which the marine algæ are generally treated very inadequately in a few pages. Recent investigations on the structure and development of seaweeds have been numerous and important, quite overturning our former views on their classification, but the results scattered through numerous journals in several languages have not hitherto been brought together in a way to be easily accessible. The excellent book by George Murray, now in charge of the botanical department of the British Museum, will be of very great service to all interested in marine algæ. In the Introduction, the most readable chapter of the book, the writer gives an admirable account of the general habits and distribution of marine vegetation, a subject on which he is specially competent to speak. There then follows a classified list of works valuable for reference. The main body of the book is devoted to an account of the three sub-classes, *Phæophyceæ*, *Chlorophyceæ* and *Rhodophyceæ*, taken up in the order named. There are also short chapters on the *Diatomaceæ* and *Cyanophyceæ.* The pages are so crammed with facts that the book is almost encyclopædic. We have here for the first time a careful collation of what has been observed in relation to the different orders up to the present time, but the writer is careful not to confound observations with purely theoretical conclusions, and is content with a statement of opposing theoretical views without feeling obliged in all cases to decide in favor of either in the present state of our knowledge. The chapters on *Phæophyceæ* and *Rhodophyceæ* will be especially appreciated by all who have to teach or lecture upon these two large and perplexing groups. The illustrations, selected from numerous monographs and special papers, are generally well executed, but we do not think that the colored plates are quite satisfactory, although, perhaps, they are as good as the low price of the book would warrant. W. G. F.

IV. Miscellaneous Scientific Intelligence.

1. *Comet of 1843 I.*—Herr Kreutz of Kiel has been engaged in the investigation of the path of the great comet 1843 I, which has seemed to bear close relations to, if not identity with, the comets of 1668, 1880 I, and 1882 II. In the *Astronomische Nachrichten*, No. 3320, he gives in advance of full publication the principal results of his computations. The most probable period of revolution is 512·39 ± 70·75 years. The period of 36 years, necessary if there is identity with comet 1880 I, as well as that of 175 years if there is identity with comet 1668, are found to be inconsistent with the observations of comet 1843 I. He finds, however, that while a parabolic orbit is inadmissible, a period of 800 years, equal to that of the great comet 1882 II, is admissible. Moreover, he finds a remarkable relation, viz : that the line of intersection of the planes of the two orbits is for each of them along the major axis of the orbit. Hence he concludes with considerable probability, 1st, that the two comets are parts of one original comet, and 2d, that the separation took place in some past epoch at or near the perihelion passage of the original body. Why it may not have separated near aphelion is apparently not considered.

2. *Harvard College Observatory.*—The Director of the Observatory of Harvard College, Professor E. C. Pickering, has recently commenced the publication of a series of Circulars, designed to furnish a prompter announcement than has hitherto been possible of the results of the Observatory work. Numbers 1, 2 and 3 have already appeared. The first describes a new star which appeared in the spring of 1895 in the constellation Carina, discovered from an examination of the Draper Memorial photographs taken at the Arequipa Station. The spectrum of the star resembles closely those of Nova Aurigæ and Nova Normæ. Circular No. 2 describes certain variable star clusters.

Circular No. 3 (Dec. 13) gives observations of a new variable star of the Algol type. This is the star B. D. +17° 4367, magn. 9·1, whose approximate position for 1900 is in R. A. $20^h\ 33^m.1$, Decl. +17° 56′. The change of brightness appears to be rapid and the range of variation to be large, exceeding two magnitudes.

3. *Distribution of the Magnetic Declination in Alaska and adjacent waters for the year* 1895, with a chart, by C. A. Schott. (U. S. Coast and Geodetic Survey, Bulletin No. 34.)—This brief pamphlet, in addition to the new and excellent declination chart for Alaska, discusses briefly the observations available and the methods by which they have been reduced for use in laying down the isogonic lines.

4. *Geodesy, Determinations of Latitude*, gravity and magnetic elements at stations in the Hawaiian Islands, including a result for the mean density of the earth. 1891, 1892, by E. D. Preston. (U. S. Coast and Geodetic Survey, W. W. Duffield, Supt. Appen-

dix No. 12.—Report for 1893, pt. 2, pp. 513–639, plates 22–37.) Washington, 1894. In this report the mean density of the earth is calculated from observations of the force of gravity at two stations (Waiau and Kawaihae) on the Island of Hawaii in comparison with the density of Mauna Kea, determined from specimens whose specific gravity was measured by G. P. Merrill of the Smithsonian Institution and E. S. Dana (this Journal, vol. xxxvii, p. 442 and 447) to be in relation to the density of the mountains as 1·77 to 1, the density of the mountain being assumed to be 2·90; this gives mean density of the earth = 5·13.

5. *Relative Schwerebestimmungen durch Pendelbeobachtungen:* ausgeführt durch die K. und K. Kriegs-marine in den Jahren 1892–1894. 630 pp. with 5 plates.—The results of a long series of pendulum observations carried through by the Austrian Government between the years 1892 and 1894 are here presented in full tabular form with explanations as to the instruments employed, etc. The stations occupied include a large number on both east and west shores of the Adriatic sea and a series of others at widely separated points distributed over the world at large.

6. *Elementary Physical Geography*, by Ralph S. Tarr. 488 pp. 8vo. New York and London, 1895. (Macmillan & Co.)—The author has given here a clear and interesting presentation of the various topics commonly included under the general head of Physical Geography. So many different branches of science have to be touched upon that in an elementary work like the one in hand, the treatment is of necessity often superficial. In the main, however, good judgment is used in the choice of matter and the work as a whole will be found a highly valuable contribution to the available text-books in a field not before well occupied. In the matter of illustrations the author has shown commendable enterprise; they are numerous, well selected from many sources and with few exceptions very satisfactorily reproduced.

7. *The Herschels and Modern Astronomy;* by Agnes M. Clerke, New York, pp. 224, 12mo, 1895. (Macmillan & Co.) Century Science Series, vol. iii.—The life of John Herschel has never been written, and the wonderful series of papers which the elder Herschel contributed through a series of years to the Philosophical Magazine have never been collected and republished, yet the lives and works of both are so well known that the present volume offers little that is new; nevertheless, being written by Miss Clerke, it will prove both interesting and profitable to laymen and specialists alike. W. B.

8. *Justus von Liebig, His Life and Work;* by W. A. Shenstone, pp. 219. (Macmillan & Co., $1.25.)—More than twenty years after Liebig's death, this essay appears as the first comprehensive and popular account of his scientific career. The author justly considers the subject of his work as one of the greatest men of this or, perhaps, any other century. He was the pioneer in four great departures in science, in organic chemistry, in the application of chemistry to agriculture and to

physiology, and in the development of the laboratory method of teaching. The book gives an excellent account of Liebig's work, most of which was important in its practical application and of great general interest, and being nearly free from technicalities, the essay is available for the general reader. H. L. W.

9. *Bibliotheca Zoologica II.*—Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten und vom Jahre 1861–1880 selbstständig erschienen sind, etc. Bearbeitet von Dr. O. TASCHENBERG. 13te Lieferung, pp. 3889–4208. Leipzig, 1895. (Wm. Engelmann.) The present thirteenth part of this great work is the last one, as announced in the prospectus. It includes signatures 481 to 520, or pages 3889 to 4208. The appearance of the earlier parts has been repeatedly announced in this Journal and attention has been called to the careful accuracy and thoroughness which characterize their preparation. The editor may well be congratulated upon the completion of his labors.

10. *Zoologisches Adressbuch:* Namen und Adressen der lebenden Zoologen, Anatomen. Physiologen und Zoopaleontologen sowie der känsterlischen und technischen Hülfs-Kräfte; herausgegeben im Auftrage der Deutschen Zoologischen Gesellschaft von R. Friedländer und Sohn, 8vo, 740 pp. Berlin, 1875.

This is a highly useful work, giving, as mentioned in the title quoted above, the names and addresses of living zoologists, in their different departments. The names are arranged geographically, all the members of the faculty at a single university being printed together and the whole presented with commendable clearness of typography. A full index at the end of the volume repeats the names, grouped under the special branches of the general science. The work cannot but be found most convenient by all in this department.

11. *New York Academy of Sciences.*—The following geological papers appear in the recently issued volume xiv of the New York Academy:

Dislocations in certain portions of the Atlantic coastal plain strata and their probable causes, by ARTHUR HOLLECK, pp. 8–20, figs. 1–5.

On a granite-diorite near Harrison, Westchester County, N. Y., by HEINRICH RIES, pp. 80–86.

The Protolenus fauna, by G. F. MATTHEW, pp 101–153, plates i–vi.

The effusive and dyke rocks near St John, N. B., by W. D. MATTHEW, pp. 187–218, plates xii–xvii.

Two new Cambrian graptolites with notes on other species of Graptolitidæ of that age, by G. F. MATTHEW, pp. 262–273.

The geological section of the East River, at Seventieth street, New York, by J. F. KEMP, pp. 273–276.

12. *Ostwald's Klassiker der Exakten Wissenschaften.*—The following list gives the recent additions to this valuable series of scientific classics:

No. 60. Die Geometrischen Constructionen, ausgeführt mittelst der Geraden Linie und eines festen Kreises, als Lehrgegenstand auf höheren Unterrichtsanstalten und zur praktischen Benutzung von Jacob Steiner (1833).

No. 61. Ein Versuch die Mathematische Analysis auf die Theorien der Elektricität und der Magnetismus anzuwenden von George Green (1828).

No. 62. Sechs pflanzenphysiologische Abhandlungen von Thomas Andrew Knight (1803–1812).

No. 63. Zur Entdeckung des Elektromagnetismus. Abhandlungen von Hans Christian Oersted und Thomas Johann Seebeck, (1820–1821).

No. 64. Ueber die Vierfach Periodischen Functionen zweier Variabeln von C. G. J. Jacobi, (1834).

No. 65. Abhandlung über die Functionen zweier Variabler mit vier Perioden, von Georg Rosenhain, (1851).

No. 66. Die Anfänge des Natürlichen Systemes der chemischen Elemente, Abhandlungen von J. W. Doebereiner und Max Pettenkofer, (1829, 1850).

OBITUARY.

GEORGE LAWSON, Professor in Dalhousie College, Halifax, Nova Scotia, died at his home on the evening of November 10. He was born in Scotland, Oct. 12, 1827. He was educated at a private school. After a few years of study by himself, in which he devoted a good deal of attention to law, he entered the University of Edinburgh, and at once began active work in Natural Science, giving much of his time to Botany. He was, for a time, Curator of the Herbarium at the University and assistant to the Professor of Botany. In 1857 he took the degree of Ph.D. at the University of Giessen, and in the following year came to Canada as professor of chemistry and natural history in Queen's University, Kingston, Ontario. In 1863 he accepted the professorship of chemistry and natural history in Dalhousie College. From the first year of his residence in Nova Scotia he engaged in the development of the agriculture of the Province, and was the secretary of the Board of Agriculture till 1885. In that year the work of the board was transferred to the provincial government and Dr. Lawson became Secretary of Agriculture for the Province.

His contributions to science have been published chiefly in the Transactions of the Botanical Society of Edinburgh, the Royal Society of Canada, and the Nova Scotia Institute of Science. His activity in bringing before the farmers of the province the latest and most trustworthy intelligence in agricultural matters was unabated up to the last of his life. Professor Lawson was a member of many learned societies in America and Europe, and was for a time President of the Royal Society of Canada. G. L. G.

M. S. BEBB.—At the moment of going to press, we learn that M. S. Bebb, of Rockford, Illinois, died in California, on the 5th of December. Although for some years in enfeebled health, he did not relinquish until recently the study of his favorite plants, the willows. We hope to give in a subsequent number of this journal some account of the useful life of this botanist, who has endeared himself to his correspondents everywhere. G. L. G.

DON ANTONIO DEL CASTILLO, founder and director of the Geological Survey of Mexico, died on the 27th day of October, 1895, in the city of Mexico.

BOOKS AND PAMPHLETS RECENTLY RECEIVED AND THUS FAR NOT OTHERWISE NOTICED.

Notes on the Nebular Theory in relation to stellar, solar, planetary, cometary and geological phenomena, by William Ford Stanley, F.R.A.S , etc. London, 1895, 259 pp. 8vo. (Kegan Paul, French, Trübner & Co.)

Laboratory Course of Elementary Physics, by W. J. Loudon and J. C. McLennan. 302 pp. 8vo. New York and London (Macmillan & Co.).

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[FOURTH SERIES.]

ART. XI.—*Researches in Acoustics*; by ALFRED M. MAYER.

Paper No. 10 containing The Variation of the Modulus of Elasticity with Change of Temperature as determined by the Transverse Vibration of Bars at Various Temperatures. The Acoustical Properties of Aluminum.
[Read before the British Association, at Oxford, Aug., 1894.]

Summary of the Research.

POISSON in his *Traité de Méchanique* (Paris, 1833, t. II, pp. 368–392)* discusses the laws of the transverse vibrations of a bar free at its ends and supported under its two nodes. He shows that the frequency of the vibrations of the bar is given by an equation, which, reduced to its simplest expression, is $N = V \times 1{\cdot}0279 \frac{t}{l^2}$; in which N is the number of vibrations per second of the bar, t its thickness, l its length and V the velocity of sound in the direction of the length of the bar.

To ascertain how near the frequency of the transverse vibrations of a bar, computed by Poisson's formula, agrees with the result obtained by experiment, the following method of experimenting was used.

Rods of steel, aluminum, brass, glass and of American white-pine (*Pinus strobus*)—substances differing greatly in their moduli of elasticity, densities and physical structures—were carefully wrought so as to have the length of $1{\cdot}5\pm$ meter; the thickness of $0{\cdot}5^{cm}$, the width of 2^{cms}, and a uniform section throughout their lengths. The velocity of sound in these rods was determined by vibrating them longitudinally at a temperatute of 20°, while held between the thumb and forefinger, and

* See, also, The Theory of Sound, by Lord Rayleigh, 1894, vol. i, ch. 8.

their frequencies of vibration ascertained by the standard forks of Dr. R. Kœnig's tonometer.

Out of each of these long rods were cut three bars of the length of 20^{cms}, and these bars, also at 20°, were supported on threads at their nodes, vibrated transversely by striking them at their center with a rubber hammer, and their frequencies of vibration determined by the forks of the tonometer.

The mean departure of the observed from the computed numbers of transverse vibrations (see Table I) is $\frac{1}{328}$; the computed frequency being always in excess of the observed, except in the case of glass, where the computed is $\frac{1}{275}$ below the observed frequency.

In Table I, l = length and t = thickness of bar in centimeters at 20°. V = velocity of sound in centimeters in bar at 20°. N = number of vibrations per second at 20°.

The close agreement of the computed and observed values shows that, by vibrating a bar at various temperatures, the variation of its modulus of elasticity with change in its temperature can be obtained. We observe, N, at various temperatures of the bar; then $V = \dfrac{N}{1{\cdot}0279\frac{t}{l^2}}$ is computed, and the modulus $M = \dfrac{V^2 d}{g}$. As t, l, and d (the density of the bar), vary with the temperature, the coefficient of expansion of each bar and its density at 4° were determined, so that the dimensions and density of the bar could be computed for each of the temperatures at which it was vibrated.

Experiments were made on five bars of different steels, on two of aluminum, on one of St. Gobain glass, one of brass, one of bell-metal, one of zinc and one of silver. The results of these experiments may be summed up as follows:

The modulus	of elasticity of	St. Gobain glass	is 1·16	per ct. less at	100°	than at 0°.
"	"	the five steels	" 2·24 to 3·09	"		"
"	"	brass	" 3·73	"		"
"	"	bell-metal	" 4·3	"		"
"	"	aluminum	" 5·5	"		"
"	"	silver	" 2·47	"	60°	"
"	"	zinc	" 6·04	"	62°	"

The decrease of the modulus of elasticity of glass, aluminum and brass is proportional to the increase of temperature; straight lines referred to coördinates giving the results of experiments on these substances. The five steels, silver and zinc give curves, convex upwards, showing that the modulus decreases more rapidly than the increment of temperature; while bell-metal alone gives a curve which is concave upwards; its modulus decreasing less than the increment of temperature. (See fig. 5, p. 95.)

The more carbon a steel contains the less is the fall of its modulus of elasticity on elevating the temperature of the steel. Thus, the modulus of the steel with 1·286 per cent of carbon is 2·24 per cent less at 100° than at 0°, while the steel containing 0·15 per cent of carbon has a modulus at 100° which is 3·09 per cent lower than its modulus at 0°.

So far as experiments on a single steel containing nickel permits of any general deductions, it appears that the presence of nickel in a low carbon steel lowers its modulus of elasticity. Thus, steels Nos. 3 and 4 having respectively ·47 and ·51 per cent of carbon have a modulus of 2131×10^6, while steel No. 5, containing ·27 per cent of carbon and 3 per cent of nickel, has a modulus of 2080×10^6, which is 2·12 per cent. lower than that of steels Nos. 3 and 4.

The presence of nickel in a steel may, in a diminished degree, have the effect of carbon in lessening the lowering of the modulus when the temperature of the steel is increased. Thus, the percentage of the lowering of the modulus, by heating from 0° to 100°, of steel No. 5 containing 0·27 of carbon and 3 per cent of nickel, is the same as that of steel No. 3 with 0·47 per cent of carbon.

If a bar of any one of the substances experimented on is struck with the same energy of blow, by letting fall on the centre of the bar a rather hard rubber ball from a fixed height, the sound emitted by the bar diminishes in intensity and in duration as the temperature of the bar is raised. Thus:

Brass	at 0° vibrates during	75	secs.;	at 100°	it vibrates during		45	secs.
Bell-Metal	"	"	55	"	"	"	15	"
Aluminum	"	"	40	"	"	"	12	"
J. & C. Cast Steel	"	"	80	"	"	"	5	"
Bessemer Steel	"	"	45	"	"	"	1·5	"
St. Gobain Glass	"	"	6	"	"	"	3·5	"

Zinc at 0° vibrated during 5 secs.; at 20° only during 1·5 secs. At 62° it vibrated for so short a time that it only gave three beats with forks of 1090 and 1082 v. s. At 80° it was not possible to determine the pitch of the bar, and at 100° the bar when struck gave the sound of a thud. The bar of silver acted in a similar manner to the bar of zinc—it was even less sonorous than zinc—thus flatly denying the "silvery tones" attributed to it.

These phenomena do not depend on the fall of modulus but on changes in the structure of the metal on heating, which cause the blow to heat the bar and not to make it vibrate.

Bell-metal was found to be an alloy peculiarly well suited for bells, as the intensity and duration of its vibrations were the same at 50° as at 0°; all other substances showing a marked diminution of intensity and duration of sound at 50°.

A bar of unannealed drawn brass, after it has been heated to 100°, has its modulus increased $\frac{36}{100}$ per cent. See Table III and fig. 11, p. 98.

In this research I had the good fortune to have had the assistance of Dr. Rudolph Kœnig, of Paris. He not only placed at my service the resources of his laboratory and workshop, but generously gave me constant assistance during the experiments; making the determinations of the numbers of vibration of the rods and bars with the standard forks of his tonometer. Without his aid this work could not have been done. For instance, in the cases of the bars of silver and zinc the beats they give with a fork are so few that they cannot be compared with a chronometer; but Dr. Kœnig, from his long experience in the estimation of beats, was enabled to form an accurate judgment of their number per second from the *rhythm* of the beats. The determination of pitches extending through such a range of vibrations as occur in this research can only be made with Dr. Kœnig's "grand tonomètre," a unique apparatus of precision, giving the frequency of vibrations from 32 to 43690 v. s., and really indispensable to the physicist who would engage in precise quantitative work in acoustics.

We now proceed to give accounts of the several operations performed in the progress of this research.

Determination of the Velocity of Sound in Rods.

In the determinations of the velocity of sound in the rods of 1·5 m. in length I used the method of Chladni.* Kundt's method of obtaining nodal lines of fine powders in a tube, by vibrating a rod whose end carries a cork which fits loosely the end of the tube, is not accurate. The weight and friction of the cork, the necessity of firmly clamping the rod at a node, and, above all, the want of knowledge of the velocity of sound in the air of glass tubes of different diameters, renders this method, so beautiful and ingenious, worthless for accurate measures of the velocity of sound in solids.

The curves in fig. 1 show the very diverse determinations of the velocity of sound in the air in tubes of different diameters by the physicists Kundt†, Schneebeli‡, Seebeck§, and Keyser‖. The velocity of sound in metres is given on the axis of Y; the diameter of the tube in centimeters on the axis of X. Ku stands for Kundt, Sch for Schneebeli, Se for Seebeck, and Ke for Keyser. The most precise measures of

* Traité d'Acoustique, Paris, 1809, p. 318 *et seq.*
† Bericht. der Akad. der Wiss. zu Berlin, 1867.
‡ Pogg. Ann.. 1869, vol. cxxxvi.
§ Pogg. Ann., 1870, vol. cxxxix.
‖ Wied. Ann., 1877, vol. ii, p. 218.

velocities are those of Keyser, who closed the end of the tube with a cork attached to the end of a steel-bar, while the other end of the bar was securely clamped. The frequency of the transverse vibrations of the bar was registered by a style describing the sinusoids of the vibrating bar. Thus the

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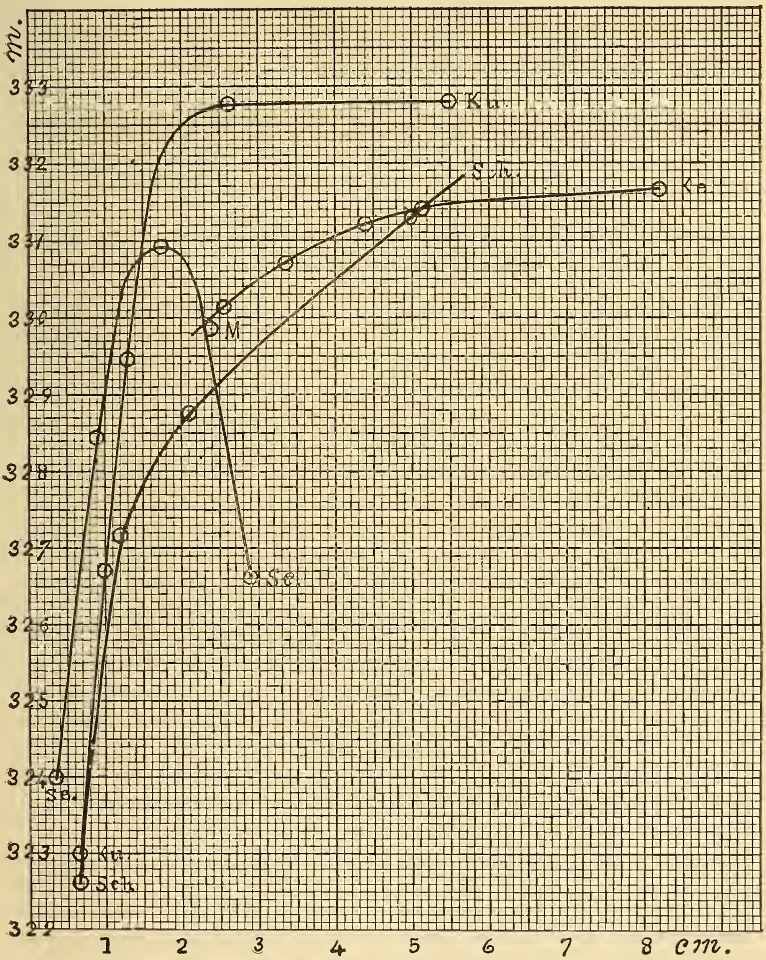


weight and friction of the cork introduced no error. In a similar manner I obtained the velocity, marked M in fig. 1, by vibrating a rod of aluminum. The frequency of the vibrations of the rod were measured while the cork at the end of the rod was vibrating in the mouth of the tube. The result agrees closely with Keyser's. It is needless to discuss the curves of fig. 1.

The method of Chladni, used exactly as that eminent man used it, remains the best we have. It is important, however, to note that the rod must be held between the thumb and forefinger when it is vibrated and not *clamped* when vibrated. When clamped it always gives a higher frequency, as shown by the following experiments :

Steel rod clamped	3429·2	Aluminum rod clamped	3377·0
Steel rod held between fingers	3428·4	Aluminum rod held between fingers	3376·4

The frequency of the vibrations of the rods of steel, brass, aluminum, glass and pine wood, when held at the middle of their lengths and vibrated so as to give their fundamental tones, gave exactly the octaves of these fundamental tones when held at one-quarter of their lengths and vibrated.

Determination of the lengths of the long rods and of the lengths and thicknesses of the bars.

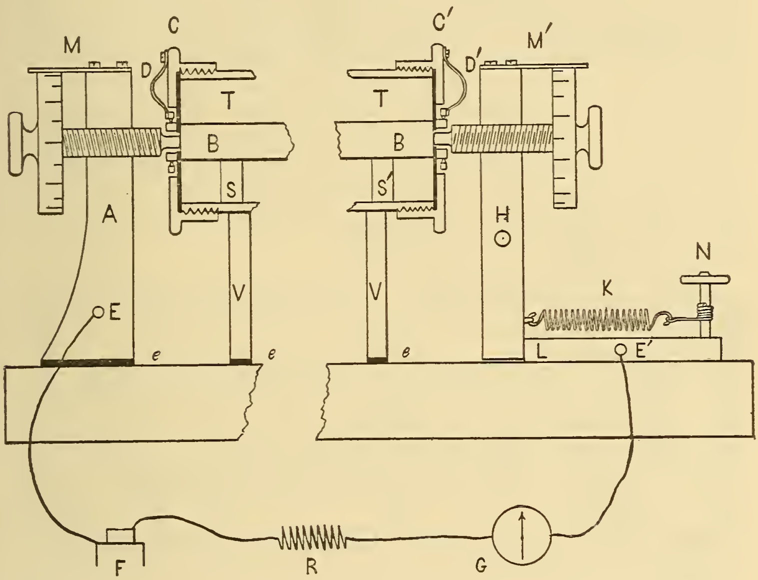
The lengths of the rods of 1·5± meters were ascertained by comparison with the rod of steel whose length was measured at the Bureau International des Poids et Mesures. The lengths and thicknesses of the bars which were vibrated transversely were measured with micrometer calipers. The readings of these calipers were tested by comparison at 20° with a series of standards of various lengths of inches and fractions of inches, made for me with great care by Mr. George M. Bond, who has charge of the gauge department of the Pratt, Whitney Co. In reducing the comparisons to centimeters I adopted the value of the inch as equal to 25·4 millimeters. In obtaining the length of a bar, the mean of several measures in the axis of the bar and in directions parallel to the axis and at various distances from it was adopted. The thickness of a bar was taken as the mean of measures taken throughout the length of the bar at points designated by the intersections of lines drawn parallel and at right angles to the axis of the bar.

The dimensions of the bars were measured at 20°, except those of steels Nos. 3, 4, 5, which were measured at 18°·25.

Determinations of the Coefficients of Expansion of the Bars.

To determine the coefficients of expansion of the bars I devised the apparatus shown in fig. 2. In a brass tube, T, the bar, B, rests in slots in the supports, S, S′. The tube, T, is slightly shorter than the bar, B. Washers of rubber (shown in black in the figure), of the same diameter as the outside diameter of the tube, are placed in the screw-caps, C, C′. These washers are perforated with holes of diameters smaller than the thickness of the bar. When the caps are screwed up the rubber washers press against the ends of the bar. This pressure is further increased by flat rings which surround the holes in the washers and are pressed against these washers by means of the springs, D, D′. By this arrangement the surfaces of the ends of the bars are exposed, while the contact of the washers on the bars makes a water and steam tight joint.

2.



Thus the bar may be surrounded with ice, or, with steam, or, with a current of water of different temperatures, and be cooled or heated up to its terminal planes, while the holes in the washers allow the micrometer screws, M, M′, to be brought in contact with the terminal planes of the bar. Two helical springs are attached to the column, A. The other ends of these springs are fastened to rods projecting from the tube, T. Thus the same pressure of contact is always made between the bar and the end of the micrometer screw, M. The tube, T, is supported in Vs, V, V′, and the greater part of the weight of the tube is taken off the Vs by helical springs fastened to a frame above the apparatus. The tension of these springs can be so regulated that the tube rests on the Vs with the same pressure when the tube has steam passing through it or when it is filled with ice. The column, A, and the Vs, V, V′, are insulated from the base of the apparatus by thin plates of ebonite, *e*. Between the binding screws, E and E′, and connected by wires, are the voltaic cell, F, the galvanometer, G, and a box of resistance coils, R. The micrometer-screw, M′, with which the variations in length of a bar are measured, is mounted as follows: The screw passes through its nut in a massive brass plate which rotates around nicely fitted centers at H. These centers are supported by two side plates not shown in the figure. A spring, K, is fastened to the lower part of the swinging nut-plate and brings this plate against the plate, L, firmly fastened to the base of the apparatus. When the swinging plate is vertical and the axis of the screw horizontal the swinging plate fits accurately the surface of the fixed plate, L. By turning the rod, N, the swinging plate and its screw can be rotated away from the bar. This arrangement allows the screw to be swung out of the way while the tube, T, is being placed in the Vs. Also, it prevents any strain between the micrometer-screw, M′, and the column, A; which would take place if M′ were fixed and it should be brought in contact with a hot bar in the tube, T.

With careful manipulation successive electric-contacts can be made on a bar in the tube, T, surrounded by ice, so that the variations in a series of measures will not exceed $\frac{1}{000}$ mm., with a resistance of about 200 ohms placed in the circuit.

It may be reasonably objected to this apparatus that when the micrometer-screw touches the bar at 0° it is cooled and shortened, and that when it touches the bar at 100°, or at temperatures higher than that of the screw, the latter is heated and elongated. This error, however, is quite small, and may be neglected in our work. If we assume that one centimeter of the screw is heated 10°, which is a large estimate, considering the duration of contact of screw and bar during a measure, the shortening or elongation of 1 cm. of the screw by cooling or heating it 10° amounts to only ·0012 mm., or $\frac{1}{166666}$ of the length of the bar. This change in the length of the screw will affect the coefficient of expansion of the bars only ·00000006.

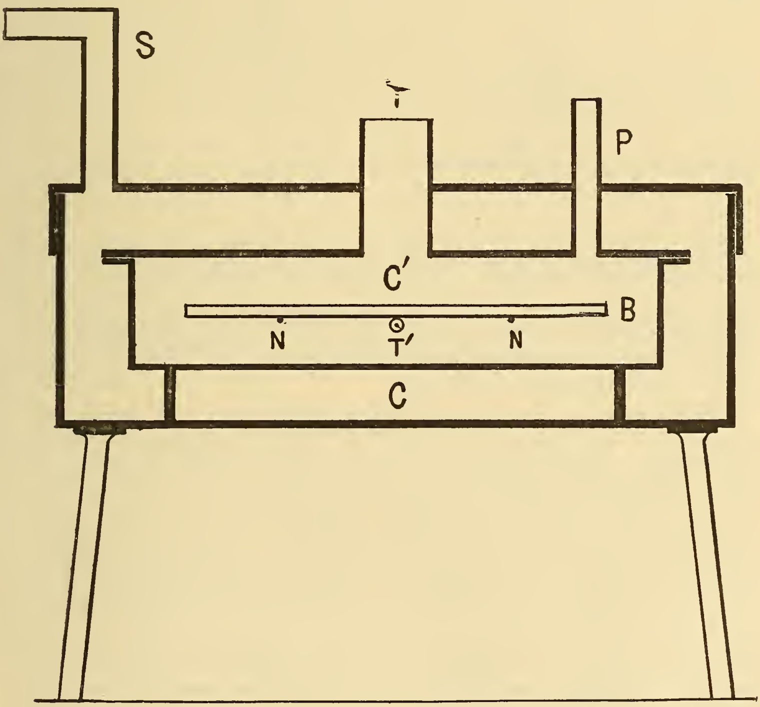
Determination of the Densities of the Bars at 4°.

The bar, whose density was to be determined, was immersed in water at 4° for a couple of hours. The bar was then suspended by a platinum wire in water at 4° and weighed. The bar was then removed from the wire and a quantity of water equal in volume to the volume of the bar was added to the water in the vessel, and the platinum wire, now immersed exactly as it was when the bar was attached to it, was weighed. This weight, subtracted from the previous weighing, gave the weight of the bar in water. Every precaution was taken to prevent, by means of screens, the action on the balance of the currents of cold air in the balance-case, which are produced by the constant descent of air from the sides of the cool vessel.

The Apparatus in which the bars were heated and cooled. On the precautions used so that one is sure of having the real temperature of the bar when it is vibrated.

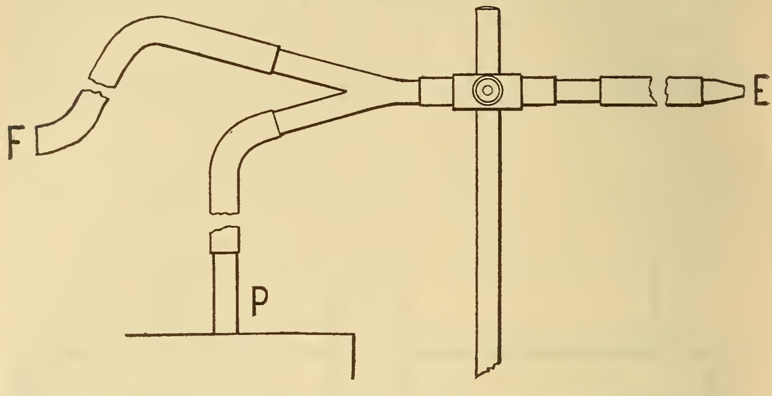
The apparatus used to heat and cool the bar is shown in fig. 3. In a brass box, C, is inclosed a box, C′, containing the

3.



bar, B, supported on its modes, N, N, by threads held by upright rods. From this central box two tubes, T, P, pass through the outer box C. The inner box is made water-tight and steam-tight by a rubber washer which is pressed between the top of the box and its cover by means of screws. Through the tube, T, the bar is vibrated by letting fall upon its center a rubber ball fastened to a light wooden rod. On the blow of the ball it rebounds and the rod is caught by the fingers in its upward motion. The cork is then at once replaced in the tube, T. The sound from the bar is conveyed to the ear, at E, by means of a tube (fig. 4). One branch of this bifurcated tube leads through a rubber tube to the pipe, P, of the box, fig. 3. The other branch leads to the fork, F, the number of

4.



whose beats per second made with the vibrating bar is measured by a chronometer. The pipe, S, allows the steam to issue when water is boiled in the box, C′, by a gas lamp. The flow of gas through this lamp was neatly regulated by a stopcock turned by a long lever. The box, C, is covered, except at the bottom, with thick felt.

To determine the frequencies of vibration of a bar through a range of temperature from 0° to 100°, the following method was used: The box, C, was filled with ice, surrounding the inner box, C′. It thus remained for an hour so that the boxes were cooled down to 0′, and the moisture in the inner box has been condensed so far as it can be at 0°. The bar, which has been in ice for two hours, is wiped dry and quickly introduced into the inner box. A thermometer, T (made by Baudin and corrected), entered the boxes through stuffing boxes, and whose bulb touched the under surface of the bar, was read till it became stationary. The bar was now vibrated and its frequency of vibration determined for the temperature given by the thermometer.

The lamp was now placed under the box and the water in it boiled till the thermometer reached its maximum reading and the reading remained stationary during a half-hour. The vibration frequency at this temperature was taken. The flame of the lamp was now lowered and the box allowed to cool very slowly, at the rate of 1° fall of temperature in about eight minutes. When the thermometer read 80°, 60°, 40°, the flame of the lamp was carefully adjusted, so that these successive temperatures were maintained during 15 minutes. We then took the frequency of vibration of the bar.

The numbers of vibrations of the forks used in the determinations of the pitches of the bars were corrected for temperature by the coefficient ·0001118, determined by Dr. Kœnig in 1880 (Quelques Experiences d'Acoustique, Paris, 1882, p. 172, *et seq*).

The subsequent tables show the results of the experiments and give the computations of velocities and moduli founded on them. The curves express graphically the effect of change of temperature on the modulus of elasticity of all the bars experimented on. The circles, on or near the curves, give the data as determined by the experiments.

In Table III, T=temperature of bars, l=the length, t=the thickness, and V=the velocity of sound through the bars, in centimeters. M=the modulus in grams per square centimeter section of the bar. g, at Paris, equals 980·96. D=the density, and N=the number of vibrations of bar per second at temperature, T.

All of the bars were annealed, except those of Jonas and Colver steel, of the French aluminum and of brass; these were experimented on just as they came from the draw-bench.

For the analyses of the substances of the bars experimented on, I am indebted to my colleagues, Professors Stillman and Leeds.

TABLE I.

Bar.	l.	t.	V at 20°=	N computed by $N=V\,1{\cdot}0279\frac{t}{l^2}$	N observed at 20°.	Diff.
Steel No. 1	20·022	·5025	150·02 × 3427·4 v. s.	662·49 v. d.	660·8	+1·69= $\frac{1}{390}$
" No. 2	20·0246	·5037	=514178cms	663·91 "	661·0	+2 91= $\frac{1}{227}$
" No. 3	20·0225	·5022		662 07 "	660·3	+1·77=+$\frac{1}{379}$
Aluminum.						
No. 1	20·0253	·4993	150·05 × 3377 v. s.	648·51 "	646·6	+1·91= $\frac{1}{333}$
No. 2	20 0296	·4991	=506719cms	647·97 "	647·0	+0·97= $\frac{1}{656}$
No. 3	20·0233	·4998		649·80 "	648·0	+1·8 = $\frac{1}{360}$
Brass.						
No. 1	20·02	·50116	150·05 × 2386·4 v. s.	460·23 "	459·0	+1·23= $\frac{1}{373}$
No. 2	20·02	·50147	=358079cms	460·53 "	458·95	+1·58= $\frac{1}{290}$
No. 3	20·02	·50108		460·16 "	458·35	+1·81= $\frac{1}{253}$
St. Gobain Glass	23·516	·747	152·2 × 3582 v. s. =538016cms	747·03 "	749·75	−2·72= $\frac{1}{275}$
White Pine. Density=·365	41·15	·803	171·18 × 3072·75 v. s. =525993cms	256·38 "	256·0	+0·38= $\frac{1}{673}$

Mean departure of computed from observed value $=\frac{1}{328}$ of observed value.

TABLE II.

Table of Analyses, of Densities at 4°, and of Coefficients of Expansion of Bars.

	Iron.	Carbon	Silicon	Phos.	Sulph.	Mang.	Nickel	
J. & C. Steel	98·259	1·286	0·015	0·059	0·031	0·350	----	Density @ 4°, 7·827, coef't. expan., ·0000110
No. 3 "	98·738	0·47	0·15	0·022	----	0·62	----	" " 7·848, " ·0000118
No. 4 "	98·628	0·51	0·158	0·024	----	0·68	----	" " 7·845, " ·0000120
No. 5 "	95·719	0·27	0·101	0·031	----	0·69	3·189	" " 7.851, " ·0000119
Bess'r. "	99·03	0·15	0·02	0·09	0·06	0·65	----	" " 7·841, " ·0000122

Brass.

Copper	64.34
Zinc	34 97
Lead	·58
Iron	·11
Density	8·476
Coeft. expan.	·0000185

Bell Metal.

Copper	80·08
Tin	18·97
Lead	·12
Zinc	·49
Density	8·347
Coeft. expan.	·0000187

Aluminum (Amer.).

Aluminum	98·99
Free Carbon (graphite)	·19
Combined Carbon	·16
Tin	·21
Silicon	·32
Iron	·15
Density	2·702
Coeft. expan.	·0000232

Aluminum (French).

Aluminum	97·80
Carbon with Si	·14
" free	·04
" with Copper	·09
Copper	1·29
Silicon	·64
Density	2·730
Coeft. expan.	·000022

Silver, Pure.

Density	10·512
Coeft. expan.	·0000184

Zinc.

Zinc	99·75
Iron	·10
Lead	·04
Density	6·8107
Coeft. expan.	·0000296

St. Gobain Glass.

Silicon	72·3
Alumina	·8
Lime	15·3
Soda	11·8
Density	2·545
Coeft. expan.	·00000777 (Fizeau.)

TABLE III.

Bar.	T.	l.	t.	$\frac{t}{l^2}$	D.	N.	$V=\frac{N}{1{\cdot}0279\frac{t}{l^2}}$	$M=\frac{V^2d}{g}$	M.
Jonas & Colver Cast Steel.	0·2	20·0207	·5036	·0012564	7·828	662·0	512602	2097585540	2097×10^6
	20	20·0246	·5037	·0012562	7·823	661·0	511908	2089805486	2090×10^6
	40	20·0286	·5038	·0012561	7·818	659·6	510112	2080863837	2081×10^6
	61	20·0328	·5039	·0012560	7·814	658·6	509389	2072936852	2073×10^6
	80	20·0366	·5040	·0012554	7·809	657·1	508470	2064153151	2064×10^6
	99·8	20·0406	·5041	·0012551	7·804	655·14	507065	2050537870	2050×10^6
Steel No. 3.	0	20·3513	·64049	·0015464	7·849	820·38	516124	2131430318	2131×10^6
	18·25	20·3558	·64063	·0015460	7·844	818·91	515329	2123515662	2123×10^6
	34	20·3594	·64074	·0015457	7·8395	817·50	514539	2115797406	2116×10^6
	60	20·3657	·64094	·0015453	7·832	814·70	512907	2100383667	2100×10^6
	80	20·3705	·64109	·0015449	7·8265	812·40	511586	2088031273	2088×10^6
	99·5	20·3752	·64124	·0015446	7·821	810·00	510175	2075047288	2075×10^6
Steel No. 4.	0	20·3517	·64295	·0015523	7·846	824·71	516238	2131556968	2135×10^6
	18·25	20·3562	·64312	·0015520	7·841	822·71	515708	2125826869	2126×10^6
	40	20·3614	·64328	·0015517	7·8345	821·25	514893	2117356581	2117×10^6
	51·5	20 3643	·64337	·0015514	7·831	819·67	514002	2109091886	2109×10^6
	81	20·3715	·64360	·0015508	7·823	816·30	512088	2091259452	2091×10^6
	97·6	20·3755	·64373	·0015505	7·819	814·00	510745	2079256951	2079×10^6
Steel No. 5.	0	20·3513	·64188	0015498	7·852	813·29	510527	2086250350	2086×10^6
	18 25	20·3559	·64202	·0015494	7·847	811·84	509757	2078637463	2078×10^6
	40	20·3609	·64218	·0015490	7·841	809·68	508529	2067052961	2067×10^6
	60	20·3657	·64233	·0015486	7·835	807·31	507168	2054430194	2054×10^6
	80	20·3706	64248	·0015482	7·829	805·02	505856	2042249532	2042×10^6
	99·5	20·3753	·64264	·0015479	7·824	802·71	504506	2030066264	2030×10^6
Bessemer Steel	0·4	20·451	·60144	·0014380	7·8421	761·37	515093	2121057163	2121×10^6
	20	20·456	·60160	·0014377	7·8364	759 80	514032	2110783287	2111×10^6
	40	20·461	·60176	·0014374	7·8306	757·70	512960	2100440462	2100×10^6
	60	20·466	·60190	·0014370	7·8248	755·41	511409	2086216940	2086×10^6
	80	20·471	·60205	·0014367	7·8192	752·90	509710	2070893085	2071×10^6
	100	20·476	·60220	·0014363	7·8134	749·90	508026	2055702283	2056×10^6
Brass when bar was cooled from 99°·6 to 1°.	1°	22·0128	·5009	·0012506	8·4774	460·64	358337	1109672142	1109×10^6
	21·8	22·0208	·5011	·0012501	8 4677	458·95	357307	1102010322	1102×10^6
	40	22·0274	·50126	·0012497	8·4592	457·40	356103	1093479554	1093×10^6
	60	22·0348	·50144	·0012492	8·4498	455·70	355052	1085864045	1086×10^6
	80	22 0422	·50162	·0012488	8·4404	454·00	353727	1076578495	1076×10^6
	99·6	22·0494	·50180	·0012483	8 4312	452·30	352678	1069044150	1069×10^6
Brass before bar was heated to 99° 6.	0·4	20·0127	·5008	·0012504	8·4778	460·04	357928	1107191685	1107×10^6
	20	20·0208	·5011	·0012501	8·4685	458·35	356698	1098388907	1098×10^6
Bell Metal.	0	22·2402	·82054	·0016589	8·3490	572·05	335300	956864118	$956{\cdot}8\times10^6$
	21	22·2490	·82114	·0016588	8·3390	569·50	333806	947214927	$947{\cdot}2\times10^6$
	40	22·2568	·82168	·0016587	8·3302	567·12	332411	938324839	$938{\cdot}3\times10^6$
	50	22·2610	·82196	·0016587	8·3256	566·02	331766	934172231	$934{\cdot}2\times10^6$
	60	22·2650	·82224	·0016586	8·3208	564 94	331133	930074354	$930{\cdot}1\times10^6$
	74	22·2780	·82266	0016586	8·3144	563·61	330354	924989117	$925{\cdot}0\times10^6$
	99·75	22·2818	·82338	·0016584	8·3025	561·21	328946	915914824	$915{\cdot}9\times10^6$

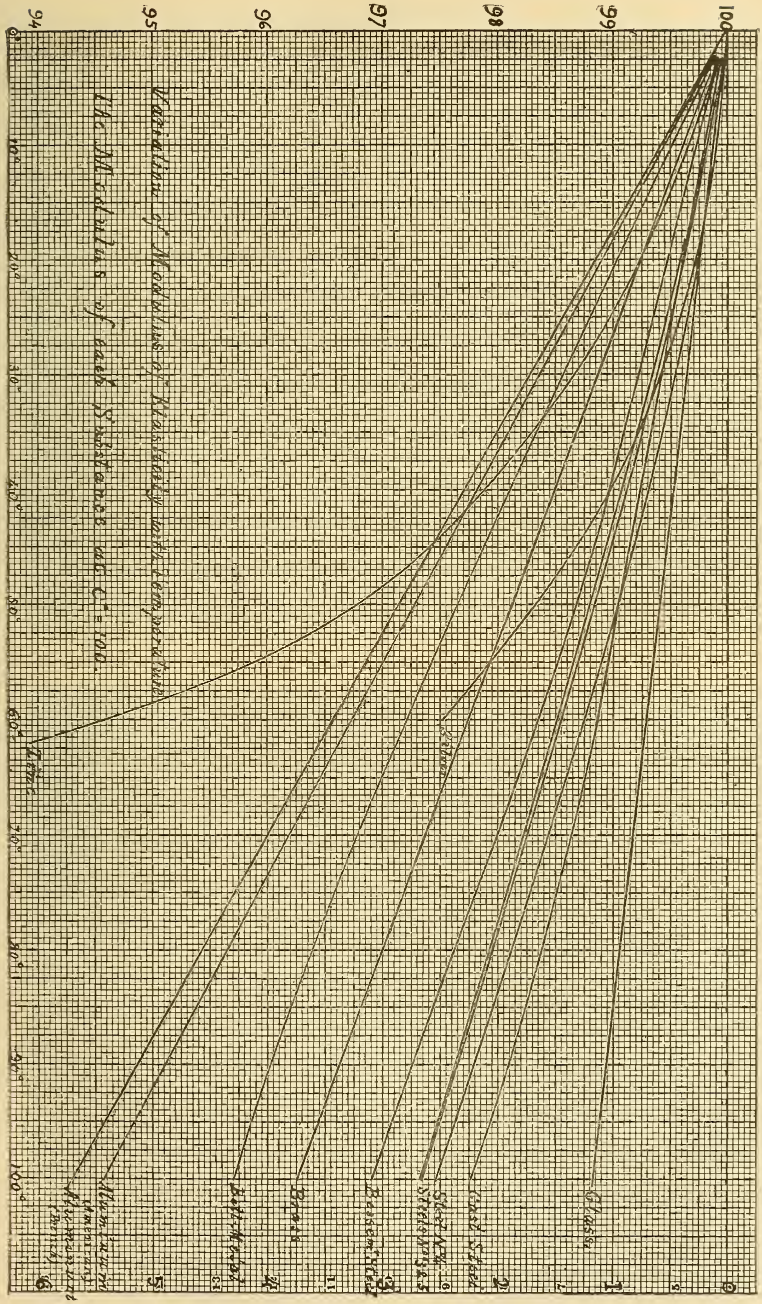
Bar.	T.	l.	t.	$\frac{t}{l^2}$	D.	N.	$V = \frac{N}{1·0279 \frac{t}{l^2}}$	$M = \frac{V^2 d}{g}$	M
Aluminum	0·4	21·612	·55176	·0011813	2·7027	621·00	511423	720621232	720·6 × 10^6
(American).	20	21·622	·55200	·0011807	2·6990	618·10	509032	712929083	712·9 × 10^6
	45	21·6346	·55232	·0011800	2·6943	613·90	505993	703215278	703·2 × 10^6
	60	21·6422	·55250	·0011796	2·6915	611·60	504516	698390199	698·4 × 10^6
	82	21·654	·55278	·0011789	2·6874	607·88	501447	688868686	688·8 × 10^6
	99·5	21·662	·55300	·0011785	2·6840	604·71	499247	681974176	681·9 × 10^6
Aluminum	0·5	20·0170	·49914	·0012457	2·7306	650·00	507632	717306505	713·0 × 10^6
(French).	20	20·0253	·49930	·0012451	2·7270	646·60	505375	710002959	710·0 × 10^6
	40	20·0340	·49950	·0012445	2·7232	642·78	502388	700672761	700·6 × 10^6
	60·5	20·0428	·49965	·0012438	2·7194	639·19	499977	692975831	692·9 × 10^6
	81	20·0518	·49980	·0012430	2·7156	635·50	497477	685124447	685·1 × 10^6
	100	20·0600	·50000	·0012425	2·7120	632·00	494734	676700317	676·7 × 10^6
Silver.	0·3	17·2176	·4614	·0015564	10·5142	437·93	273736	803135399	803·1 × 10^6
	20	17·2250	·46158	·0015557	10·5022	437·35	273489	800762642	800·7 × 10^6
	30	17·2284	·46168	·0015554	10·4962	436·80	273201	798729900	798·7 × 10^6
	40	17·2316	·46176	·0015551	10·4900	435·80	272626	794797589	794·8 × 10^6
	60	17·2380	·46194	·0015545	10·4778	433·00	270979	783307979	783·3 × 10^6
Zinc.	0·3	18·2094	·44517	·0013426	6·8130	559·84	405663	1142925404	1143 × 10^6
	20	18·2200	·44534	·0013415	6·8010	557·84	404501	1134426237	1134 × 10^6
	40	18·2308	·44552	·0013405	6·7890	553·76	401844	1117556599	1117 × 10^6
	50·5	18·2364	·44560	·0013399	6·7826	551·22	400294	1107903320	1108 × 10^6
	62	18·2426	·44570	·0013390	6·7758	543·61	394291	1073843790	1074 × 10^6
St. Gobain	0·3	23·496	·74898	·0013566	2·5452	750·65	538313	751865836	751·8 × 10^6
Glass.	24·5	23·501	·74902	·0013562	2·5436	749·67	537769	749885431	749·8 × 10^6
	40	23·503	·74910	·0013561	2·5424	749·12	537403	788511034	748·5 × 10^6
	60	23·507	·74922	·0013558	2·5411	748·35	536909	746742620	746·7 × 10^6
	80	23·510	·74934	·0013557	2·5397	747·62	536497	745196510	745·2 × 10^6
	99·5	23·514	·74945	·0013554	2·5384	746·70	535955	743311215	743·3 × 10^6

TABLE IV.

Variation of Modulus of Elasticity with change of Temperature.

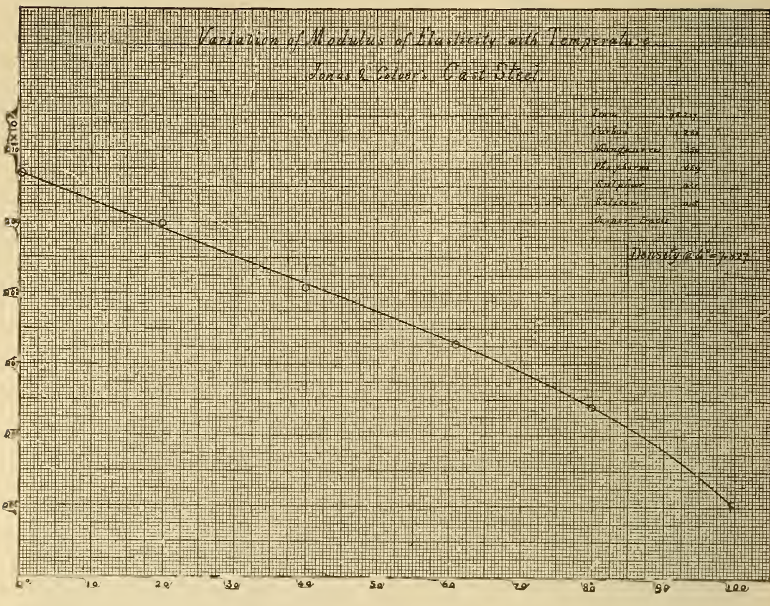
In this table the modulus of each substance is taken as 100 at 0°. In computing this table the moduli taken were those obtained from the curves passing through the mean positions of the points determined by the experiments. The results contained in this table are expressed graphically in fig. 5.

T.	J. & C. Steel.	Steel No. 3.	Steel No. 4.	Steel No. 5.	Bessemer Steel.	Brass.	Bell Metal.
0°	100·00	100·00	100·00	100·00	100·00	100·00	100·00
20°	99·61	99·57	99·70	99 58	99·53	99·26	99·03
40°	99·25	99·10	99·31	99·10	98·99	98·51	98·09
60°	98·87	98·58	98·8	99·54	98·35	97·76	97·21
80°	98·42	98·00	98·22	97·98	97·63	97·03	96·38
100°	97·76	97·34	97·54	97·35	96·91	96·27	95·70
	Aluminum (Amer.).	Aluminum (French).	Silver.	Zinc.	St. Gob. Glass.		
0°	100·00	100·00	100·00	100·00	100·00		
20°	98·92	98·86	99·73	99·26	99·88		
40°	97·83	97·73	98·97	97·78	99·76		
60°	96·75	96·58	97·53	93·96 (62°)	99·53		
80°	95·67	95·42	----	----	99·30		
100°	94·59	94·31	----	----	98·84		

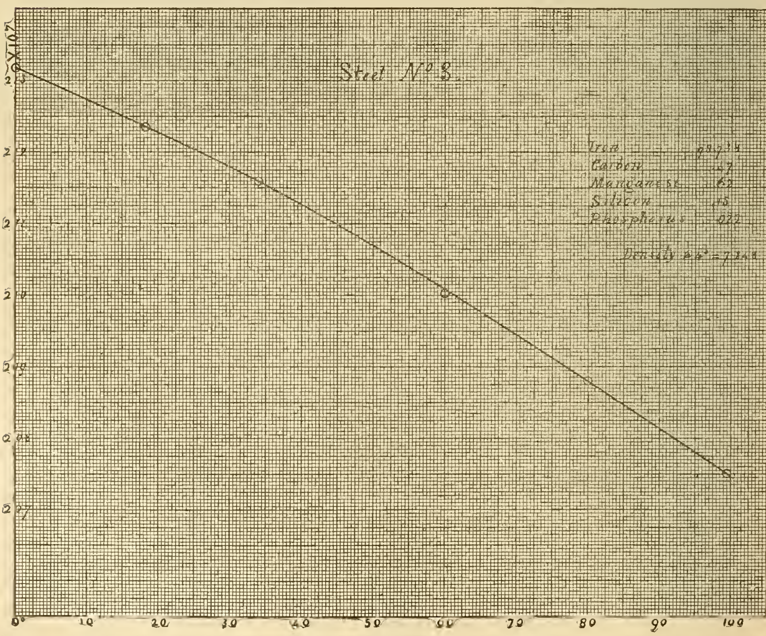

Variation of Modulus of Elasticity with temperature
The Modulus of each Substance at C° = 100.
94
95
96
97
98
99
100
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
Zinc
Silver
Glass
Cast Steel
Brass

5.

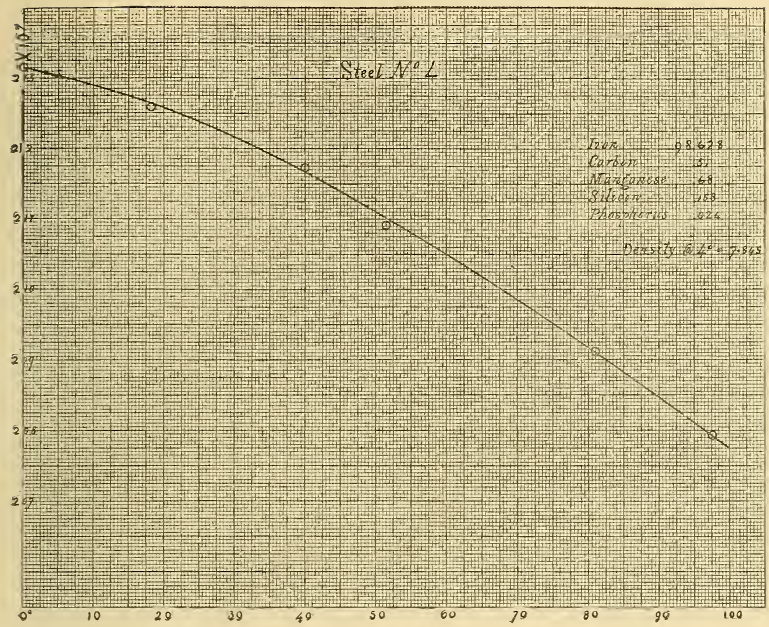
6.


Variation of Modulus of Elasticity with Temperature.
Jonas & Colver's Cast Steel.
0°
10
20
30
40
50
60
70
80
90
100

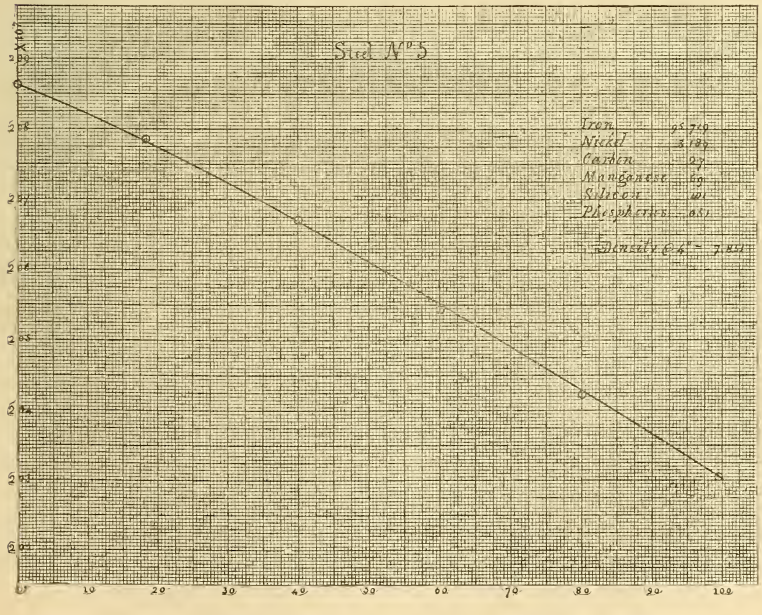
7.


Steel N° 8.
Iron
Carbon
Manganese
Silicon
Phosphorus
0°
10
20
30
40
50
60
70
80
90
100

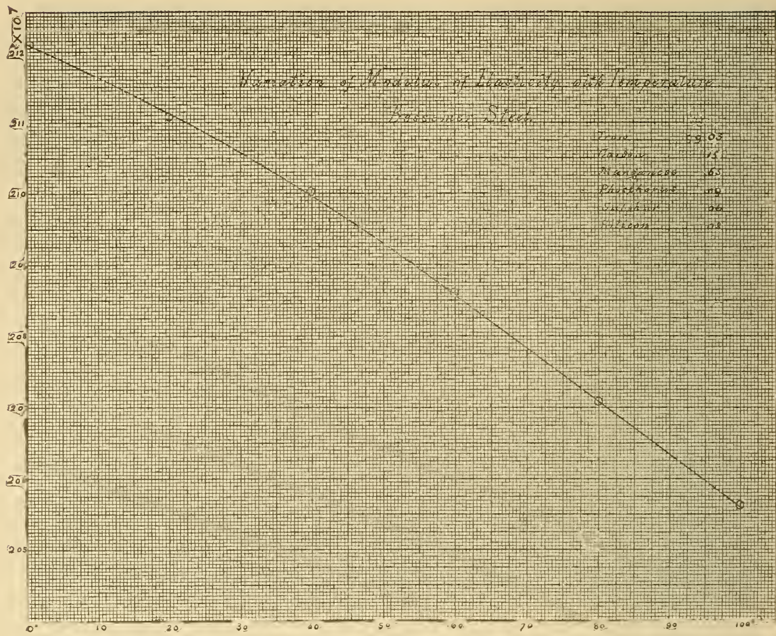
8.


Carbon
Manganese
Silicon
Phosphorus
Density @ 4° = 7.845
0°
10
20
30
40
50
60
70
80
90
100

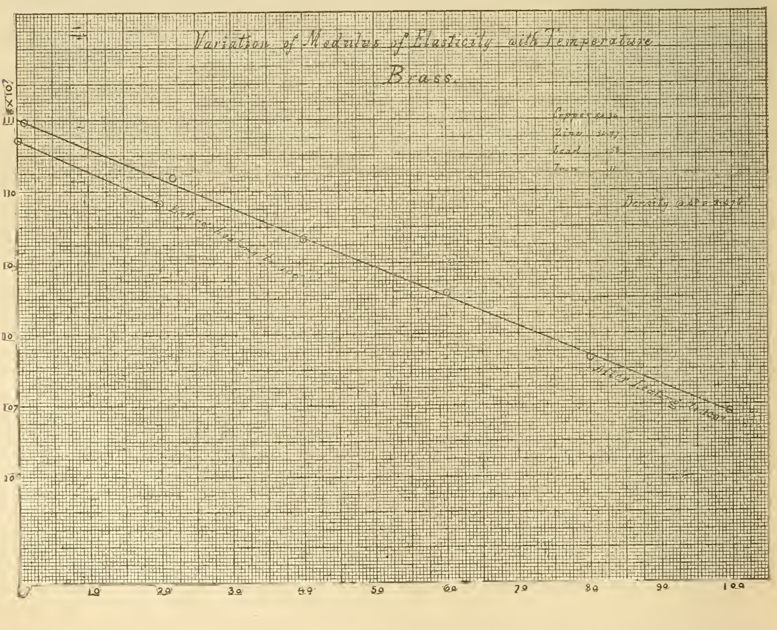
9.


Steel N° 5
Iron
Nickel
Carbon
Manganese
Silicon
Phosphorus
Density @ 4° = 7.851

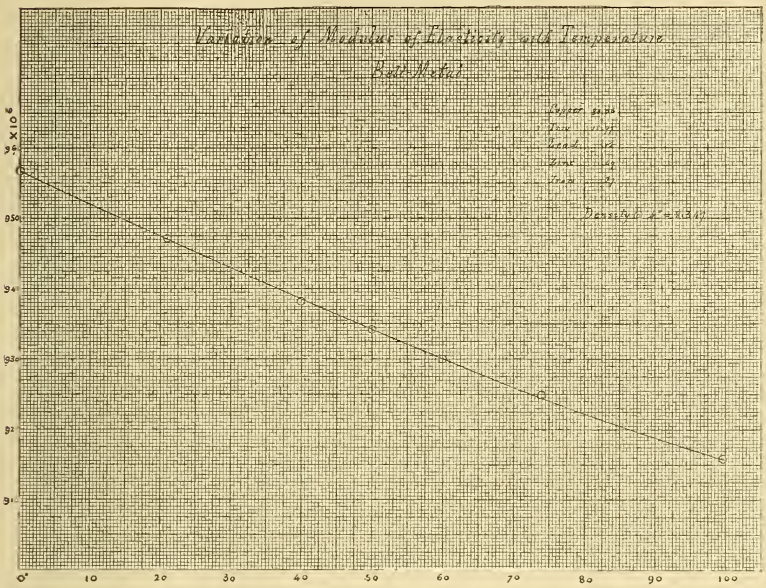
10.


Variation of Modulus of Elasticity with Temperature
Bessemer Steel.
Iron 99.03
Carbon .15
Manganese .65
Phosphorus .09
Sulphur .06
Silicon .03

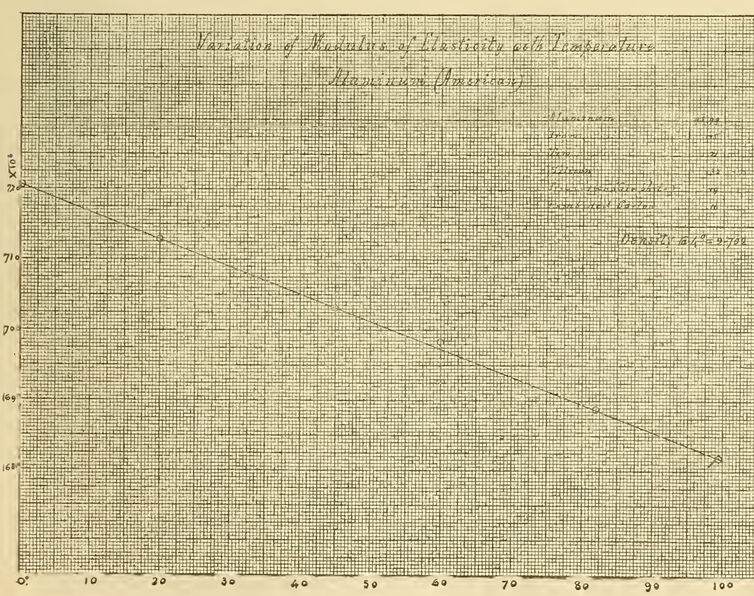
11.


Variation of Modulus of Elasticity with Temperature
Brass.
Copper
Zinc
Lead
Iron

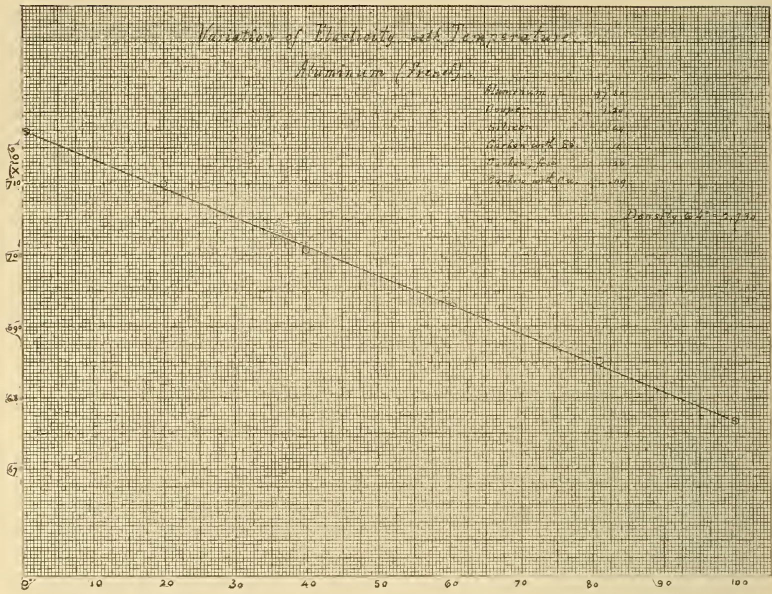
12.


Variation of Modulus of Elasticity with Temperature
Bell Metal
0°
10
20
30
40
50
60
70
80
90
100

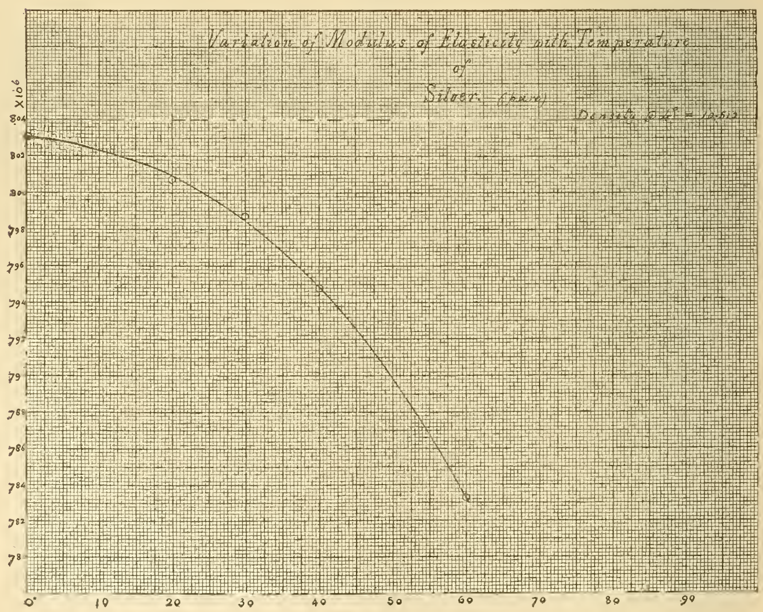
13.


Variation of Modulus of Elasticity with Temperature
Aluminium (American)
0°
10
20
30
40
50
60
70
80
90
100

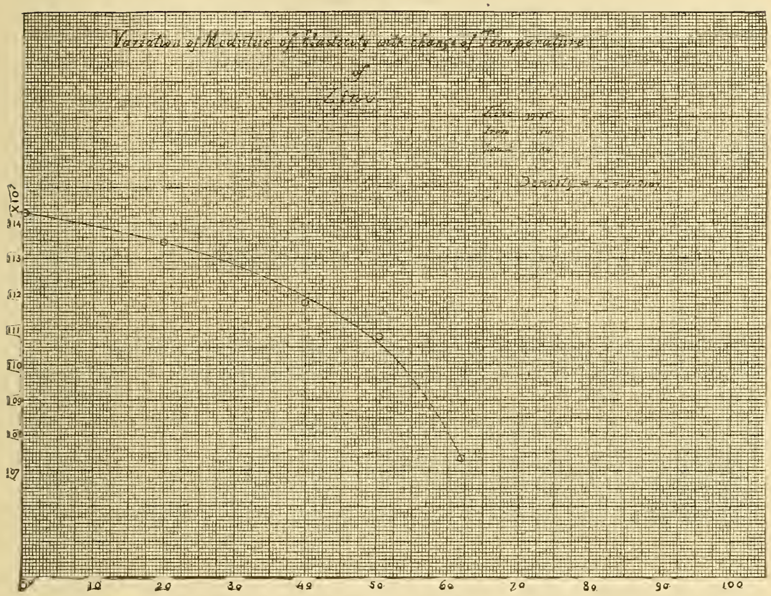
14.


Variation of Elasticity with Temperature.
0°
10
20
30
40
50
60
70
80
90
100

15.


Variation of Modulus of Elasticity with Temperature
of
Silver. (pure)
X10⁶
804
802
800
798
796
794
792
790
788
786
784
782
780
0°
10
20
30
40
50
60
70
80
90

16.


Variation of Modulus of Elasticity with change of Temperature
of
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20
30
40
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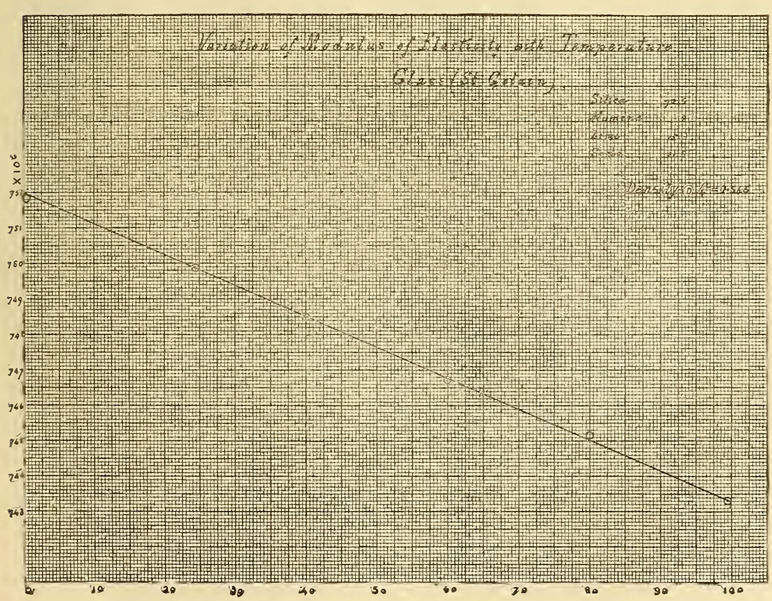
100

17.


Variation of Modulus of Elasticity with Temperature
Silica
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100

Results obtained by other Experimenters on the change of the Modulus of Elasticity with change of Temperature.

I have found five researches on this subject. I here give abstracts of results from these papers.

Wertheim, 1844. Ann. de Chim. et de Phys.

IRON.

Modulus 5·2 per cent greater at 100° than at 18°.
Modulus 19·1 per cent less at 200° than at 100°.

IRON WIRE.

Modulus 4·9 per cent greater at + 10° than at −11°·6.
Modulus 7·42 per cent greater at 100° than at 18°.

WIRE OF ENGLISH CAST-STEEL.

Modulus 23·23 per cent greater at 100° than at 18°.
Modulus 9·46 per cent less at 200° than at 100°.
Modulus at 200° is 11·57 per cent higher than modulus at 18°.

STEEL WIRE TEMPERED TO BLUE.

Modulus 1·97 per cent higher at + 10° than at −10°.
Modulus 5·1 per cent higher at 100° than at 18°.

CAST-STEEL.

Modulus 2·8 per cent less at 100° than at 18°.
Modulus 5·73 per cent less at 200° than at 100°.

SILVER.

Modulus 5 per cent less at + 10° than at −13°·8.
Modulus 1·87 per cent greater at 100° than at 18°.
Modulus 12·87 per cent less at 200° than at 100°.

COPPER.

Modulus 6·53 per cent less at + 10° than at −15°.
Modulus 6·58 per cent less at 100° than at 18°.
Modulus 20· per cent less at 200° than at 100°.

WIRE OF BERLIN BRASS (Cu.=67·55 . Zn.=32·35).

Modulus 7·95 per cent less at + 11° than at −10°.

Kupffer, 1856. Mem. de l'Acad. de St. Petersb.

Modulus of iron wire 5·5 per cent less at 100° than at 0°.
Modulus of copper wire 8·2 per cent less at 100° than at 0°.
Modulus of brass wire 3·9 per cent less at 100° than at 0°.

Kohlrausch and Loomis, 1870. Pogg. Ann.

Modulus of iron wire 5 per cent less at 100° than at 0°.
Modulus of copper 6 per cent less at 100° than at 0°.
Brass 6·2 per cent less at 100° than at 0°.

H. Tomlinson, 1887. Phil. Mag.

Says, "my own experiments show that both the torsional and longitudinal elasticities are decreased about $2\frac{1}{2}$ per cent when the temperature of steel is raised from 0° to 100°."

M. C. Noyes, 1895. The Physical Review.

Modulus of a piano wire of $\frac{4}{10}^{mm}$ diam. 5 per cent less at 100° than at 0°.

The results of Wertheim's experiments giving an increase to the modulus, as the temperature rises, of iron, iron wire, wire of English cast-steel, steel wire drawn to blue and silver, have not been confirmed in any instance by subsequent experiments; only for cast-steel *rod* and copper did he obtain a diminution of modulus for a rise of temperature from 18° to 100°. Yet, he found that a *wire* of English cast-steel had a modulus 23 per cent higher at 100° than at 18°.

On the Acoustical Properties of Aluminum.

The low density (2·7) of aluminum combined with a modulus of elasticity of only 712×10^6 renders this metal easy to set in vibration; a transverse blow given to a bar of this metal causes it to vibrate with an amplitude of vibration greater than that which the same energy of blow would have given to a similar bar of steel or of brass. This fact has given rise to the popular opinion that aluminum has sonorous properties greatly exceeding those of any other metal. This opinion is erroneous. If a bar of aluminum and a bar of brass having the same length and breadth and giving the same note, are struck transversely so that the bars have the same amplitude of vibration, the bars give equal intensity of sounds; but the bar of aluminum from its low density and because of its internal friction will vibrate less than one-third as long as the bar of brass. Thus, a bar of aluminum and a bar of brass of the same length and width and of such thickness that they gave the same note, SOL_4 of 768 v. d., were vibrated so that the sounds at the moment of the blows were, as near as could be judged, of the same intensity. The duration of the sound of the brass bar lasted 100 seconds; the sound of the aluminum bar lasted 30 seconds.

The readiness with which a bar of aluminum vibrates when acted on by aerial vibrations of the same frequency as those given by the bar, gives one the means of making many charming experiments in which "sympathetic vibrations" come into play.

I here describe an experiment which I devised to show the interference of sound in a manner similar to analogous experiments in the case of light. The resonant box on which Koenig mounts his UT_5 (1024 v. d.) fork is open at both ends and has a length of nearly a half wave of the sound of the fork. If this resonant box is held with its axis vertical, above an aluminum bar in tune with the vibrating fork, the bar does not enter into sympathetic vibration with the fork, because the sonorous pulses, on reaching the aluminum bar from the two openings of the resonant box, differ in phase by one-half wave-length. But if the axis of the box is held parallel to the axis of the bar, then the sonorous waves reaching the bar have travelled over equal lengths from the openings at the ends of the box, and these waves conspire in their action and the aluminum bar enters into sympathetic vibration.

As this experiment is an interesting one, I here give details as to the manner of making it. The bar of aluminum has a large surface, having a length of 17^{cms} and a width of 5^{cms}. The two nodal lines, which are distant from the ends of the bar equal to $\frac{2}{9}$ths of its length, are drawn on the bar. The bar is supported under these nodal lines on threads stretched on a frame. This frame is of such a height that the under surface of the aluminum bar is $8{\cdot}4^{cms}$, or one-quarter wave length, above the surface of the table, so that the vibrations of the bar and those of the waves reflected from the table will act together. The upper surface of the bar is covered with a piece of thick cardboard, in which is cut a rectangular aperture, having for length the distance between the nodal lines and a width equal to that of the bar. As this piece of cardboard rest on supports which lift it a slight distance above the surface of the bar, the latter, when it vibrates, does not send to the ear the vibrations of the surfaces of the bar included between its nodal lines and its ends, and which vibrations are opposed in phase to those given by the central area of the bar. Thus the sound emitted by the bar is much increased and the experiment rendered more delicate and improved in every way. I have found that the experiment succeeds best when the center of the resonant box is held about 58^{cms}, or, $7\frac{\lambda}{4}$ above the surface of the aluminum bar. This experiment works best in the open air, away from the action of sound-waves reflected from the walls and ceiling of a room.

The fact that aluminum gives, from a comparatively slight blow, a great initial vibration and that its vibrations last for a short time, render this metal peculiarly well suited for the construction of those musical instruments formed of bars which are sounded by percussion and the duration of whose sounds is not desirable.

I had hopes that the aluminum would prove to be a good substance out of which to make plates on which to form the acoustic figures of Chladni. Experiments have shown that aluminum is not suited to this purpose. I had plates of aluminum carefully cast, with 2^{cms} of thickness. These plates were turned down on the face-plate of a lathe to thicknesses of 2^{mm} and $3{\cdot}8^{mm}$. Three of these plates were quite homogeneous in elasticity, for the Chladni figures when obtained on them were symmetrical. Yet the Chladni figures were difficult to produce, because it is difficult to obtain a pure tone from an aluminum plate. The sound is generally more or less composite; therefore, the plate in its vibration tends to form two or more figures at the same time, and the consequence is that either no figure is formed or one is given that is not sharply defined. One square plate of $30{\cdot}8^{cms}$ on the side and $\cdot38^{cm}$ thick, gave quite clearly the three following tones: UT_2 (1), SOL_2 (2), and SOL_4 (3). Corresponding respectively to the Chladni figures of (1) two lines drawn from opposite points of the center of sides of plate; (2) figure formed of the two diagonals drawn from the corners of plate; (3) figure similar to (1) but with corners of plate cut off by curved lines. Fig. 4 corresponded so nearly to the sound of SOL_4 that a vibrating SOL_4 fork when held near the plate set the latter into vigorous vibration.

Another difficulty met with in using plates of aluminum for Chladni's figures is that sand, even when entirely free of salt and of the globular grains of wind-blown sand, does not move freely over a vibrating surface of aluminum, whether this surface has been polished or has been slightly tarnished and roughened by the action of alkali.

There is one serious objection to the use of aluminum in the construction of musical and acoustical instruments, and that is the great effect that the change of temperature has upon its elasticity. If a bar of aluminum and a bar of cast-steel be tuned at a certain temperature to exact unison, a change from that temperature will affect the frequency of vibration of the aluminum bar $2\frac{1}{2}$ times as much as the same change of temperature will affect the bar of cast-steel.

Art. XII.—*On the Improbability of Finding Isolated Shoals in the Open Sea by Sailing Over the Geographical Positions in which they are Charted;* by G. W. Littlehales, U. S. Hydrographic Office.

Many of the isolated shoals that are represented on nautical charts of the oceans have been located from the reports of mariners who have discovered them incidentally in making voyages of commerce. Previous to the year 1860, when there was no exact knowledge of the depths of the oceans, the vague reports of navigators, often doubtless based upon the observation of floating objects and of misleading appearances of the surface of the sea, caused the charting of many dangers for the existence of which there is no substantial foundation. But, as our knowledge of bathymetry increased, the existence of many of them was disproved, and they were removed from the charts.

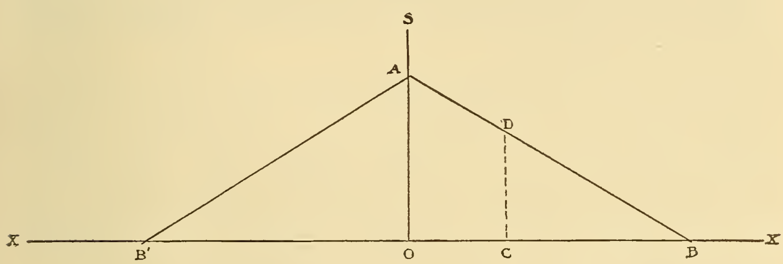
As a result of these experiences, there arose a traditional distrust among mariners and hydrographers of the existence of many of these dangers that still appear on the charts with well founded evidence, and there is perhaps a disposition on the part of many to claim that they should be removed upon scant evidence of their non-existence. It is not uncommon for a mariner to report that, being in the vicinity of a charted rock or shoal, he laid his course so as to pass over the geographical position assigned to it with one hundred fathoms of line out or with lookouts posted aloft, but was unable to detect any evidence of its existence, and that he does not believe, therefore, that the rock or shoal exists. It seems necessary, therefore, to inquire into the degree of confidence that can be placed in such a piece of evidence of the non-existence of a danger, and to establish what probability there would be of finding it under these conditions.

Suppose that A discovers, in the open ocean, a shoal r miles in radius, and determines the geographical position of its center subject to extreme errors of m miles in longitude and n miles in latitude; and that B, who is able to establish his geographical position within the same limits of extreme error as A, attempts to find the shoal again by proceeding to the geographical position assigned to it by A. What is the probability that he will find it?

If A, after making the discovery, had revisited the shoal a great number of times and had deduced the latitude and longitude of the same spot, under the same circumstances, at each visit, the latitudes would all differ from the true latitude and, likewise, the longitude from the true longitude. If we call the differences between the true latitude and each deduced latitude errors of latitude and lay them off, according to their signs, to the right and left of an assumed origin, and then, corresponding to each error as an abscissa, erect an ordinate of a length proportional to the probability of that error, these ordinates and abscissas will be the coördinates of the probability curve. And, likewise, if the errors in longitude were found and plotted in conjunction with their probabilities, a similar curve would be developed.

In this investigation the probability curve, ordinarily represented by Laplace's formula, $y = ce^{-a^2t^2}$ will be replaced by two equally inclined straight lines AB and AB′ as shown in figure 1.

1.



This substitution, which has been employed by Hèlie in his Traitè de Balistique Expèrimentale and referred to by Wright in his work on the Adjustment of Observations, causes an appreciable but extremely small error which has no practical significance when we consider that, from the nature of the calculations about to be made, absolute precision is not to be sought.

The probability of having an error between Oc $= x$ (figure 1) and $x + \Delta x$, to the right of the axis OS, is equal to $s \, . \, dx$. As, in this case, OB and OB′ measure the extreme errors, all possible errors are comprised between zero and OB, and zero and OB′; and the sum of all the elements which are singly represented by $s \, . \, dx$, or the area of the triangle ABB′, should be equal to unity, which is the measure of certainty. The equation to the straight line AB will be, calling m the extreme error OB and b the intercept on the axis of S,

$$\frac{s}{b} + \frac{x}{m} = 1$$

but, since the area ABB′ $= b \times m = 1$ or $b = \frac{1}{m}$ this equation becomes

$$sm + \frac{x}{m} = 1$$

or

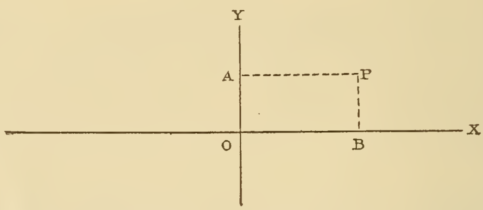
$$s = \frac{m-x}{m^2}$$

And since x can only vary between zero and m, the probability of having an error between x and $x+\Delta x$

$$p_1 = \frac{m-x}{m^2} \, . \, dx \qquad (1)$$

The causes which produce the grouping of a number of deduced geographical positions around the true one are of two kinds; one tending to place the deduced latitude to the north or south of the true latitude, and the other tending to place the deduced longitude to the east or west of the true longitude. So that a particular deduced geographical position P will be the result of having an error OA in latitude and an error OB in longitude.

2.



The probability that the geographical position deduced by A, upon his discovery of the shoal, occupies a certain position with reference to the true geographical position of the shoal is, therefore, easily deduced. Through the true geographical position of the shoal let two rectangular axes, OX and OY, be passed as shown in figure 2. Upon the former conceive errors in longitude to be measured, and upon the latter, errors in latitude. The position P, of which the coördinates are x and y, results from the concurrence of two conditions, the error of x miles in longitude and the error of y miles in latitude. The probability p_1 of the error x is, as shown by equation (1),

$$p_1 = \frac{m-x}{m^2} \, . \, dx$$

and, in the same manner, the probability p_2 of the error y will be

$$p_2 = \frac{n-y}{n^2} \, dy \qquad (2)$$

In these formulas, m and n represent respectively the extreme errors in longitude and latitude in miles.

The probability p of having, at the same time, the error x and the error y, or of deducing the geographical position P as the position of the shoal, will be the product p_1, p_2, or

$$p = \frac{(m-x)\ (n-y)}{m^2n^2}\ dx\,.\,dy \qquad (3)$$

an equation in which x can vary from zero to m, and y from zero to n. It is, therefore, applicable to the first right angle of the axes OX and OY, but, in order to make it applicable to other quadrants, it is only necessary to change the signs of x and y.

Equation 3 then expresses the probability that A's determination of the geographical position of the shoal is in error by x miles in longitude and y miles in latitude.

If the center of the shoal were really located in the geographical position assigned to it by A, and B should succeed in coming within r miles of it, he would find the shoal since its radius is r miles.

We have, therefore, as the second step in the solution of the problem, to determine what is the probability that B will come within a circular area, r miles in radius, having its center anywhere within the rectangle described about the true position of the shoal with sides equal to the extreme errors to which the determinations of latitude and longitude by A and B are subject.

To find the probability, P, of coming within any portion of the rectangle of extreme errors inclosed by a curve whose equation is $y = f(x)$, it is sufficient to integrate the expression (3) between limits depending only upon $y = f(x)$, and we shall have, in the first right angle,

$$P = \frac{1}{m^2n^2}\int dx \int (m-x)\ (n-y)\ dy \qquad (4)$$

For a circular area of radius r, we shall have for the first quadrant,

$$P = \frac{1}{m^2n^2}\int_0^r (m-x)\ dx \int_0^{\sqrt{r^2-x^2}} (n-y)\ dy$$

and for the whole circle,

$$P = \frac{4}{m^2n^2}\int_0^r (m-x)\ dx \int_0^{\sqrt{r^2-x^2}} (n-y)\ dy$$

or

$$P = \frac{2r^2}{mn}\left\{\frac{\pi}{2} - \frac{2r}{3m} - \frac{2r}{3n} + \frac{r^2}{4mn}\right\} \qquad (5)$$

The probability that B will find the shoal depends upon the concurrence of two independent conditions whose separate probabilities are represented by equations (3) and (5) respectively, and is, therefore, equal to P . p, or

$$\frac{2r^2}{mn}\left\{\frac{\pi}{2}-\frac{2r}{3m}-\frac{2r}{3n}+\frac{r^2}{4mn}\right\}\frac{(m-x)\ (n-y)}{m^2n^2}.dx.dy \qquad (6)$$

Integrating the two expressions which make up equation (3) between the limits x and $x+\Delta x$ and y and $y+\Delta y$, respectively, the above expression becomes:

$$\frac{2r^2}{mn}\left\{\frac{\pi}{2}-\frac{2r}{3m}-\frac{2r}{3n}+\frac{r^2}{4mn}\right\}\frac{\Delta x}{m}\left(1-\frac{2x+\Delta x}{2m}\right)\frac{\Delta y}{n}\left(1-\frac{2y+\Delta y}{2n}\right),$$

which, for $r = 1$ mile, $x = 2$ miles, $y = 2$ miles, $m = 10$ miles, $n = 10$ miles, and Δn and Δy each equal to 1 mile, becomes $\frac{1}{6173}$. That is, under the conditions stated, B would stand one chance in 6173 of finding the shoal.

Art. XIII.—*Notes on Sperrylite*; by T. L. Walker.

The interesting mineral sperrylite was first described by Professors Penfield and Wells in 1889.* Being a diarsenide of platinum and crystallizing in pyritohedral forms, it serves to link the platinum group of metals with the iron group, since in the latter group diarsenides and disulphides commonly crystallize in pyritohedral forms. In June, 1893, the writer obtained permission from Mr. H. P. McIntosh, secretary of the Canadian Copper Company, to visit the Vermillion mine in Algoma, Ontario, and to obtain specimens of sperrylite and associated minerals. The notes here submitted are derived from an examination of the material collected.

Professor Penfield described four crystal forms on sperrylite, (111), (001), (110) and π(210), but he also adds: "Some crystals appear to be somewhat rounded by other faces, but none of the latter could be determined."†

Some of the larger and more promising crystals were examined under the microscope. The common forms observed were (111) and (001), generally in combinations in which the former usually predominates. The form (110) was not recognized on any of the crystals examined. π(210) could be seen on most of the larger crystals, though the faces were generally small. Another form was observed which replaces the angles formed by (111), (001), and π(210). The edges formed by the intersection of these new faces with π(210) are parallel, and hence the new form belongs to the same zone as π(210). The

* This Journal, xxxvii, 67, 71, 1889; Zeitschr. f. Kryst., xv, 285 and 290.
† Zeitschr. f. Kryst., xv, 291.

edges formed by the intersection of the cubic faces with the octahedral faces and with the new faces, form on the cubic faces plane angles which gave the following measurements:

155° 35′	156° 15′
155° 55′	156° 20′
156° 10′	156° 50′

Average measurement, 156° 9′.
Calculated for $\pi(10{\cdot}5{\cdot}2)$ 156° 49′.

The calculated symbol for these new faces agrees very closely with the di-dodecahedron $\pi(10{\cdot}5{\cdot}2)$, which has not been previously determined for sperrylite; $\pi(11{\cdot}5{\cdot}2)$ occurs on pyrite and is very close to the faces here described. There are still other faces present on some of the crystals, but they are too small to be determined on the present material.

Small crystals are frequently observed, half-imbedded in the cubic faces of the larger ones. These guest crystals appear to possess the same orientation as the host, and generally show combinations of (001) and (111). The hemihedral faces may occur on the smaller individuals, but could not be determined. In intergrowths of pyrite, the pyritohedral faces are so disposed that the whole is regarded as interpenetration twins with the twinning axis normal to (110). This is well seen in the so-called "iron cross." That the crystals of sperrylite follow the same law of twinning is highly probable, but we cannot regard it as proved from the present observations. The detection of pyritohedra or di-dodecahedra on the guest crystals and the determination of their position with regard to that of the corresponding faces on the larger crystal, would settle the question beyond dispute.

Sperrylite occurs in loose decomposition products of chalcopyrite, pyrrhotite and other iron-nickel sulphides. The concentrates obtained by "panning" consisted principally of grains of chalcopyrite and pyrrhotite along with crystals of magnetite, sperrylite, and cassiterite. The chalcopyrite grains showed on closer examination that they frequently contain crystals of sperrylite. The fragments of pyrrhotite were carefully examined, but in no case could crystals of sperrylite be observed on them. The chalcopyrite is therefore the original host of the sperrylite. In this connection it may be mentioned that in all the copper-nickel mines of the Sudbury district, traces of the metals of the platinum group are found, and also that nickel matte from mines low in copper contains very little nickel, while mines richer in copper afford a matte proportionally richer in platinum. In short, the platinum contents of nickel matte in the Sudbury district is directly proportional to the copper contents, viz: proportional to the amount of copper pyrites in the original ore. This fact, taken in connection with the detection of sperrylite in fragments of chalcopyrite, while a careful search did not reveal it in the pyrrhotite fragments, renders it very probable that the platinum found in the Sudbury district, in the copper-nickel mines, in general occurs as sperrylite and that this mineral occurs generally if not exclusively in chalcopyrite. It should be mentioned here, however, that according to some analyses,* polydymite, which occurs very sparingly in some of the Sudbury mines, contains from 0·006 per cent to 0·024 per cent platinum. Sperrylite dissolves slowly in strong hot hydrochloric acid, more readily in aqua regia, while in nitric, sulphuric and hydrofluoric acids it is practically insoluble.

An analysis of Manhée matte from Murray mines gave the following results :

Nickel (with trace cobalt)	48·82%
Copper	25·92
Iron	2·94
Sulphur	22·50
Gold	·000075
Silver	·001775
Platinum	·000430
Iridium	·000056
Osmium	·000057
Rhodium	small quantity
Palladium	small quantity
Total	100·182393%

In this as in similar analyses made by others the presence of iridium and osmium is noted. In Professor Wells's analyses† of sperrylite these metals are not detected, though he was at special pains in searching for iridium. Baron H. B. von Foullon‡ concludes, from the presence of these metals in the Sudbury ores, that there is another mineral present which contains the iridium. This is possible, but more probably in some cases part of the platinum in sperrylite is replaced by the elements iridium and osmium. This would not appear to be the case, however, in the Vermillion mine sperrylite as shown by Professor Wells's analyses.

The above observations were carried on in the laboratories of the School of Mines at Kingston, Ontario, and at the Mineral Institute at Leipzig. For advice and assistance I am especially indebted to Dr. W. L. Goodwin and Professor Nicol of Kingston and also to Herrn Geheimrath Professor Zirkel of Leipzig.

Leipzig, Saxony, November, 1895.

* Bull. U. S. Geol. Survey, No. 64, p. 21.
† This Journal, 1889.
‡ Jahrb. d k. k. geol. Reichsanstalt, 1892, p. 301.

ART. XIV.—*Note on the Glaciation of Pocono Knob and Mounts Ararat and Sugar Loaf, Pennsylvania;* by HENRY B. KÜMMEL, PH.D.

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DURING the past field-season an opportunity was given me, in connection with my work on the glacial deposits of Northern New Jersey, to visit Pocono Knob, Monroe County, and Mounts Ararat and Sugar Loaf, Wayne County, Pennsylvania. The Pennsylvania State geologists* have held that during the glacial period these peaks were nunataks.

Pocono Knob is an outlier of Pocono Plateau, situated about nine miles northwest of Stroudsburg. The terminal moraine is well developed on its north and south flanks, about two-thirds of the way up the slope. Since this knob was examined by Lewis and Wright, a wagon road has been constructed up the northwest side and along the top of the hill for more than half a mile. This road affords almost continuous exposures to a depth of from one to three feet, along the top of the knob. Here was found a considerable variety of material, chiefly shales and sandstones of different color, texture, and lithological constitution, with some coarse conglomerate. Not a few of these had been worn to subangular form with more or less well marked planation surfaces. Fragments bearing striæ, of whose origin there can be no doubt, are not abundant, but ten or twelve cobbles were found, which bore unmistakable glacial scratches. Some of these occurred not more than thirty feet below the summit. The evidence is conclusive that the ice covered the western part of the hill to within at least thirty feet of the highest point. That it also covered the crest is very probable.

When one leaves the road and examines the weathered material on the surface, hidden, as it is, by vegetation, it is next to impossible to convince oneself, that there is any glacial debris on the knob, and during the earlier part of my investigation, before I had examined the exposures along the road, I held the same opinion as those who had earlier studied the ground.

On the highest point of the hill, the surface is strewn with large bowlders of disintegration, and the ledges show no signs of glacial action. No evidence of glaciation could be found on that part of the hill which lies east of the summit, where there are no exposures, but in view of what was found along the road, where the opportunity for observation is good, there can

* Lewis, Second Geological Survey of Pennsylvania, Terminal Moraine, Z, pp. 75, 271. White, idem., Susquehanna and Wayne, G5, pp. 25, 159.

hardly be any doubt but that the whole knob was covered by the ice. The amount of material left by it was, however, small.

North of Dry Gap, as the col connecting the knob with the plateau is called, the characteristic topography of the terminal moraine is strongly developed. Fresh cuts along the recently constructed line of the Wilkesbarre and Eastern railroad give fine exposures of the glacial deposits. Since the data now at hand prove that the ice covered the knob, the connection between these two parts of the moraine is probably through Dry Gap,* but the typical morainic topography is not developed at that point.

Sugar Loaf and Ararat, in the northwestern part of the State, are 2475 and 2650 feet high,† respectively, and rise about 500 and 700 feet above the general level of the surrounding plateau. Both are thickly covered with underbrush and timber, and exposures are almost entirely wanting. On the north face of Sugar Loaf, glacial material was found along an old wood road, two-thirds of the way up (as far as the road extended). Above that height nothing definite could be made out for lack of exposures. The surface, however, was not radically unlike that of the lower part of the hill. The few rock ledges which occur do not bear striæ, nor have they roche moutonnée surfaces. However, ledges of sandstone so exposed to the weather could hardly be expected long to retain glacial markings.

On Ararat the facts are much the same. From want of opportunity for critical examination I was unable to prove that the ice covered the highest points, nor was I able to satisfy myself that it did not.

Although in the present state of things, it is impossible to obtain conclusive data, there are certain considerations which indicate that the excepted view is probably not the correct one. At the Delaware Water Gap, the ice filled the gorge and overrode, with very little deflection, the crest of Kittatinny mountain, which rises 1300 feet above the river and 600 to 700 feet above the general level of Kittatinny valley. If the ice was of sufficient thickness to accomplish this at points less than seven miles from its margin, it seems improbable that the ice-sheet was not thick enough to override hills such as Ararat and Sugar Loaf, which rise less than 700 feet above the surrounding plateau, and which are seventy miles north of the margin of the ice. There can be no doubt but that, were the crests of these hills cleared and excavations made, traces of glacial drift would be found here as at Pocono Knob.

Geological Survey of New Jersey,
Trenton, N. J.

* This was suggested by Lewis in a supplementary note to his report (l. c., p. 271), although in the report he had mapped the moraine as extending around the eastern end of the knob.

† White, l. c., p. 17.

ART. XV.—*The Counter-twisted Curl Aneroid*;* by CARL BARUS, Hazard Professor of Physics at Brown University.

INTRODUCTORY.

1.—IT seems plausible to argue that much goes on in the atmosphere immediately related to pressure which the ordinary pneumatic barometer merely integrates, and of which it can give no detailed account. I refer both to the changes referable to the gusty character of the wind † and to pressure variations of a more subtle nature,‡ the origin of which may be considered in relation to the earth's magnetic and electrical field.

2.—The problems, therefore, are beyond the immediate scope of instruments of large mass like the ordinary mercury or water barometers. The conditions to be fulfilled are (1) great sensitiveness and (2) instantaneous indications; (3) registry subject to corrections of a purely scientific kind. It is when these three conditions are simultaneously demanded that the problem becomes formidably difficult. No matter what form of mechanism is selected, one is brought face to face at once with viscosity and with the thermal variations of both viscosity and of elasticity.

I desire in this paper to find out how far one can go with suitable modifications of the Bourdon tube. In certain measurements§ of high pressure made with such a tube coiled helically I received much encouragement, inasmuch as the instrument could be read off closely enough, without the aid of subsidiary mechanism. The difficulties which I then encountered were purely technical. In flattening and coiling the necessarily heavy tube, I had to remove the temper at a sacrifice of strength and resilience, and the gauge actually burst at 1000 atmospheres. I abandoned it simply because of the difficulty in fashioning this cumbersome apparatus in the laboratory.

In relation to low pressures, however, all of these difficulties fall away at once, and it becomes merely a question of patience to find the limit of constancy and precision to which a gauge of this kind can be pushed.

The conditions of sensitiveness were discussed not long ago

* The present research was encouraged by a fund kindly placed at my disposal by the Secretary of the Smithsonian Institution.

† Cf. S. P. Langley: "The Internal Work of the Wind," Smithsonian contributions, No. 884, 1893, Washington, D. C.

‡ Considerations of this kind originated, I believe, with the late Prof. Balfour Stewart. Recently the subject has been attacked more seriously, notably by Prof. F. H. Bigelow.

§ Barus: Bulletin U. S. Geological Survey, No. 96, p. 29, 1892. Cf. Proc. American Acad., xxv, p. 106, 1890.

by Prof. Worthington,* and in a more elaborate article by Prof. Greenhill.† There is not much succor to be gained from theory. The most lucid expression of the case is due to Lord Rayleigh.‡ His explanation meets the conditions of the present paper very fully, since the gauges are to be constructed with sharp edges and a spindle-shaped section, in order that the changes of shape occurring may be pure bending. § 8. Stretching would necessarily introduce resistances large as compared with the feeble forces to be measured. Since in the flexure of an inextensible surface, the product of the principle radii of curvature at a point of the surface remains constant (Gauss), any uniform sectional flattening of the walls of the tube due to increased external pressure must be compensated by an increased curvature of the axis ; and vice versa.

If the edges are sharp, there seems to be no advantage in increasing the height of the section, for the elastic resistances increase at the same time as the external pressure. There is, on the other hand, a disadvantage in wide tubes, for the length of the helix is thereby necessarily increased and the curl made more cumbersome, while the shape of the section cannot long remain regularly and uniformly arched.

Simple curls.

3. *Apparatus.*—There is, therefore, a demand for extremely thin metallic tubes, flattened nearly to the point of actual contiguity of the walls and left with almost sharp edges. Tubes made of metal as thin-walled as $0{\cdot}01^{cm}$ are manufactured abroad ;§ but American makers usually fall short of this remarkable accomplishment. I found, however, that it was quite possible to derive full advantage from the American tubes by *dissolving* off the outside layers in a suitable acid bath.

The tube at my disposal was made of copper, being like the material I formerly used in my calorimetric work.‖ This metal is elastically unpromising, apart from the technical advantages of smooth solution in diluted nitric acid, of easy flattening and bending, and of a small modulus of elasticity. Results, however, which can be obtained with copper tubes, can be much improved by the use of other more suitable metals, and for this reason the data of sensitiveness and constancy obtained would be an index of the possibilities of the gauge erring markedly on the side of safety.

Two methods suggest themselves for flattening: the tube

* Worthington: Nature, xli, p. 296, 1890.

† Greenhill: Nature, xli, p. 517, 1890.

‡ Rayleigh: Proc. Roy. Soc., Dec., 1888.

§ I owe most of my information in relation to thin tubes to Prof. Langley.

‖ Barus: Proc. Am. Acad., xxvi, pp. 316–317, 1891. The liquid was examined in a very thin tubular helix of copper, to insure rapid cooling in the calorimeter.

may either be compressed between steel rollers, then neatly coiled on a steel mandrel at the lathe with the turns one or two millimeters apart, so that the finished tube has the general form of a curl, and finally dissolved to the required thinness of wall in the nitric acid bath; or the tube may first be dissolved to the required lightness, then flattened and coiled as stated. The second of these methods is the best, though it requires a long tubular bath with a cistern at the top to avoid spilling the acid during the more or less violent effervescence in solution. The ends of the tube are stopped with corks, covered over with a cement of resin and beeswax, and all imperfect parts of the tube are similarly protected. The progress of solution is tested by taking weights from time to time, and when the tube is so light as to begin to float, it is suitably held down. A spring balance arrangement attached to the tube and out of the reach of the acid fumes, obviates the need of repeatedly removing the tube from the bath. Holes are sometimes eaten through the walls at defective places, probably from galvanic action. Should this occur, the tube must be cleaned at once, and cut apart at the defective place.

The first of the methods sketched above is more convenient, as the curl requires a much smaller bath. Unfortunately solution is most active at the edges; the tube becomes very fragile and is in danger of fissuring on continued use.

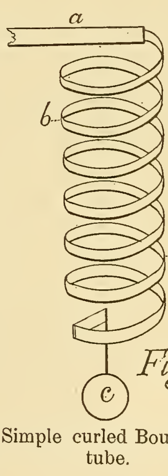


Fig. 1.

Simple curled Bourdon tube.

Tubes rolled down and coiled under a tense pull are apt to be quite closed. The way in which this can be remedied by *counter-twisting* will be described below (§ 8, et seq.), where closed tubes may even be an advantage. But in this place it is best to stretch two fine wires of brass or copper (say $0{\cdot}02^{cm}$ in diameter) from end to end of the tube, so that complete closure is avoided.

An interesting structural result was observed in this work. Open helices, with the turns about $0{\cdot}3^{cm}$ apart, after solution became closed helices with the turns all but touching at the edges, showing that the layers of the metal were subjected to unequal strains with a maximum of deformation at the outside.*

As a rule tubes must first be cleansed internally (to remove pulverulent or fatty matter) with ammonia, hydrochloric acid and water, and then thoroughly dried by a current of warm air. The finished curl is closed at one end, with the other

* Compare this with the gradual loss of explosive tendency of a Prince Rupert drop, when the external layers are successively etched off (Barus and Strouhal,

soldered to a suitable terminal tube to connect it with the air pump. The accompanying figure 1 shows the curl ready for experiment; *a* is the terminal tube leading to the air pump, *bb* the curl aneroid, *c* a mirror or other form of index, to register the rotation of the lower end of the curl relatively to the upper, when the air within is being exhausted. For convenience in drawing only a few turns of tube are shown in the figure.

4. *Results.*—In the first experiments the object sought was some *guidance* as to the effect of varying the diameter of the curls. Copper tube, with walls $0{\cdot}025^{cm}$ thick, was flattened till the spindle-shaped section was about $0{\cdot}5^{cm}$ high and $0{\cdot}08^{cm}$ wide, then wound so as to make an open helical spring. The diameter of the curl was successively reduced by winding on smaller mandrels, and the corresponding sensitiveness was found by comparing the curl with a mercury gauge when both were joined to the receiver of a Sprengel pump. The index at the bottom end of the centered curl moved over a graduated circle about a foot in diameter and divided in quarter degrees.

Table 1 contains an example of the results. The curl lengths are approximate, due to unavoidable irregularities of winding. In addition to the direct readings I will give the pressure difference in centimeters of mercury per degree of deflection (i. e. per degree of deviation between the terminal tangents of the helix), and the same datum taken per turn of the curl and per centimeter of the length measured along the turns of the helix. In general pressure denotes the difference of pressure between the outside and the inside of the tube and is always given in centimeters of mercury.

It appears therefore, that within the range of accuracy of these experiments, the untwisting of the curl in degrees of arc is very nearly proportional to the pressure difference in cm. of mercury, remembering that the pressure on the outside of the tube acts on the cistern of the barometer. In the second place, the sensitiveness of the coil for a given length of tube is somewhat greater for small radii than for large radii; thus for the diameter $3{\cdot}1^{cm}$, a degree of arc corresponds to $4{\cdot}07^{cm}$ of mercury, whereas for the diameter $2{\cdot}0^{cm}$, a degree corresponds to $3{\cdot}5^{cm}$ of mercury. The changes, however, are small and irregular and possibly largely influenced by temperature, which was not taken. At all events, the data for cm. of mercury per degree of deflection, per turns of curl, increases so rapidly, that in view of the objectionably great length of curls of small diameter, they offer no advantage. As a rule the diameter $2{\cdot}8^{cm}$ will be adhered to in the present paper.

this Journal, xxxii, p. 182, 1886); and with another result (this Journal, xxxiv, p. 183, 1887), in which the limit of torsional resilience of soft iron was reached whenever the obliquity of the external fiber of the wire exceeded about 0·003 radians.

TABLE 1.—*Behavior of Curls of different diameters, for the same length of tube coiled to a helix.*

Description of curl.*	Mercury Manometer.	Inflection of curl.	Cm. of Hg per degree of arc.	Cm. of Hg per degree per turn.	Cm. of Hg per degree per cm. of diameter.
Diam. of curl $3{\cdot}1^{cm}$	cm	°arc			
Turns of curl 21	76·7	18·7	4·07	85	1·3
Length of curl 18^{cm}	67·9	16·6	4·07		
	61·5	15·0	4·08		
	54·3	13·2			
	41·5	10·1			
	32·1	7·8			
Diam., $2{\cdot}8^{cm}$	76·3	21·1	3·55	87	1·5
Turns, 24	70·5	19·5	3·55		
Length of curl $19{\cdot}5^{cm}$	65·3	18·0	3·57		
	59·8	16·4	3·63		
	52·5	14·4			
	47·4	13·0			
	41·4	11·3			
	29·3	8·0			
Diam., $2{\cdot}0^{cm}$	60·3	17·4	3·45	121	1·7
Turns, 35	52·0	14·9	3·49		
Length of curl 22^{cm}	31·0	8 9			
	0·0	0·0			

Practically, in estimating the effect produced on thinning the walls by etching, I may therefore either express the number of cm. of mercury which correspond to a degree of arc per turn of the tube, in which case the same diameter should occur throughout or be specified; or I may make similar reference to the diameter; or finally (and probably best), I may state the centimeters of mercury per degree of deflection, of the coil per unit (cm.) of length of the tube used in winding the curl. Lumping the results of Table 1, where the length of tube used was about 210^{cm} throughout, it appears that in these initial experiments a pressure of about 780^{cm} of mercury would produce 1° of deflection between the ends (tangents) of a tube 1^{cm} long, and having the size and thickness specified.

The endeavor was now made to dissolve down this curl, but the action was carried too far and it was eventually lost in the process. After about $\frac{1}{3}$ of the weight had been etched off however, 61^{cm} of mercury corresponded to a degree of twist per turn for the diameter of curl $2{\cdot}9^{cm}$, or 550^{cm} of mercury per linear cm. per degree, showing a decided gain over the general data† of Table 1.

5. Another curl, No. V, was now wound, etched off and tested with the following results, after having been exhausted for some time. The original weight was 39^{g} and after etching

* The length of the curl and the length of the tube used in winding the curl must be carefully distinguished.

† A slight digression was made in coiling the next tube like a watchspring; but the experiment showed no special advantages.

20g, so that the walls must have been reduced in thickness from 0·025cm to about one-half this value,

Diam. of curl, 2·8cm	Pressure, 71·9cm, Hg	Deflection, 111°
Turns of curl, 22	59·5cm	97°
Length of curl 14·7cm	0·0	20°
	(later) 0·0	0°
	(next day) 0·0	−2°

Pressure per degree of arc per turn, 14·6cm, Hg.
Pressure per degree per linear cm., 130cm, Hg.

There has therefore been a considerable gain in sensitiveness,* inasmuch as the deflection of one degree between the ends of a linear centimeter of the coiled tube is now equivalent to 130cm of mercury. A new feature has been introduced in the apparent occurrence of marked viscosity, as shown by the gradual displacement of the "zero" reading for pressure difference. The cause of this will be further studied, but it is probably due to the tendency of external pressure to quite close the tube,† so that it takes the air some time to reënter.

This curl was now cut in two parts, V_a and V_b, of 9·5 and 11 turns respectively, in order to test whether the air had quite reached the extreme parts of the tube. An examination showed the following results:

			Pressure:	Deflection:
V_a	Diameter of curl,	2·88cm	72·0cm, Hg	49·6°
	Turns of curl,	9·5	64·3	43·7°
	Length of curl,		55·8	38·3°
			33·3	23·4°
			0·0	1·6°
			(later) 0·0	0·0°
	Pressure per degree per turn, 14·0cm.			
	Pressure per degree per linear cm., 122cm.			
V_b	Diameter of curl,	2·8cm	62·7cm, Hg	56·3°
	Turns,	11	53·9	49·6°
	Length,		46·2	43·8°
			35·6	35·3°
			0·0	7·9°
			(later) 0·0	0·0°
	Pressure per degree per turn, 14·3cm.			
	Pressure per degree per linear cm., 127cm.			

These results agree substantially with the data for the uncut curl, the discrepancies being due to the difficulties of estimating the number and diameter of the turns and to the occurrence of viscosity. It is seen that viscosity has in no way disappeared, though it is much more marked in V_b than in V_a.

* Data of the table taken in accord with other similar experiments on the same curl.

† There may also be a displacement of the zero due to friction of the walls of the tube on each other. Such displacement, however, would probably be permanent.

From this it follows that the viscosity in question must be in large measure *apparent* but not real. While V_b was preserved for other purposes, V_a was now further etched off. In so doing some of the turns had to be sacrificed, being eaten through. The results in these cases were more irregular, and apparent viscosity more marked. I will not therefore give them in full. After the first solution, 9 turns of V_a showed 13^{cm} pressure per degree per turn, or 107^{cm} Hg per degree per linear cm. After the second solution V_a showed $8{\cdot}7^{cm}$ pressure per degree per turn, or 77^{cm} pressure per degree per linear cm. It was imposible to carry the solution further, because the edges were too thin to withstand flexure without fissuring; but the walls were $0{\cdot}01^{cm}$ in thickness, and might easily have been reduced. cf. § 3.

Summary.—Remembering, therefore, that if viscosity were excluded, the curl would have been more sensitive, I may state that it takes from 50^{cm} to 75^{cm} of flat copper tubing, the walls being $0{\cdot}01^{cm}$ thick, to make a curl aneroid such that a degree of arc shall correspond to 1^{cm} of the barometer. If, therefore, the reading be made with mirror and telescope, with the scale at a distance of 286^{cm} from the mirror, 10 linear cm. of the scale correspond to 1^{cm} of the barometer. If the tube be wound on a mandrel a little over $2{\cdot}8^{cm}$ in diameter, 7 or 8 turns would suffice, and the length of the curl need therefore not exceed 8^{cm}. Hence, 10 such curls joined in series end to end and suitably supported, would show 100^{cm} at the telescopic scale per cm. of the barometer, and the curl would be less than a meter long. § 12.

Counter-twisted Systems.

7.—In the results thus far, the object has been merely to exhibit the possibilities of the curl aneroid. If the apparatus is to attain precision, the apparent viscosity must be brought quite under control, and the effect of the temperature of the medium evaluated and reduced to the smallest margin. I have in a measure fulfilled both these conditions by using counter-twisted systems in the way presently to be specified. As a first step in this direction, I will cite some data obtained with curl VIII, in which two fine brass wires (diameter $0{\cdot}02^{cm}$) were drawn through the tube before flattening and coiling. The walls were $0{\cdot}013^{cm}$ thick, and all but 5·2 turns were lost during solution.

Diam. of curl,	$2{\cdot}8^{cm}$	Pressure, $73{\cdot}7^{cm}$, Hg.	Deflection, 38·3°
Turns,	5·2	63·2	33·4°
Length of curl,	$3{\cdot}3^{cm}$	48·5	26·0°
		0·0	0·6°
		0·0	0·0°

Pressure per degree, per turn, $10{\cdot}4^{cm}$.
Pressure per degree, per linear cm., 91^{cm}.

The small residue of viscosity left here is very probably not even yet a true phenomenon, i. e. it is due to strictures which prevent the free passage of air, and to friction between the contiguous walls of the tube and wire; but the improvement over the preceding cases is obvious.

8.—To enter into this question somewhat more fully and from a different point of view, a wider tube was selected (the walls of which were but $0{\cdot}12^{cm}$ thick), flattened and coiled *without* closing the section. Indeed a blunt edge was left and the section was about $0{\cdot}06^{cm}$ broad and $1{\cdot}6^{cm}$ high. The data for this coil (IV) were as follows:

Diam. of curl,	$3{\cdot}2^{cm}$	Pressure, $75{\cdot}9^{cm}$, Hg.	Deflection, $11{\cdot}1°$
Turns of curl,	4·5	69·5	10·3°
Length of curl,	$14{\cdot}0^{cm}$	57·8	8·8°
		41·3	6·6°
		36·8	5·9°
		0·0 zero.	0·0°

Pressure per degree, per turn, $32{\cdot}5^{cm}$.
Pressure per degree, per linear cm., 330^{cm}.

In this curl there is no evidence of viscosity, but the relation of pressure-difference and deflection is not quite linear, as was the case with sharp-edged coils. The data are mean ratios. The sensitiveness (330^{cm}, Hg, per degree per linear cm.) is of low order, in spite of the thin walls ($0{\cdot}012^{cm}$) and broad tube. § 2.

This curl was now replaced on the metallic mandrel, and the edges hammered quite sharp from end to end. On removing the curl from the mandrel I found that *no air* could be sucked through it. The walls, therefore, overlapped each other, *imperviously* to air. When, however, the curl was somewhat uncoiled in the hands, the air came through quite freely. This suggested a novel method of making the curl aneroid, requiring no inclosed wires, and partaking of other advantages, since the uncoiling can be done with a suitable spring. In a counter-twisted system of this kind:

(1.) The sharp-edged coils can be opened by an amount compatible with the free access of air. Therefore this system is adapted for extreme sensitiveness.

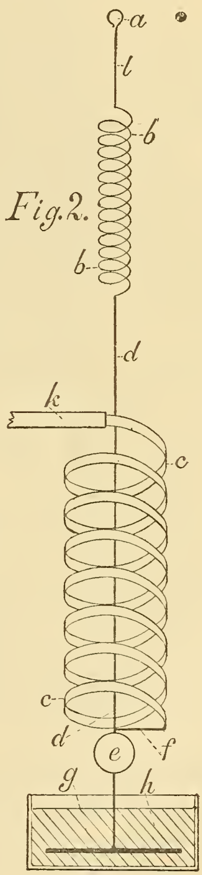
(2.) The system is differential; or, in other words, the *differences* of viscosity and of elasticity of curl and spring, and the *differences* of the thermal variations of these quantities come into play. Thus if a spring and curl could be made having the same effective viscosity* and the same thermal coefficients of viscosity and elasticity, respectively, *the system would be perfectly elastic and independent of temperature;* or,

* Depending therefore both on the material and on the lengths of the two helices.

(3.) If the adjusted curl aneroid, exhausted and therefore twisted by external pressure, be untwisted to the same degree by the spring, the curl is now nearly without strain, excepting such of higher orders; and the viscosity and thermal relations of viscosity and rigidity of the counter-twisting spring alone come into play. Hence a metal of low rigidity may be chosen for making the curl, while the counter-twisting spring is selected for high viscosity. One would use, for instance, hard steel annealed at 400° or even a sufficiently thick quartz fiber.

It is clear that the counter-spring must be weak, so that it may make a number of rotations for each rotation of the curl; for the resistance of the counter-spring is incremented at the expense of the deflection of the curl. Hence a long fiber, or spiral spring, or a watch spring is adapted. Finally, to prevent knotting of the spring, a weight is (*temporarily*) added to the system, preferably suspended in a basin of water to deaden vibrations. The curl aneroid has now taken the form of figure 2, where *cc* is the curl, communicating at one end, *k*, with the air pump. The other end is closed and carries the horizontal, radial stylus *f*, to which the stiff wire *dd* of the spring *bb*, the mirror *e* and the damping plate *g* are attached symmetrically to the curl. The plate *g* is of lead, thus serving as a weight (as well as a damper) to pull out the spring *bb*. A dish *h* (shown with *g* in cross section) containing a liquid, surrounds *g*. The spring *b* is attached above to a rigid clamp at *a*, by means of a stiff wire *l*, the clamp (not shown) being so constructed that the spring can be both raised and twisted.

Fig. 2.



Counter-twisted system of curled Bourdon tube, spring and appurtenances.

The weight *g* and the damping arrangement are only permissible in calibration work like the present. If the registry of the aneroid is to be instantaneous, the mass must be kept down to the lowest limit possible, and no ballast is to be attached. Hence a delicate watch-spring, or a double helical spring is preferably employed, and a suitable method of damping vibrations must be investigated. An elastic fiber fastened at both ends, with the end of the helix attached near the middle, is also contemplated.

9.—To obtain preliminary evidence, I took curl IV, just discussed (§ 8), though it had become somewhat leaky from hard usage. The counter-twisting was done by a long steel wire with the following results:

Turns uncoiled from 4·5 to 3·7.	Pressure per degree, per turn, $13{\cdot}4^{cm}$, Hg. Pressure per degree, per linear cm., 167^{cm}.
Turns uncoiled from 4·5 to 3·0.	Pressure per degree, per turn, $5{\cdot}1^{cm}$, Hg. Pressure per degree, per linear cm., 79^{cm}.

In all these cases the deflections were instantaneous, and there was no apparent viscosity. The curl itself has been improved from one of low sensitiveness (330^{cm}) to nearly the same range of high sensitiveness (77^{cm}), actually obtained in § 6 for extremely thin copper tubes.

This result deserves special study; but it already appears that so long as the coil is sharp-edged in section—so long as the strain is a case of nearly pure bending—the coil increases in sensitiveness as its spindle-shaped section is more highly arched. The smaller the medial radius of curvature of a right section of the tube, the greater proportionately is its variation for the same pressure-difference; and the greater proportionately must the corresponding variations of the longitudinal radius of curvature (coil radius) also be, since the product of two radii is to remain constant. Hence *a rotundly arched, spindle-shaped section, maintained in an excessively thin-walled tube, is compatible with the greatest amount of rotation at the registering index.*

10.—A copper tube having walls $0{\cdot}01^{cm}$ thick was flattened and rolled down as usual. The curl (No. VII) contained 9 turns and it was $2{\cdot}8^{cm}$ in diameter and about $12{\cdot}5^{cm}$ long, each turn in section being $0{\cdot}8^{cm}$ high, with blunt edges about $0{\cdot}05^{cm}$ wide. So constructed, the sensitiveness (conformably with the data in § 8) was low, for the pressure in cm. Hg per degree per turn was 50, and the pressure per degree per linear cm. of the curl 440^{cm}.—in spite of the thin copper walls stated. This tube was now hammered flat and sharp-edged on the steel mandrel. A part, VII_b, free from flaws was then cut from this tube and used in the following tests, Table 2. For want of better material a helical spring of brass spring wire was used in the counter-twisting and the system was weighted to prevent knotting (cf. § 8).

These results are given graphically in the chart figure 3, where the ordinates are pressures in cm. of mercury, corresponding to a deflection of 1° for a length of 1^{cm} measured on the turns of the curl. The abscissas show the amount of counter-twisting at the lower end of the system in degrees. The sensitiveness therefore increases in marked degree with the amount of counter-twisting, and apparently reaches a limit at about 150°. From here on, however, the evidences of permanent set were met with. They are in the direction of the uncoiling, showing the spring to have acted on the curl. At the end of the experiment, when the spring was released, about 90° of permanent set had been imparted to the curl. I believe therefore, that the curl could have been made even more sen-

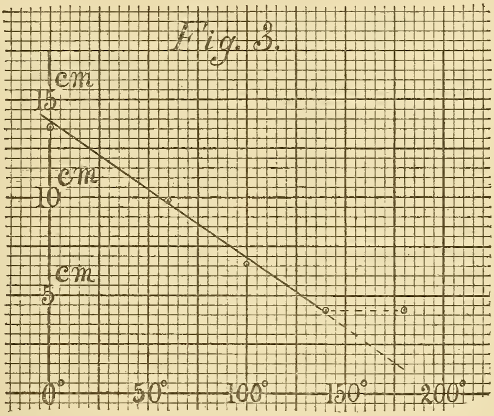


Chart showing the inverse sensitiveness (ordinate) of a counter-twisted system varying with the amount of counter-twist (abscissa).

sitive than shown in figure 3, if its material had been resilient and of high viscosity. At all events, the datum reached (50^{cm} Hg corresponding to a degree of deflection between the ends of a linear cm. of the turns of the curl) is markedly in excess of the results given at the end of § 7, while the apparent viscosity of the metal has now no serious significance. Indeed since the viscous set above was actually negative (uncoiled curl), whereas in the simple curl (§ 5 et seq.) it is positive, a virtual elimination of viscosity is clearly possible.

TABLE 2.—*Showing the increased sensitiveness resulting from increased counter-twisting.*

Turns of VII_b	Counter-twist in degrees of arc.	Pressure per degree, per turn.	Pressure per degree, per linear cm.	Remarks.
No.	°	cm., Hg.	cm., Hg.	
2·5	0	13·6	120	No viscosity.
2·3	60	9·9	95	" "
2·1	100	6·6	69	" "
1·9	140	4·3	50	" "
1·7	180	4·3	56	Curl shows negative viscosity.
2·3 (released)	0	10·0	98	Curl shows 90° set after releasing spring.

11.—I want finally to put the remarks made in the above paragraphs to an actual test in continuous series of measurements with mirror and scale. A figure of the apparatus is given in § 8. A curl, No. II, was wound for the purpose, of copper tube. A very small leak was purposely left, so that the exhausted curl might gradually (several days) fill with air, while comparison with the attached mercury manometer were in progress. Preliminary tests made on the graduated circle showed the following results :

Description.		Pressure.	Deflection.	Pressure per degree.	Pressure per degree, per turn.	Pressure per degree, per linear cm.
Diameter curl,	$2 \cdot 8^{cm}$	cm., Hg.	°arc.			
Turns,	15·5	76·80	84·75	0·926	14·1	124
Length,	12^{cm}	57·92	64·80	0·894		
		40·70	45·75			
		0·0	0·0			

The relation is not linear, though the discrepancy may be thermal. The curl is only *moderately* sensitive (for in § 10 this sensitiveness has been doubled), and not quite free from viscosity. It is therefore interesting to see in how far precision can be obtained with this short and not very favorable coil, when suitably counter-twisted.

The spring used in counter-twisting was of brass spring wire, $0 \cdot 05^{cm}$ diameter. It consisted of 31 turns about $1 \cdot 5^{cm}$ in diameter and when stretched was $1 \cdot 7^{cm}$ long. The counterpoise weighed something over 25^{g}.

The system was adjusted by first exhausting the curl aneroid to a nearly perfect vacuum, after which the mirror was brought back to its original position (that is before exhausting) by the spring. There was thus but little strain left in the curl. The method adopted was therefore the third in § 8.

A thermometer hung beside the mercury manometer and the curl, giving the temperature of both, though not closely enough (as observation showed). A fine bulb thermometer placed within the coils is essential. The scale was at a distance $3 \cdot 5^{met}$ from the mirror.

Of the two continuous series of observations made I shall, for brevity, only give an example of part of the second. The first is defective in temperature. Table 3 contains the results, showing in the first three columns the height (b) of the mercury in the manometer (reduced to 0° C.), the temperature (t) of the air near the curl, and the reading (s) in the telescope of the deflections of the curl. Observations were made in groups of four or more, during different parts of the day for different days. Temperature was very variable, thus adding to the severity of the test.

The column headed B is the virtual barometer, to be obtained in a way presently to be given.

TABLE 3.—*Showing the behavior of the curl aneroid as compared with the mercury manometer.*

b Manometer. cm., Hg.	s Curl. cm.	t Temperature. ° C.	B Manometer at 25°. cm., Hg.	b Manometer. cm., Hg.	s Curl. cm.	t Temperature. ° C.	B Manometer at 25°. cm., Hg.
75·49	54·75	25·6	75·53	75·69	58·80	29·0	75·99
74·89	49·40	25·8	74·95	75·16	54·30	28·8	75·44
74·58	46·70	26·0	74·65	74·36	46·30	28·4	74·61
73·95	40·30	26·3	74·05	72·97	32·00	28 0	73 19
75·58	56·50	27·3	75·75	76·06*	57·40	23·1	75·92
75·38	54·60	27·3	75·55	75·29	50·70	23·1	75·15
74·95	50·60	27·5	75.14	74·72	45·00	23 2	74·59
74·66	47·90	28·0	74·88	74·02	38·40	23.6	73·92
75·59	57 60	29·2	75.90	76·01	58·00	23·5	75·90
75·15	54·00	29 6	75 50	75·69	54·90	23·5	75·58
74·22	44·70	30 0	74 59	75·18	50·00	23·5	75·07
73·89	41·60	29·8	74·24	74·76	45·80	24·2	74·70
75·57	57·90	30·2	75·96	76 46†	60·70	21·8	76·22
75·35	56·50	30·2	75·74	75·70	54·55	22·3	75·50
74·95	52·30	30·0	75·32	75·22	50·50	22·8	75·05
71·92	21·10	29·6	72·25	73·94	37 85	23·4	73 82
75·54	57 45	29·4	75·87	76·36	63·00	26·0	76·44
74·95	52·40	29·2	75·26	75·86	57·30	26·1	75·92
74·45	46·60	29·2	74·76	75·42	54·50	26.3	75·52
74·02	42 70	29 2	74·33	74 78	47·60	26·2	74·87
75·64	58·50	29·4	75·97	76·34‡	57·60	20·8	76·02
75·16	54·30	29·4	75·49	75·93	54·65	21·0	75·63
74·33	45·80	29·1	74·63	75·49	51·10	21·2	75·20
73·38	36·10	29·0	73·67	74·86	45 20	21·6	74·61

* One day after. † Three days after. ‡ Four days after.

If the deflections (s) are platted as a function of the pressure (b,) a series of detached lines are obtained, which usually lie at some distance apart and are not quite straight even for a single group. Inspection shows these discrepancies to be principally due to temperature. It is not at once obvious how the temperature coefficient is to be computed, unless it be assumed, conformably with § 4, that the corrected loci are really straight.

The following is a method of calculating the temperature corrections without entering into unduly complex computations: Let s be the deflection (scale reading) at the pressure b and the temperature t; let s', b', t' have a similar relation, and let s_0, c and α be constants. For any two groups, put

$$\begin{aligned}(s+s_0)(1+\alpha t)&=bc,\\(s'+s_0)(1+\alpha t')&=b'c.\end{aligned} \quad (1)$$

If by aid of the chart of detached lines just referred to, the values of b be taken for $s=s'$, then

$$\alpha=\frac{b'-b}{bt'-b't} \quad (2)$$

Proceeding thus, I found $a=0{\cdot}001$; and with this value I reduced the observations by placing (1) under the form

$$s=\frac{b}{1+\alpha t}c-s_0=Bc-s_0 \qquad (3)$$

Hence s is a linear function of B; and this postulate can be tested graphically without computing c and s_0. B is given in the last column of Table 3.

The conditions under which these data were obtained were very unfavorable. As a result of the delicate suspension, the jar of wagons and cars passing the laboratory often made it impossible to read the scale millimeters in the telescope. Moreover I was unprepared for so large a temperature coefficient, α, as has just been adduced; and I did not therefore take such special precautions against currents of air which should have been taken, seeing that the thin metallic helix adjusted itself at once to temperature, whereas the thermometer follows sluggishly after. Nor was the latter placed near enough to the coil. Hence since a single degree of temperature corresponds to nearly $0{\cdot}1^{cm}$ of the barometer, discrepancies* of half a millimeter of pressure must have been incident to the work, and the table and chart bear this assertion out. Points which lie out of position are isolated in each group and the discrepancy is the result of a current of air.

In spite of the unfavorable choice of metals (copper and brass) the behavior of the copper curl is thus seen to be satisfactory so far as the present purposes go: for a development of principles of construction has only been aimed at. The telescope reading for this small curl is $9{\cdot}8^{cm}$ per cm. of the mercurial barometer.

12. *Conclusion.*—Having reached this stage of progress, it seemed expedient to break off the work, for it would not be worth while to proceed with fine measurement without making the system of more highly viscous material at the outset. In brief: tubing preferably of resilient brass 3–4 millimeters in diameter or less, with walls $0{\cdot}01^{cm}$ thick or less (by solution) is desirable. The tube should be heated in steam to remove excesses of drawn strain and thereafter flattened and coiled until the walls all but touch. The counter-twisting spring is to be either helical or watchspring-shaped, and of steel annealed at 400° C., or a suitable long quartz fiber. A long curl would not be self-sustaining; but it could be made so without interfering with its free action, by a series of equidis-

* In the face of the large thermal effect discussed in the text it would be useless to endeavor to evaluate the effect of viscosity. Nor would a metal of low viscosity, like a spring of drawn brass, be chosen in tests of a final character.

tant radial spokes attached at the inner face of the curl with their central ends fastened to a fiber of silk.

If, therefore, the conditions investigated at the end of §§ 6, 10, be called to mind, a non-differential curl aneroid (§ 8, case 3) less than a meter long, provided with a mirror for registry, will give account of variations of atmospheric pressure of a thousandth of a millimeter of the barometer, provided the mounting is sufficiently free from tremor, and temperature be kept constant to a few thousandths of a degree during the interval of observation.

These conditions will be much less severe if the parts of the counter-twisted system are especially chosen (as stated in § 8, case 2) and twisted with reference to viscosity, rigidity and temperature. Indeed the chief result of the present paper is the exhibition of the properties of the counter-twisted system. A continuous mechanism has been brought forward which not only minimizes the hurtful effects of viscosity and of the thermal changes both of viscosity and of rigidity, but which accomplishes these desirable results in such a way as to remarkably increase the sensitiveness of the instrument.

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Art. XVI.—*Fayalite from Rockport, Mass., and on the Optical Properties of the Chrysolite-Fayalite Group and of Monticellite*; by S. L. Penfield and E. H. Forbes.

In the fall of 1890, Mr. J. H. Sears of the Peabody Academy of Science, Salem, Mass., while visiting the Rockport Granite Quarry, found a crystalline mass of a dark colored mineral, which proved on examination to be fayalite. The occurrence of this mineral is so unusual that it was considered worthy of a special investigation and was sent for that purpose to the Mineralogical Laboratory of the Sheffield Scientific School.

The material offered an excellent opportunity for an investigation of the optical properties of fayalite, which had never been determined, and the results were of such a nature that it seemed best to extend the study to the different members of the chrysolite group, in order to determine the effect upon the optical properties due to the mutual replacement of iron and magnesium.

Fayalite.

The material from Rockport was a crystalline mass, found at a depth of 60 feet, near the base of a large boss, or vein of pegmatite. It occurred at one side of the pegmatite vein in the massive hornblende-biotite granite, as a lenticular shell of varying thickness, about 12 to 16 inches in diameter, filled on the inside with loose earthy material and enveloped by a layer of magnetite about one inch thick.

The material showed no crystal faces, but two distinct cleavages at right angles to each other. The color of the mineral on a fresh fracture is a dark resinous green, but thin edges transmit a yellowish light. On examining fragments with a microscope it was found that they were fresh and transparent, but permeated with grains of magnetite. The material for analysis was therefore prepared by pulverizing and sifting to a uniform grain and freeing from magnetite with a magnet. The material thus prepared was of exceptional purity. The specific gravity taken with the pycnometer and the results of the analysis are as follows:

Specific gravity 4·323, 4·316, 4·317. Average 4·318

	I.	II.	Average.	Ratio.		
SiO_2 ...	30·11	30·05	30·08	·501		1·00
FeO ...	68·04	68·19	68·12	·946		
MnO ...	·77	·65	·72	·010	1·004	2·00
H_2O ...	·88	·87	·80	·048		
Total...	99·80	99·76	99·80			

The ratio indicates almost pure ferrous ortho-silicate Fe_2SiO_4 with only a trace of manganese and no magnesia, although a careful test was made for the latter. The small amount of water is considered as basic. A high temperature is needed to expel it, and limonite, the most likely mineral to be formed by decomposition, was wanting. If the water is disregarded, the analysis shows a slight excess of silica.

The cleavages served for the orientation of the optical properties and plates cut parallel to these, as described by Penfield and Pratt,* proved to be parallel to the pinacoids 001 and 010. The first of these gave no interference figure in polarized light, while the second showed the emergence of the acute bisectrix. The divergence of the optical axes was measured on a large Fuess axial angle apparatus, and although it could be measured in air, it was found best to measure it in α-monobromnaphthalene. The plates also served for determining the pleochroism.

The indices of refraction were obtained from prisms carefully oriented by the cleavages. The results are as follows: for yel-

* This Journal, vol. l, p. 387, 1895.

low Na, $\alpha = 1{\cdot}8236$, $\beta = 1{\cdot}8642$, $\gamma = 1{\cdot}8736$, $\gamma - \alpha = {\cdot}050$, the orientation being $a = \mathfrak{c}$, $b = \mathfrak{a}$, $c = \mathfrak{b}$ as in crysolite.

The plane of the optic axis is the base and $\mathfrak{a}$ is the acute bisectrix. The double refraction is, therefore, negative. The dispersion is $\rho > \nu$, 2H, Li = 57° 27′; 2H, Na = 56° 32′; 2H, Tl = 55° 2′. The index of refraction for α-mono-bromnaphthalene being 1·6577 at 23° C. for yellow, $V_y = 24° 55'$ and $2E_y = 103° 25'$. $2E_y$ was also measured and found to be 103° 4′. From the values of α, β and γ, according to the usual formula, V_o was found to be 64° 42′, hence $V_a = 25° 18'$, agreeing closely with 24° 55′ as given above. The pleochroism is distinct, in sections about $0{\cdot}5^{mm}$ thick for rays vibrating parallel to $\mathfrak{b}$ orange yellow, parallel to $\mathfrak{a}$ and $\mathfrak{c}$ greenish yellow.

To make sure of the orientation of the optical properties as given above, where only cleavages were available, a comparison was made with the excellent crystals from the obsidian of the Yellowstone Park described by Iddings and Penfield.* For this purpose, material was supplied by Mr. Arnold Hague of the U. S. Geological Survey, to whom the authors desire to express their thanks. On these transparent, but minute crystals, the basal cleavage and the emergence of the obtuse bisectrix at right angles to the pinacoid 100 were distinctly seen, the plane of the optic axis being 001. No indication of a cleavage parallel to the pinacoid 100 was observed on the fayalite from Rockport, and the statement in many mineralogies of a cleavage in that direction is probably erroneous.

Hortonolite.

Under this name Professor Brush† has described a member of the chrysolite-fayalite group, found in an iron mine at Monroe, Orange Co., N. Y., and characterized by its dark color and high iron percentage. In appearance it resembled the fayalite from Rockport. In order to ascertain the chemical composition of the mineral upon which the optical properties were to be determined, a new analysis was made upon material from a large mass, showing cleavage in two directions, which served for the optical orientation, this cleavable material being better adapted for optical work than the crystals at our disposal.

Grains of magnetite were disseminated through the mineral and the material for analysis was therefore purified as described under fayalite.

The results of the analysis are given below, together with those obtained by Mixter and quoted by Brush :

* This Journal, vol. xxx, p. 58, 1885.
† Ibid., vol. xlviii, p. 17, 1869.

Specific gravity 4·047, 4·030, Average 4·038.

	I.	II.	Average.	Ratio.			Mixter. Sp. gr. 3·91
SiO_2	33·60	33·94	33·77	·562	·562	1·00	33·59
FeO	47·19	47·32	47·26	·656			44·37
MnO	4·76	4·32	4·54	·064	1·093	1·95	4·35
MgO	14·02	13·74	13·88	·347			16·68
H_2O	0·48	0·48	0·48	·026			K_2O 0·39
							H_2O 0·26
	100·05	99·80	99·93				99·64

The ratio of the $SiO_2 : RO = 1 : 1·95$ or nearly $1:2$, giving the formula $(FeMgMn)_2SiO_4$, and, therefore, the mineral holds an intermediate position between fayalite and the iron-rich chrysolites. The cleavages are poorer than in fayalite, but parallel to the same faces 001 and 010. Plates and prisms were prepared as in fayalite, the optical orientation and the character of the double refraction being the same.

The following results were obtained:

For yellow light Na, $\alpha = 1·7684$, $\beta = 1·7915$, $\gamma = 1·8031$, $\gamma - \alpha$ ·0347. 2H, Li $= 76° 59'$; 2H, Na $= 76° 00'$; 2H, Tl $= 75° 45'$; hence with n Na for α-mono-bromnaphthalene $=$ 1·6567 at 25° C., $V_{ay} = 34° 42'$. From the values of α, β and γ, V_o was found to be 54° 55′; hence $V_a = 35° 5'$, which agrees closely with V_a as given above. The pleochroism was similar to that of fayalite but weaker, for rays parallel to $\mathfrak{a}$ and $\mathfrak{c}$ very pale yellowish green, and parallel to $\mathfrak{b}$ pale yellow.

Chrysolite.

For the optical constants of chrysolite we are indebted to Des Cloizeaux* who gives $\alpha = 1·661$, $\beta = 1·678$, $\gamma = 1·697$, for yellow Na, $2V_y = 87° 46'$, the double refraction being positive and the dispersion $\rho < \upsilon$. The amount of ferrous iron, however, is not given. He also determined the constants for fosterite, the white chrysolite from Vesuvius, containing presumably, according to the published analyses, about two per cent of ferrous oxide with the following results: $\beta_r = 1·657$, $\beta_y = 1·659$, $\beta_{bl} = 1·670$, $2V_r = 86° 1'$, $2V_y = 86° 10'$, $2V_{bl} = 86° 32'$.

Zimanyi† has recently given the following determinations on chrysolite from the East Indies, but also without any determinations of ferrous oxide; for yellow, Na, $\alpha = 1·6535$, $\beta = 1·6703$, $\gamma = 1·6894$, $2V_a = 87° 15'$.

* Memoirs De L'Institute De France, Tome xviii, p. 591.

† Zeitschrift für Krystallographie und Mineralogie, Band 22, p. 338, 1893.

For our own investigation chrysolites were selected from specimens in the Brush collection. The percentages of ferrous iron were determined by means of potassium permanganate, but unfortunately in the available material the range in the replacement of magnesia by iron was not great, leaving a wide gap in the series between the one richest in iron and hortonolite. The varieties examined are arranged below according to the decrease in the percentage of iron. The divergences of the optical axes, 2H, were all measured with yellow light, Na, in α-mono-bromnaphthalene at a mean temperature of 25° C.

Auvergne, France.—Loose crystals were chosen of a dark green color and well developed; similar to fig. 4, page 452, Dana's Mineralogy, 6th Ed. The plate for optical examination was made parallel to 010. FeO = 13·02 per cent, $\beta = 1·6916$, 2H = 92° 1′; hence $2V_a$=89° 36′.

Vesuvius, Italy.—Small loose crystals were selected of dark olive green color, showing distinct faces with 010 prominent, parallel to which the plate was cut. FeO = 12·6 per cent, 2H = 92° 9′, and considering $\beta = 1·6916$ as in the Auvergne crystals, $2V_a$ = 89° 42′.

Hawaii, Sandwich Islands.—The material of olive green color was collected by Prof. J. D. Dana on the southeastern shore, south of Hilo. It consisted of waterworn grains, showing occasionally a cleavage face parallel to 010 which served for orientation, and parallel to which the plate was cut. FeO = 10·3 per cent, 2H = 92° 30′, and using $\beta = 1·678$ as given by Des Cloizeaux, $2V_o$= 91° 2′.

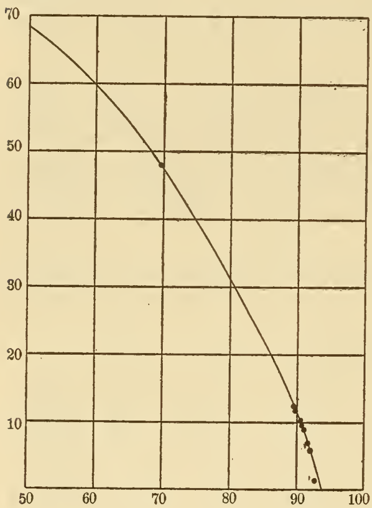
Egypt or the Orient.—A fragmentary crystal was used, of light olive green color and with crystal faces, which served for orientation. The plate was cut parallel to 100. FeO = 9·16 per cent, 2H = 89° 39′, $\beta = 1·679$; hence $2V_a$= 88° 41′.

Northwestern Corner of New Mexico.—A rounded fragment was selected from material collected by the Indians and sold to lapidaries for gem purposes. The fragment showed no crystal faces, but a cleavage parallel to 010 served for orientation, and parallel to this the plate was cut. FeO = 8·6 per cent, 2H = 92° 57′, and using $\beta = 1·678$, $2V_o$=91′ 24′.

The result of this investigation can be seen best from the following table, where 2V is given for yellow Na, measured over $\mathfrak{a}$, or the crystallographic axis b. The dispersion in all cases when measured in this way is $\rho > \upsilon$. The last three are the determinations of Des Cloizeaux and Zimanyi already referred to.

Material.	Locality.	Per Cent of FeO.	Axial Angle 2V measured over α.	β.
Fayalite,	Rockport,	68·1	49° 50′	1·864
Hortonolite,	Monroe,	47·3	69 24	1·791
Chrysolite,	Auvergne,	13·0	89 36	1·692
"	Vesuvius,	12·6	89 42	
"	Hawaii,	10·3	91 2	
"	Egypt,	9·2	91 19	1·678
"	New Mexico,	8·6	91 24	
"	Unknown,	?	92 14	1·678
"	East Indies,	?	92 45	1·670
Fosterite,	Vesuvius,	2?	93 50	1·657

The effect of a decrease in iron is to constantly increase the value of 2V, which, at the iron end of the series, changes much more rapidly than at the magnesia end, as may be seen by the curve which has been plotted, and where the percentages of FeO have been taken as ordinates and the values of 2V as abscissas.



The decrease in FeO is accompanied by a decrease in the value of β and also in the strength of the double refraction. With the FeO about 12 per cent 2V for yellow equals nearly 90°. Chrysolites containing less than 12 per cent FeO have c, or the crystallographic axis *a* for the acute bisectrix and are optically positive with dispersion $\rho < \upsilon$, and those richer in iron are optically negative with dispersion $\rho > \upsilon$.

Monticellite.

In order to make the investigation of the chrysolite group more complete, we have included monticellite $CaMgSiO_4$, which in its crystallographic relations is very close to chrysolite, the crystals from Magnet Cove, Arkansas, investigated by Genth and Pirsson* furnishing excellent material for the purpose. An abundant supply of this rare mineral was generously furnished to us by Messrs. Geo. L. English & Co. of New York, to whom we take pleasure in expressing our thanks. As

* This Journal, vol. xli, p. 399, 1891.

Genth's analysis showed a loss by ignition of 2·29 per cent and 2·03 per cent of P_2O_5, it evidently was made on impure material and consequently a new analysis seemed necessary.

The material which we were able to select was of exceptional purity and yielded the following results:

	I.	II.	Mean.				Genth.
Specific gravity	3·022	3·047	3·035				
Analysis I.	II.	Average.	Ratio.				
SiO_2 36·86	36·70	36·78	·613	·613	1·00		33·47
FeO 4·61	4·89	4·75	·066				5·01
MnO 1·58	1·67	1·62	·023	·629	1·02		1·12
MgO 21·44	21·75	21·60	·540				20·61
CaO 34·23	34·39	34·31	·613	·613	1·00		35·25
H_2O ·97	·93	·95				Ign	2·29
						P_2O_5	2·03
Total 99·69	100·33	100·01				Al_2O_3	·17
							99·95

The ration of SiO_2:(MgFeMn)O:CaO = 1·00:1·02:1·00 is very satisfactory, and gives the usually accepted formula $CaMgSiO_4$ in which a little Mg is replaced by Fe and Mn. A careful test was made for P_2O_5 but none was found, and undoubtedly Genth's material, as assumed by him, was contaminated with apatite. From the crystal from which the material for analysis was taken, a few colorless and transparent grains were selected which when heated in the closed tube gave only the merest trace of water, the pure mineral is therefore practically anhydrous, but in order to obtain sufficient material for the analysis it was necessary to include some slightly brownish grains, and these were permeated with cracks along which decomposition had commenced, which accounts for the water.

For the determination of the optical properties a single crystal like the one figured by Pirsson was used. The indices of refraction, determined by means of prisms, are as follows: for yellow light, Na, $\alpha = 1·6505$, $\beta = 1·6616$, $\gamma = 1·6679$, $\gamma - \alpha = 0·0174$; also β, Li = 1·6594 and β, Tl = 1·6653. The optical orientation is $a = \mathfrak{c}$, $b = \mathfrak{a}$, and $c = \mathfrak{b}$ as in chrysolite. The plane of the optical axes is 001 and $\mathfrak{a}$ is the acute bisectrix, consequently the double refraction is negative. The dispersion is $\rho > \upsilon$ as follows: 2H,Li = 75° 55′, 2H,Na = 75° 21′, and 2H,Tl = 74° 52. The measurements being made in α-mono-bromnaphthalene, V_a,Li = 37° 51′, V_a,Na = 37° 31′ and V_a,Tl = 36° 28′, while from the values of α, β and γ as given above V_a,Na by calculation, was found to be 37° 9′.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, October, 1895.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Recent investigations on hydrogen peroxide.*—Our knowledge of the chemical nature of this interesting substance was much advanced by the work of Traube, chiefly recorded in the "Berichte" of the German Chemical Society from 1882 to 1893. Traube came to the conclusion that hydrogen peroxide cannot possess the same constitution as the peroxides of manganese, lead and silver, because it is not produced, like these, at the anode in electrolysis, but is produced along with hydrogen at the kathode, especially when oxygen is blown against this electrode. He considered it, therefore, not an oxidation-product of water, but a reduction-product of molecular oxygen. This view is also supported by the fact that hydrogen peroxide is never formed by the oxidation of hydrogen by nascent oxygen or other oxidizing agents, while, moreover, it reduces all the powerful oxidizing agents or is destroyed by them. Traube therefore rejected the generally-accepted di-hydroxyl formula, HO.OH, and advanced the view that the substance is a hydride of molecular oxygen, as expressed by the formla H[O:O]H.

The interest taken in hydrogen peroxide has been considerably increased since Wolffenstein showed that the substance could be purified and concentrated, with but small loss through decomposition, by distillation under diminished pressure, (Berichte, 1894, 3307). To perform this operation it is necessary that the solution should be free from compounds having an alkaline reaction as well as from every trace of salts of the heavy metals and from solid substances of all kinds. Wolffenstein recommends a simple distillation of the commercial 3 per cent solution under a pressure of about 68^{mm} for the production of small quantities of the pure solution. For larger quantities he advises evaporation at ordinary pressure upon the steam-bath until a concentration of about 20 per cent is reached, then concentration under diminished pressure to 50–55 per cent, after that, extraction with ether (Brühl considers this step dangerous, as will be seen beyond), and finally distillation under diminished pressure. By repeated fractionation he obtained a product which boiled at 84–85° at 65^{mm}, and which contained 99·1 per cent of the substance.

Spring (Zeitschr. anorg. Chem., viii, 424) has prepared large quantities of hydrogen peroxide by Wolffenstein's method and has determined some of its physical properties. He found it to have a blue color about half-again as intense as that of water, and concludes that this fact supports Traube's theory concerning the constitution of the compound, because Olszewski having shown that liquid oxygen has a blue color about fifty times as strong as that of water, he concludes that oxygen retains more of its original properties in hydrogen peroxide than in water. Spring concludes also, from determinations of the specific heat of hydrogen peroxide, that the potential energy of the elements is not completely used in forming this compound.

Brühl (Berichte, 1895, 2847) has recently described some important work upon the subject under consideration. Using Wolffenstein's process, usually omitting, however, the extraction with ether, he has prepared hydrogen peroxide in a water-free condition. The boiling-point of his purest product was 69·2° at 26^{mm}. He observed that the distilled substance is much more stable than that which is less pure, and that the nearly water-free liquid suffered scarcely any decomposition when kept cool and in a dark place for five or six weeks. Agitation promotes decomposition, as does also an increase in the surface with which the substance is in contact. Sharp points and rough surfaces have a marked action, and when the compound is brought into contact with a ground-glass surface the decomposition is violent. Paper, cloth, wool and asbestus cannot be used for filtering the concentrated liquid; in fact, wool is ignited by contact with a small amount of it. Gun-cotton does not decompose it and can be used for its filtration. Brühl considers the specific gravity of hydrogen peroxide as the best criterion of its purity. The highest specific gravity which he obtained was, $d\frac{0}{4}=1·4584$, while a liquid containing 99·48 per cent of the pure substance, according to analysis, had a density of 1·4094. He experienced no trouble from explosions when solutions were concentrated and purified simply by evaporation and distillation, but some material which had been repeatedly treated with ether gave off much gas with an odor of ozone upon distillation, and an oily, colorless residue, which did not volatilize at 100° was left. This fluid, amounting to only 1 or 2^{cc} showed but slight explosive properties when a drop of it was conveyed into a Bunsen flame by means of a platinum spatula; but when a glass rod with a sharply cut end was brought into contact with the remainder, a fearfully violent explosion took place which caused much damage in the laboratory. A part of this particular sample of hydrogen peroxide had previously caused a serious explosion in Spring's laboratory. Brühl believes that the explosive compound is formed by the action of hydrogen peroxide upon ether, but nothing is as yet known concerning its composition.

Having determined the molecular refraction and dispersion of the pure hydrogen peroxide, with the result that the numbers found were much larger than those calculated for di-hydroxyl, Brühl concludes that the oxygens in the compound must have a multiple linking between themselves. This conclusion conforms with Traube's formula, H·O:O·H, but Brühl objects to this on the ground that neither oxygen nor the other members of the same periodic group show trivalence. But since sulphur, selenium and tellurium show tetravalence, and since there is already ground for supposing the existence of tetravalence in oxygen, as, for example, the existence of Ag_4O and $HCl(CH_3)_2O$, he proposes the formula H·O ⁝ O·H. The author calls attention to the advantage of tetravalent oxygen in explaining the constitution of carbon monoxide, C⁝O, but he recognizes the fact that this involves the assumption of unsaturated oxygen in all other organic compounds containing this element. He believes, however, that this view presents no greater difficulty than exists at present in regard to trivalent nitrogen and phosphorus and bivalent sulphur.

H. L. W.

2. *On the constitution of water and the cause of its power of dissociation.*—As mentioned in the preceding notice, Brühl has advocated the existence of tetravalent oxygen in hydrogen peroxide. He believes that this view throws new light upon the constitution and the behavior of water, to which he gives the $H\cdot\dot{\underset{\cdot}{O}}\cdot H$, considering it an unsaturated compound. He points out that water shows the criteria of an unsaturated compound in a marked degree, since nearly all bodies combine with it, innumerable hydrates and compounds with water of crystallization exist, and finally it is the most general solvent. He believes, moreover, that the supplementary valences of tetravalent oxygen are the cause of ionization, and of the power of water to dissociate molecular aggregations.—*Berichte deutsch. Chem. Gesell.*, 1895, 2868. H. L. W.

3. *On the action of prolonged, moderate heating upon detonating gas.*—Victor Meyer and Wilhelm Raum have investigated the slow combination of oxygen and hydrogen. The theoretical question involved was the view advanced by the representatives of physical chemistry, that a substance having a catalytic action cannot produce a reaction which is not already existent, and that it merely increases the rapidity of such a reaction. On this assumption hydrogen and oxygen, which combine rather rapidly at 500°, must combine to some extent at ordinary temperatures, even though this action may be so slow that it would require hundreds or thousands of years for the production of an amount of water that could be detected, and it is this slow action that is increased to great rapidity by the presence of a catalytic agent, such as finely divided platinum. The authors have attacked the problem by finding the temperature just low enough so that the gases do not react appreciably when heated for several days, then greatly prolonging the time of action at that temperature. It was found that at 300° no water could be detected after ten days' heating, but after heating uninterruptedly for 65 days, water was found to have been formed. The authors conclude from their results that the reaction under consideration is retarded but not stopped by lowering the temperature and that the assumption of action at ordinary temperatures is justified. —*Berichte deutsch. Chem. Gesell.*, xxviii, 2804. H. L. W.

4. *The absorption of nitrogen by metallic lithium in the cold.*—It has been found by H. Deslandres that the combination of nitrogen and lithium takes place more readily than has been sup-

posed. He states that the two elements combine in the cold in a manner analogous to the slow absorption of oxygen by phosphorus. The absorption is, moreover, complete, for when the operation is performed in a closed tube, the spectral bands characteristic of nitrogen absolutely disappear. The blackish tarnish produced upon the surface of metallic lithium by exposure to the air appears to prevent the action, hence a fresh surface is necessary.—*Compt. Rend.*, cxxi, 886. H. L. W.

5. *The decomposition of silicates by boric acid.*—In a preliminary notice, P. JANNASCH states that he and H. HEIDENREICH have found the decomposition of silicates for analysis has been accomplished with entire success by the use of boric acid. For this purpose 1^g of the finely pulverized silicate is mixed with 5 or 6 parts of the previously dehydrated acid, then the mixture is strongly ignited for 15 or 20 minutes. The resulting fusion is then almost completely soluble in hot water and alcohol, or a considerable quantity of flocculent silicic acid may be left undissolved. This solution is now evaporated to dryness, and the evaporation is repeated after the addition of methyl alcohol and strong hydrochloric acid, in accordance with the observation of Gooch concerning the volatility of methyl borate. The author states that a series of exact silica determinations have been carried out by this method, and he recommends it as much more simple and expeditious, for the analysis of insoluble silicates in general, than the lead carbonate method which has been recently advocated by him.—*Bericht deutsch. Chem. Gesell.*, xxviii, 2822.

6. *Lighting*, Vol. II ot Chemical Technology, edited by GROVES and THORP, 8vo, pp. 398, Philadelphia. 1895, (P. Blakiston, Son & Co. $4.00).—The present volume is an elaborate work on applied chemistry dealing with fats and oils, the stearine industry, candle manufacture, the petroleum industry and lamps. The subjects are treated very thoroughly and comprehensively, and the book is supplied with profuse illustrations of excellent character. A subsequent volume will take up the subjects of gas-lighting, electric lighting, etc. H. L. W.

7. *Movable Light phenomena in rarified gases occasioned by Electrical oscillations.*—J. ELSTER and H. GEITEL in the course of an investigation on kathode rays, observed a remarkable movement of the kathode rays which evidently was due to a wave motion. They employed a step-up transformer connected with an alternating machine to produce the electrical discharges and modified Lenard's kathode ray apparatus in certain respects. The kathode rays could apparently be formed in the rarified chamber as if they proceeded from an electrode in the rarified media, entirely apart from the metallic kathode. The streams could be made to extend from one portion of the glass wall of the Geissler tube in a bent form to another portion. The authors conclude from their experiments that the kathode rays are due not to matter repelled from the electrode but to movements of the ether.—*Ann. der Physik und Chemie*, No. 12, 1895.

J. T.

8. *Ratio between the Electrostatic and Electromagnetic units.*—M. D. Hurmuzesca in his measures employed Maxwell's method in which an electrostatic attraction is balanced by an electrodynamic repulsion. The difference of potential at the ends of a resistance, R, was measured by an absolute electrometer, and the current through this resistance by an electro-dynamometer, the movable coil of which was attached to the lever which carried the movable portion of the electrometer. The value obtained was $V=3{\cdot}0005\times10^{10}$ and $V=3{\cdot}0020\times10^{10}$. The author believes that the measurements of the electrical dimensions are correct to one part in three thousand, and that the accuracy in the determination of V is controlled by that of the determination of the ohm. —*Comptes Rendus*, Dec. 2, 1895. J. T.

9. *Discharges of Electricity through Gases.*—If the discharge tube is surrounded by water, alcohol, turpentine and other media the discharge no longer takes place. This effect is not due to conduction. If a point electrified by a Holtz machine is moved near the tube the discharge is facilitated, and the discharges take place under atmospheric pressure.—*Ann. der Physik und Chemie*, No. 12, 1895, pp. 700–716. J. T.

10. *Double Refraction of Electric Waves.*—R. Mack proves that the electric rays through wood undergo double refraction, and that these rays travel with different velocities. The values obtained for the indices of refraction were $N_1=1{\cdot}75$ and $N_2=2{\cdot}15$.—*Ann. der Physik und Chemie*, No. 12, 1895, pp. 717–732. J. T.

11. *Relation between the atom and the charge of Electricity carried by it.*—Prof. J. J. Thomson, in the course of an important paper, illustrates the phenomena in the electric field in which the movement of the atoms take place by various mechanical and hydrodynamical analogies. In the course of his investigation he employed the transformer of Elihu Thomson, which consists of a species of secondary Ruhmkorf coil, the primary of which is connected in circuit with Leyden jars, the spark of which is blown out. The blowing out apparatus serves, so to speak, as the break for the secondary of few turns wound on this primary. In this way intense electromotive force can be obtained. The author discusses the question of the relative velocities of the negative and positive atoms, and shows that if the negative atoms move more quickly than the positive, then in a discharge tube in a steady state, the pressure at the positive electrode must be higher than that at the negative. In the case, for instance, of a tube 1^{mm} in diameter, 10^{cm} in length, filled with hydrogen at a pressure of one ten-thousandth of an atmosphere, and conveying a current of one ten-thousandth of an ampere, supposing the velocity of the negative atom to be much greater than that of the positive, the pressure at the positive electrode would exceed that at the negative electrode by about twenty per cent.—*Phil. Mag.*, Dec. 1895, pp. 511–544. J. T.

12. *The duration of Electrical Shadows with solid and fluid insulators.*—Electrical shadows produced by the brush discharge of the conductor of a Holtz machine were first noticed by Professor A. W. Wright, who used as the shadow-giving bodies the finger, wire gratings, paper and cork. Holtz has also worked upon this subject, and used for one electrode a metallic point, and for the other a circular metal plate which was covered with a thin layer of silk. The point can be made positive or negative. One can consider the space between both electrodes as a field of electric force, the force lines of which are made visible by the brush discharge. The electric force in this field is not of the same strength, being greatest along the shorter line between the point and the plate. When one brings a dielectric into this field, an electric polarization occurs between the smallest particles, or according to Maxwell's theory, a displacement current arises. The work expended in causing these polarization or displacement effects produces the shadows. The duration of the electric shadows measures the time of the setting up of the polarization effects or the duration of the displacement currents in the dielectric. Quincke has measured this element of time with a large number of dielectrics. There does not seem to be a simple relation between the duration of the electric shadows and the dielectric constants.—*Sitzungsberichte der Academie der Wissenschaften*, Berlin, May 30, 1895. J. T.

13. *A Laboratory Course of Experimental Physics;* by W. J. Loudon and J. C. McLennan. 8vo, 302 pp. New York and London, 1895 (Macmillan and Co.).—The present volume is the result of the experience of the authors at the University of Toronto in their efforts to provide a suitable course in experimental physics for a large college class. The difficulties that they have met with and try here to overcome are such as many teachers encounter elsewhere and the latter cannot fail to be benefited by their work. The volume is divided into two parts. The first is elementary and gives such experiments as can be performed by beginners, and which require only a knowledge of elementary mathematics. The second part is for advanced students and involves a ready familiarity with the use of the Calculus. In the first portion are given the experiments dealing with the departments of hydrostatics, gases and light, while those belonging to acoustics, heat and electricity are introduced in the second part. Some teachers may find it advantageous to deviate from this rather arbitrary order of subjects. The work as a whole has been very well carried through and is a valuable addition to the available text-books in this department.

14. *Terrestrial Magnetism.* An international quarterly journal published under the auspices of the Ryerson Physical Laboratory, A. A. Michelson, Director. Edited by L. A. Bauer. Vol. I, No. 1. Chicago (The University of Chicago Press. Two dollars a year). —This new journal is to be devoted exclusively to terrestrial magnetism and its allied subjects, as earth currents, auroras,

atmospheric electricity, etc. It thus fills a place never occupied before and it may be safely predicted that under the able editorship of Dr. L. A. Bauer, who has himself made notable original contributions to terrestrial magnetism, it will do much to stimulate research and observation in this important but difficult branch of science. The editor-in-chief will be aided by a large number of associates, both in this country and abroad. The opening number contains the following articles (pp. 1–28): On electric currents induced by rotating magnets and their application to some phenomena of terrestrial magnetism, A. Schuster; die Vertheilung des erdmagnetischen Potentials in Bezug auf beliebige Durchmesser der Erde, A. Schmidt, Gotha; Halley's earliest equal variation chart, reproduced in fac-simile for the first time from a photograph furnished by Thos. Ward, Esq., of the chart in his possession, text by L. A. Bauer. The remainder of the number, pp. 28–54, is occupied by letters to the editors, notes, reviews, etc.

II. Geology and Mineralogy.

1. *U. S. Geological Survey. 16th Annual Report of the Director*, Chas. D. Walcott.—The present director of the United States Geological Survey has succeeded in presenting in printed form to the Secretary of the Interior at the opening of Congress in December a report of the operations of the survey for the year ending June 30, 1895. Although no radical changes either in policy or personnel were made by the new administration of the survey, a few changes have been made in the way of development of its usefulness. Among these changes may be noted the raising of the quality of the topographic maps and adding the representation on the maps hereafter surveyed in the public-land States of the land-subdivisions; the planning of a system of triangulation to supplement that already done by the Coast and Geodetic Survey and by the Geological Survey; the placing of the entire topographic force within the classified service, so as to limit all appointments to men whose qualifications have been tested by an impartial and thorough examination; the obtaining of authority to print the mineral resources as a part of the annual report; and several other important changes. The appropriation for the work of the survey was $421,600, and in the appropriation act separate sums were set apart for the separate departments of the survey. There was in addition the appropriation for printing which was committed to the public printer—and the salaries of the director and his staff of immediate helpers and office needs were provided for by a separate act—thus limiting the discretionary powers of the administration but giving it a more compact and business-like organization. The internal work of the survey is more minutely divided than it was in former years, giving each field party responsibility for its own work, and each geologist now reports directly to the director of the survey. The work of the survey is

distributed in four groups, Geologic, Topographic, Publication and Administration. Under the geologic branch, there are the divisions of Geology, Paleontology, Chemistry, Hydrography and Mineral Resources. The division of geology was conducted by twenty-six field parties, each party in charge of a geologist or assistant geologist who reported directly to the director. Some of the results reached during the year are the following: The Shaler party in New England have developed the facts regarding the coal field in Rhode Island and made experiments tending to prove a practical use for the large stores of anthracite of this region—also a report on the road-building stones of Massachusetts will appear in the accompanying documents. The Dale party was engaged in mapping the areal geology of the roofing-slate belt of New York and Vermont. Valuable scientific information regarding the Devonian and Silurian rocks was developed by the Willis party working at the coal regions of West Virginia and Maryland. The Campbell party developed the fact that in the extension of the Pottsville coal series of Pennsylvania southward into West Virginia the series itself was increased by the addition of lower beds. The Hayes party have done much in the Tennessee, Georgia and Alabama regions to increase the knowledge of the coals, iron ores, manganese, bauxite and phosphate beds of this region. The R. D. Lacoe collection of carboniferous coal plants recently presented to the National Museum by its maker is of great value and has engaged part of Mr. David White's time during the year, he reports it as containing upward of 80,000 specimens of paleozoic plants. Its scientific value is great, as it contains nearly two-thirds of the original specimens described and figured from the carboniferous flora of the United States. The Georgia and Carolina gold belt was examined by the Becker party, notice of the results has already appeared in these pages. The Van Hise party were working in the Lake Superior region; in their survey they used successfully the magnetic needle in tracing the connection between the Marquette and Michigamme iron-bearing formations over an area where the exposures were very rare. Mr. Gilbert's party have done great service in the Colorado region by determining the depth and position of strata which are likely to furnish successful artesian well supplies. Mr. Hill's party in Texas sent in some pure white chalk from the Cretaceous of that region for illustration of this rock from the United States.

Mr. Emmons carried on laborious and extensive underground examinations of the mines of the Leadville region in the preparation of a supplementary report on this important mining district. He reports the probability of developments of new gold deposits along the contacts between the porphyry and limestones, but on account of the great irregularity of the porphyry intrusions it is impossible to locate exactly where the deposits will occur. Valuable results are also reported from the examination of the Oquirrh mountain range of Utah. Gold and silver being found beneath thin sheets of eruptive rock occupying a geologic horizon which is probably at the base of the carboniferous limestone. The Cripple Creek gold district was examined and reported on by Mr. Cross, and the ore deposits were studied by Prof. Penrose. An important work has been done by Mr. Diller in the preparation of the educational series of rocks. The work is far advanced and with the accompanying bulletin the specimens are expected to be soon ready for distribution. Other valuable results have been accomplished by the Weed and Eldridge parties in the Rocky mountains; by the Chamberlin party on glacial deposits; by the Turner, Lindgren and Lawson parties in the Pacific region. The director personally made a wide reconnaissance survey over the mining fields of the western United States; thus bringing the survey in touch with a large number of persons taking a vital interest in its proceedings. The Paleontological division was cramped in its work by the smallness of appropriations but several parties were in the field and work already begun was continued with as much vigor as was possible under the circumstances.

The division of Hydrography is the continuation of the work originally assigned to the irrigation division of the survey of 1888, and its investigations are now confined to questions of water supply for the arid region including the location and the volume of rivers. The work has been chiefly done under the charge of Mr. Newell; and investigations have been carried on during the year in the States of Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, N. and S. Dakota, Oregon, Texas, Utah, Washington, Wyoming and, to some extent, in the Eastern States.

The "Mineral Resources of the United States" prepared by Dr. Day will hereafter appear as a part of the Director's Annual Report, it will constitute parts iii and iv of the present annual report.

The organization of the topographic branch has been radically changed. It is now consolidated under the name of topographic branch of the survey under the charge of Mr. Gannett, with two divisions, one of triangulation and the other of topography, and the work is classified by region into four sections, as the Atlantic, Central, Rocky mountain and Pacific sections. The work has been pushed forward with renewed energy and precision.

The other departments of the survey are alike in admirable organization, and the report presents a thoroughly business-like account of its work, which indicates that the survey has lost none of the admirable qualities of its former administration, and that its director is as excellent an executive as geologist. H. S. W.

2. *U. S. Geological Survey; recent Publications.*—The following portions of the sixteenth annual report have already appeared: *Sixteenth Annual Report of the Director, 1894–95;* by CHARLES D. WALCOTT, 4°, pt. I, pp. 130, pl. i. The operations and results

of the geologic work are briefly but comprehensively described.* The condition and progress of the topographic work are illustrated by a general map.

A Geological Reconnoissance across Idaho; by GEORGE H. ELDRIDGE, pt. II, pp. 66, 3 pl., 4 figs. Between Salmon City and Boise ten formations besides a great variety of eruptive rocks are noted. The granites and syenites, in part at least, are probably Archæan; the schists are Algonkian. Quartzites are distributed from the Algonkian to the Carboniferous, while the limestones may include both Silurian and Carboniferous. The age of the great calcareous shale series of the Wood River district is undoubtedly Paleozoic and probably Carboniferous. The sandstones and clays are all of Tertiary age and Post-Pliocene gravels are abundant. In the Continental divide the structure is anticlinal, trending northwest and southeast, but at some other points, especially in the western part of the state, the structure lines trend east-northeast.

Mineral Resources of the United States; by DAVID T. DAY, pt. III, Metallic Products, 646 pp., 13 pl., 9 figs., and pt. IV, Non-metallic Products, 735 pp., 6 pl. By an act of Congress the reports on mineral resources, which were heretofore published in separate volumes, are now included in the annual report of the director but the parts are bound separately. Most of the 37 articles contained in these parts are of a statistical nature, but some of them, as for example *Reconnoissance of the Gold Fields of the Southern Appalachians* by G. F. Becker (see this Journal for Jan. 1896, p. 57), and *Bauxite* by C. W. Hayes, pt. III, p. 547, contain valuable contributions to economic geology.†

A Mineralogical Lexicon of Franklin, Hampshire and Hampden Counties, Massachusetts; by B. K. EMERSON. Bulletin No. 126, 8vo, 180 pp., 1 pl., 5 figs. This bulletin gives a condensed history of each mineral species occurring within the area indicated and is conveniently arranged for reference.

The Bear River Formation and its characteristic Fauna; by C. A. WHITE. Bulletin No. 128, 8vo, 108 pp., 11 pls. Its fauna, which is non-marine, consisting of 48 species, is fully illustrated and described. The position of the formation is designated as at or near the base of the Upper Cretaceous series, thus correcting earlier opinions and confirming the author's suggestion as well as the investigations of T. W. Stanton, who published an article upon the same subject in this Journal, III, vol. xliii, pp. 98–115.

Earthquakes in California in 1894; by C. D. PERRINE. Bulletin No. 129, 8vo, 23 pp.

Report of Progress of the Division of Hydrography for the calendar years 1893 and 1894; by F. H. NEWELL. Bulletin No. 131, 8vo, 126 pp. J. S. D.

* See the preceding review.

† Six papers in part I of the Sixteenth Annual Report and five in part II are yet to appear and will be noticed when issued. Parts III and IV are now complete.

3. *Geology of the Green Mountains in Massachusetts;* by Raphael Pumpelly, J. E. Wolff, and T. Nelson Dale (U. S. Geol. Survey Monograph, vol. xxiii, 1894), pp. i–xiv, 1–206, pls. 1–23.—This monograph is the result of thorough investigations of the structure, petrography and minute texture of the rocks of a most difficult metamorphosed region, which were begun in 1885, and although the grander features of the interpretation were substantially reached in 1888, later studies have enabled the authors to correct and confirm the interpretations as now published.

The monograph is composed of three separate parts; the first, by Raphael Pumpelly, defines the nature of the problems involved, and their importance and bearing in bridging over from the discrete formations in the western undisturbed regions to the thoroughly metamorphosed schists of the more eastern areas of New England. The chief difficulties lay in the correlation of the continuous series of metamorphosed schists of the Hoosac mountain series with the series of conglomerates, limestones and schists of the Graylock area. Regarding the lower members of the series, Mr. Pumpelly interprets the "transitional coarse gneisses" to be the result of a Cambrian transgression. He imagines the Cambrian transgression to have found an Archæan elevation, forming the western border of an Archæan dry region, and that the rocks of this dry area had become disintegrated the products varied from kaolin and quartz to semi-kaolinized material, and the detritus of sand and pebbles arising from this disintegrated material was deposited with varying proportions of its constituents in a continuous sheet in progressive "transgression" over the previously dry land. Thus quartzite in one place is interpreted as of the same horizon as the gneiss in another. The white gneisses and conglomerates of Hoosac mountain are correlated with the Cambrian quartzite, the albitic schists of Hoosac mountain with both the limestone and schist of the valley. The metamorphism of the Paleozoic rocks is interpreted as intimately connected with the folding which the rocks of the whole region have suffered; but while structural differences are so explained, differences in composition are explained by the exceptional character of the original sediments.

The second part, by J. E. Wolff, "The Geology of Hoosac Mountain and adjacent Territory," gives a petrographic description of the rocks, with beautiful photo-reproductions of the structures of the metamorphic conglomerates, the albitic schists, the Stockbridge limestone and the amphibolites, together with a detailed elaboration of the structural geology of the region. Although this author concludes that the metamorphic rocks are chiefly of detrital origin, he is not prepared to say that the granitoid gneiss is an altered sediment.

Mr. Dale's paper, Part III, "Mount Graylock; its areal and structural geology," is particularly interesting for its application of a microscopic study of the structure of the foliation of the rocks to the interpretation of the original planes of sedimentation, and therefrom their present deformation. The author says "the key to the structure is in the distinction between cleavage foliation and stratification." He has not only recognized means of detecting these latter by the former, but has produced beautiful illustrations of the principal types of the phenomena, and has formulated a number of general rules for their practical application which have served him in interpreting the original stratigraphical sequence and their present structural relations of the Graylock mountain series. His paper is further enriched by numerous plates illustrating the topography and geological sections of the region.

The three papers together constitute a valuable illustration of modern methods of conducting geological correlation in regions where fossils fail and original structure is masked by later metamorphism. H. S. W.

4. *The Geological Society of America.*—The eighth annual meeting was held in Philadelphia, Pa., beginning Thursday, December 26, 1895, in the Art Department, University of Pennsylvania. The officers of the Society elected for the year 1896 are as follows: President, Joseph LeConte, California; First Vice-President, Charles H. Hitchcock, New Hampshire; Second Vice-President, Edward Orton, Ohio; Secretary, H. L. Fairchild, New York; Treasurer, I. C. White, West Virginia; Editor, J. Stanley-Brown, Washington, D. C.; Councilors, B. K. Emerson, Amherst, Mass., J. M. Safford, Nashville, Tenn.

At the opening session memorials of the four fellows whose death occurred during the past year were read. The memorial of James D. Dana was prepared by Joseph LeConte, that of Henry B. Nason by T. C. Chamberlin, that of Albert E. Foote by George F. Kunz, and that of Antonio del Castillo by Ezsquiel Ordonez.

At the several sessions the following papers were presented:

George P. Merrill: Disintegration and decomposition of diabase at Medford, Mass.

Charles R. Keyes: The geographic relations of the granites and porphyries in the eastern part of the Ozarks.

J. F. Kemp: Illustrations of the dynamic metamorphism of anorthosites and related rocks in the Adirondacks.

N. S. Shaler: The importance of volcanic dust and pumice in marine deposits; The relations of geologic science to education (Presidential address).

L. V. Pirsson: A needed term in petrography.

John J. Stevenson: The Cerrillos coal field of New Mexico.

W. M. Davis: Note on the outline of Cape Cod; Plains of marine and subærial denudation.

F. P. Gulliver: Cuspate fore-lands.

M. R. Campbell: Drainage modifications and their interpretation.

N. H. Darton: Some fine examples of stream robbing in the Catskill Mountains; Notes on relations of lower members of coastal plain series in South Carolina; Resumé of general stratigraphic relations in the Atlantic coastal plain from New Jersey to South Carolina.

Robert Bell: Proofs of the rising of the land around Hudson Bay.

C. R. Van Hise: Movements of rocks under deformation.

Alfred C. Lane: Possible depth of mining and boring.
Harry Fielding Reid: Notes on glaciers.
Frank Leverett: The relation between ice lobes, south from the Wisconsin driftless area; The lœss of western Illinois and southeastern Iowa.
G. Frederick Wright: High level terraces of the middle Ohio and its tributaries.
H. L. Fairchild: Four great kame areas of western New York.
Warren Upham: Preglacial and postglacial channels of the Cuyahoga and Rocky rivers.
C. H. Hitchcock: Paleozoic terranes in the Connecticut valley.
C. Willard Hayes: The Devonian formations of the southern Appalachians.
T. C. Chamberlin: The Natchez formations.
Arthur Keith: Some stages of Appalachian erosion.

5. *The Cerrillos Coal Field;* by John J. Stevenson. (Abstract of a paper presented at the winter meeting of the Geological Society of America.)—This paper describes a small portion of the area formerly known as the Placer coal field, south from the Rio Galisteo and about 25 or 30 miles south from Santa Fe, New Mexico. The only rocks within this area are Laramie and Eruptive. The latter proceed from the laccolite known as the Placer or Ortiz mountains and occur in two sheets separated by about 400 feet of Laramie beds. These sheets, each about 200 feet thick, are intruded between the stratified rocks and follow their dip closely. The rock has been identified by Prof. Kemp as trachyte but closely allied to andesite. The Ortiz or Placer mountains are about two miles from the most southerly locality visited.

The column of Lamarie exposed is not far from 1,000 feet thick and contains several coal beds of economic importance, only three of which are discussed in this paper. The highest bed, about 900 feet from the base of the column and known as the *White Ash*, has been opened at many places along the principal gorge, Coal cañon. At the most northerly mine, the White Ash, its coal is bituminous, containing 39 per cent of volatile combustible, but at the Lucas mine, not more than 3,000 feet further up the cañon, it is anthracite with but 1 per cent of volatile. The interval between these mines contains for the most part coal so crushed as to be practically unmarketable; but as shown in one level of the White Ash mine, the transition from soft to anthracite coal is gradual. Further up the cañon, toward the Ortiz mountains, the coal becomes harder and at one opening resembles the Rhode Island anthracite.

The lower important bed on Coal cañon is the *Cook-White*, which is not mined at present. It shows the same changes, being distinctly anthracite at the old openings up the cañon, but becoming bituminous lower down, where it contains 30 per cent of volatile. A small bed, midway between the *White Ash* and the *Cook-White*, shows no variation, being bituminous at the most southerly point visited, although the *White Ash* is anthracite in the same locality. But this bed is much cut by clay seams and is not continuous. The cause of the metamorphosis of the coal is contact with eruptive rocks. The clay seams of the smaller bed prevented transmission of the heat and changes in the coal. Actual contact with the molten rock appears necessary to produce change, for the upper sheet of trachyte comes down to within a few feet of the *White Ash* and evidently has no effect upon its composition; the transition from bituminous to anthracite in that coal bed is regular from the north southward under the sheet, and apparently in no greater ratio than in the *Cook-White*, 150 feet lower, which in turn is fully 200 feet above the lower sheet.

6. *Note on the Trap Rock of the Palisades;* by BENJ. SMITH LYMAN (from a letter to the editors, dated Philadelphia, Jan. 7, 1896).—In the January number of this Journal (p. 4), Prof. Wm. M. Davis refers to my recent report on the New Red of Bucks and Montgomery counties, in the Pennsylvania Geol. Surv., final report, vol. iii, p. 2621, for a brief argument of mine against the intrusive character of the trap of the Palisades. It may be worth while, for the benefit of those interested in the subject, to call attention also to a little fuller discussion of the point in the Proceedings of the American Philosophical Society, vol. xxxiii (1894), p. 195. The intrusive character seems to him "undoubtable." To others it seems not only doubtable, but entirely contrary to observed facts. He speaks of the great length (over fifty miles) of the Palisades trap as the only argument against him; and, indeed, it seems to be of itself an invincible one when taken in connection with the other circumstances, such as the soft shaliness of the sedimentary beds, their gentle dip, the great crookedness of the outcrop, and the exact conformity of the trap beds (not a single bed) to the shales, as made thoroughly evident by the topography of the whole region—not merely "rough" conformity, as he conjectures without substantial proof.

It used to be imagined that volcanic rock, or trap, forced its own way, as a solid wedge might, through hitherto unbroken rock beds, separating them and even lifting them up, to open a passage. It is sufficiently incredible that such a passage would adhere to one bedding plane around basins and saddles in soft, gently dipping shales for a distance of fifty miles. But, taking the view that igneous rock in general merely flows into crevices it finds open, it becomes still more inconceivable that they could have opened along a single bedding plane in such shales, with such dips and such an irregular structure, for such a distance.

7. *Missouri Geological Survey.*—The Annual Report for 1894, received November, 1895, contains the 3d biennial Report of the Director, pp. 1–79; the subjects discussed are: The Crystalline Rocks of Missouri, ERASMUS HAWORTH, pp. 81–224—map, and plates xii–xxx, chiefly micro-photo lithographs; Dictionary of Altitudes, by C. F. MARBUT, pp. 225–316; Characteristics of Ozark Mountains, by CHAS. R. KEYES, pp. 317–352, and Coal Measures of Missouri, by GARLAND C. BROADHEAD, pp. 353–395.

8. *Iowa Geological Survey.*—The third Annual Report, 1894, under the present state geologist, SAMUEL CALVIN (pp. 1–467,

plates i–xi, figures 1–54, and 6 geological maps), contains detailed reports upon the geology of counties of Allamakee, Linn, Van Buren, Keokuk, Mahaska and Montgomery, written by several members of the geological corps.

9. *Illinois State Museum of Natural History.*—Bulletin No. 6. Description of New Species of Paleozoic Echinodermata, by S. A. Miller and Wm. F. E. Gurley, pp. 1–62, plates i–v. Springfield, Ill., April, 1895.

10. *Geological Survey of Canada.*—The second part of the third volume of "Paleozoic Fossils" was published September, 1895 (pp. 45–128, plates ix–xv), and contains the following papers by J. F. Whiteaves, viz: 2. Revision of the fauna of the Guelph formation of Ontario, with descriptions of a few new species. 3. Systematic list, with references, of the fossils of the Hudson River or Cincinnati formation of Stony Mountain, Manitoba.

11. *A needed Term in Petrography*, by L. V. Pirsson. (Abstract of paper read at the winter meeting of Geological Society of America.)—The term crystal when properly used carries with it essentially the idea of an outward geometric form bounded by planes arranged according to certain laws of symmetry, though it implies also a certain interior molecular structure with definite physical properties. There is thus at present no good term to express the formless or rounded masses in which minerals occur, especially in eruptive rocks, and which possess the interior molecular structure of crystals though not their outward form. For such formless or rounded masses the term *anhedron* (without planes) is proposed, and such mineral masses may also be spoken of as having an anhedral development.

12. *Manual of Lithology*, by E. H. Williams, 2d ed., revised and enlarged, 8°, 418 pp., 6 plates. New York, 1895 (Wiley Pub.). —In this new edition of his little manual Prof. Williams has so greatly enlarged and in so many details changed the character of the work that it bears little resemblance to the former edition. After a short introduction and discussion, the chief rock-making minerals are described; then follows an explanation of the terms (of structure, etc.) used in lithology, which is succeeded by the description of the different kinds of rocks, which comprises all three groups, the igneous, sedimentary and metamorphic. The volume closes with a scheme for determining rocks by their megascopic character combined with physical and chemical tests.

In the brief limits of this notice it is impossible to give any extended review of the work. We note, however, that the proposed basis of classification for the igneous rocks, based as it is on the predominance of the ferro-magnesian silicate present, must present so many uncertainties, together with some absolute contradictions, that it is scarcely probable that it will be generally adopted. We notice also in places obscurities in the author's style which render it difficult to ascertain his precise meaning.

L. V. P.

13. *Handbuch der Mineralchemie;* von C. F. Rammelsberg, Zweite Ergänzungsheft zur zweiten Auflage. 8vo, 478 pp. Leipzig, 1895. (Wilhelm Engelmann.)—This second supplement to the second edition of Rammelsberg's great work on *Mineralchemie*, follows the first after the long interval of nearly ten years. During this period many important additions have been made to the literature of mineral chemistry and much progress has been made in the knowledge of the composition of rare species. All of this material has now been collated and worked over by the veteran mineral chemist. The work follows the same line as its predecessor by the same author. His suggestions are based in each case on careful thought and new calculations and always deserve respectful consideration, but many will not follow him in some of his conclusions; for example, in his sweeping refusal to accept the idea that hydroxyl (OH) may replace fluorine in a mineral compound, nor his explanation that in such cases the water yielded on analysis (e. g. topaz, herderite, amblygonite) is due to gradual alteration.

III. Botany.

1. *Plant-breeding. Being five lectures upon the amelioration of domestic plants;* by L. H. Bailey. (Macmillan & Co., 1895.).—Professor Bailey, of Cornell University, gives in this handy work, of less than three hundred pages, sufficiently explicit directions to guide any person of ordinary judgment in the interesting task of crossing plants. While we miss in its pages references to the very important work by Nägeli, we find enough of essentially the same method of treatment to give the volume high value, not only as a practical treatise, but also as stimulating speculation. The hand-book can be heartily recommended to all classes of persons interested in living plants. G. L. G.

2. *Tubercles on the roots of the Soja bean.*—Professor Kirchner (Cohn's Beiträge zur Biol. der Pflanzen, xvii, 2, 1895) has conducted a few remarkably interesting experiments in regard to the production and character of these swellings. When the Soja beans were cultivated in good soil, such as one would ordinarily employ for experimental purposes, no conspicuous tubercles were formed, but when to this soil was added a small amount of earth brought from Japan, and presumably infected with the bacteria associated with the plant, tubercles were abundantly formed, and the plants grew more thriftily than under previous conditions. The soil came from Japan in well-soldered metallic boxes. It was black, uncommonly light, volcanic ash. It was moist when it arrived, and contained fragments of the roots of the Soja plants which had been cultivated therein.

While the observation is not wholly new, it confirms some kindred results, and tends to open up still farther the possibility of more successful cultivation of *Papilionaceæ* in infected soil. Gonnermann (Land w. Jahr b. xxiii, 1894) has apparently demonstrated that root tubercles are not produced by only one species of bacterium, varying, as some have thought, according to the kind of soil in which they occur.

Although much advance has been made in the direction of settling some of these disputed points, a great deal remains to be learned in regard to turning the observations to practical account. Two of our southern plants, the so-called "Cow-pea," in its multiform varieties, and *Arachis*, appear to be the best subjects of research in this department. The increasing utility of the former as a direct or indirect fertilizer, and of the latter in its new applications in the production of a food, after the extraction of the oil, indicates the desirability of experiments at the southern stations. G. L. G.

3. *Modifications of the Cell-wall.*—There are two recent communications relative to changes in the cell-wall which may be conveniently considered together. VAN WISSELINGH points out numerous differences between the formation and character of Suberin and Cutin, of which we here recount only the most important. Suberin is always laid down at a later period than Cutin, and appears on the inner side of the cell-wall, in direct contact with protoplasmic matter, whereas Cutin arises on the outside of epidermal cells, and possesses between itself and the protoplasm a layer of well-marked cellulose. Suberin is more easily saponified by potassic hydrate that Cutin is, and the products of saponification differ in appearance from those arising from Cutin.

The other paper deals with the mucilaginous modification of the walls of cells. MANGIN (Bulletin Sec. Fr., xli) classifies mucilages into simple and complex, dividing the former again into (1) cellulose mucilages; which are rather rare (a good example is afforded by Salep), (2) pectose mucilages, common in *Malvaceæ*, *Tiliaceæ*, and certain algæ; (3) callose mucilages, confined in the higher plants to the sieve tubes. The second group of mucilages, the mixed, or complex, belong to various seeds. Here we find the cellulose and pectose-mucilages commingled in different amounts.

According to Guiraud, the mucilage in *Malvaceæ* is found to some extent in all organs, and comes from the breaking down of the walls of certain cells in the secondary parenchyma. It may be retained in special cells, or it may overflow from them.

The existence of nitrogen in the so-called mucilage of at least two species of *Dioscorea* may be regarded as settled by the work of ISHII, of Japan. The mucin here found is essentially like that occurring in animals. G. L. G.

4. *On the accumulation of sugar in the root of the Beet.* (Comptes Rend., 2 Dec. 1895.)—L. MAQUENNE calls attention to the difficulty of explaining the equilibrium which exists between the leaves and the root of beets, considering the chemical composition of the two. It is easy to understand how the carbhydrates elaborated by the chlorophyll-bearing cells reach the root by

diffusion; but it is not so easy to tell why, after taking the form of sugar, these carbhydrates do not return to the leaves again, in virtue of the very same laws of diffusion. Since uniformity does not exist between the chemical composition of cell-contents in different parts of the plant, diffusion must be assumed to be balanced by some other force. The author regards this as a simple question of osmotic balance. Applying the doctrine of osmotic equivalents to the special case in hand, he states that the saccharose in the root, to satisfy the demands of existing conditions, should be, in concentration, double that of the reducing sugars found in the leaves. Further, a similar equilibrium may be supposed to exist between the root and the soil. MAQUENNE's recorded results are suggestive from many points of view. From them he enunciates the following law, which he regards as of general applicability to Physiology,—any immediate principle can accumulate whenever its formation gives rise to a reduction of osmotic pressure. It is interesting to notice that this substantially restates a law applied by DEHERAIN to the appropriation of mineral matters and the transfer of elaborated substances in plants. G. L. G.

5. *Guide to the British Mycetozoa;* by ARTHUR LISTER, pp. 42, fig. 44.—This little book is the second of the botanical series intended to serve as a guide to specimens exhibited in the British Museum. It gives a condensed account of British Mycetozoa taken from the author's monograph of the Mycetozoa, of which a notice was given a few months ago, preceded by a short account of the general structure and development of the order. The collection of British Mycetozoa and the series of colored drawings explaining their structure, now exhibited in the botanical gallery of the Museum, were presented by Mr. Lister, as well as over eight hundred mounted slides kept in a cabinet of the cryptogamic herbarium. This valuable collection, taken in connection with Mr. Lister's guide, will make it comparatively easy for students to recognize British species of this difficult order.

W. G. F.

6. *The Norwegian Forms of Lithothamnion;* by M. FOSLIE, pp. 180, 8°, pl. 23. Trondhjem, 1895.—In this elaborate monograph the author gives a critical study of the species of Lithothamnion and Lithophyllum of northern Europe, with occasional references to species of North America. Our knowledge of the confused species of the Corallinaceæ comprised in the Lithothamnion group has been much increased in recent years owing to the writings of Kjellman, Rosenvinge, Strömfelt and Foslie. The present paper is a revision of previous papers in the light afforded by fresh material from America as well as Europe. The writer reduces Lithophyllum to a subgenus of Lithothamnion, instead of regarding it as most closely related to Melobesia, where it was placed by Batters and ourselves; and the subgenus Eulithothamnion he divides into two sections, Innatæ, with innate, and Evanidæ, with superficial sporangial conceptacles. The definition of species in algæ of this

group is always a difficult matter, for both sporangia and cystocarps are often wanting, and the habit of the thallus depends upon the place of growth and the surroundings. Furthermore, the older descriptions were frequently very vague and incomplete. The author has reduced a number of the species of previous Scandinavian writers to synonyms, but has created a number of new species, so that we now have the surprising number of thirty-nine species in the region studied. Apart from Greenland species, the North American species noted are L. fruticulosum (Kütz) Fosl., and L. colliculosum Fosl., to which are referred the L. fasciculatum of Farlow's Marine Algæ of New England; L. flabellatum Rosenv., to which is doubtfully referred a sterile specimen found by Collins in Maine; L. compactum Kjellm., the common New England form usually referred to L. polymorphum; L. evanescens Fosl., collected by Collins at Marblehead, Mass.; L. lævigatum Fosl., from Kennebunkport, Me., Collins; and L. Strömfeltii Fosl., and L. Lenormandi (Phil.) Fosl., to which is referred in part the Melobesia Lenormandi of Farlow's Marine Algæ of New England. The habits of the different species are given in twenty-three good photo-lithographic plates. The monograph closes with a short chapter on Fossil Lithothamnia.

W. G. F.

IV. Miscellaneous Scientific Intelligence.

1. *The composition of expired air and its effects upon animal life;* by J. S. Billings, M. D., S. Weir Mitchell, M. D., and D. H. Bergey, M. D.—A memoir bearing the above title has been recently issued in the series of Smithsonian Contributions to Knowledge, No. 989. It gives the result of investigations carried on under a grant from the Hodgkins Fund of the Smithsonian Institution, for the purposes of determining the nature of the peculiar substances of organic origin contained in the air expired by human beings, with special reference to the practical application of the results obtained to problems of ventilation of inhabited rooms. The conclusions contain so much of general interest that they are printed here in full:

I. The results obtained in this research indicate that in air expired by healthy mice, sparrows, rabbits, guinea-pigs, or men, there is no peculiar organic matter which is poisonous to the animals mentioned (excluding man), or which tends to produce in these animals any special form of disease. The injurious effects of such air observed appeared to be due entirely to the diminution of oxygen, or the increase of carbonic acid, or to a combination of these two factors. They also make it very improbable that the minute quantity of organic matter contained in the air expired from human lungs has any deleterious influence upon men who inhale it in ordinary rooms, and hence it is probably unnecessary to take this factor into account in providing for the ventilation of such rooms.

II. In ordinary quiet respiration, no bacteria, epithelial scales, or particles of dead tissue are contained in the expired air. In the act of coughing or sneezing, such organisms or particles may probably be thrown out.

III. The minute quantity of ammonia, or of combined nitrogen, or other oxidizable matters found in the condensed moisture of human breath, appears to be largely due to products of the decomposition of organic matter which is constantly going on in the mouth and pharynx. This is shown by the effects of cleansing the mouth and teeth upon the amount of such matters in the condensed moisture of the breath, and also by the differences in this respect between the air exhaled through a tracheal fistula and that expired in the usual way.

IV. The air in an inhabited room, such as the hospital ward in which experiments were made, is contaminated from many sources besides the expired air of the occupants, and the most important of these contaminations are in the form of minute particles, or dust. The experiments on the air of the hospital ward, and with the moisture condensed therefrom, show that the greater part of the ammonia in the air was probably connected with dust particles which could be removed by a filter. They also showed that in this dust there were micro-organisms, including some of the bacteria which produce inflammation and suppuration, and it is probable that these were the only really dangerous elements in this air.

V. The experiments in which animals were compelled to breathe air vitiated by the products of either their own respiration or by those of other animals; or were injected with fluid condensed from expired air, gave results contrary to those reported by Hammond, by Brown-Séquard and d'Arsonval, and by Merkel, but corresponding to those reported by Dastre and Loye, Russo-Giliberti and Alessi, Hoffmann-Wellenhof, Rauer, and other experimenters referred to in the preliminary historical sketch of this report, and make it improbable that there is any peculiar volatile poisonous matter in the air expired by healthy men and animals, other than carbonic acid. It must be borne in mind, however, that the results of such experiments upon animals as are referred to in this report may be applicable only in part to human beings. It does not necessarily follow that a man would not be injured by continually living in an atmosphere containing two parts per 1000 of carbonic acid and other products of respiration, of cutaneous excretion, and of putrefactive decomposition of organic matters, because it is found that a mouse, a guinea-pig, or a rabbit seems to suffer no ill effects from living under such conditions for several days, weeks, or months; but it does follow that the evidence which has heretofore been supposed to demonstrate the evil effects of bad ventilation upon human health should be carefully scrutinized.

VI. The effects of reduction of oxygen and increase of carbonic acid to a certain degree appear to be the same in artificial mixtures of these gases as in air in which the change of proportion of these gases has been produced by respiration.

VII. The effect of habit, which may enable an animal to live in an atmosphere in which, by gradual change, the proportion of oxygen has become so low, and that of the carbonic acid so high, that a similar animal brought from fresh air into it dies almost immediately, has been observed before, but we are not aware that a continuance of this immunity produced by it had been previously noted. The experiments reported in the Appendix, VII, 17 to 28, show that such an immunity may either exist normally or be produced in certain mice, but that these cases are very exceptional, and it is very desirable that a special research should be made to determine, if possible, the conditions upon which such a continuance of immunity depends.

VIII. An excessively high or low temperature has a decided effect upon the production of asphyxia by diminution of oxygen and increase of carbonic acid. At high temperatures the respiratory centers are affected, where evaporation from the skin and mucous surfaces is checked by the air being saturated with moisture; at low temperatures the consumption of oxygen increases, and the demand for it becames more urgent.

So far as the acute effects of excessively foul air at high temperatures are concerned, such, for example, as appeared in the Black Hole at Calcutta, it is probable that they are due to substantially the same causes in man as in animals.

IX. The proportion of increase of carbonic acid and of diminution of oxygen, which has been found to exist in badly ventilated churches, schools, theatres or barracks, is not sufficiently great to satisfactorily account for the great discomfort which such conditions produce in many persons, and there is no evidence to show that such an amount of change in the normal proportion of these gases has any influence upon the increase of disease and death-rates which statistical evidence has shown to exist among persons living in crowded and unventilated rooms. The report of the commissioners appointed to inquire into the regulations affecting the sanitary conditions of the British army (1), properly lays great stress on the fact that in civilians at soldiers' ages, in twenty-four large towns, the death-rate per 1000 was 11.9, while in the foot-guards it was 20.4, and in the infantry of the line 17.9, and showed that this difference was mainly due to diseases of the lungs occurring in soldiers in crowded and unventilated barracks. These observations have since been repeatedly confirmed by statistics derived from other armies, from prisons, and from the death-rates of persons engaged in different occupations; and, in all cases, tubercular disease of the lungs and pneumonia are the diseases which are most prevalent among persons living and working in unventilated rooms, unless such persons are of the Jewish race. But consumption and pneumonia are caused by specific bacteria, which, for the most part, gain access to the air-passages by adhering to particles of dust which are inhaled, and it is probable that the greater liability to these diseases of persons living in crowded and unventilated rooms, is, to a large extent, due to the special liability of such rooms to become infected with the germs of these diseases. It is, however, by no means demonstrated as yet, that the only deleterious effect which the air of crowded barracks or tenement-house rooms, or of foul courts and narrow streets, exerts upon the persons who breathe it, is due to the greater number of pathogenic micro-organisms in such localities. It is quite possible that such impure atmospheres may affect the vitality and the bacterioidal powers of the cells and fluids of the upper air-passages with which they come in contact, and may thus predispose to infections, the potential causes of which are almost everywhere present, and especially in the upper air-passages and in the alimentary canal of even the healthiest persons, but of this we have as yet no scientific evidence. It is very desirable that researches should be made on this point.

X. The discomfort produced by crowded, ill-ventilated rooms in persons not accustomed to them, is not due to the excess of carbonic acid, nor to bacteria, nor, in most cases, to dusts of any kind. The two great causes of such discomfort, though not the only ones, are excessive temperature and unpleasant odors. Such rooms as those referred to are generally overheated, the bodies of the occupants and, at night, the usual means of illumination contributing to this result.

The cause of the unpleasant, musty odor which is perceptible to most persons on passing from the outer air into a crowded, unventilated room is unknown; it may, in part, be due to volatile products of decomposition contained in the expired air of persons having decayed teeth, foul mouths, or certain disorders of the digestive apparatus, and it is due, in part, to volatile fatty acids given off with, or produced from, the excretions of the skin, and from clothing soiled with such excretions. It may produce nausea and other disagreeable sensations in specially susceptible persons, but most men soon become accustomed to it, and cease to notice it, as they will do with regard to the odor of a smoking-car, or of a soap factory, after they have been for some time in the place. The direct and indirect effects of odors of various kinds upon the comfort, and perhaps also upon the health of men, are more considerable than would be indicated by any tests now known for determining the nature and quantity of the matters which give rise to them. The remarks of Renk (38, p. 174) upon this point merit consideration. Cases of fainting in crowded rooms usually occur in women, and are connected with defective respiratory action due to tight lacing or other causes.

Other causes of discomfort in rooms heated by furnaces or by steam are excessive dryness of the air, and the presence of small quantities of carbonic oxide, of illuminating gas, or of arsenic derived from the coal used for heating.

XI. The results of this investigation, taken in connection with the results of other recent researches summarized in this report, indicate that some of the theories upon which modern systems of ventilation are based, are either without foundation or doubtful, and that the problem of securing comfort and health in inhabited rooms requires the consideration of the best methods of preventing or disposing of dusts of various kinds, of properly regulating temperature and moisture, and of preventing the entrance of poisonous gases like carbonic oxide, derived from heating and lighting apparatus, rather than upon simply diluting the air to a certain standard of proportion of carbonic acid present.

It would be very unwise to conclude from the facts given in this report, that the standards of air-supply for the ventilation of inhabited rooms, which standards are now generally accepted by sanitarians as the result of the work of Pettenkofer, De Chaumont and others, are much too large under any circumstances, or that the differences in health and vigor between those who spend the greater part of their lives in the open air of the country hills, and those who live in the city slums, do not depend in any way upon the differences between the atmospheres of the two localities except as regards the number and character of micro-organisms.

2. *Report of the Agricultural Experiment Stations of the University of California, for the year 1892-3 and part of 1894, being a part of the Report of the Regents of the University. Sacramento State Office, 1894.*—This volume of 506 pages is the most recent of a dozen very valuable Reports on the instruction and investigations undertaken by Prof. E. W. HILGARD and his colleagues. Besides the central experiment station at Berkeley, seven branch stations in various parts of California are carried on, the station staff consisting of eight scientists (also professors and instructors in the university) and twelve foremen. As California, with one exception, exceeds all other States of our Union in area and surpasses all in variety of soil, climate and vegetation, so she takes the lead in investigating the questions of science and practice which are involved in her agriculture.

In the introduction, Prof. Hilgard who, with leave of absence, spent the year 1892–3 in Europe, gives an interesting "report of observations on European agricultural schools and experiment stations." He found the agricultural university at Berlin with a faculty of fourteen professors, sixteen assistants and fifteen instructors, and using buildings and equipment that cost $632,000, exclusive of extensive museum collections. Of the 400 students in annual attendance, 200 were taking instruction in surveying and agricultural engineering; about 50 were fitting for government employment as clerks and fiscal officers, while 150 were agricultural students strictly considered, aiming to be managers of or employés on large estates.

Part I is a report and discussion of work in the general agricultural laboratories, comprising highly interesting researches into the chemical and mechanical composition and physical characters of soils, by Messrs. Hilgard, Loughridge and Jaffa; special study and reclamation of alkali soils, by Messrs. Hilgard, Colemore and Shinn; analysis of seventy natural waters, by Messrs. Jaffa and Curtis; chemical composition of various foods and fruits, by Messrs. Colby and Jaffa; an elaborate paper on olives, olive culture and olive oil, by Mr. Hayne; and one on the ash of grapes and fertilization of vineyards, by Mr. Bioletti.

Prof. Hilgard contributes important papers on nitrogen-contents of soil humus in arid and humid regions; on influence of climate upon the formation and composition of soils; the Cienegas of southern California; crops and fertilizers with reference to California soils and practice; fruits and fruit soils in the arid and humid regions.

Part II is occupied with reports of culture work at the several stations by Messrs. Wickson, Shinn, Kellner, Davy, Tyson, and Forrer.

Part III, by Prof. Woodworth, is devoted to entomology and plant diseases.

This volume altogether is one of great scientific and practical value. S. W. J.

3. *Dark companion to one of the components of the binary star 70 Ophiuchi.*—The star 70 Ophiuchi is composed of two components of the 4th and 6th magnitudes severally, whose greatest distance is less than 7 seconds. The period of rotation is about 90 years. The brightness of the components and their comparatively rapid angular motion make this system one of peculiar interest, and numerous computed orbits for it have been published. Professor See of Chicago University, in No. 363 of the Astronomical Journal (Jan. 1896), from an elaborate discussion of the measures made since Herschel in 1779 discovered that it was a double star, concludes that there must be a dark companion to one of the components. The deviations from pure elliptic motion seem to indicate quite unmistakably the existence of such dark body.

BOOKS AND PAMPHLETS RECENTLY RECEIVED AND THUS FAR NOT OTHERWISE NOTICED.

Contribution a l'Étude des Lapiés.—La topographie du désert de Platé (Haute-Savoie); par ÉMILE CHAIX. (Extr. du GLOBE, Journal géographique organe de la Société de Géographie de Genève, tom. xxxiv), pp. 1-44. plates i-xvi, 1895.

Soils of Illinois; by FRANK LEVERETT. (Extracted from Final Report, Ill. Board World's Fair Com.), pp. 77-92, 1895.

Preglacial Valleys of the Mississippi Tributaries; by FRANK LEVERETT. (Journ. Geol., vol. iii, Oct.-Nov., 1895), pp. 740-763, 1895.

The duration of Niagara Falls and the History of the Great Lakes; by J. W. SPENCER, pp. 1-126, figs. 1-27, plates i-v. Humboldt Publishing Co., New York 1895.

Geographical Evolution of Cuba; by J. W. SPENCER. (Extr. Bull. Geol. Soc. Am, vol. vii,) pp. 67-94, Dec., 1895.

Clay Industries of New York, prepared under the direction of FREDERICK J. H. MERRILL, by HEINRICH RIES. (Extr. N. Y. State Museum, vol. iii), pp. 96-262, illustrated, 1895.

The Animal Nature of Eozoön; by Sir WILLIAM DAWSON, C.M.G., LL.D., F.R.S., etc. (Extracted from the Geological Magazine, October, November, December.) London: Dulau & Co., 37 Soho Square, W.

Geology of Moriah and Westport townships, Essex Co., N. Y., with a Geol. map. prepared under the direction of FREDK J. H. MERRILL; by J. F. KEMP. (Extr. Bull. N. Y. State Mus, vol. iii,) pp. 323–355. Sept., 1895.

Preliminary Report on the Geology of Essex Co., N. Y.; by J. F. KEMP. (Extr. Rept. State Geol. for year 1893), pp. 431–472. 1895.

On a well-marked horizon of Radiolarian rocks in the lower Culm measures of Devon, Cornwall, and West Somerset; by G. J. HINDE and HOWARD FOX. (Extr. Quart. Jour. Geol. Soc, vol. li), pp. 609-668, plates xxiii–xxviii. Nov., 1895.

On a new species of Diplacodon, with a discussion of the relations of that genus to Telmatotherium, and

Discovery, in the Oligocene of South Dakota, of Eusmilus, a genus of Sabre-toothed Cats new to North America; by J. B. THATCHER. (Extr. Am. Nat., pp. 1084–1093, plates xxxviii–xl. Dec., 1895.)

Glacial deposits of southwestern Alberta in the vicinity of the Rocky Mountains; by GEORGE M. DAWSON with the collaboration of R. G. McConnell. (Extr. Bull. Geol. Soc. Am., vol vii), pp. 31–66, pl. 1, Nov., 1895.

On the Structure and Development of the vertebral column of Amia; by O. P. HAY. (Extr. Field Columbian Museum, Publication 5, Zool. Series, vol. i, No. 1), pp. 1–54, pls. i–iii. Oct., 1885

On certain portions of the skeleton of Protostega gigas; by O. P. HAY. (Extr. Field Columbian Mus., Publ. 7, Zool. Ser., vol. i, No. 2), pp. 57–62, pls. iv, v, Nov., '95.

Ueber das Alter der thüringer Tentaculiten- und Nereiten-Schichten; von E. KAYSER. (Extr. Zeitschr. d. Deutsch. geol. Gesellschaft, 1894, heft 4), pp 823–827, 1895.

Ueber das Alter von Myalina bilsteinensis, von E. KAYSER. (Extr. Jahrb. d. Königl. preuss. geol. Landesanstalt f. 1894), pp. 122–138, pls. iii–iv, 1895.

Sur une faune du Sommet de la série Rhénane, a Pepinster, Goé et Tilff; par E. KAYSER. (Extr. Ann. de la Soc. géol. de Belg, t. xxii), pp. 175–216, pls. 1–4. 1895.

A contribution to the neocene corals of the United States; by H. S. GANE. (Extr. Johns Hopkins Univ. Circ'ls., No. 121, Oct., 1895.

The neocene of the Santa Cruz Mountains. 1. Stratigraphy; by GEORGE H. ASHLEY. (Extr. Proc. Cal. Acad. Sci., Series 2, vol. v), pp. 273–367, pls. xxii–xxv. 1895.

Edward Hitchcock; by C. H. HITCHCOCK. (Extr. Am. Geol., vol. xvi), pp. 133–149, pl. vii, Sept., 1895.

Edward Hitchcock. (Obituary notice with portrait. Extr. Pop. Sci. Monthly, Sept., 1895.)

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Timber: an Elementary Discussion of the Characteristics and Properties of Wood; by PHILIBERT ROTH, Special Agent in charge of Timber Physics, under the direction of B. E. Fernow, Chief of the Division of Forestry. Washington: Government Printing Office, 1895.

Grundzüge der marinen Tiergeographie, Anleitung zur Untersuchung der geographischen Verbreitung mariner Tierre, mit besonderer Berücksichtigung der Dekapodenkrebse; von Dr. ARNOLD E. ORTMANN in Princeton, N. J., Mit Karte. Jena: Verlag von Gustav Fischer, 1896.

North American Fauna, No. 10. Washington (Government Printing Office), 1895. U. S. Department of Agriculture, Division of Ornithology and Mammalogy.

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PLATES II–VII.

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[FOURTH SERIES.]

Art. XVII.—*Recent and Fossil Tapirs*; by J. B. Hatcher. (With Plates II–V.)

[This investigation was aided by a grant from the Elizabeth Thompson Fund of the A. A. A. S.]

The existing *Tapirs* present many characters of peculiar interest, and in some respects, as for example, geographical distribution and conservativeness in accomplishing anatomical changes, they are unique among living Perissodactyls. Remains of fossil Tapirs and closely allied forms, though comparatively rare, have been found in Tertiary deposits belonging to nearly every period, from the Wahsatch, of the lower Eocene, up to, and including, the Quaternary, and in widely separated localities.

It is the purpose of this article to describe a new species of *Protapirus* from the *Protoceras beds* of the White River (*Oligocene*) of S. Dakota; and to add something to our knowledge of the osteology of this genus, especially in regard to the skull and fore limb; to give some additional characters diagnostic of the various species of *Protapirus* and *Colodon* already described by Leidy, Marsh, Wortman, Earle and Osborn; to point out distinctive osteological and dental characters in the skulls of the five generally accepted species of recent *Tapirs;* and to review previous work of others on the phylogeny of the *Tapiridæ* and *Helaletidæ.*

Protapirus (Filhol).

Wortman and Earle* have recently described, from the Oligocene of S. Dakota, remains of two species of *Tapiroids*,

* See Bull. Am. Mus. Nat. Hist., vol. v, pp. 159–180.

at present not distinguishable from the genus *Protapirus*, described by Filhol from the *Phosphorites du Quercy*, France. The species described by these authors are *P. obliquidens*, based on a nearly complete superior dentition (*No.* 659 *Am. Mus. Col.*). The authors do not give the horizon in which it was found, but from the matrix enclosing it I am led to believe that it is from the *Protoceras beds.* The other species is *P. simplex*, based upon a series of superior premolars and fragments of the lower jaw (*No.* 660 *Am. Mus. Coll.*) found in the *Oreodon beds.*

The Princeton Scientific Expedition of 1894 was fortunate in securing material, representing a third American species of this genus, besides other material which will increase our knowledge of the known species of *Protapirus* and the somewhat similar genus *Colodon.*

The following is given as a key to the *American* species of *Protapirus.*

1. Internal cone of all the superior premolars absolutely simple, showing no signs of division, with very rudimentary posterior cross-crests, especially in pms. 3 and 4 --- *P. simplex.*
2. Internal cone of the fourth superior premolar just commencing to divide, posterior cross-crests moderately developed on all of the last three superior premolars -------- *P. validus.*
3. Internal cones of last two superior premolars commencing to divide, posterior cross-crests of the last three superior premolars like intermediate tubercles --------- *P. obliquidens.*

Protapirus validus, sp. nov.

The type of the present species (*No.* 10899 *Princ. Coll.*) consists of a nearly complete skull, without the lower jaw and a complete atlas, humerus, radius, ulna and parts of other bones. It is from the *Protoceras sandstones*, about four miles south of White river and five miles below the mouth of Porcupine creek in S. Dakota; about one mile from the spot where the type of *Protoceras celer* was secured. It was found by Mr. H. F. Wells of Sturgis, S. Dakota, a most energetic collector of vertebrate fossils, who was the first to distinguish the *Protoceras beds* and the rich vertebrate fauna contained in them. These beds were shown by Mr. Wells to Dr. J. L. Wortman, who was the first to name and describe them.*

In most of the more important characters, *Protapirus validus* is intermediate between *P. simplex* and *P. obliquidens*, as for example, the structure of the internal cone of the sup. pms., but in some respects, notably, the development of the posterior cross-crests of these teeth, it is in advance

* See Am. Mus. Bull., vol. v, pp. 95–105.

of both of these species. (Compare fig. 3, plate II, of the present paper with A. & B., fig. 1, of Wortman and Earle.) From these and other characters *P. simplex* appears to have been the ancestor of *P. validus* and *P. obliquidens*. There seems to be little doubt that the former is a direct successor of *P. simplex*, while the latter has been derived from that species either directly through *P. validus* or some other as yet unknown form with all its characters intermediate.

The Skull: In many respects the skull of *Protapirus* resembles that of the recent Tapir, especially of *Tapirus roulini*, the least specialized of all the species of modern Tapirs. In the type specimen of *P. validus* the occipital condyles are sessile and as deep as broad. The condylar foramen is placed well forward and inward just opposite the base of the paroccipital process, which is a slender, styliform bone directed straight downward much as in *Tapirus roulini*, but quite different from *T. indicus*, in which species this process is broad and flat with its distal end curving inward. The post-tympanic process is low and broad and is confluent but not coössified with the paroccipital process; its lower extremity is curved forward, abutting against the post-glenoid and entirely enclosing the *meatus auditorius externus*, a condition not present in any of the living Tapirs. The post-glenoid process is low, broad and thin, and curves forward inferiorly; it is set obliquely to the longer axis of the skull, at an angle of about 45 degrees, much as in all the species of recent Tapirs. The zygoma is slender, only slightly expanded, and nearly parallel with the longer axis of the skull. There is no post-orbital process on the malar. The floor of the orbit is much deeper than in *Tapirus*, but not quite so deep as in some specimens of *Elasmognathus*. The infraorbital foramen is situated well in front of the orbit, and directly above pm. 4, at the bottom of a deep groove, which commences just above pm. 2 and runs obliquely backward and upward, from this point, until reaching the fronto-maxillary suture, where it turns abruptly backward and terminates at the post-orbital process of the frontal. This groove is, perhaps, homologous with a similar excavation on the surface of the skulls of modern species of Tapir. In recent Tapirs it is deepest at, or near, the base of the nasals, and its function, as has been shown by Parker,* is the lodgment of a cartilaginous air sinus; it very likely served the same purpose in *Protapirus*; the apparent and actual change in its position having been accomplished by the shifting of the nasals to a more posterior position in recent forms. The greatest depth of this groove, in *Protapirus*, is at a point just opposite the

*See: Some Points in the Anatomy of the Indian Tapir, by W. N. Parker, P. Z. S., 1882, pp. 768–777.

base of the nasals, where it attains a depth of 8^{mm}, and a width at the top of 12^{mm}. The premaxillaries in the present specimen are broken off at the base of the canines; they were strong, and had an extended contact with the maxillaries.

The most striking differences between the skull of *Protapirus* and that of the recent Tapirs are to be seen in the conformation of the superior aspect of the skull, and in the position of the frontals and nasals, relative to the other elements of the skull. In *Protapirus* the top of the skull, from the tip of the nasals to the occipital crest, is a nearly straight line, while in most recent Tapirs it is somewhat convex, and in *T. terrestris* (*Americanus*) it is strongly convex, especially in the region of the parietals and frontals. In the characters just mentioned *T. roulini*, among modern Tapirs, is most like *Protapirus*. In recent Tapirs the nasals occupy a position considerably posterior to that of the nasals in *Protapirus*, in which the posterior border of the nasal opening is directly above the anterior border of the orbit; while in recent Tapirs it is always back of the posterior constriction of the orbit.

The nasals are slightly injured in the present specimen, and it is impossible to determine their exact length, they could hardly have reached much in front of the posterior border of the premaxillaries; they are applied closely to each other, but are not coössified. They are narrow, deep, and triangular in cross-section anteriorly, but gradually expand and present a greatly thickened lateral edge, posteriorly. On the upper surface, and a little in front of the middle of the nasals, there is a ridge, running from the inner margin obliquely forward to the outer, and giving to these bones a peculiar twisted appearance. The frontals are low and broad, with distinct postorbital processes; from which temporal ridges extend obliquely backward and inward and unite to form a low, sharp, sagittal crest. The lateral edges of the frontals, above the orbits, are thickened and bent upward so as to form the external wall of the groove above described. The fronto-parietal suture marks the point of greatest constriction in the temporal fossa. The parietals are moderately expanded, and unite superiorly in a low, sharp, sagittal crest; which becomes broader in the region of the supra-occipitals, and gradually expands into the occipital crest, which is deeply emarginate, and considerably overhangs the occipital condyles. The combined length of the parietals and frontals in *Protapirus* is considerably greater than that of the same bones in *Tapirus indicus* or *Elasmognathus bairdii*, the two largest species of recent Tapirs, notwithstanding that skulls of either of the latter are fully two-thirds longer than the skull of *Protapirus;* from this comparison the remarkable reduction of the length of those bones, in modern Tapirs, becomes apparent.

In *Protapirus*, the anterior border of the posterior nares is opposite the middle of m. 2. The pterygoids are slightly bifid and rather strong. The *post-glenoid foramen*, *foramen lacerum medium* and *foramen lacerum posterius* are confluent, much as in recent Tapirs. The petrosal is deeply inserted. The tympanic is not present in our specimen ; it probably was of the nature of that element in recent Tapirs, in which, according to Parker,* it is small, and does not become ankylosed to the surrounding bones, so that it is usually lost in the process of maceration, and rarely seen in dry skulls. I have never seen it, although I have examined about fifty skulls. The foramen ovale is in the alisphenoid, at the base of the pterygoid.

The teeth: The incisors are wanting and only the roots of the canines are present; they indicate that this tooth was rather small. The crown of pm. 1 is gone from both sides, and the roots indicate that there was a considerable individual variation in the size of this tooth. In the present specimen, the one on the left side was much the larger, and was fixed in the jaw by two roots; while that on the right was quite small, and had only one root. The succeeding superior premolars gradually increase in size, from before backwards; they all have external, and anterior and posterior basal cingula, and anterior and posterior cross-crests. The internal cone of pm. 4 shows a shallow, median groove, on its inner surface; an indication of division, which is absent in pms. 2 and 3. The posterior cross-crest in pms. 2 and 3 is rather better developed than in pm. 4. The latter tooth has a somewhat prominent parastyle, and its postero-external cone is situated a trifle farther in than the antero-external. Molar 1 is very much worn and its characters, consequently, not well defined; there is a pronounced basal cingulum, and the postero-external cone is situated farther in than the same element in pm. 4. In ms. 2 and 3, which are both well preserved, and scarcely at all worn, the antero-external cone is much larger than the postero-external, and the latter is placed far in from the former. The parastyle is nearly as high as the antero-external cone, and is continuous with the anterior basal cingulum. The anterior cross-crest is much larger than the posterior, and is united with the antero-external cone and not with the parastyle. Both of the external cones are convex externally. There is a deep median sinus which opens internally, but is closed externally. At the head of the median sinus there is a buttress. For an illustration of the more important characters of the skull and sup. dentition see figs. 1, 2, 3, plate II.

The lower jaw: No lower jaw was found with the type specimen, but a lower jaw (*No.* 10,900 *Princ. Coll.*), found in

* P. Z. S. 1882, p. 776.

the same locality and the same horizon, agrees perfectly, in size, with the type, and I have referred it to the same species, and made it a collateral type, figuring it in position in fig. 1, plate II. The inferior border is gently convex, the angle is slightly deflected, and its border turned inward, as in recent Tapirs. The mental foramen is a little in front of pm. 2. The symphysis is long and much constricted, as in *Tapirus.*

The teeth: Incisors 1 and 2 are of about equal size and much larger than I. 3, which is quite small, they are all spatulate and slightly cupped. The canine is small, conical and placed close to I. 3. The number of the inferior premolars is reduced to three. There is a long diastema between the canine and pm. 2. All of the pms. have two anterior cones, united by cross-crests notched in the middle; these cross crests are better developed in pms. 2 and 3 than in pm. 4, as has been shown to be the case in the posterior cross-crests of the sup. pms. The antero-external cone is situated farther forward than the antero-internal. There are also two posterior cones, but no posterior cross-crest; the postero-internal is the smaller and there is a low ridge running obliquely forward and inward from the postero-external cone and uniting with the base of the cross-crest. In addition to the elements already described there is a fifth cusp on the anterior border of pm. 2. The true molars each have two anterior and two posterior cones connected by high, sharp cross-crests. There are anterior and posterior basal cingula on all the inf. molars and premolars, but no external or internal cingula. The principal characters of the inf. dentition are well shown in fig. 4, plate II.

The Atlas: The articular surfaces for the occipital condyles are deep; those for the axis are of only moderate extent and curve inward exteriorly. There is a short dorsal spine, and a small posterior protuberance on the inferior arch. The transverse processes are only moderately expanded laterally, and posteriorly they extend but little beyond the articular surfaces for the axis. There is a vertebrarterial canal, and foramina, for the inferior and superior branches of the first spinal nerve. The present specimen agrees in every essential character with the atlas of *Elasmognathus bairdii.**

The fore limb: The humerus is proportionately rather strong and does not differ materially from that bone in recent Tapirs. The head is broad and sub-triangular in cross-section; the articular surface is continued upon the inner surface of the greater tuberosity, which is much larger than the lesser, and is produced, anteriorily, into an obtuse point which overhangs the bicipital groove. The deltoid ridge is prominent,

* An atlas of *E. bairdii* in the Princ. Coll. has the vertebrarterial canal present on one side and absent on the other.

and without the hook seen in recent Tapirs. The supinator ridge is rather more prominent than in recent Tapirs. The internal condyle is broader and stronger than the external. The anconeal fossa is deep and the supratrochlear shallow: there is no intercondylar foramen. The axis of the trochlea is at nearly right angles to that of the shaft. The intercondylar ridge is prominent and situated well outward, the ulnar articulation being much larger than the radial.

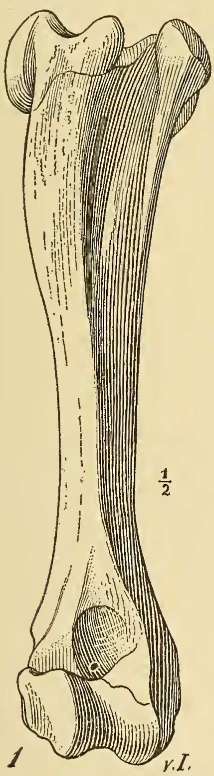


FIG. 1. Humerus of *Protapirus validus.*

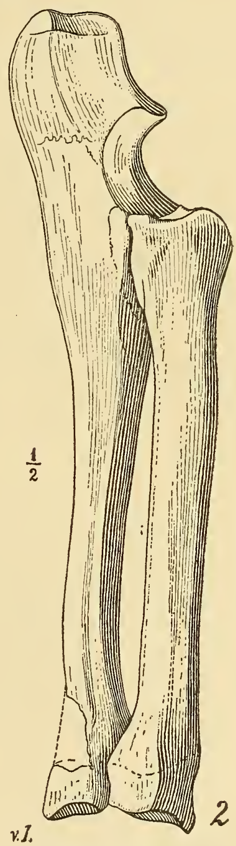


FIG. 2. Radius and ulna of *Protapirus validus*

The radius and ulna are proportionally rather more slender than the humerus. The olecranon is not pointed superiorly as in *Elasmognathus*, but is of nearly equal breadth from top to bottom. The proximal articulations of the radius and ulna bear about the same relations to each other, and to the humerus as those of *Elasmognathus*. Our material does not enable me to add anything to what Wortman and Earle have already made known respecting the structure of the carpus.

Measurements of Protapirus validus.

Length of skull from base of canine to occipital condyle	242^{mm}
Length of frontals and parietals	151
Distance between postorbital processes of frontals	73
Greatest length of lower jaw	227
Depth of jaw below pm. 2	33
“ “ “ 4	46
Length of inferior diastema	32
“ superior “	27
“ “ premolar molar series	102
“ “ molar series	53
“ inferior premolar-molar series	102
“ “ molar series	57
“ humerus	203
Breadth of distal end of humerus	41
Length of radius	158
Breadth of proximal end of radius	32
Breadth of distal end of radius	29
Length of ulna	216
Height of olecranon process above articular surface	40

Protapirus simplex W. & E.

This species is known only from the superior premolars and fragments of the lower jaw. There is in our collection a lower jaw (11165), with the inferior dentition and both rami nearly complete, found by Mr. H. F. Wells in the *Protoceras beds*, in the same locality as the material just described. Notwithstanding the horizon in which this specimen was found on account of its size and the structure of the premolars I refer it to *Protapirus simplex*. It is smaller than the jaw referred to *P. validus*, and the premolars are in a less advanced stage, the postero-internal cone being quite rudimentary. It differs, also, from *P. validus* in that the cross-crest on pm. 4 is in advance of the same element in pms. 2 and 3, while just the opposite is the case in the latter species. A further structural difference is noticeable in pm. 2; in this tooth in *P. validus* the ridge, which runs forward from the postero-external cone, unites with the antero-external, while in the present specimen it unites with the antero-internal. The principal dental characters of this specimen are shown in figs. 5 and 5*a*, plate III; the last molar is dropped down in each to accommodate the figures to the size of the plate.

Measurements.

Greatest length of jaw	220^{mm}
Depth of jaw below pm. 2	31
" " " m. 3	40
Length of diastema	30
Length of premolar-molar series	98
" molar series	55

Colodon (Marsh).*

The present genus is distinguished from *Protapirus*, which it most resembles, by the presence of a fifth cusp on the last inferior molar; by the reduction of the number of lower incisors to two on either side; by the more molariform superior premolars and by the shape of the postero-external cone of the superior molars, which in the present genus is concave on its external surface. The inferior premolars of *Colodon* are distinct from those of *Protapirus*, in that the postero-external cone is always connected with the antero-external by a low ridge. The second inferior premolar is proportionately very much shorter in *Colodon* than in *Protapirus*.

Although remains of *Colodon* are rarely found, yet five species have already been proposed, viz: *C.* (*Lophiodon*) *occidentalis* (Leidy)†, founded on a last inferior molar; *C. luxatus* (Marsh)‡, founded on a lower jaw in which pm. 2 is absent; *C. dakotensis* (O. and W.)§, founded on a complete superior dentition, with a portion of an inferior dentition and sup. pm. 4, from another individual as a collateral type; *C. procuspidatus* (O. and W.),‖ founded on a superior dentition from one side in which m. 3 is wanting and pm. 1 is injured, and *C.* (*Mesohippus*) *longipes* (O. and W.),¶ founded on a hind foot now provisionally referred to Colodon although first described as *Mesohippus longipes*. Prof. Marsh's type of *C. luxatus* agrees, in size and all essential characters, with Leidy's *occidentalis* in so far as we are able to determine those of the latter, from Leidy's description and figures, and both apparently belong to the same species.

Osborn and Wortman remark, in closing their description of *C. procuspidatus*, that "the only means at present known of distinguishing *C. procuspidatus* from *C. occidentale* (spelling theirs) is by the smaller size and generally less robust character of the latter." They give the horizon as the Metamyno-

* See this Journal, June, 1890, p. 524, and Nov., 1893, p. 411.
† See Extinct Mam. Fauna, Dak. and Neb., p. 239.
‡ Loc. cit.
§ See Bull. Am. Mus. Nat Hist., vol. vii, p. 362.
‖ See Bull. Am. Mus. Nat. Hist., vol. vii, p. 364.
¶ See Bull. Am. Mus. Nat. Hist., vol. vii, p. 366, and vol. vi, p. 214.

don layer. Mr. Gidley, who found the specimen, informs me that it is from the *Oreodon beds* below the *Metamynodon layer*. No measurements of the type are given, except to say that, "so far as the measurements are concerned, it agrees very closely in size with *C. dakotensis*." In giving the measurements of the latter species they place in another column, for comparison, corresponding measurements of *C. occidentalis*, but they do not give the measurements of Leidy's type, but those of a smaller individual. referred by Wortman and Earle* to that species; in this way they obtain as the comparative length of the last lower molar of *C. procuspidatus* and *C. occidentalis* ·025 of a meter for the former and ·019 for the latter, while the natural size figure of that tooth in *C. occidentalis*, published by Leidy in his description of the species, measures a little more than ·022 of a meter, showing, that both the smaller measurements and the larger are well within the limits of specific variation. I have therefore considered it best to regard *procuspidatus* as also a synonym of *occidentalis*.

Disregarding *C. longipes*, which may or may not belong to the genus *Colodon*, and which, if it should prove to belong to that genus will quite likely be found to pertain to one of the previously known species, the following is submitted as a key to the species of Colodon.

1. The internal cusps of sup. pms. 2, 3, 4, showing signs of division. Postero-internal cone of inferior pms. smaller than postero-external *C. dakotensis.*
2. Two distinct internal cusps on sup. pms. 2, 3, 4. Postero-internal cone of inf. pms. as large or nearly as large as postero-external *C. occidentalis.*

Colodon (*Lophiodon*) *occidentalis* Leidy.

Syn. C. luxatus, C. procuspidatus, and *C. longipes?*

There are in our collections several jaws and groups of teeth referable to this species, a crown view of the inf. dentition of one of these (No. 10953) is shown in fig. 6, plate III. It is peculiar in the structure of pm. 2, in which tooth there is but one anterior cusp, a character not seen in any other specimen of *Colodon*. The postero-internal cone on all the premolars in the present specimen equals in size the postero-external. These characters might be regarded as of specific importance, but I prefer to consider them as only individual variations, after studying, with some care, the individual variations in the structure of the teeth of modern Tapirs. In all of the jaws in our collection referred to *C. occidentalis*, the teeth are propor-

* Bull. Am. Mus. Nat. Hist., vol. v, p. 178.

tionately narrower than in those referred to *C. dakotensis*. The present specimen is from the Oreodon beds, below the Metamynodon layer.

Milk dentition: Portions of two lower jaws (Nos. 10507 and 10506, fig. 2 and 7, plate III) in our collection are of interest, inasmuch as they show successive stages in the eruption of the milk and permanent dentitions. In 10507 the first milk molar has been broken off and lost, but the second and third are still in place, and immediately behind them is the first permanent molar fully erupted and behind it m. 2 may be seen just commencing to cut the gum. Beneath the deciduous molars and the anterior half of the first permanent molar, the bone from the inside of the jaw has been removed, exposing the unborn premolars in position. By a glance at fig. 2, plate III, it will at once be seen that these teeth, as well as permanent molar 2, occupy a position in the ramus considerably posterior to that which they will assume when fully erupted. In other words, in the process of eruption they will move forward and upward. No. 10506 has all the deciduous molars in place and the first permanent molar just coming into place. As has been remarked by O. & W., the last two milk molars closely resemble the permanent set, while the first is like the corresponding premolar. These specimens were found by Mr. J. W. Gidley in the upper Titanotherium beds.

Measurements of C. occidentalis (No. 10953 Princ. Coll.)

Length of inf. premolar-molar series	82^{mm}
" " " series	32
" " molar "	50
" last inferior molar	21

Colodon dakotensis, O. & W.

In describing this species, Osborn and Wortman have described the postero-internal cusp of the last lower premolar as double, placing considerable importance upon this character, and the absence of external and internal basal cingula on the superior premolars. The double character of the postero-internal cusp of the last lower premolar is, probably, of little importance, since in their collateral type specimen it is very faint, and has more the nature of a basal cingulum than of a cusp, and moreover, a similar state of affairs is noticeable on some of the smallest of our specimens, referred to *C. occidentalis*. Too much importance should not be given to the presence or absence of basal cingula, which have been shown by Nathusius* to depend, in living animals, largely upon the abundance or

* See Der Schweinschadel.

scarcity of nourishment. The more molariform superior premolars and the usually larger size and more robust character of all the teeth of *C. dakotensis* at once distinguish it from *C. occidentalis*. Several specimens in the Princ. Coll. are referred to this species, one of which (No. 11159) consists of a median ungual phalanx, found associated with a fragmentary lower-jaw, in which the inferior dentition, excepting the canine and m. 3, is complete and in a splendid state of preservation. The ungual phalanx and a crown view of the teeth are shown in figs. 3 and 3a, plate III. This specimen was found by Mr. Wells, and no record was kept as to the horizon; from the nature of the matrix it appears to be from the Oreodon beds below the Metamynodon layer. There may be some doubt as to whether the ungual found associated with the teeth really belongs with them, but from the texture of the bone, color, etc., I believe they pertain to the same individual; it is in shape remarkably like the same bone in Mesohippus, but much larger than that in any species of that genus known from the lower Oreodon beds. It also resembles the same bone in the third digit of *Elasmognathus* and like that bone in this genus and in *Mesohippus* it is notched in front.

The incisors in the present specimen are very large, chisel shaped and their crowns are slightly excavated or cupped. The premolars and molars are very strong.

Measurements of C. dakotensis (No. 11159 Princ. Coll.)

Length of inf. pms. and ms. 1 and 2	75mm
" "	40
Depth of ramus below m. 1	35
Length of ungual phalanx	24
Breadth " "	22

Recent Tapirs.

I do not expect to be able to add much to our present knowledge of recent Tapirs, but rather to collect and condense a part of what is already known of the dental characters, and the osteology of the skull, in the five now generally accepted species; with a list of the synonymy of each, complete, in so far as the literature available will permit. The following key to genera and species is submitted.

A. *Maxillaries greatly expanded superiorly and embracing the mesethmoid cartilage, which in adult specimens is ossified and extends as a bony plate far in front of the nasals. Premaxillaries short and obtuse posteriorly* .... *Elasmognathus.*

1. Nasals longer than their combined width, and applied to one another throughout the greater part of their length, each usually ossified from a single center.......... *E. bairdii.*
2. Nasals broader than long, more or less separated by an anterior prolongation of the frontals, each usually ossified from two separate centers .... *E. dowi.*

B. *Ossification of mesethmoid cartilage never extending much in front of middle of nasals. Superior border of maxillaries low, and widely separated from each other. Premaxillaries long and acute posteriorly* .... *Tapirus.*

1. Premaxillo-maxillary suture bisecting alveole for canine. Premaxillary deeply embraced by superior and inferior branches of the maxillary. Sagittal crest broad and low. Nasals broad and long, sup. pm. 2 molariform .. *T. indicus.*
2. Premaxillo-maxillary suture passing in front of alveole for canine. Premaxillary not deeply embraced by superior branch of maxillary. Sagittal crest sharp and high. Nasals broad and short. Sup. pm. 2 molariform..... *T. terrestris.*
3. Premaxillo-maxillary suture passing in front of alveole for canine. Premaxillary scarcely at all embraced by superior branch of maxillary. Sagittal crest sharp and low. Nasals long and narrow. Sup. pm. 2 submolariform .. *T. roulini.*

Tapirus, Brisson (1756) Regne Anim., p. 118.

Syn. Rhinochœrus (*Gray*), *Rhinochœrus* (*Wagner*) *in part*, *Hydrochœrus* (*Erxleben*) *in part*, *Sys. Reg. An.*, *1777*, *p. 191.*

Tapirus roulini Fischer.*

Syn. T. pinchacus, *T. villosus*, *T. leucogenys*, *T. œnigmaticus* and *Tapir pinchaque.*

A skull and the sup. dentition of the present species are shown in fig. 2, plate V, and figs. 2 and 2a, plate IV, drawn from No. 204 in the Yale osteological collection. *T. roulini* is the smallest and least specialized of all the recent Tapirs. The skull is low, narrow and flat, the nasals are long, pointed, coössified, and posteriorly, they are but little lower than the frontals. The premaxillaries are scarcely at all embraced by a superior arm of the maxillaries and the latter projection is not higher than the embraced portion of the premaxillary. The ossified septum does not extend in front of pos. border of nasal opening. The cavity for lodgment of cartilaginous air sinus is deep, but extends but slightly upon the base of the nasals. The floor of the orbit is shallow but deeper than in *T. indicus.* The foramen magnum is absolutely and relatively larger than in any of the other species. Sup. pm. 1

* Fischer's Synops. Mam. Add., p. 406.

is much longer than broad and the internal cone is situated on the extreme postero-internal angle and is quite rudimentary. The antero-internal cone in sup. pm. 2 is a mere tubercle and the anterior cross-crest is absent.

Tapirus (*Hippopotamus*) *terrestris*, Linn.*

Syn. T. americanus, T. anta, T. suillus, T. laurillardi, T. equadorensis.

The principal characters of the skull and sup. dentition of this species are shown in fig. 1, plate V, and 1 and 1a, plate IV, which have been drawn from No. 157 in the Yale Coll. The present species seems to be most closely related to the preceding; the skull, like that of the former, is compressed and there is a sharp sagittal crest in both; but in the present species the sagittal crest is convex antero-posteriorly and elevated far above the nasals, which are short and broad in marked contrast to those conditions which have been found in *T. roulini.* The premaxillaries have an extended contact with the maxillaries and are slightly embraced posteriorly by a superior branch of the latter which is not elevated above the premaxillary. The excavation for the air sinus is mainly in the frontals and maxillaries, near the base of nasals and does not encroach much upon the latter. The first sup. premolar is nearly as broad as long and the internal cone is near the middle of the tooth. Sup. pm. 2 is entirely molariform.

Tapirus indicus Desm.†

Syn. T. sumatranus, T. maylayanus, T. bicolor, T. me.

A skull and sup. dentitian of *T. indicus* are shown in figs. 3, plate V, and 3 and 3a, plate IV, drawn from No. 200 in the Yale Coll. As has been noticed by Gill the present species more nearly resembles species of *Elasmognathus* than do either of the other species of *Tapirus*, among the points of resemblance the following are noteworthy. The premaxillaries are embraced by the maxillaries and the superior branches of the latter are produced above the premaxillaries and approach each other medially. The mesethmoid cartilage is ossified as far forward as the middle of the nasals in adult specimens. The frontals are broad and abruptly elevated above the base of the nasals, precisely as in Elasmognathus. The premaxillo-maxillary suture bisects the alveole for the canine, in this respect *T. indicus* is unique among modern Tapirs, and I have found this character absolutely constant in

* Sys. Nat., 10th ed., 1758. † Desm. Mam., p. 411.

all the skulls I have been able to examine and in the published figures of them. The nasals are long, broad posteriorly, narrow anteriorly and separated throughout their entire length, near their base there is a deep excavation for the lodgment of the cartilaginous air sinus. Sup. pm. 1 is longer than broad, the internal cone is placed farther forward than in *T. roulini.* The cross-crests in sup. pm. 2 are not complete in the present specimen, but I notice that in other specimens they are quite complete.

Elasmognathus Gill.*

This genus has not been generally accepted, but the characters assigned to it by Dr. Gill are constant and seem to be of generic importance. In addition to the characters already pointed out. I may mention the extreme breadth of the top of the skull which may almost be described as without a sagittal crest, and the invariably complete molariform condition of sup. pm. 2. Species of the present genus rival in size *T. indicus*, the largest of the species of *Tapirus*, and include the most specialized forms belonging to the Tapiridae.

Elasmognathus bairdii Gill.†

The principal characters of the skull and sup. dentition of this species are shown in figs. 4, plate V, and 4 and 4a, plate IV, drawn from No. 515 in the Yale Coll. The ascending posterior arm of the maxillaries, which articulate with the lachrymals and frontals is much compressed and entirely concealed by the latter bones, when the skull is viewed from the side. The premaxillary is short and obtusely pointed, posteriorly. The post-tympanic and postglenoid processes approach each other inferiorly but do not meet. The nasals are longer than broad, are closely applied throughout their entire length and coössified in old individuals; they usually ossify, each, from a single center, and posteriorly, they are but little separated by the anterior median prolongation of the frontals.

Elasmognathus dowi Gill.‡

In general, the skull and dentition of the present species resembles so closely those of the preceding that it is not necessary to figure the latter. Alston§ has shown that most of the specific characters ascribed to *E. dowi* are quite variable, and hardly of specific importance. He says on page 98 of the work

* See Proc. Phil. Acad. Sci., 1865, p. 183.
† See Proc. Phil. Acad. Sci., 1865, p. 183.
‡ See this Journal, 1870, p. 142.
§ See Biologia Centrali-Americana, Mammalia by Edward R. Alston, 1879–1882.

just cited: "The comparison of a sufficient series of skulls in any species of Tapir shows the existence of a very remarkable extent of individual variation in minor dental and cranial characters; and I have not found any of the differences pointed out by Dr. Gill as distinguishing *T. dowi* from *T. bairdii* to be constant, except the extraordinary modification of the fronto-nasal region." After figuring and describing at some length the different characters in the region of the nasals, on page 100, Alston summarizes these characters as follows:

"1. *T. bairdii.* Nasals well developed, each ossified from a single center, separate throughout life, thick at their base, and articulated with one another for the greater part of their length."

"2. *T. dowi.* Nasals very small, each ossified from two centers, thin, more or less separated from one another by an anterior prolongation of the frontals, with which they become partially or entirely ankylosed before the animal reaches maturity."

Had Alston had more material he would doubtless have arrived at the same conclusion regarding the nasal characters that he did in regard to those of other parts of the skull. I find these characters exceedingly variable, and in the very extensive collection of skulls of *Elasmognathus* in the National Museum, which I have had the privilege of examining and figuring, every gradation between these two types of nasals is shown. I have selected a series of five of these skulls, showing as many different degrees of variation, and have had the fronto-nasal region in each drawn, and they are shown here in pl. III, figs. A, B, C, D, E. From an examination of these figures in connection with what has already been said, it will at once be seen that as yet no character has been found by which it is possible always to distinguish *E. dowi* from *E. bairdii*, and they might be considered synonyms, although I have preferred to retain both, and consider the former as the less specialized of the two, and the direct ancestor of the latter, which has not as yet been fully differentiated from it. It might better be considered as a sub-species.

Phylogeny.

Wortman* and Earle in their most excellent paper entitled "*Ancestors of the Tapir from the Lower Miocene of Dakota*," have reviewed very fully the work done by Marsh, Cope, Scott and Osborn on the phylogeny of the Tapirs. They (Wortman and Earle) derive the true tapirs from the Wind River genus

* See Bull. Am. Mus. Nat. Hist., vol. v, pp. 159–180.

Systemodon through the intermediate forms *Isectolophus* (*Helaletes*) *latidens* of the Bridger, *Isectolophus annectens* from the Uinta, *Protapirus simplex* and *P. oliquidens* from the White River and perhaps *Tapiravus* from the Loup Fork. They cite as evidences against this line of descent, the union of the protoloph with the parastyle instead of the paracone in both species of *Isectolophus* and the submolariform character of sup. pms. 3 and 4 in that genus as described by Osborn.* I have carefully examined both of these types and can say that the union of the protoloph is with the paracone rather than the parastyle, the real union being with the ectoloph a little in front of the paracone. In regard to the sup. pms. Prof. Osborn says (on page 519 of the paper just cited): "These are wanting in the Uinta specimens, but the Bridger species which was formerly referred by us to *Helaletes* (*H. latidens*) is closely related to *Isectolophus*, if not generically the same, and shows double internal lobes upon both pm. 3 and pm. 4;" and just below on the same page in his *Generic characters* he says, "Fourth and probably third premolars in both jaws submolariform or with double internal cones." These are certainly errors of observation and description, since in sup. pm. 4, which is the only superior premolar complete and in position in the type of *H. latidens*, *the internal cone is absolutely simple and without the faintest signs of division*, the same may be said of the only sup. pm. at present known of *Isectolophus annectens*. Prof. Osborn further states on page 521 that the first inferior premolar abuts against the canine; and on page 519, that there is no diastema behind the canine, these are characters not shown in any of the type specimens of the genus; and if we stop to consider the characters which obtain in this region of the skull in the White River Tapiroids, together with the extreme conservativeness of this entire group in accomplishing any dental or other changes, we may infer that it is quite probable, that in the Uinta Tapiroids, there was a considerable post-canine diastema, with a marked constriction of the symphysis of the lower jaw, otherwise we shall have to conclude that the Tapirs, toward the close of the Uinta, began to progress very rapidly, and in the interim between that and the beginning of White River times they outstripped all other Perissodactyls in accomplishing anatomical changes, a very improbable assumption.

After studying carefully all the material referable to *Isectolophus annectens* I can only substantiate the views of Scott, Osborn, Wortman and Earle in referring *Isectolophus* to the *Tapiridæ*. I do not consider *Isectolophus* (*Helaletes*) *latidens* from the Bridger as belonging to the genus *Isectolophus*.

* The Mam. of the Uinta Form. Trans. Am. Phil. Soc., 1889, pp. 461–572.

There are marked differences in the structure of the sup. true molars in the two species and when the complete dentition of the Uinta species is known, the dental formula and arrangement of the teeth will doubtless be found to differ in the two. If *Isectolophus* (*Helaletes*) *latidens* can be shown to differ generically from *Helaletes* it should be made the type of a new genus. I have never seen any of Prof. Marsh's types of *Helaletes* and his descriptions do not permit of an identification of other material.

The discovery of a nearly complete skull of *Protapirus* with characteristic tapirine characters, already pointed out, may be considered as additional evidence in favor of Wortman and Earle's views in considering that genus as the White River ancestor of the *Tapirs*. In taking this view of the question, however, the fact must not be lost sight of, that in *Protapirus* the character of the metacone of the sup. molars is not what we should expect to find in a White River *Tapir*, and the inferior, external, lateral incisor is much smaller than we should expect it to be, since it persists in recent Tapirs and is even proportionately larger than in *Protapirus*. The metacone in *Protapirus* is placed father in, and is less prominent and not so convex externally as in *Isectolophus*, while the same element in recent Tapirs is more prominent and has a more external position than in *Isectolophus*. Thus, according to our present phylogenetic arrangement we should have to allow for first a gradual shifting inward of the position of this cone followed by a period when it commenced to move outward to its normal position in modern *Tapirs;* a rather extreme case of oscillation but not entirely inconsistent with what Scott has shown to have taken place in the Equine series.

Very little is known of the American Miocene representatives of the Tapir line. Prof. Marsh has mentioned the occurrence of two Miocene species of Tapiroids which he considers as standing ancestral to the Tapirs. One of these is from the Miocene of New Jersey and the other is from the Loup Fork or late Miocene (early Pliocene of Marsh) from east of the Rocky Mountains, no more definite locality being given by Marsh. These specimens are made the type of a new genus *Tapiravus;* the one from New Jersey is described as *Tapiravus validus*, while the one from the west is called *T. rarus*. I have never seen either of these specimens and they have not been figured, and are only very briefly described by Prof. Marsh. There would seem to be little doubt that they belong to the direct line leading to the recent Tapirs.

In Europe the paucity of Tapir remains in the Miocene is almost as marked as in America. In *Tapirus helveticus* of Meyer, from the lower Miocene of Eselsberg near Ulm, we doubtless have one of the direct ancestors of the modern Tapir. In this species sup. pm. 4 is entirely molariform except that the posterior cross-crest is not complete. Sup. pm. 3 is in the same stage as sup. pm. 2 in *T. roulini* of recent Tapirs. *Tapirus helveticus* Meyer is perhaps the European equivalent of *Tapiravus validus* Marsh, from New Jersey. The European species should be referred to the latter genus rather than to Tapirus. In regard to the American species at present referred to Protapirus, there may be considerable doubt as to whether they should not be referred to a distinct genus; from Filhol's description and figures there would seem to be a considerable difference in the relations of the protoloph to the parastyle in the sup. true molars and in the structure of the posterior cross-crest in sup. pm. 4. The importance of these differences can only be determined by an actual comparison of the specimens.

Of recent Tapirs it can be pretty well demonstrated that *Elasmognathus bairdii*, the most specialized of all, has been derived from *T. roulini* directly through *T. terrestris* and *E. dowi;* while *T. indicus* had a common ancestry and became separated from the others, probably in late Miocene times, since when it has paralleled *Elasmognathus* in some of its characters though not showing the same degree of specialization.

In regard to *Colodon* and the earlier genera of *pseudo-tapirs*, I cannot agree with Osborn and Wortman that their line of descent has been entirely distinct from that of the true *Tapirs*. On account of the, in many respects, very similar tooth and foot structure of the two, it would seem that they were both derived from a common Bridger ancestor, most likely some one of the species now referred to *Helaletes* and which had its immediate ancestor in *Systemodon*. The true genus *Helaletes* with sup. pms. 3 and 4, already molariform according to W. and E., terminates a third line, and is descended directly from Heptodon of the Wind River.

The figures in the plates accompanying this paper were drawn by Mr. Rudolph Weber. I wish here to express my thanks to Prof. Scott for his kindness in allowing me to describe the important and rare skull of *Protapirus* as well as the other fossil material. To Prof. Marsh I am especially indebted for the free use of the very complete collection of skulls and skeletons of recent Tapirs in the Yale Museum. I wish also to thank Mr. F. A. Lucas of the National Museum and Prof. Osborn and Dr. Wortman of the Am. Mus. of Nat. Hist. for the use of material in their charge.

Princeton, N. J., Jan. 13, 1896.

EXPLANATION OF PLATES.

Plate II.

Figure 1.—Side view of skull of *Protapirus validus*, $\frac{1}{3}$ natural size.
Figure 2.—Top " " " " " "
Figure 3.—Bottom " " " " " "
Figure 4.—Crown view of inf. dentition of same, $\frac{3}{4}$ natural size.

Plate III.

Figures A, B, C, D, E.—Comparative series of nasals of *E. dowi* and *E. bairdii*
Figure 2.—Inside view of young lower jaw of *Colodon occidentalis*, showing milk and permanent teeth.
Figure 3.—Crown view of inf. dentition of *Colodon dakotensis.*
Figure 3*a*.—Ungual phalanx of *Colodon dakotensis.*
Figure 4.—Crown view of sup. m. 3 of *Colodon* sp.
Figure 5&5*a*.—Side and crown view of inf. dentition of *Protapirus simplex.* M. 3 dropped down in each to accommodate size of plate.
Figure 6.—Crown view of inf. dentition of *Colodon occidentalis.*
Figure 7.—Crown " " milk dentition of " "

Plate IV.

Figure 1.—Crown view of sup. dentition of *Tapirus terrestris*, $\frac{3}{7}$ nat. size.
Figure 2.— " " " " *roulini*, " "

Figure 3.— " " " " *indicus*, " "
Figure 4.— " " of *Elasmognathus bairdii*, " "
Figure 1*a*.—Top view of nasals and crest of *Tapirus terrestris*, $\frac{3}{14}$ nat. size.
Figure 2*a*.— " " " " " *roulini*, " "
Figure 3*a*.— " " " " " *indicus*, " "
Figure 4*a*.— " " " " *Elasmognathus bairdii*, $\frac{3}{14}$ nat. size.

Plate V.

[All figs. $\frac{1}{4}$ nat. size.]

Figure 1.—Side view of *Tapirus terrestris.*
Figure 2.— " " *roulini.*
Figure 3.— " " *indicus.*
Figure 4.— " *Elasmognathus bairdii.*

Art. XVIII.—*A method for the Separation of Selenium from Tellurium based upon the difference in volatility of the Bromides*; by F. A. Gooch and A. W. Peirce.

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

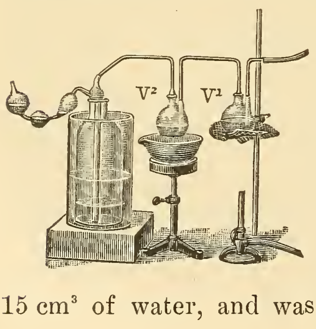
It has been shown in previous articles from this laboratory* upon the reducibility of selenic acid by the action of the halogen acids, that when small amounts of selenic acid are boiled in aqueous solution with potassium iodide and hydrochloric acid, selenium is precipitated, while the iodine set free simultaneously may be collected in the distillate, estimated, and taken as the measure of the selenic acid originally present; that if the iodide is omitted from the mixture, so that the hydrochloric acid alone shall be the reducer, the reduction proceeds only to the point of formation of selenious acid, provided the boiling is not continued after the hydrochloric acid has reached the condition of half-strength at which it boils unchanged under normal atmospheric pressure; and that a solution of selenic acid, potassium bromide, and sulphuric acid of regulated dilution and proportions also yields under defined conditions selenious acid as the product of reduction. When, however, the ebullition of a solution of selenious acid in hydrochloric acid is continued after the acid has reached the condition of half-strength, traces of selenium appear in the receiver and connecting tubes, the distillate sets free iodine from potassium iodide, and it is evident that the selenious acid is undergoing further reduction. So also when the boiling of the mixture of sulphuric acid, potassium bromide, and selenious acid is pressed beyond the point at which the solution begins to be colored, selenium appears in traces in the tube leading to the receiver and the distillate liberates iodine from an iodide. Obviously the conditions have been at this time reached in the processes of concentration when selenium tetrachloride and selenium tetrabromide, respectively, are forming from the acid, and that the appearance of the elementary selenium is due to partial decomposition of the halogen salts. We have observed more recently phenomena of a similar nature (as would naturally be expected under the conditions), when aqueous solutions of selenious acid, phosphoric acid, and sodium chloride are submitted to distillation: that is to say, there comes a time in the process of boiling such mixtures when the appearance of elementary selenium and the action of the distillate upon potassium iodide make evident the volatilization and partial decomposition of the selenium compounds of the

*This Journal, l, 254, 400, 402.

halogens, and the further continuance of the treatment results in the more or less complete removal of the selenium compounds to the distillate. From the mixture containing the phosphoric acid, selenious acid, and sodium chloride we have been able to secure only a partial volatilization of the selenium chloride. The transfer of the selenium bromide, however, from the mixture of the acids and potassium bromide is rapid and complete, and this fact points out a possible method for the separation of selenium from substances which do not form volatile products under similar conditions of treatment. Tellurium proves to be such a substance, and the work to be detailed has to do with a process for the separation of selenium from tellurium, based upon the volatility of selenium tetrabromide and the non-volatility of tellurium tetrabromide under definite conditions.

The selenious acid which we used was made by dissolving in water a known weight of the white, crystalline, anhydrous dioxide prepared from pure selenium by oxidation with nitric acid, treatment in solution with barium hydroxide to remove selenic acid, and repeated sublimation in a current of oxygen. The tellurium was obtained in solution in its lower condition of oxidation by dissolving in potassium hydroxide a known weight of tellurium dioxide (made by oxidizing presumably pure tellurium by nitric acid and igniting the product at a low red heat), neutralizing with phosphoric acid, and redissolving in a sufficient excess of that acid the precipitate formed in the process of neutralization.

In our preliminary experiments we made use of a form of apparatus previously employed for similar purposes and described in former articles from the laboratory, viz: a Voit flask, serving as the retort, sealed to the inlet tube of a Drexel wash-bottle, used as a receiver, the outlet tube of which was trapped by sealing on Will and Varrentrapp absorbtion bulbs. Later the apparatus was changed to the form shown in the accompanying figure by introducing a second Voit flask, in order that the selenium might be estimated in the distillate more conveniently.



Into the first Voit flask, V^1, were put measured amounts of the solution of selenious acid with 20 cm^3 of syrupy phosphoric acid (sp. gr. 1·70), 1 grm. of potassium bromide, and water enough to make the entire volume of liquid 50 cm^3. The second flask, V^2, contained about 15 cm^3 of water, and was kept cool by immersion in water.

The Drexel bottle and bulbs contained a solution of potassium iodide. A current of carbon dioxide was passed slowly through the apparatus to secure quiet ebullition and to aid in the transfer of the distillate to the receiver. Upon applying heat to the first flask, V^1, the solution boiled quietly and without change until the volume of liquid had decreased to about 30 cm^3, when traces of red selenium began to deposit in the tube joining the first and second flasks. When the volume had further diminished to about 25 cm^3 the liquid began to take on color, darkened rapidly, and evolved bromine, which at once attacked the selenium previously deposited. The greater part of the bromine was absorbed in the second flask, V^2, but a trace found its way to the Drexel bottle, in which it set free a slight amount of iodine from the iodide, as was afterward proved by the effect upon starch. As the operation progressed, an orange-yellow crystalline solid, presumably selenium tetrabromide for the most part, appeared in the tube where the selenium had been, while a dark oily liquid, consisting largely, no doubt, of the monobromide, condensed in drops upon the walls of the flask and returned to form a floating layer upon the hot liquid. Finally, when the volume had diminished to 15 cm^3, the liquid had become perfectly clear and colorless, white fumes of hydrobromic acid were evolved, and the tube between the two flasks had been cleared. At this point the operation was stopped and the apparatus allowed to cool. The addition of potassium iodide to the contents of the first flask neither liberated iodine nor precipitated selenium, and so proved that no reducible compound of selenium still remained in that flask. The amount of selenium which had been volatilized we determined directly by means of a method worked out in this laboratory and to which reference has already been made.* We introduced into the second flask, V^2, which now contained (beside a trace of selenium corresponding to the slight amount of bromine which had escaped to the Drexel bottle) the colorless selenious acid regenerated by the action of the water and free bromine upon the mixed bromides which had distilled, 1 grm. of potassium iodide and 5 cm^3 of hydrochloric acid and, after removing the first flask, V^1, and connecting the carbon dioxide generator with the inlet tube of V^2, boiled the solution ten minutes while a current of carbon dioxide passed through this apparatus. At the end of this time the iodine set free by the action of the iodide had been almost completely removed to the Drexel bottle, leaving a nearly colorless solution containing particles of dense, crystalline selenium. The iodine in the receiver, including of course the small amount set free by the bromine which reached the

* Gooch and Reynolds, this Journal, l, 254.

receiver in the first stage of the process, together with the small amount remaining in the flask, was titrated with sodium thiosulphate and taken as the measure of the selenium dioxide acted upon originally. In this way we obtained the following results :

SeO_2 taken. grm.	SeO_2 corresponding to iodine found in the distillate. grm.	Error. grm.
0·0366	0 0372	0·0006 +
0 0366	0·0377	0·0011 +
0·1098	0·1090	0·0008 −
0·1098	0·1101	0·0003 +

It is obvious from these results that the iodine finally found in the receiver is actually an accurate measure within reasonable limits of the selenium dioxide originally put into V^1 and volatilized therefrom by the action of phosphoric acid and potassium bromide.

When tellurium dioxide is subjected to similar treatment the phenomena are different. The solution containing the tellurous acid, potassium bromide, and phosphoric acid, in the proportions used in the experiments with selenious acid, colors at about the same degree of concentration at which the solution containing the selenious acid began to darken. As the concentration progresses the color deepens, ruby red crystals (probably hydrated tellurium tetrabromide) form, which accumulate upon the walls of the flask and turn yellow, and when the volume of the solution is diminished to 15 cm^3 a green vapor begins to distil. During the process no iodine is set free in the Drexel bottle, and upon stopping the boiling we found that the addition of potassium iodide to V^2 liberated no iodine, even when the boiling had gone so far that a trace of the green vapor had condensed and run into the water in the flask. In view of these facts it seemed probable that the process of treatment which we have described might be applied to the determination of selenium associated with tellurium. In the following experiments, made to test the point, tellurium dioxide was weighed out and dissolved in strong potassium hydroxide, the alkali was neutralized and the precipitate thus formed was redissolved by phosphoric acid, and 20 cm^3 of the acid of sp. gr. 1·70 were added in excess. To the solution were added definite amounts of selenium dioxide taken in a standardized solution and 1 grm. of potassium bromide, and the whole was introduced into the first flask, V^1, with enough water to make the entire volume of the solution 50 cm^3. The second flask, V^2, contained 10 cm^3 of water, and the Drexel bottle and trap were charged with a solution of potassium iodide. Carbon dioxide was passed through, and the solution in V^1 was boiled. The phenomena of each individual set of experiments with the selenious and tellurous acids occurred now together—the coloring of the liquid, the evolution of bromine, the distillation of the selenium bromides, the crystallization of the tellurium tetrabromide, the disappearance of the selenium compounds from the connecting tube, and the final stopping of the distillation when the volume of the residue has diminished to 15 cm^3. After cooling, the first flask V^1 was removed, 1 grm. of potassium iodide and 5 cm^3 of hydrochloric acid were added to the contents of the second flask, V^2, the current of carbon dioxide was again started through the apparatus, the mixture was boiled ten minutes, and the iodine in the flask, receiver and trap was determined by titration with sodium thiosulphate and taken as the measure of the selenium dioxide. In some preliminary experiments trouble was experienced in removing the last traces of the selenium bromides held back mechanically by the oily tellurium compound which collected upon the walls of the distillation flask and in the connecting tube; but the difficulty was satisfactorily overcome by cloaking the flask with a mantle of asbestos board and flaming the connecting tube gently toward the close of the process of distillation. The results obtained are gathered in the following table:

TeO_2 taken. grm.	KBr taken. grm.	H_3PO_4 (Sp. gr. 1·70) taken. cm^3.	Final volume. cm^3.	SeO_2 taken. grm.	SeO_2 found. grm.	Error. grm.
0·1	1	20	15	0·0733	0·0735	0·0002 +
"	"	"	"	0·0997	0·0995	0·0002 −
"	"	"	"	0·1004	0·1003	0·0001 −
"	"	"	"	0·0916	0·0914	0·0002 −
"	"	"	"	0·0997	0·0995	0·0002 −
"	"	"	"	0·1010	0·1014	0·0004 +
"	"	"	"	0·1015	0·1008	0·0007 −
"	"	"	"	0·1019	0·1022	0·0003 +
"	"	"	"	0·1010	0·1012	0·0002 +
"	"	"	"	0·1002	0·1000	0·0002 −
"	"	"	"	0·1006	0·1004	0·0002 −
"	"	"	"	0·1006	0·1001	0·0005 −

Obviously the error of the process, when carefully conducted and applied to the amounts of material which we have employed, is very small.

ART. XIX.—*Results of Recent Pendulum Observations;** by G. R. PUTNAM.

SOME additional relative measurements of the force of gravity were made by the Coast and Geodetic Survey during the summer of 1895. This work was done at certain primary telegraphic longitude stations of the Survey, and as it was incidental to the longitude work, the points were not selected with especial reference to their value as gravity stations. Notwithstanding this fact and their small number, they happen to be so located as to be of interest in several ways, and it is therefore thought desirable to give this preliminary summary of the results. The observations were made with the Mendenhall half-second pendulums, and the instruments and methods used were almost identical with those employed by the writer at 26 stations in 1894 and already fully described.† About the only change was in the use of two knife-edges instead of one. For the purpose of further insuring the independence of the pendulums, two pendulums were always swung upon one knife-edge and the third upon the second knife-edge. The pendulums were swung at the base station in Washington in January, 1895, and again after the return from the south in August; the mean corrected period of the three was in January $^{s}\cdot5007121$, and in August $^{s}\cdot5007113$. This difference may in part be due to some slight uncertainty in the temperature coefficient. To compare these periods with those obtained by the same pendulums at Washington in 1894, a small correction of $+^{s}\cdot0000004$ must be added to these means to allow for the fact that one pendulum was swung on a different knife-edge, which diminished the period of that pendulum. When this comparison is made there is found a slight but unimportant diminution in the average period, as seems to be the general tendency of the effect of use on pendulums. Because of the fact that Austin, Texas, formed one end of several of the longitude lines, opportunity was there afforded to make some additional tests in regard to the agreement of repeated but entirely independent determinations. A full series of observations was made at the end of April in a very favorably located basement room in the granite Capitol of the state of Texas. The apparatus was then used at Laredo and Galveston

* Published by permission of the Superintendent of the U. S. Coast and Geodetic Survey. Read before the Philosophical Society of Washington, Jan. 18, 1896.

† Report U. S. Coast and Geodetic Survey for 1894, Appendix No. 1; also "Results of a trans-continental series of gravity measurements;" Bulletin Philosophical Society of Washington, vol. xiii, p. 31.

and brought back to Austin, where early in June it was set up in the basement of the State University, somewhat more elevated and to the northward of the Capitol. Here two complete and independent sets of observations were carried out, with the pendulums swinging in the prime vertical in the first set and in the meridian in the second set. After applying a correction to the Capitol observations to reduce to the elevation and latitude of the University, the corrected periods were found to be:—

	Pendulum A4.	Pendulum A5.	Pendulum A6.	Mean.
	s.	s.	s.	s.
Capitol	·5010508	·5008777	·5008407	·5009231
University, prime vertical,	10508	8784	8417	9236
University, meridian	10504	8784	8424	9237

A comparison of the last two results indicates, as was anticipated, that the position of the planes of oscillation with respect to the meridian has no effect on the period.

Favorable locations, always in basements of buildings, were found for the observations at the other stations also, with the exception of New Orleans. At Laredo the instruments were in the commissary of Fort McIntosh, at Galveston and Calais in high-school buildings, and at New Orleans in the City hall. The necessity of being near the longitude station compelled this location in the latter place, though on account of close proximity to a heavily travelled street and the unstable nature of the underlying ground it was unfavorable, as the jar of passing vehicles was quite noticeable. The coincidences were sometimes irregular, but the periods of the three pendulums are in good accord and no discrepancy appears between the day and night observations.

The following table gives a summary of the results for these stations, the relative values of gravity being based as before on that provisionally adopted for Washington, and the computed values being derived from a theoretical formula depending on Clarke's figure of the earth (1880). The observed values have been reduced to sea level by two methods, first Bouguer's, in which the attraction of the entire mass above sea level is subtracted, and second, Faye's, in which in the attraction term only the difference from the average surrounding elevation is allowed for (in this case the average within a radius of 100 miles has been estimated as before). The usual elevation and topographical corrections are of course included in both of these methods. The residuals observed minus computed gravity are given in the table for these two methods of reduction to sea level.

Station.	Latitude north.	Longitude w. of Greenw.	Elevation.	g observed.	g reduced to sea level.		g computed.	Residuals, g reduced minus g computed.	
					Bouguer's reduction.	Faye's reduction.		Bouguer's reduction.	Faye's reduction
	° ′ ″	° ′ ″	meters	dynes	dynes	dynes	dynes	dynes	dynes
Austin. Texas (Capitol)	30 16 30	97 44 16	170	979·274	979·307	979·333	979·369	—·062	—·036
Austin, Texas (University)	30 17 11	97 44 14	189	979·269	979·306	979·332	979·370	—·064	—·038
Laredo. Texas	27 30 29	99 31 12	129	979·068	979·095	979·109	979·160	—·065	—·051
Galveston, Texas	29 18 12	94 47 29	3	979·258	979·259	979·259	979·294	—·035	—·035
New Orleans, La.	29 56 58	90 04 14	2	979·310	979·311	979·311	979 344	—·033	—·033
Calais, Maine	45 11 11	67 16 54	38	980·618	980·626	980·632	980·647	—·021	—·015

The continuation of the investigation of the question of reduction to sea level and of the anomalies of gravity is essential to a satisfactory application of pendulum observations in geodesy. The four stations in the south are of interest in this connection as well as from a geological point of view because of their comparative location. Two, Austin and Laredo, are situated toward the interior about 150 and 135 miles (241 and 217 kilometers) respectively from the Gulf coast, and in a region of erosion. Galveston is on a sandy island close to the main land, from which it is separated by a bay into which empty some small rivers. New Orleans is on the banks of the Mississippi in the midst of the vast alluvial region built up by that river, but is about 85 miles (137 km.) from the present mouth of the river. Galveston and New Orleans are about equally distant (nearly 100 miles or 161 km.) from the 100 fathom (183 meter) curve in the Gulf of Mexico, beyond which line the water depths rapidly increase. It has been estimated that an area of about 1,800,000 square miles is drained by the Mississippi, Rio Grande and neighboring rivers emptying into the Gulf of Mexico from the north, and that the enormous amount of sediment carried by these rivers is deposited within an area of 300,000 square miles along the northern part of the Gulf.* If this added load accumulating for ages and displacing sea water of only about one-third its density, were sustained by a rigid earth, it would seem that there must be an effect on the force of gravity measured at the surface which would be quite within the range of observation, and gravity in the loaded region would be found greater than normal. If, on the other hand, there existed a perfect condition of equilibrium, and an area so loaded continually adjusted itself and sank in proportion to the load, in accordance with the theory of isostasy, we would expect to find the force of gravity quite normal. Should there be a lag between cause

* These drainage and deposition areas are shown in the map, here reproduced, with the author's permission, from Mr. McGee's paper, later referred to. The positions of the gravity stations are also shown.

and effect, that is, should the load accumulate to a certain extent before the sinking occurred because of the partial rigidity of the crust or some other retarding cause, we would again expect to find gravity in excess, but only to a small amount. It is of interest, therefore, in this connection to examine the gravity residuals at the four southern stations (differing as they do but little in latitude) as given in the last two columns of the table. The minus sign indicates a defect of gravity as compared with that given by the theoretical

Stations: N. O., New Orleans; G., Galveston; A., Austin; L., Laredo.

formula used, but it is only the comparative values between the coast and interior stations that need be considered here. There is practically no difference in the results for the two coast stations, New Orleans and Galveston. With Bouguer's reduction, gravity at the coast stations, however, is apparently about ·030 dyne greater than at the interior stations, but this is probably due to the fact that the interior stations are more elevated, as negative residuals almost invariably appear in elevated regions with this method of reduction. With Faye's reduction, gravity at the coast stations is ·017 dyne greater than at Laredo and only ·003 greater than at Austin, or an average excess of ·010.* As far as it is safe to draw an inference from so small a number of observations (and considering the unfavorable location of the station at New Orleans), gravity is apparently slightly in excess near the Gulf coast as compared with interior stations. A determination nearer the present delta† of the Mississippi would be of interest in this connection, as well as observations in the same latitude on the other coasts of the continent. The smallness of the differences found indicate a close approach to the condition of hydrostatic equilibrium in this region. The fact that the slight excess is at the coast stations points possibly to some retardation in reaching this condition. It is interesting to compare the conclusion reached by Mr. McGee in discussing the condition of the same region as deduced from geological and other considerations, in these words: "So the data relating to the condition of the earth's crust derived from the modern Gulf of Mexico indicate that throughout the vast geologic province of southeastern North America, isostasy is probably perfect, i. e., that land and sea bottom are here in a state of hydrostatic equilibrium so delicately adjusted that any transfer of load produces a quantitatively equivalent deformation."‡

While coast stations have in general shown less apparent irregularity in the force of gravity than is often found in the interior, doubtless because they are situated so near the sea level and are therefore more free from the uncertainties associated with the sea level reduction, still greater discrepancies appear than can be attributed to errors of observation. In the following table are collected the residuals observed minus computed gravity, for the stations on or near the coasts, thus

* The attraction of an extended horizontal plate of rock of average density 31 feet (9·4 meters) thick corresponds to ·001 dyne force of gravity.

† The interesting fact has been recently brought out by an Engineer officer, that a rise of one foot, since 1877, in the level of mean high water in the Gulf of Mexico is indicated by the tidal observations at Port Eads at the delta of the Mississippi. This change would correspond to a subsidence of the land of like amount, but may possibly be accounted for by a local settling near the bench mark.

‡ "The Gulf of Mexico as a Measure of Isostasy," W. J. McGee, this Journal, Sept., 1892, vol. xliv, p 189. The following conclusions are also quoted as bearing on the same subject:

"It appears that the crust, in the form in which it exists, must be in a condition of approximate hydrostatic equilibrium, such that a considerable addition of load will cause any region to sink, or any considerable amount denuded off an area will cause it to rise." "Physics of the Earth's Crust" (2d edition), by Rev. O. Fisher, p. 355.

"It may be laid down as a general rule that where great bodies of sediment have been deposited over extensive areas, their deposition has been accompanied by a subsidence of the whole mass." "On some of the greater Problems of Physical Geology," by Major C. E. Dutton, Phil. Soc. of Washington, vol. xi, p. 55.

far determined in the United States (exclusive of Alaska) and for the two methods of reduction to sea level already mentioned. (— indicates gravity smaller than normal, + greater than normal.)

Summary of gravity residuals for Coast Stations.

Coast.	Station.	Latitude north.	Residuals, observed minus computed *g*.	
			Bouguer's reduction.	Faye's* reduction.
		° ′	dynes	dynes
North Atlantic	Calais, Maine	45 11	—·021	—·015
	Cambridge, Mass.	42 23	—·009	—·003
	Boston, Mass.	42 22	—·007	—·001
	Hoboken, N. J.	40 44	+·008	+·019
	Princeton, N. J.	40 21	—·038	—·032
	Philadelphia, Pa.	39 57	+·004	+·011
	Baltimore, Md.	39 18	—·034	—·023
	Washington, D. C.	38 53	+·014	+·026
Gulf of Mexico	New Orleans, La.	29 57	—·033	—·033
	Galveston, Texas	29 18	—·035	—·035
North Pacific	Seattle, Wash.	47 36	—·135	—·090
	San Francisco, Cal.	37 47	—·016	—·049

The variations in these residuals, while not considerable except in a single case (Seattle), are nevertheless of much interest. It will be noted that with either method of reduction the largest excess of gravity appears at Washington.†

A computation of the amount of flattening of the earth has been made from the 33 results for gravity obtained in the United States in 1894 and 1895. These observations are of course not well suited for this purpose except in combination with results in other parts of the world, as the work of 1894 was intended to develop the effect of elevation and continental position, and not the variation of gravity with latitude, and for this reason those stations differed little in latitude, and even with the few southern and northern stations added during the past season the extreme range in latitude is less than 18° (from 27° 30′ to 45° 11′). Nevertheless it is of interest to see how

* Some slight differences in the last column of this table from values previously given, are due to revised estimates of average elevation. The results from Hoboken, Baltimore, Seattle and San Francisco are from earlier determinations.

† Commandant Defforges, comparing results obtained on the shores of various oceans came to the conclusion that each ocean possesses a characteristic anomaly in the force of gravity along its shores. "Memorial du Dépôt Général de la Guerre, Observations du Pendule," vol. xv, p. 194.

reliable a value can be obtained from such meager data, derived entirely within the borders of the United States. The values reduced to sea level by Faye's reduction were used, and to simplify the computation were averaged together for each degree of latitude. Conditional equations were formed of the form $g_\phi = x + y \sin^2 \varphi$, representing the variation of gravity with latitude, where x is gravity at the equator, y is the difference between gravity at the pole and the equator, and g_ϕ is observed gravity at latitude φ; x and y were then computed by the method of least squares, and substituted in Clairant's theorem. Using Helmert's expansion of Clairant's theorem,* the value $\frac{1}{301.0}$ was obtained for the amount of flattening, or the difference between the earth's polar and equatorial axes divided by the equatorial axis.† Helmert in 1884 obtained the value $\frac{1}{299.3}$ from a discussion of pendulum observations in various parts of the world, and Clarke from a similar discussion in 1880 obtained $\frac{1}{292.2}$. Two of the most important values obtained from arc measurements are those of Bessel (1841) $\frac{1}{299.2}$, and Clarke (1880) $\frac{1}{293.5}$. A variation of one unit in the denominator of these ratios corresponds to a change in the difference between the earth's major and minor axes, of about 481 feet (147 meters), and from the discrepancies in the above and other results one may judge that the actual uncertainty may be nearly a mile.‡ The value derived from the pendulum observations in the United States is not very different from Helmert's and Bessel's, but it is of significance only in showing that a fairly accordant result may be obtained from so few observations very narrowly distributed in latitude, and in further confirming the validity of the reduction to the sea level tentatively employed, and the theory of the condition of the earth's crust on which that reduction is based, the equilibrium or isostatic theory.§ This result has been obtained by combining observations made at altitudes above sea level ranging from 6 ft. to 14085 ft. (2 m. to 4293 m.), and in a great variety of continental locations.

* "Geodasie," by F. R. Helmert, vol. ii, p. 83.

† A result for the flattening of $\frac{1}{296}$ was obtained by comparing the four southern stations, Austin, Laredo, Galveston and New Orleans, with four stations in nearly the same longitude near the 39th parallel in the central plains, St. Louis, Kansas City, Ellsworth and Wallace.

‡ Prof. Harkness says: "Indeed the facts thus far advanced scarcely warrant any conclusion more definite than that the flattening probably lies between $\frac{1}{290}$ and $\frac{1}{300}$, but we shall see presently that there is some further evidence which tends in the direction of the smaller limit" [$\frac{1}{300}$].—"The Solar Parallax and its Related Constants," p. 103.

§ For discussions of the relation of the Coast and Geodetic Survey pendulum observations to these theories, see papers by Mr. G. K. Gilbert, Bulletin Phil. Society of Washington, vol. xiii, p. 61; by Rev. O. Fisher, Nature, vol. lii, p. 433, Sept. 5, 1895; and by M. Faye, Comptes Rendus de l'Académie des Sciences, 20 May, 1895.

ART. XX.—*On Trinidad Pitch;* by S. F. PECKHAM and LAURA A LINTON.

THE bitumen found on the Island of Trinidad in the so-called Pitch Lake and in its neighborhood, has entered commerce under the name of Trinidad Pitch. That which is found within the lake is called "Lake Pitch;" that found outside the lake is called "Land Pitch."

As it occurs it is a unique substance found nowhere else in nature. It consists of a mixture of bitumen, water, sand, decayed vegetation and gas in such definite proportions that within certain limits the composition of the entire mass is uniform. The bitumen has never yet been investigated in such manner as to determine its relations to other bitumens, but it appears to be of vegetable origin and convertible into solid asphaltum by processes of nature. In its natural condition about one-third of it is water. Deprived of water it is about one-third sand. When the bitumen is dissolved away from the sand under the microscope, the silica appears to be in exceedingly minute amorphous particles from $\frac{1}{10000}$ to $\frac{1}{1000}$ of an inch in thickness. When freed from organic matter by burning, the silica appears in small sharply angular grains, stained by iron and a small quantity of bluish clay. The organic matter not bitumen consists of fragments of vegetation and disorganized cellular tissue, with products of the decomposition of wood.

As the bitumen rises in the center of the so-called lake it is inflated with gas. When the masses are broken into the structure resembles vesicular lava. The gas cavities are of all sizes, some of them very large and in the aggregate occupy at a rough estimate from one-third to one-half the volume of the pitch. At any point in the deposit removed from the center of the lake, the gas, in part, has escaped from the asphaltum and the mass become more compact. Both within and without the lake the pitch is saturated with water. It is in this condition without viscosity and can be trodden upon or squeezed in the hands without adhesion to either hands or feet. In this condition it cuts like cheese, hence the name, "cheese pitch." When freshly dug the color is brown, but if left in the sun it soon darkens, finally becoming a bluish-black. If a mass of any considerable size is laid in the sun, it will melt to a thin pellicle upon the exposed surface, and retain the larger part of the water at a temperature sufficient to remove every trace of water if it were dried in the shade. A mass exposed to the air out of the sun, immediately begins to dry out and in a short time loses nearly all of the water, which is in part readily re-absorbed if again exposed to dampness.

The evaporation of the water precipitates within the pitch a small percentage of saline matter, chiefly sulphates of the alkalies and alkaline earths, that the natural water holds in solution. The hygroscopic property of the pitch is no doubt largely due to the presence of these salts.

In selecting specimens that would fairly represent the character of the mass of pitch both within and without the lake, we were largely governed by the appearance of the pitch and the relation of the several localities to one another and the center of the lake.

No. 1 was picked up at random from the pitch taken from an excavation from which the cargo of the bark "Ella" was dug, during February and March, 1895. The excavation was upon a village lot about three-quarters of a mile from the lake towards Point La Brea.

No. 2 is from a village lot which we have named the "Photograph Lot." It was here that a pit was dug and photographs taken of the pit at intervals of ten days to determine whether any movement in the pitch was in progress by which a cavity dug in the pitch would refill. No. 2 was taken from the pitch removed from the pit. This lot had been excavated about six months previous and had nearly refilled, and was then being uncovered preparatory to the removal of a fresh supply of several thousand tons. It was about twenty rods nearer Point La Brea than No. 1.

No. 3 is so-called "Iron pitch" from the Photograph lot. This is pitch that has been melted and deprived of its water and gas. It is solid, of a bluish-black color, with a dull earthy fracture and is slightly sonorous when struck.

No. 4 was taken from a lot on the right hand side of the road approaching the lake, that was being excavated by Mr. Ghent. It came from a point 10 or 15 feet below the surface on the western border of the mass filling the ravine down which the overflow of pitch from the lake has taken place, and nearly on the opposite side of the road from the point from which No. 10 was taken.

No. 5 is No. 4, boiled to form Èpureè, in Mr. Ghent's boiling works near Point La Brea.

Nos. 6 and 7 were from opposite corners of a mass about 12 inches square and four inches in thickness. This mass was taken from a point on the northeast side of the lake on the outside of and near to the tramway, and was selected of convenient size from among a quantity that had been broken with a pick preparatory to removal in the tram cars or carts by the Trinidad Asphalt Co.

No. 8 is from an average from the same piece made up by breaking fragments from many points upon its surface.

No. 9 is from the center of the lake or near it. The mass was soft enough to flatten in the shade, but did not stick to the paper in which it was wrapped. After drying it became ridged and brittle.

No. 10 is an average from a large piece taken from an excavation being made by the Trinidad Asphalt Co. on the Bellevue estate near the road leading to the lake. The excavation extended along the road for perhaps 1500 feet and was narrow. The pitch was clean and pure but was covered by rank vegetation that grew upon and in the pitch itself, and not upon soil that covered it. This fact accounts for the high percentage of organic matter not bitumen, although the piece was taken several feet below the surface.

No. 11 is a decomposition product of the pitch from the photograph lot.

No. 12 is another decomposition product from the same lot. It resembled coke and may have been heated. It is the only material resembling coke that we saw in or around the lake and the amount was only a few pounds.

No. 13 is also a decomposition product resembling No. 11, from the south side of the lake. It was enclosed by a pellicle of sun-dried, melted pitch, within which it was of a light brown color with a columnar structure, like starch, and was very easily powdered. It had the external appearance of asphaltene that had been precipitated from solution.

No. 14 is from a pile of land pitch melting on the beach at Point La Brea, said to have come from the same lot as No. 1.

No. 15 was brought from the lake about 1865, by the late William Attwood of Portland, Me.

No. 16 is from the southeast side of the lake inside the road and was cut from the surface at a spot free from vegetation. The point was about half way from the tramway to the border of the lake.

No. 17 is from the west side about mid-way of the tramway loop, where men were loading tram cars. It was picked up from under the feet of the men.

No. 18 is iron pitch from the northeast side of the lake near where the left limb of the tramway, looking south, enters upon the lake.

No. 19 is refined land pitch, from the refinery of the Trinidad Bituminous Asphalt Co. at Jersey City, N. J. It came from the same lot as No. 2.

No. 20 is refined lake pitch, purchased in New York of the Warren, Scharf Co.

No. 21 is from the northeast side of the lake near the left limb of the tramway looking south.

No. 22 is from the northeast side of the lake near the right of the left limb of the tramway loop looking south, about one hundred feet from No. 21.

No. 23 is from the northwest side of the lake on the west side of the right limb of the tramway loop looking south.

No. 24 is from the south side of the lake near where the road leaves the lake.

No. 25 is from the northwest side of the lake on the west side of right loop of tramway looking south near a "blow-hole."

No. 26 is from the south side of the lake near where the road leaves it, about one hundred feet from No. 24.

No. 27 is Èpureè from the boiling works of the Trinidad Asphalt Co., at Point La Brea. It was made by boiling a mixture of No. 10, No. 8 and No. 9.

Nos. 6, 7, 8, 9 and 17 represent commercial lake pitch.

Nos. 16, 21, 22, 23, 24, 25 and 26 represent the contents of the lake occupying the annular space outside the tramway and embracing hundreds of thousands of tons. The area is about 60 per cent. of the surface of the lake.

Nos. 1, 2, 4, 10 and 14 represent an average of commercial land pitch.

Nos. 5 and 19 represent refined land pitch.

Nos. 20 and 27 represent refined lake pitch.

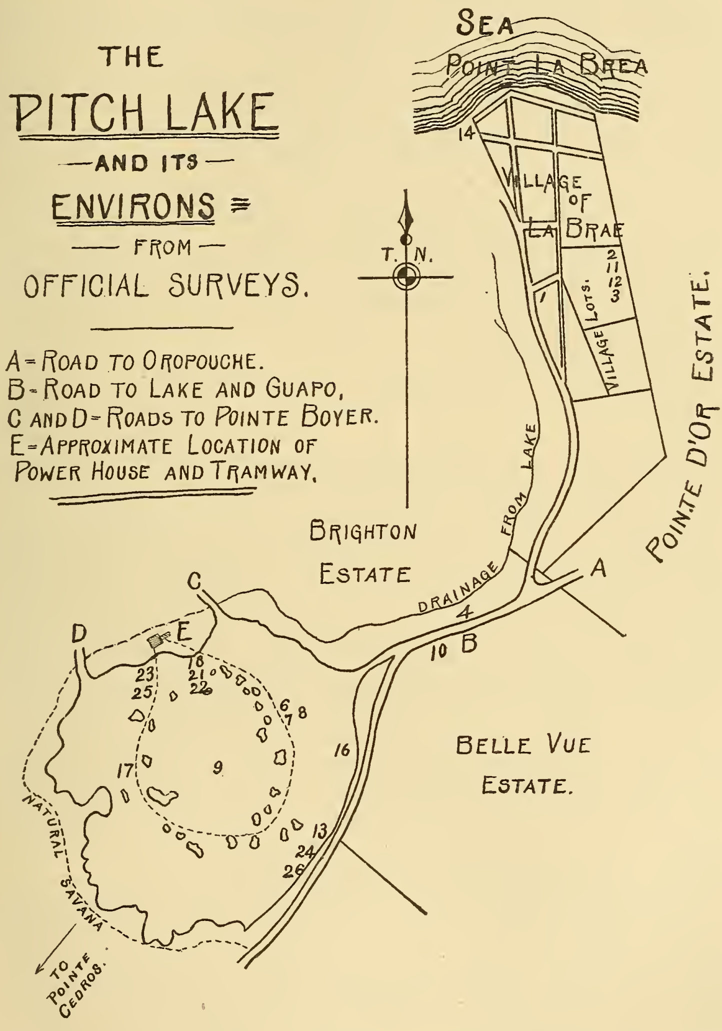
Nos. 3, 11, 12, 13 and 18 are rubbish so far as commerce is concerned, and are introduced here to show that there is rubbish in the lake as well as outside of it, and also the relation of alteration products to the commercial pitch.

The locations of the several specimens are shown on the accompanying map.

No specimens were taken from near the border of the west side of the lake, because the pools of water were so wide as to make it quite difficult to get around among them. These specimens are believed to furnish a fair representation of the pitch as it occurs both within and without the so-called lake, and also the refined pitch and Èpureè made from the same.

As before stated, the condition of the pitch in the entire deposit is that of complete saturation with water. Water is reached everywhere within a few feet of the surface and often stands in the areas from which pitch has been excavated. Both outside and upon the borders of the lake it appears to render the re-filling of the areas less rapid. In and near the center of the lake, the enormous volume of gas constantly rising, forces the pitch into any excavation more rapidly.

The pitch is removed from near the tramway soon after it is dug, and before it has time to melt is weighed full of water and immediately thrown into the hold of the ship. The pitch from other parts of the deposit is dug up in large pieces and removed in carts to the beach, where it is immediately put into lighters and transferred as soon as possible to the hold of the



ship anchored off shore. In either case the pitch reaches the hold of the ship containing from 25 per cent to 30 per cent of water and considerable gas, especially that removed from the lake. Before being discharged, heat, the motion of the ship and the weight of the mass upon itself have rendered the mass within the hold of the ship nearly solid and the material is no longer the natural crude pitch, but something more or less removed from it by loss of water and gas.

In the case of samples like those taken by ourselves and packed in a trunk, labelled and carefully wrapped in paper, the loss of water was nearly complete before they reached New York. In fact it required only a week or ten days in Port of Spain to completely transform the cheese pitch from a moist, porous substance, cutting with a knife like cheese, to a hard brittle solid, readily broken into fragments that could only be cut with considerable difficulty, provided it was kept out of the sun. It is therefore manifest that commercial samples of crude pitch are not samples of natural crude pitch; nor is it possible to bring away from Trinidad samples of "cheese" pitch in the natural condition. We therefore determined to analyze the specimens selected free from water and gas, and thus render the results comparable.

The samples were severally coarsely powdered and air dried by placing them upon the laboratory table in the sun. In dry weather they soon dried to a constant weight. In damp weather they lost and gained within narrow limits indefinitely. Heated in an air bath to 50° C., they were soon brought to a constant weight. Heated at 100° C., to a constant weight, a varying loss of volatile oils invariably followed, which showed that determinations of water at 100° C. as a constituent of the pitch leads to vitiated results from two sources: first, the percentage of water is not constant in the same specimen but varies with the condition of the atmosphere; second, pitch that is apparently very dry gives off an appreciable amount of volatile oils below 100° C. The samples were therefore dried to a constant weight, at a temperature below 50° C. Of course, if, for any reason, the amount of water in a given specimen of pitch is desired, it is easily ascertained, but it should not be reported as a constituent of the pitch, as the varying percentage of water causes all of the other percentages to vary in the same specimen at different times.

The dried specimens were then exhausted with petroleum ether. In the present instance the petroleum ether used for all the specimens came from the same barrel and was of specific gravity 74° B. The exhausted residues were dried at 100° C. and the difference in weight was computed as petrolene. The dried residues were then exhausted with boiling spirits of turpentine, washed with ethyl alcohol and dried at 100° C. to a constant weight. The loss was noted. The dried residues were then exhausted with chloroform and dried and the loss noted. The loss by turpentine plus the loss by chloroform is estimated as asphaltene. The distinction made by the use of these two solvents will be noted farther on. The dried residue from the chloroform exhaustion was then put into a platinum crucible and the organic matter burned off. The residue was inorganic or mineral matter, sand, and the small percentage of soluble and non-volatile salts present. The pitch was thus divided into that portion soluble only in petroleum ether, or "petrolene," that portion soluble only in boiling spirits of turpentine, and chloroform which together form "asphaltene," and with the petrolene constitutes the "total bitumen"; also the "organic matter not bitumen" and the "inorganic matter."

Table No. 1 represents the results of the analysis of the 27 specimens described above. Any attempt to classify them as to the locality from which they were obtained by means of these analyses will inevitably fail. Our analyses prove that an average of specimens will show an increase in the proportion of "mineral matter" and of "organic matter not bitumen," as the point from which the specimen is taken is removed from the center of the lake; yet, the exceptions to this rule are so numerous and marked, that no certainty can attach to the use of these criteria.

Great value is attached by some experts on asphaltum to the determination of the specific gravity and temperature at which the different specimens soften and flow. These tests might have some value if applied to a pure bitumen which had been proved to change in specific gravity, etc., as it underwent chemical and other changes; but no such investigation and proof in relation to any asphaltum has been attempted. Such a relation has been assumed but not proved. The fact that Trinidad pitch is a mixture so indefinite that it is almost, if not quite impossible, to select two pieces that have the same proportions (as is proved by Nos. 6, 7 and 8) is a sufficient reason why no such distinctions can be based upon such determinations. The average proportions of mineral matter to bitumen in the 5 samples of commercial lake pitch taken from near the center of the lake is 100 : 151. No two of them are exactly alike, and the extremes are, lowest 100 : 148, highest 100 : 155. The seven specimens from outside the tramway show greater uniformity, yet no two are alike and all are below the lowest of the five mentioned above. The average ratio of the land pitch is still a little lower, while the extremes of variation are 134 and 146. It is manifest that between these extremes of proportion of 100 : 134 and 100 : 155 a marked variation in specific gravity and flowing test must occur, as the sand is about twice as heavy as the bitumen. These extremes of variation include one-sixth of the average amount of bitumen present.

These observations apply with equal force to the ingredient of the mixture denominated "organic matter not bitumen." In the five specimens of commercial lake pitch the average amount of this material is 10·651 per cent. The extremes of variation include 1·482 per cent, which is 14·8 per cent or nearly one-sixth of the average amount present. The smallest amount is found in the average pitch from near the center of the lake, yet No. 17, which was picked up from under the feet of the men who were loading the tram cars on the west side of the tramway near the middle, contains nearly 12 per cent. This average lake pitch is found where the mass is in constant motion from escape of gas. Here there is no organic matter added by vegetation to the amount originally found in the pitch. The growth of vegetation upon and in the pitch itself is the source from which the excess of organic matter found in the lake pitch taken from points outside the center and from the so-called land deposits is derived. As this excess consists mainly of coarse roots it is removed by refining, so that when the pitch is ready for use the difference in the organic matter has largely or entirely disappeared. See numbers 2 and 19, 8 and 20.

Table No. 2 shows the results of a comparative examination of the bitumen contained in the different samples without regard to the amount present. The first division of this table shows the percentage of the crude pitch dissolved only by petroleum ether, boiling spirits of turpentine and chloroform respectively. The middle column gives the percentage of the total bitumen in the crude pitch. The next three columns give the percentages of the total bitumen present dissolved only by petroleum ether, boiling spirits of turpentine and chloroform respectively. The last column shows the percentage of the total bitumen dissolved by boiling spirits of turpentine. This item is represented by adding together the items of the first and second columns, as all of the material that is dissolved by petroleum ether is soluble in boiling spirits of turpentine. A comparison of these numbers along each horizontal line shows that there is no necessary connection between the amount of *crude pitch* dissolved by petroleum ether and the *quality* of the total bitumen. As an example, in No. 1, which is a land pitch, 100 parts of bitumen are mixed with very nearly 100 parts of sand and organic matter, not bitumen, while in No. 9 from the center of the lake 100 parts of bitumen are mixed with about 92 parts of foreign matter. Now while the percentage of crude pitch dissolved by petroleum ether from No. 1 is 2·333 per cent less than the percentage of No. 9 dissolved by the same menstruum, the *proportions* of the total bitumen dissolved in the two cases are almost identical, viz: 66·5 per cent and 66·544 per cent. Again, No. 17 was broken off a piece of pitch as a negro raised it and threw it into a tram car. It fell under his feet and was secured as a piece of convenient size for a specimen. On analysis it gave 34·2 per cent soluble in petroleum ether, while the total bitumen was 52·997 per cent. These results give 64·531 per cent of the total bitumen soluble in petroleum ether and 89·372 per cent soluble in boiling spirits of turpentine. Of the five samples of commercial land pitch, Nos. 2, 4 and 10 contain 33·62, 33·736 and 33·730 per cent of matter soluble in petroleum ether. The average is 33·705, yet the average per cent of the total bitumen present soluble in petroleum ether is 64·283 per cent, almost identically the same as that yielded by No. 17. In fact No. 2 and No. 17 represent the extremes of location from the west side of the tramway to the village lot furthest from the lake and the difference in the percentage of the total amount of bitumen soluble in petroleum ether is only (·255 per cent) two hundred and fifty-five thousandths of one per cent—a difference wholly without significance. No. 9 was from the center of the lake and No. 1 from a village lot about 20 rods nearer the lake than No. 2, yet the difference in the amount of total bitumen present soluble only in petroleum ether, is only forty-four thousandths of one per cent. Arranged in a table these samples of commercial pitch appear as follows:

No. 1.	Land	66·500
No. 9.	Lake (center)	66·544
No. 2. No. 4. No. 10.	Land Average	64·283
No. 17.	Lake	64·531

Of the specimens representing the pitch filling the annular space outside the tramway and beyond, to the boundaries of the lake, Nos. 21 and 22 were taken from the bottom of an excavation on the right of the left limb of the tramway loop as it descends upon the lake and within 140 feet of each other. Nos. 23 and 25 were taken from points very near each other on the right or west side, of the right limb of the tramway loop. These four points are on the north side of the lake and near the border. No. 16 was taken from a point on the south-east side of the lake about half way from the tramway to the border of the lake. The spot was free from grass, yet it was within the area covered with vegetation. Nos. 24 and 26 were from points on the south side of the lake directly opposite Nos. 21, 22, 23 and 25 and about 100 feet apart.

The percentage of total bitumen soluble in petroleum ether is shown in the following table:

No. 21	51·555
" 22	65·809
" 23	64·960
" 24	62·974
" 25	68·431
" 26	70·691
" 16	66·933

Nos. 25 and 26 from opposite sides of the lake and very near the border, are the highest in the list and higher than No. 9 from the center of the lake, and higher than No. 6 which is the highest commercial lake pitch. The differences and identities of these different groups, as well as between the individual members of the groups, can be readily traced by reference to table No. 2.

The portion soluble in petroleum ether is called "petrolene." It is a constituent and essential part of the pitch, and embraces all that is most volatile in the pitch, including those etherial or oily fluids that are given off at a temperature below the boiling point of water, and which are found in all specimens from all parts of the deposit (land and lake) that have not been previously heated or decomposed. It is contended that petrolene is the cementitious portion of the pitch, because the remaining portion of the bitumen is solid and insoluble in residuum oil. It might just as well be contended that water is the cementitious principle of glue and that glue has no cementing properties because it is not soluble in alcohol. The fact is, that the bitumen of Trinidad pitch consists of asphaltene dissolved in petrolene and that its cementitiousness is just as much due to one as the other. Sand cannot be cemented with either petrolene or asphaltene alone, neither can wood be cemented with either water or glue alone. The cementitiousness of the pitch depends upon the amount and quality of the bitumen present.

What meaning is intended to be given the word "dry" in connection with pitch is not very clear. It cannot be freedom from moisture, for no specimen of crude pitch is entirely free from water. As found in the deposit, the pitch both outside and inside the lake is saturated with water, and its condition after removal from the deposit depends entirely upon what is done with it. The use of the word "dry" appears to imply that the pitch from outside the lake has lost the whole or a large part of the most volatile oils originally contained in it. No proof whatever has been offered to sustain such assertions. It has been contended that the sun heats the land pitch to

140°–150° F. Outside the lake the deposit is covered with from 2 to 15 feet of earth, rubbish and vegetation. The large area in the center of the lake from which, for convenience, the commercial lake pitch is removed, is bare and black, exposed to the full rays of the tropical sun. Shallow pools of water on the surface of the lake appear to have a temperature of about 100° F. The pitch is probably hotter. It is therefore reasonable to suppose that if evaporation of light oils were taking place that the pitch in the lake would be "driest." Our examination has shown us that both land and lake pitch contain oils volatile under the boiling point of water in about the same proportion; small in both cases.

The use of both turpentine and chloroform as solvents for asphaltene is based upon observations made a year ago upon the methods employed for the technical analysis of asphaltum. Is was found that in the United States carbon disulphide has been almost exclusively used as a solvent for asphaltene, while in Europe spirits of turpentine has been used for the same purpose. Careful experiment showed that neither of these solvents would dissolve all of the bitumen from the specimens in our possession, among which were those from the valley of the Rhone. It was observed that turpentine left a large and varying residuum when applied to nearly all of the American specimens, including Trinidad, and that only a very small percentage was left from the Rhone specimens and those from the Indian Territory. It was also found that in either case chloroform alone effected a complete extraction of the bitumen. Later we received a specimen of Neufchatel asphaltic rock from which turpentine completely dissolved the bitumen. This led to an examination and classification of the various bitumens with reference to the action of turpentine. It was found that a large percentage of the asphaltene of Grahamite and a varying percentage of the asphaltene of Trinidad pitch and the asphaltums of California is insoluble in turpentine. It was also found that the asphaltene of the bitumens of Texas and the valley of the Rhone is almost wholly soluble in turpentine, and further that when the bitumen is removed from solution from these asphaltic rocks it is not a solid asphaltum but a semi-solid viscous fluid, that does not become solid by exposure, but has remarkable stability in the atmosphere. These facts lead to the belief that the proportion of asphaltum soluble only in chloroform furnishes an indication of the extent to which a bitumen has been affected by "aging."

It has been asserted that land pitch had matured through geological time and reached a condition approaching "glance pitch." The word glance as applied to pitch has nothing to do with its age, or with any other property except its appearance. The word glance is from the German word "glanz," which means glistening. Pure asphaltum that has been melted has a smooth glistening fracture like rosin or anthracite coal. It would be impossible to produce glance pitch by melting a material containing so much mineral matter as Trinidad pitch. Iron pitch is the nearest approach to it that can be found in the neighborhood of the Pitch lake, and that was found both within and without the lake. If it has been intended to convey the impression that asphaltum becomes glance pitch by aging, and that the land pitch is farther on the way through geological time towards glance pitch than that in the lake, it must also be admitted that so far as anyone knows to the contrary the whole phenomenon of the pitch lake may have been produced within five hundred years. Our analyses have not furnished the slightest evidence that the bulk of the pitch outside the lake has aged any more than that within it. Our analyses also show that the bulk of the pitch is in good condition throughout the deposit; and that the effects of aging are about equally distributed.

These analyses do not sustain the allegation that land pitch is any less uniform in composition than lake pitch. The following figures represent the extremes in the percentage composition of total bitumen in the five samples of commercial lake pitch and the five samples of commercial land pitch soluble in

	Land.	Lake.
Petroleum ether	3·445%	3·601
Boiling spirits turpentine	9·746%	7·110
Chloroform	9·622%	9·716
Total soluble in turpentine	9·621%	9·696

The correspondence between them is remarkable.

It makes no difference whether these results of analysis are taken as a whole, or compared severally, or in the different elements that make up each analysis, the same conclusion is inevitable, viz: that the entire deposit both within and without the boundaries of the lake is one and the same substance and in substantially the same condition.

There are five specimens in the collection that represent the rubbish of the deposit. Nos. 3 and 18 are respectively land and lake "iron-pitch," Nos. 11 and 13 are decomposition products from the land and lake respectively, that may be what has been called "chocolate pitch," No. 12 may be what has been called "grey pitch." None of these are commercial articles, yet they are shown by these analyses to have scientific relations to the commercial pitches full of interest. By comparing these five specimens with any other five in the tables, it will be found that they are low in material soluble in petroleum ether; high in material soluble in boiling spirits of turpentine and chloroform, and at the same time they are low in the percentage of total bitumen soluble in boiling spirits of turpentine. This apparent contradiction is easily accounted for when the high percentage of material soluble only in chloroform is observed. The proper interpretation of these results in reference to the aging of asphalt awaits the completion of investigations now in progress.

TABLE NO. 1.—*Analyses of Trinidad Pitch.*

No.	Petrolene.		Asphaltene.		Total Bitumen.	Organic Not Bitumen.		Inorganic.	
a.	33·600		17·150			11·625		37·625	
b.	33·635		17·200			11·850		37·300	
1. Mean		33·617		17·175	50·791		11·737		37·462
a.	33·640		18·888			11·347		36·123	
b.	33·600		18·468			11·652		36·280	
2. Mean		33·620		18·678	52·297		11·499		36·201
a.	33·637		23 621			7·840		34·902	
b.	33·511		23·034			8·988		34·467	
3. Mean		33·574		23·327	56·901		8·414		34·684
a.	33·769		18·764			10·564		36·903	
b.	33·703		18·498			11·138		36·555	
4. Mean		33·736		18·631	52·367		10·851		36·729
a.	33·600		18·000			10·500		37·900	
b.	33·650		18·500			9 800		38·050	
5. Mean		33·625		18·250	51·875		10·150		37·975
a.	36·650		17 200			10·800		35·350	
b.	36·650		17·250			10·775		35·325	
6. Mean		36·650		17·225	53·875		10·787		35·337
a.	36·392		17·151			10·491		35·961	
b.	36·392		17·245			10·410		35·990	
7. Mean		36·372		17·198	53·570		10·450		35 975
a.	36·300		17·975			9·900		35·725	
b.	36 650		17·800			9·850		35·700	
8. Mean		36·475		17·887	54·362		9·875		35·712
a.	35·950		18·050			10·875		35·125	
b.	35·950		18·100			10·690		35·260	
9. Mean		35·950		18·075	54·025		10·782		35·192
a.	33·730		18·948			11·390		35·930	
b.	33·730		18·750			11·667		35·842	
10. Mean		33·730		18·849	52·579		11·528		35·886
a.	21·200		30·375			9·600		38·500	
b.	21·525		30·250			10·100		38·450	
11. Mean		21·362		30·312	51·674		9·850		38·475
a.	0·000		3·000			43·525		53·475	
b.	0·000		3·000			43·550		53·450	

No.	Petrolene.	Asphaltene.	Total Bitumen.	Organic Not Bitumen.	Inorganic.
12. Mean	0·000	3·000	3·000	43·537	53·462
a.	19·200	33·050		9·650	38·000
b.	19·300	33·575		9·475	37·750
13. Mean	19·250	33·312	52·562	9·562	37·875
a.	31·800	18·725		11·925	37·550
b.	31·750	18·525		12·355	37·370
14. Mean	31·775	18·625	50·400	12·140	37·460
a.	32·176	43·649		5·570	18·605
b.	32·450	43·300		5·960	18·290
15. Mean	32·313	43·474	75·787	5·765	18·447
a.	35·375	17·475		11·000	36·150
b.	35·425	17·600		10·925	36·050
16. Mean	35·400	17 537	52·987	10·962	36·100
a.	34·200	18·775		11·275	35·750
b.	34·200	18 820		11·440	35·540
17. Mean	34·200	18·797	52·997	11·357	35·645
a.	22·275	22·225		8·925	46·575
b.	22·225	22·475		8·950	46·350
18. Mean	22·250	22·350	44·600	8·937	46·462
a.	39·350	17·175		9 225	34·250
b.	39·300	17·400		9·100	34·200
19. Mean	39·325	17·287	56·612	9·162	34 225
a.	38·150	18·750		8·100	35·000
b.	38·125	18·921		7·923	35·031
20. Mean	38·137	18·835	56·973	8·011	35·015
a.	26·925	25·325		11·375	36·375
b.	26·925	25·275		11·100	36·700
21. Mean	26·925	25·300	52·225	11·237	36·537
a.	34·750	18·035		10·970	36·245
b.	34·700	18·050		10·875	36·375
22. Mean	34·725	18·042	52·767	10·922	36·310
a.	34·400	18·550		11·500	35·550
b.	34·425	18·575		11·325	35·675
23. Mean	34·412	18·562	52·974	11·412	35·612
a.	33·275	19·325		11·100	36·300
b.	33·100	19 700		11·150	36·050
24. Mean	33·187	19·572	52·699	11·125	36·175
a.	34·950	16·100		10·600	38·350
b.	34·850	16·100		10·475	38·575
25. Mean	34·900	16·100	51·000	10·537	38·462
a.	35·600	14·650		11·100	38·650
b.	35·125	14·675		11·325	38·875
26. Mean	35·362	14·662	50·024	11·212	38·762
a.	34·725	20·175		8·425	36·675
b.	34·775	19·625		8·925	36 675
27. Mean	34·750	19 900	54·650	8 675	36·675

TABLE NO. 2.—*Analyses of Trinidad Pitch.*

No.	Percentage of Crude Pitch only soluble in				Percentage of Total Bitumen only soluble in			
	Petroleum Ether.	Boiling Spts. Turpentine.	Chloroform.	Total Bitumen.	Petroleum Ether.	Boiling Spts. Turpentine.	Chloroform.	Total in S. Tur.
1.	33·617	10·887	6·287	50·791	66·500	21·250	12·250	87·750
2.	33·620	10·494	8·183	52·297	64·276	20·066	15·658	84·342
3.	33·574	13·802	9·819	57·195	58·702	24·131	17·167	82·833
4.	33·736	10·511	8·120	52·367	64·422	20·071	15·506	84·493
5.	33·625	15·575	2·675	51·875	64·819	30·022	5·159	94·841
6.	36·650	12·800	4·425	53·875	68·132	23·700	8·168	91·832
7.	36 372	11·683	5·514	53 570	67·896	21·862	10·242	89·758
8.	36·475	15·750	2·137	54·362	67·096	28·972	3·932	96·068
9.	35·950	12·310	5·762	54·022	66·544	22·788	10·668	89·332
10.	33·730	15·670	3·179	52·579	64·151	29·812	6·036	93·963
11.	21·362	15·200	15·112	51·674	41·340	29·415	29·245	70·755
12.		1·700	1·300	3·000	Alter	ation	Pro-	duct
13.	19·250	20·487	12·825	52·562	36·621	38·976	24·403	75·597
14.	31·775	11·875	6·750	50·400	63·055	23·547	13·398	86·602
15.	32·313	21·249	22·225	75·787	42·636	28·038	29·326	70·674
16.	35·400	12·300	5·237	52·937	66 935	23·162	9 903	90·097
17.	34·200	11 575	7·222	52·997	64·531	21·841	13 648	86 372
18.	22·250	9·735	12·615	44·600	49·921	21·837	28·252	71·758
19.	39·325	11·285	6·002	56·612	69·465	19·933	10·602	89·398
20.	38·137	12·538	6·297	56·973	66 959	22·016	11·025	88·975
21.	26·925	18·612	6·687	52·224	51·555	35·640	12·805	87·195
22.	34·725	13·175	4·867	52·767	65·809	24·968	9·223	90·777
23.	34·412	13·100	5·462	52·974	64·960	24·720	10·320	89·680
24.	33·137	14·237	5·275	52·699	62·974	27·016	10·010 .	89·990
25.	34·900	9·200	6·900	51·000	68·431	18·039	13·530	86·470
26.	35·362	9·862	4·800	50·024	70·691	19·714	9·595	90·405
27.	34·750	10·712	9·187	54·650	63·526	19·592	16·882	83·118

University of Michigan,
Ann Arbor, Michigan, November 30, 1895.

ART. XXI.—*A Meteorite from Forsyth Co., North Carolina;* by E. A. DE SCHWEINITZ, M.D., PH.D.

ABOUT three years ago there was ploughed up on a farm in the southwestern portion of Forsyth Co., a mass about 50 lbs. in weight which, upon cursory examination, appeared to be pure iron, probably of meteoric origin. The mass had an irregular wedge-like shape and was covered with a thin scale of oxide of iron. The metal beneath was exceedingly tough, could be cut with the greatest difficulty, and fragments obtained by means of chipping with a cold chisel showed a crystalline structure. A polished surface etched with nitric acid did not show the Widmanstätten figures distinctly, but a mottled crystalline structure. The appearance of the meteorite when found can be seen from the accompanying figures, 1 to 4 (one-fourth natural size). Subsequently, two slices were cut from the meteorite and etched respectively with nitric and hydrochloric acids, without producing any very characteristic markings.

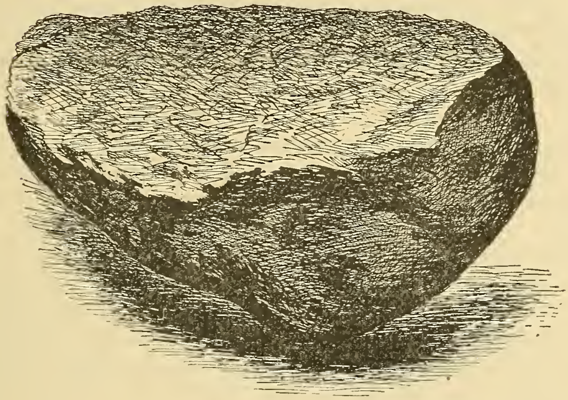
A preliminary analysis made from a piece chipped off the end of the meteorite by means of a cold chisel gave the following results:

Fe	94·90	per cent.
S	·22	"
Ni	4·18	"
Co	·33	"
P	trace	

From this it would seem to be closely allied to the Guilford County meteorite, possibly a chip of the same find. This iron is now in the possession of Mr. G. F. Kunz of New York.

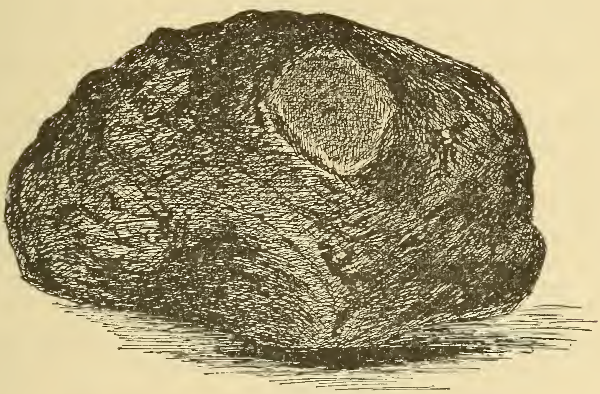
Biochemic Laboratory, Columbian University,
Washington, D. C., November 30, 1895.

1.



Haines, del.

2.



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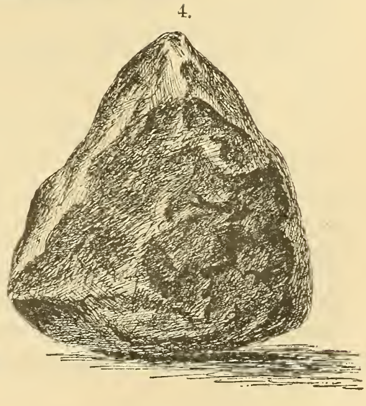


Haines, del.

Art. XXII.—*On a new Alkali Hornblende and a titaniferous Andradite from the Nepheline-Syenite of Dungannon, Hastings County, Ontario;* by Frank D. Adams and B. J. Harrington, McGill College, Montreal.

In a paper which appeared in the number of this Journal for July, 1894, the discovery of a large area of nepheline-syenite in the township of Dungannon, in the Province of Ontario, was announced and the geological relations and mineralogical characters of the mass briefly described.

One of the many peculiarities of this rock is the absence from it of the mineral pyroxene, which is usually the chief iron-magnesia constituent in rocks of this class, its place being taken by hornblende and mica, but even these minerals are present in comparatively small amount. Of the hornblende two varieties, occurring in different parts of the mass, were distinguished. The first, from near the York river, has a large axial angle with strong pleochroism in tints varying from pale yellow to deep green, and although containing a considerable amount of soda, probably approaches common green hornblende in composition. The second variety, which occurs in a series of exposures about two miles to the east of the village of Bancroft, is quite different in character, having a small axial angle with high extinction and a much stronger pleochroism in the bluish tints suggestive of arfvedsonite.

A number of additional thin sections have been prepared and in the present paper the results of a further investigation of the optical properties and chemical composition of this second variety of hornblende are presented.

Hornblende—The mineral occurs in hypidiomorphic grains, which show the usual hornblende cleavages; it is optically negative, $\mathfrak{a}$ being the acute bisectrix, but the double refraction is weak.

It possesses, as has been mentioned, a strong pleochroism as follows:

$\mathfrak{a}$ = yellowish green. $\mathfrak{b}$ and $\mathfrak{c}$ = deep bluish green.

The absorption is $\mathfrak{c} = \mathfrak{b} > \mathfrak{a}$. $\mathfrak{b}$ and $\mathfrak{c}$, if not quite equal in absorption, are nearly so, hence sections cut at right angles to the acute bisectrix show but little pleochroism and are nearly isotropic. $\mathfrak{c}$ lies nearest the vertical axis, but whether toward the acute angle β or on the opposite side cannot be determined as the mineral does not possess a good crystalline form; it makes with the vertical axis a large angle the extinction amounting to 30°. The plane of the optic axes is the clinopinacoid, and there is a strong dispersion—red greater than violet. What drew especial attention to this hornblende in the first instance was the fact that it appeared to be nearly uniaxial. When a section, cut at right angles to the acute bisectrix, is examined between crossed nicols in convergent light, a black cross is seen somewhat thickened toward the intersection of the arms. This cross, on revolving the stage, divides into two hyperbolas, but these separate from one another but very little, and appear to separate less than they really do, on account of the fact that the low double refraction and deep color of these sections causes the hyperbolas to be ill-defined, while the whole field is very dark. The dispersion, however, makes itself evident in the varying colors on the sides of the hyperbolas. When, however, a gypsum plate giving a red of the first order is inserted above the objective the hyperbolas become a little better defined, although still not sufficiently definite to allow the axial angle to be accurately measured. The axial angle is found to be over 30°, possibly as much as 45°, which, however, is still very small for hornblende, being about one-half the usual value. Our thanks are due to Professor Rosenbusch for his assistance in working out these optical relations.

On examining a large series of thin sections of nepheline-syenites representing most of the important occurrences hitherto discovered, only two rocks were found which contain a hornblende at all similar to that above described. The first of these is the nepheline-syenite from the Corporation Quarry at Montreal, in which hornblende with the same small axial angle, low double refraction, intense color and pleochroism, large extinction angle and high specific gravity, occurs intergrown with the augite. The second is the hornblende described by Hackman under the name of arfvedsonite and which occurs intergrown with aegerine in the nepheline-syenite from Umptek in the Kola peninsula.* This mineral, however, differs from typical arfvedsonite in having an extinction of about 40° as well as in several other important respects. It possesses moreover a very small axial angle, although this fact is not noted by Hackman, while in true arfvedsonite the axial angle is very large. This Kola hornblende is much lighter in color than the hornblende from either of the above mentioned Canadian localities.

In order to determine the chemical composition of this somewhat remarkable variety of hornblende from the Dungannon rock, it was decided to separate a portion for analysis. A considerable quantity of the rock was accordingly reduced to

* "Petrographische Beschreibung des Nephelinsyenites vom Umptek," von Victor Hackman. Kuopio, 1894, p. 14.

powder and passed through a sieve of 43 meshes to the inch—the rock being rather coarse in grain—and after having been freed from dust was treated with Thoulet's solution, having a specific gravity of 3·13, in a large separating funnel. In this way an almost complete separation of the colored constituents was effected. These latter, which sank in Thoulet's solution, were subjected to the action of a bar magnet and then treated with dilute hydrochloric acid, and various impurities thus removed. The purified powder was then treated first with Klein's solution, having a specific gravity of 3·22, and then with methylene iodide, having a specific gravity of 3·323. In both fluids practically everything sank, only a few composite grains floating. A microscopic examination showed the powder now to consist of grains of hornblende and of garnet with some composite grains consisting partly of nepheline. Further separation became difficult since, as was subsequently ascertained, the hornblende had a specific gravity of 3·433, and the specific gravity of the garnet was 3·739, while many composite grains consisting of garnet and nepheline had a specific gravity practically identical with that of the hornblende. As the electro-magnet was found to be useless, both minerals being readily attracted by it, Retger's silver nitrate method was employed.* The silver nitrate was fused in a properly arranged test tube, and after the introduction of the powder, potassium nitrate in powder was gradually added to the fused mass until the garnet fell, the whole being frequently stirred and maintained at a temperature of from 200° to 240° C. On allowing the mass to solidify, a portion of the powder was found to have collected at the top of the mass, while the rest was at the bottom, the intervening part being quite free from mineral grains. The solid mass was then cut in two and the salts dissolved by treatment with water. After three successive separations the hornblende was obtained quite free from grains of garnet—the only impurities present being some composite grains consisting of garnet and nepheline. This powder was then placed under a lens and all the composite grains picked out by means of a fine needle. In this way a quantity of pure hornblende sufficient for purposes of analysis was obtained, while the garnet was obtained directly in a state of purity without the necessity of a final separation by hand.

Both minerals were found to be quite fresh and bright and quite unacted upon by the fused salts.

The hornblende† was then analyzed by Dr. Harrington with the following results:

* "Ueber Schwere Flussigkeiten zur Trennung von Mineralien." Neues Jahrbuch für Mineralogie, etc., 1889, ii, p. 190.

† We would suggest Hastingsite as a varietal name for this hornblende, connecting it with the region where it occurs.

Silica	34·184
Titanium dioxide	1·527
Alumina	11·517
Ferric oxide	12·621
Ferrous oxide	21·979
Manganous oxide	·629
Lime	9·867
Magnesia	1·353
Potash	2·286
Soda	3·290
Water*	·348
	99·601
Specific gravity	3·433

The atomic and quantivalent ratios deducible from the above analysis are as follows:

	Atomic.	Quantivalent.	
Si	570×4=2280	2356 (Si, Ti)	2356
Ti	19×4= 76		
Al	226×3= 678	1152 (Al, Fe^{III})	2354
Fe^{III}	158×3= 474		
Fe^{II}	305×2= 610	1202 (Fe^{II}, Mn, Ca, Mg, K, Na)	
Mn	9×2= 18		
Ca	176×2= 352		
Mg	34×2= 68		
K	48 48		
Na	106 106		

The ratio of $(R_2O+RO):R_2O_3:SiO_2$ is 601 : 192 : 589, or approximately 3 : 1 : 3, and obviously the mineral is a true orthosilicate agreeing fairly with the formula $(\overset{I}{R}_2\overset{II}{R})_3\overset{III}{R}_2Si_3O_{12}$, or, more fully, $(Fe, Mn, Ca, Mg, K_2, Na_2)_3(Fe, Al)_2(Si, Ti)_3O_{12}$ —a constitution analogous to that of garnet.

So far as we are aware no other hornblende containing so small a proportion of silica has been analyzed; but the small percentage of silica is explained by the large proportions of ferrous and ferric oxides. This is made plain by the following formulæ and the corresponding percentages of silica deduced from them:

Formula.	P. C. of SiO_2.
$3FeO, Fe_2O_3, 3SiO_2$	32·19
$3CaO, Fe_2O_3, 3SiO_2$	35·43
$3FeO, Al_2O_3, 3SiO_2$	36·14
$3Na_2O, Al_2O_3, 3SiO_2$	38·38
$3CaO, Al_2O_3, 3SiO_2$	40·00

* Loss after igniting for about fifteen minutes. On further ignition the powder gained in weight owing to oxidation of the ferrous oxide.

The Dungannon hornblende is interesting in connection with the views of Scharizer, who suggested in 1884* that many of the aluminous hornblendes might be regarded as molecular compounds of the metasilicate actinolite, $Ca(Mg,Fe)_3Si_4O_{12}$, and the orthosilicate $(\overset{I}{R}_2\overset{II}{R})_3\overset{III}{R}_2Si_3O_{12}$, for which he employed the name syntagmatite, originally given by Breithaupt to a black hornblende from Vesuvius. The hornblende from the Island of Jan Mayen, analyzed by Scharizer,† and that from Bohemia, analyzed by Schmidt,‡ agree closely with the so-called "syntagmatite molecule." The Stenzelberg mineral, analyzed by Rammelsberg,§ also approximates to it; but these three and the Dungannon hornblende are the only ones yet examined, so far as we are aware, that give at all closely the syntagmatite ratios. The following table gives the analyses of these four minerals and the molecular ratios deducible from them:

	Jan Mayen.	Molec. R.		Bohemia.	Mol. R.		Stenzel-berg.	Mol. R.		Dungan-non.	Mol. R.	
SiO_2	39·167	653	653	39·66	661	672	39·62	660	662	34·184	570	589
TiO_2	----	----		0·89	11		0·19	2		1·527	19	
Al_2O_3	14·370	140	218	14·83	145	222	14·92	146	210	11·517	113	192
Fe_2O_3	12·423	78		12·37	77		10·28	64		12·621	79	
FeO	5·856	81	648	1·97	27	663	7·67	106	685	21·979	305	620
MnO	1·505	21		---	--		0·24	3		0·629	9	
MgO	10·521	263		14·25	356		11·32	283		1·353	34	
CaO	11·183	200		12·74	227		12·65	226		9·867	176	
K_2O	2·013	21		1·25	13		2·18	23		2·286	24	
Na_2O	2·478	40		2·47	40		1·12	18		3·290	53	
H_2O	·396	22		----	--		0·48	26		0·348	19	
	99·912			100·43			100·67			99·601		

In all four analyses the ratios for $(R_2O+RO) : R_2O_3 : SiO_2$ (including TiO_2 when present) are practically 3 : 1 : 3, or, to give the exact figures (excluding water):

	(R_2O+RO)	:	R_2O_3	:	SiO_2
Jan Mayen	2·87	:	1	:	2·99
Bohemia	2·99	:	1	:	3·02
Stenzelberg	3·14	:	1	:	3·15
Dungannon	3·12	:	1	:	3·07

The ratio $(R_2O+CaO) : (Mg, Mn, Fe)O$ is, as observed by Scharizer in the case of the Jan Mayen and Bohemian hornblendes, approximately 3 : 4, thus:

* N. Jahrb. f. Min., 1884, ii, p. 143.
† loc. cit.
‡ Min. Mitth., iv, 23, 1881.
§ Pogg. Ann., 1858, ciii, 454.

	Including Water.			Excluding Water.		
	(R_2O+CaO)	:	(Mg, Mn, Fe)O.	(R_2O+CaO)	:	(Mg, Mn, Fe)O.
Jan Mayen	3	:	3·87	3	:	4·17
Bohemia	3	:	4·10	3	:	4·10
Stenzelberg	3	:	4·02	3	:	4·38
Dungannon	3	:	3·84	3	:	4·11

Scharizer adopts the foregoing ratios (3 : 1 : 3 and 3 : 4) as those of syntagmatite in calculating the composition of hornblendes intermediate between $(\overset{I}{R}_2\overset{II}{R})_3\ \overset{III}{R}_2Si_3O_{12}$ and actinolite. He assumes in the first place that all the alumina and ferric oxide belong to the syntagmatite molecule (Σ). The sum of the Al_2O_3 and Fe_2O_3 molecules (from the molecular ratio) multipled by *three*, gives $(SiO_2)\Sigma$ on the one hand and $(R_2O+RO)\Sigma$ on the other. The sum of $(R_2O+RO)\Sigma$ divided in the proportion of 3 : 4 gives $(R_2O+CaO)\Sigma$ and $(MgO+FeO)\Sigma$. Subtracting $(MgO+FeO)\Sigma$ from the sum of the correspondin molecules deduced from the analysis gives $(MgO+FeO)_A$—that is the number of molecules of magnesia and ferrous oxide belonging to the actinolite molecule (A)—and $(MgO+FeO)_A$ divided by three (see actinolite formula) gives the lime molecules of the actinolite $(CaO)_A$. This value subtracted from the total number of lime molecules gives $(CaO)\Sigma$, and $(CaO)\Sigma$ subtracted from $(R_2O+CaO)\Sigma$ gives the alkali molecules (in some cases including H_2O). Finally $(MgO+CaO)_A$ gives $(SiO_2)_A$. These statements will be made clearer by the following example, one of those selected by Scharizer.

HORNBLENDE FROM EDENVILLE, ANALYZED BY RAMMELSBERG.

Original analysis.		Molec. R. deduced from analysis.	Syntagmatite.		Actinolite.	Calculated composition.	Original analysis calc. to 100.
SiO_2	51·67	861	222		609	51·97	52·66
Al_2O_3 ..	5·75	56	56	74	---	5·99	5·86
Fe_2O_3 ..	2·86	18	18		---	3·00	2·91
MgO ...	23·37	584	127	222	457	24·35	23·82
CaO ...	12·42	222	70		152	12·96	12·66
Na_2O ...	0·75	12	12		- -	0·78	0·78
K_2O	0·84	9	9		---	0·88	9·86
H_2O	0·46	25	4		---	0·07	0·47
	98·12					100·00	100·00

Here $(SiO_2)\Sigma = 3(56+18) = 222$

$$(R_2O+RO)\Sigma = 3(56+18) = 222$$

$$(R_2O+CaO)\Sigma = 3\frac{(R_2O+RO)}{7}\Sigma = \frac{222\times 3}{7} = 95$$

$$(MgO)\Sigma = 4\frac{(R_2O+RO)}{7}\Sigma = \frac{222\times 4}{7} = 127$$

$$(MgO)_A = 584-(MgO)\Sigma = 584-127 = 457$$

$$(CaO)_A = \frac{(MgO)_A}{3} = \frac{457}{3} = 152$$

$$(CaO)\Sigma = 222-(CaO)_A = 222-152 = 70$$

$$(Na_2O+K_2O+H_2O)\Sigma = (R_2O+CaO)\Sigma-(CaO)\Sigma = 95-70 = 25$$

But $(Na_2O+K_2O)\Sigma = 12+9 = 21$

$$\therefore (H_2O)\Sigma = 4$$

Finally $(SiO_2)_A = (MgO+CaO)_A = 457+152 = 609$

Having thus deduced the molecular ratios of the syntagmatite and actinolite, the numbers for each constituent are multiplied by the corresponding molecular weights, in order to obtain the theoretical relative weights of the constituents of the mixed hornblende.

Syntagmatite.		Actinolite.	
222×60	$= 13320$	609×60	$= 36540$
$56\times 102{\cdot}6$	$= 5745$	----	----
18×160	$= 2880$	----	----
127×40	$= 5080$	457×40	$= 18280$
70×56	$= 3920$	152×56	$= 8512$
12×62	$= 744$	----	----
9×94	$= 846$	----	----
4×18	$= 72$	----	----
	32607		63332

Then,

$$(32607+63332):(13320+36540)::100:x$$

and $x = 51{\cdot}97$ = p. c. of SiO_2 in the mixed hornblende. And in like manner the percentages of the other constituents are calculated.

But 32607 : 63332 practically as 1 : 2, and therefore the formula of the Edenville hornblende might be regarded as

$$\overset{II}{R}_3\overset{III}{R}_2Si_3O_{12}+2(Mg_3CaSi_4O_{12})$$

or as Scharizer gives it

$$10(\overset{II}{R}_3\overset{III}{R}_2Si_3O_{12})+20(Mg_2CaSi_4O_{12})$$

The analyses selected by Scharizer agree remarkably well with his theory, but there are aluminous hornblendes whose constitution cannot be readily explained in this way and which at the same time cannot be referred to the pargasite orthosilicate.*

Garnet.—In the hand specimens the garnet is seen to possess a deep reddish-brown color. In the thin sections it is a paler brown although still deeply colored. It is not found in all parts of the mass and where it does occur is usually present only in small amount. It possesses the usual high index of refraction and is quite isotropic, occurring usually in irregular shaped grains but in some few cases showing distinct crystalline form. It frequently holds a few large inclusions which usually consist of calcite in single individuals, although the garnet is perfectly fresh and the calcite shows no distinct evidence of a secondary origin. It moreover sometimes holds inclusions of the hornblende above described, of pyrite, iron ore and even of nepheline. A garnet resembling this occurs in small amount associated with a similar hornblende, as above mentioned, in the nepheline-syenite of the Corporation Quarry at Montreal, and it also contains as inclusions most of the other constituents of the rock. The same is also true of the melanite in the nepheline-syenite of Alnö.†

Before analysis the garnet was purified by several separations with fused silver nitrate and on careful examination with the microscope the grains appeared to be entirely free from foreign matter. With the pycnometer their specific gravity at 16° C. was found to be 3·739. Chemical analysis gave the following results:

Silica	36·604
Titanium dioxide	1·078
Alumina	9·771
Ferric oxide	15·996
Ferrous oxide	3·852
Manganous oxide	1·301
Lime	29·306
Magnesia	1·384
Loss on ignition	·285
	99·577

The atomic and quantivalent ratios deduced from the above analysis are as follows:

* See Scharizer's paper, loc. cit., p. 156.

† "Ueber das Nephelinsyenitgebiet auf der Insel Alnö," von A. G. Högbom. Geol. Fören. i. Stockholm Förh., 1895, p. 144.

	Atomic.		Quantivalent.	
Si	610×4 =	2440	2492	2492
Ti	13×4 =	52		
Al	192×3 =	576	1176	2466
Fe^{III}	200×3 =	600		
Fe^{II}	53×2 =	106	1290	
Mn	18×2 =	36		
Ca	523×2 =	1046		
Mg	35×2 =	70		
H	32	32		

The ratio for $RO : R_2O_3 : (SiTi)O_2$ is 629 : 196 : 623, or, calculating the titanium as Ti_2O_3, 629 : 203 : 610 = 3 : 1 : 3. The analysis therefore accords well with the ordinary garnet formula $3RO, R_2O_3, 3SiO_2$ or $\overset{II}{R}_3\overset{III}{R}_2Si_3O_{12}$, and the mineral may be regarded as a titaniferous andradite, with a considerable proportion of the ferric oxide replaced by alumina. In composition it resembles somewhat the brown garnet from the Island of Stokö, analyzed by Lindström.*

By way of comparison the analysis of the Stokö garnet and also one of a garnet from the nepheline-syenite of the Island of Alnö† are included in the following table.

	Stokö.	Molec. R.		Alnö.	Molec. R.		Dungannon.	Molec. R.	
SiO_2	36·63	610	610	31·15	519	603	36·604	610	623
TiO_2	----	---	---	6·73	84		1·078	13	
Al_2O_3	9 97	98	182	3·14	31	180	9·771	96	196
Fe_2O_3	13·45	84		23 83	180		15·996	100	
FeO	2·28	32	698	----	---	616	3·852	53	645
MnO	·63	9		·58	8		1·301	18	
CaO	35·90	641		33·44	597		29·306	523	
MgO	·28	7		----	---		1·384	35	
Na_2O	---	---		·68	11		----	---	
Ign.	·16	9					·285	16	
	99·30			99·55			99·577		

* Zeitschr. fur Kryst. u. Min., xvi, 160, 1890.

† Sahlbom, in the paper by Högbom already cited.

Art. XXIII.—*Proofs of the Rising of the Land around Hudson Bay;* by Robert Bell, of the Geological Survey of Canada.

[Read before the Geological Society of America, Philadelphia, 27th December, 1895. Abstract.]

In the provinces of Ontario and Quebec, it has been found from actual levellings by Gilbert, Spencer and Upham, that the old shore-lines are not perfectly horizontal, but that they slope upward in a northeasterly direction at rates varying in different regions from a few inches to a foot and even two feet per mile. If this upward slope were continued in the same direction to the northeastern extremity of Labrador, 1300 miles from Lake Huron, the increase in the elevation might there amount to 1000 or 2000 feet. It is scarcely probable that the differential elevation is constant and regular for such a great distance. Still, it is a fact that well preserved shore-lines are to be seen at great heights in the northern parts of Labrador. In my Geological Survey Report for 1884, I have mentioned ancient beaches at Nachvak, 140 miles south of Hudson Strait, which have an estimated altitude of 1500 feet above the sea.

The two sides of Hudson Bay present very different physical characters. The eastern is formed mostly of crystalline rocks and, as a rule, is more or less elevated, with a broken surface sloping somewhat rapidly westward or towards the bay; while the western side is mostly very low and much of it is underlaid by nearly horizontal Silurian and Devonian strata. These low shores are accompanied by shallow water extending far to seaward. The head of James Bay, which forms the southern prolongation of Hudson Bay, is extremely shallow, but the various rivers which flow into it have cut channels through the soft shallows, and by means of these the land may be approached with sea-going vessels. The whole of Hudson Bay may be said to be shallow in proportion to its great area, as the soundings show that it does not average more than 70 fathoms in depth.

The shores of the bay everywhere afford abundant evidence that there has been a comparatively rapid rise in the land and that the elevation is still going on. I have mentioned numerous proofs of this in my various official reports on the geology of these regions from 1875 to 1886, and I shall now recall a few of those and give fresh ones in addition, some of which came to my knowledge on a journey to the bay during the past summer. It is well known to those who have paid any attention to the subject that since the establishment of the posts of the Hudson's Bay Company in the mouths of the rivers around the bay, 200 years ago, there has been an ever-increasing difficulty in reaching these establishments from the sea.

On the eastern side the most striking evidence of the rising of the land is afforded by the numerous well-preserved and conspicuous terraces cut in the till and other deposits. Near the sea these may be seen at various heights, up to about 300 feet, but above this elevation the scarcity of soft material out of which terraces might be excavated, renders this kind of evidence less apparent than it might otherwise be, at higher levels.

On this side of the bay, one of the best evidences that the elevation of the land is still going on is furnished by the long lines of driftwood which one sees in many places far above the reach of the highest tides. The old beaches, on which this wood is plainly seen, occur at various levels up to about thirty feet above high tide, but the remains of rotten wood may be detected in some localities up to nearly fifty feet, above which it has disappeared from the ancient shores by long exposure to the weather. This driftwood consists principally of spruce, but a little white cedar and other kinds, which have been brought down by the rivers, are also mixed with it. The bark having been worn off by the action of the waves while the trunks were still fresh, has tended to their preservation. Owing principally to the salt water and the cold climate, wood endures for an incredibly long time in exposed situations in this region wherever it has an opportunity of drying quickly after rain. Some of the wood which may still be seen upon the higher levels may be upwards of 600 years old.

It has been suggested that all this driftwood along hundreds of miles of coast may have been thrown up by some extraordinarily high tide. But there are many reasons why this is quite unlikely. It seems impossible that any modern tide could rise to such a great height and deposit so much wood at different levels all at once and in such even lines, following all the sinuosities of more than one of the raised beaches. The suppositious extraordinary tide would necessarily be of brief duration and would be accompanied by a tremendous gale blowing upon the coast. This would have the effect of throwing the wood in confused heaps and only into situations favorable for catching it, such as angles of the shore. But instead of this, we find it at different levels laid longitudinally all along, as if accumulated by slow degrees with moderate winds from every quarter. The fact that the wood is freshest along the lower lines and becomes progressively more and more decayed as we ascend, and that finally only traces remain on the higher levels, shows that it must have been stranded from time to time as the land was rising above the sea, and we are forced to adopt this obvious view of the case.

In support of the paroxysmal tide theory, it is related that once during a northern gale the tide was forced as high as the front gate in the palisaded enclosure at Rupert House near the head of James Bay, and it is added that this would be equivalent to a height of about thirty feet. When at Rupert House last summer, I could hear no authentic account of such an extraordinary rise in the water and besides the gate referred to did not appear to be more than fifteen feet above the sea-level. But even if such a great rise in the water had once occurred at this place, it would prove nothing in regard to the raised beaches on the long straight shore out on the open sea. Hudson Bay is about 1000 miles long and its outline is funnel-shaped, with James Bay representing the contracted extremity. Rupert House is situated near the end of this narrow continuation, so that just here we should expect very high water with a spring tide and northern gales driving the sea in from the broad expanse outside and heaping it up at the extremity of the constantly narrowing termination.

The gravel terraces seen at various elevations around the coves and upon the thousands of small islands along the east coast of James Bay are remarkably sharp and well-preserved and almost as fresh-looking as if they had been formed but yesterday. They are generally bare of trees or bushes and the yet smooth surface-pebbles are only partially covered by lichens. Similar terraces may be seen farther north on this coast and in Hudson Strait, wherever material exists out of which they may be formed. On Marble Island the raised beaches are very plainly visible on account of the whiteness of their smooth, quartzite shingle.

On the west side of Hudson Bay the land is generally too low to admit of the relatively higher sea-levels of former times having been recorded in the shape of terraces near the present shore line, but if we go back into the woods we shall find unmistakable evidence of the existence of such higher levels at comparatively recent periods. These consist of long, low ridges of drifted materials, such as we see in a fresher state at the present high tide mark. They are made up of driftwood and other vegetable debris in a completely decayed condition, covered by moss and having trees and shrubs growing upon them. In some places we may still trace the forms of the larger trunks which had been cast ashore by the waves at high tide. Between these ridges and the present shore there is a thick growth of the coniferous forest and the ground is carpeted with moss, over which the tide has never passed. Examples of these low ridges may be seen near the head of tide-water at the mouth of Nelson River, at Attawapishkat River and in places between the latter and Albany River.

To the west and southwest of James Bay the till, covering the nearly flat Silurian and Devonian rocks, is generally overspread by stratified clays. Marine shells are found in these up to an elevation of 400 to 500 feet, but on the eastern side of the bay no fossils have yet been detected at such high levels, owing perhaps to the scarcity there of marine deposits and to the fact that but little search has yet been made for them. In the sandy deposits among the hills about twenty miles south of Cape Wolstenholme, I saw abundance of *Saxicava rugosa* and *Tellina Grœnlandica* with smaller numbers of a few other species, at heights varying from the sea level up to about 200 feet; and last summer I found brackish water varieties of a number of the commoner species of our northern marine shells up to 70 feet above the sea in the clay banks along the lower portion of the Noddawai River.

Around the head of James Bay and up its western side the encroachment of the outer lines of the forest upon the wide alluvial flats which extend all along these shores and are constantly broadening towards the sea is good evidence that a rising of the land is now going on. The existing condition in this part of the bay is well described by Mr. A. P. Low in speaking of Agoomski Island. On page 24 J. Geol. Survey Report for 1887, he says:

"The island closely resembles the adjoining mainland in physical character, being very low and swampy. The shore-line above high-water mark is made up of muddy flats covered in part with grasses and sedges, followed further inland by thick growths of small willows, these in turn giving place to small black spruce and tamarac as slightly higher ground is reached. The line of these trees is often over two miles inland from high-water mark, itself a long distance from the sea at low water."

No living mollusks are to be found in James Bay except perhaps in the northern part, owing probably to the muddy and brackish nature of the water, but abundance of the dead shells of a considerable number of kinds are washed out of the clays forming the present shores. Some of these belong to moderately deep-water species and are well-preserved, retaining the epidermis. This, of course, shows a recent elevation of the sea bottom.

Richmond Gulf on the eastern side is separated from the main bay by a high bar of stratified rocks, which strike with its length and dip westward or towards the open sea. This bar is cut through by several gaps, all resembling one another, except in their heights above the sea, and all bearing evidence of their having been well worn channels of communication at more or less remote times according to the greater or less elevation of their beds above the sea. Only one narrow passage now remains open or low enough to admit the water, but two others are as yet only slightly raised above the tides.

Some of the aboriginal geographical names around the head of James Bay are significant of considerable changes in the topography since these shores became inhabited by the natives who still occupy them. The large peninsula between Hannah and Rupert bays is called Ministik-oo-watum, which means wooded island with a cove or hole in it, ministik being the Cree for a wooded island and watum for a cove or hole. The heads of the channels, which now run in behind the present peninsula from the opposite sides, are separated by a strip of low ground some ten miles long covered by bushes. Midway across this strip, the elevation is estimated to be about fifteen feet above high tide. The most prominent point on the coast between Moose Factory and Fort Albany is now called "Cockispenny" by the whites, but the Cree name is Ka-ka-ki-sip-pin-a-wayo Minis, or Island where the Crow-duck (Cormorant) lays eggs. Since this island became connected with the mainland, bushes have taken the place of the grasses and sedges which first grew upon the low ground between them, and the former are constantly acquiring a stronger growth. Many years ago the winter trail of the coast passed over the neck of this peninsula, but now it has become necessary to go outside of it, because the bushes have grown so large that they catch the snow which, in such situations, remains too soft for dog teams and snow-shoers.

The salt marshes along the west coast of James Bay and also in the vicinity of York Factory, which used to attract vast numbers of wild geese and ducks, have been gradually drying up, much to the inconvenience of the Hudson's Bay Company's people, who depended largely upon them for food.

The character of the lower portions of such rivers as the Moose, Albany and Attawapishkat shows a recession of the sea. This is particularly observable in the lower thirty miles of the Moose, where very long and narrow or ribbon-like islands run parallel to one another for many miles. The process of their formation appears to have been a constant drawing out of their lower extremities as the sea receded from them, just as the lowest islands of the present day are growing.

On the east-main coast, where the land is comparatively high, the grade of the rivers is rapid as they approach the bay, and in some of them, as the Nastapoka and the Langlands, there are perpendicular falls of about 100 feet almost directly into the sea. This condition indicates recent elevation.

One of the best evidences of the modern rising of the land is to be found in the beach-dwellings of the Eskimos, which may be seen at all elevations up to about 70 feet. In summer these people generally camp on the shore, and their favorite locations are at the mouths of small streams into which the sea trout run at high tide. Here they construct weirs of stones, which impound the fish when the tide retires. On Outer Digges Island, I have found these fish traps and the rings of stones and other structures marking their old camping places, up to a height estimated at 70 feet.

Among the historical evidences bearing upon this question since the advent of the white man, may be mentioned the fact that in 1610, Henry Hudson, the navigator, wintered in a bay full of islands on the east coast south of latitude 53°. None of the bays in this region would now be possible for this purpose, showing that a considerable change in the level of the sea has taken place in less than 300 years.

In 1674, Charles Bayley, then local governor for the Hudson's Bay Company, sailed through in a sloop between Agoomski Island and the main west shore of James Bay. It would now be impossible to pass here in a sea-going vessel of any kind. In 1886 I found it difficult to get through in bark canoes, drawing only a few inches of water. The shoaling is not due to a silting up, since the almost dry bottom consists of a level surface of till with bowlders scattered thickly over it.

From 1675 to 1685 the Hudson's Bay Company's establishment in the mouth of Moose River was upon Hayes' Island, which, it is to be presumed, was selected for convenience of landing goods from their vessels and shipping out their returns. This island is now unapproachable except by canoes and small boats. For more than 200 years the factory* has stood upon Moose Island, the next below Hayes' Island. The annual ship from England anchors in the channel cut through the sands off the mouth of Moose River. On account of the risk of rough water, it is necessary to discharge the cargo by schooners. Within the memory of living men, these schooners could ascend to a wharf built opposite the large storehouse of the factory. But for many years, the same schooners have been unable to ascend all the way, and the cargo requires to be transferred into scows, which complete the trip to the wharf; and the distance to which the schooners can ascend is constantly diminishing. In the beginning of the present century Princess Island, a narrow bushy strip immediately in front of the factory, was separated by a channel with a good depth of water at the lowest tides. Last autumn I saw it quite dry on several occasions during ebb tide. It is well known to every one who has lived at this post in the present generation that every now and then a new "lump" will appear in the bed of the river

* Factory, a residence of a factor or agent.

and become permanent, growing higher and higher, eventually escaping submergence at most tides and at length becoming covered with grass and then with bushes. Some islands which were covered only with bushes forty or fifty years ago, now support a growth of young trees. The small one on the west side of Middleboro', below Moose Island, is an example of this and the appearance of the trees upon it is within the memory of Mr. Broughton, the gentleman now in charge of Moose Factory. Middleton Island, between the mouths of Rupert and Noddawai rivers, lies close to the east shore of Rupert Bay. Up to a few years ago, canoes and boats could pass at high tide through the long narrow grassy channel behind this island, but last autumn I found it impossible to do so with my canoes and we were obliged, at great inconvenience, to go round outside.

Two hundred years ago, the ships of the Hudson's Bay Company appear to have had no difficulty in entering the mouths of various rivers on the Eastmain coast which cannot now be used as harbors. In old times the principal post of the company on that coast was in the mouth of Eastmain River, which had no doubt been chosen because it afforded a good harbor. It is only a few years since the mouth of Little Whale River, several hundred miles farther north, had to be abandoned as a harbor on account of the increasing shallowness of the water.

At York Factory there is a "ship hole" in the channel of Hayes' River, directly in front of the storehouse. The sea-going vessels of light draft employed in the Hudson's Bay Company's trade have been accustomed to anchor in this hole and formerly they remained afloat at all stages of the tide, but of late years, vessels drawing even less than those of former times have begun to "take the ground" at low water. In objection to the belief that the land is rising it may be said this may be due to a silting up of the hole, but on examining the material brought up on the flukes of the anchors, I found it to consist of light colored stiff bowlder clay or till.

In 1782, after the French Admiral Lepeyrouse had destroyed Fort Prince of Wales at the mouth of Churchill River, he landed with cannons on the southeast side of Nelson River and hauling them across the point between it and Hayes' River, captured York Factory. Two ships belonging to the Hudson's Bay Company which were then lying in Hayes' River, laden with valuable cargoes, escaped under cover of the darkness of the following night and got safely to England. At the present time, it is only possible for a sea-going vessel to get out from this river at the top of high water with favorable wind and careful piloting in daylight. To say nothing of the difficulty caused by the darkness, it is unlikely that all the other conditions now necessary to enable a vessel to leave the river, conspired to aid the escape of these ships. It is much more reasonable to believe that the water was deeper then than it is now. The landing of Lepeyrouse with his guns on the shore of Nelson River abreast of York Factory was a feat the like of which could not be accomplished at the present day, owing to the extreme shallowness of the water.

The present Fort Churchill or "New-Fort," as it is still called, was built in 1782 on the west side of the river about four miles and a half above Fort Prince of Wales as soon as the French had retired after destroying the latter establishment. The residents now suffer much inconvenience on account of the continued shoaling of the water and they have been obliged to lengthen out their "launch" or long landing tressel from time to time in order to be able to reach the outer end of it with their coast boats.

Off the western side of the lagoon within the mouth of Churchill River is Sloop's Cove, a small elliptical pond connecting with the lagoon by a very narrow entrance, through which the water barely passes at high tide. On the arkose rocks beside this little cove many inscriptions have been cut and some ring-bolts have been fastened, for mooring vessels, all of which indicate that the cove was used for wintering ships in old times. Indeed it is known that the "Furnace" and the "Discovery," two small ships commanded by Captain Middleton, passed the winter of 1741–42 in this cove. I have examined the place on various occasions and have copied most of the sketches and inscriptions on the rocks, and it always appeared to me that the conditions which we observe indicate a rise in the land since the last ship wintered there. At the present time, the tide does not rise high enough to allow of the passage into it of crafts larger than ordinary row-boats. No sea-going vessel could now enter it, which would indicate an elevation nearly equal to the draft of the ships formerly frequenting it. It would be a boon to the agents of the Hudson's Bay Company at Churchill if they could now winter their small schooner in this cove instead of being obliged to send her every autumn to winter at York Factory. The captain who commands her happens to be the person now in charge of the company's post at Churchill, and both he and his crew are obliged to walk back 150 miles through the mud from York Factory after leaving their vessel there in the autumn and to walk the same distance again to bring her back in the spring. Mr. J. B. Tyrrell visited Sloop's Cove in the autumn of 1893, and in a paper published in the Geological Magazine for August, 1894, says he thinks the land is here in a state of equilibrium. Two inscriptions which he saw on the rocks, namely, "May 25th and May 27th, 1753," were about seven feet above the present high tide and he thinks these were cut by men standing on the ice. This, however, does not prove much, for the men were quite as likely to have sat as stood while engraving these inscriptions. As the tide still enters the cove and keeps it full of water, the average relative level of its ice to the rocks surrounding it may not have differed much from what it is now. When I visited Fort Prince of Wales in 1879, oak planks brought from England while the fort was still occupied as well as timbers of native wood, all charred by Lepeyrouse's fire, were found stranded far out of reach of the present tides and still in perfect preservation. On the occasion referred to, I met at the "New Fort" children of some of the people who were living at the "Old Fort" when it was captured by the French, and from them some information could be obtained as to the conditions at that time. We have, besides, the description and illustrations in the book by Samuel Hearne, who was then in charge of the place. Any light which these accounts may throw on the state of matters then as compared with the present time, points in the direction of some elevation having taken place.

Among the photographs which I took around Fort Prince of Wales in 1879 is one which shows strips of dry land grasses alternating with little parallel ridges of gravel thrown up by the waves and now above the highest tide-mark, but *below* the level of the spot which was pointed out to me as the landing place of Lepeyrouse. The ground on which the fort stands was an island during high tide at the time the place was occupied and a bridge was thrown across the narrowest part of the little separating channel to connect the island with the main land. This channel is now entirely dry.

If anything further were wanting to show that an elevation of the land is now going on in this region we have some direct personal evidence in the lifetime of the witness himself in support of the facts already cited. About twenty years ago, a very aged Indian, who was said to have "seen more than a hundred winters," and who was quietly passing the last years of his extraordinarily long life at Norway House, told me in presence of the factor, Mr. Roderick Ross, and the other gentlemen of that establishment that he had, when a boy, witnessed the landing of Lepeyrouse and the destruction of Fort Prince of Wales. He gave graphic details of every circumstance, which agreed perfectly with Lepeyrouse's own account, and he answered all my questions on other points entirely satisfactorily and without a moment's hesitation. Among other things, he mentioned that the spot where the Frenchmen's boats landed was quite close to that portion of the western wall which they undermined and blew up with gunpowder. He said that when all was ready, they laid "a rope" (train) of gunpowder across the beach and setting fire to the end of it, ran off to a safe distance to witness the effect. It is now a considerable distance from this spot to the nearest point of water at high tide.

The proofs of the rising of the land around Hudson Bay in post-glacial times would be admitted by any geologist, and the question of the continuance of the movement at the present time is, I think, answered in the affirmative by the actual general shoaling of the water which is going on and the encroachment of the land on all sides, some proofs of which have been given in the foregoing pages. All the facts which have been mentioned (and many more might be added) point in the same direction, while there appears to be no evidence of a contrary character. The officers of the Hudson's Bay Company are an intelligent set of men, and their universal opinion, based upon lifetimes of observation, is that the land all around the bay is rising. The following is part of a letter recently received from Mr. Joseph Fortescue, lately a chief factor in the Hudson's Bay Company, in answer to my request for his opinion on this subject:

"Regarding the rising of the shores of Hudson Bay, I have no doubt whatever. When I was at York Factory, I heard several Indians say that the sea or tide had retired two miles from places they remembered when they were young, and my own observations during twenty years there would lead me to entertain the same opinion. When I revisited Moose Factory, after nearly forty years absence, I found a great change in the appearance of the coast and river. Channels which were navigable at all times of the tide formerly, could now only be used at high water."

ART. XXIV.—*On the Occurrence of Thaumasite at West Paterson, New Jersey;* by S. L. PENFIELD and J. H. PRATT.

IN 1878 Baron von Nordenskiöld* described a mineral from the copper mines of Åreskuta, Jemtland, Sweden, which, according to the analyses of Lindström,† had the composition $CaSiO_3$, $CaCO_3$, $CaSO_4$, $14H_2O$ and to which the name thaumasite was given, from *θαυμάζειν, to be surprised.* The mineral was not found in distinct crystals but was crystalline and on a fracture showed a fine fibrous structure. Its homogeneous character and its right to be considered a distinct mineral species rested upon the following: The material seemed to be homogeneous when examined with the microscope, and the three analyses of Lindström, made upon material collected in the early part of this century by Polheimer, in 1859 by Nordenskiöld, and in 1878 by Engberg, agreed not only very closely with one another but also with the theory demanded by the formula.

That a mineral with such a remarkable composition was capable of existence was not accepted by all mineralogists, and Bertrand,‡ on examining thin sections of it with the microscope was led to believe that it was a mixture, composed of a uniaxial mineral with negative double refraction supposed to be calcite, of a biaxial mineral gypsum, and of a third mineral, the optical properties of which could not be made out, probably calcium silicate or wollastonite.

The idea of Bertrand's that thaumasite was a mixture was not accepted by Nordenskiöld, and the latter to sustain his position presented the following arguments,§ which were very convincing: First, if it were possibly a mixture it certainly would be very remarkable that three independent samples, collected at such widely separated periods, should agree so closely in percentage composition. Second, there is no known hydrated calcium silicate which, when mixed with calcite and gypsum, could yield a product containing over 42 per cent of water. Third, it would not be possible for a mixture of calcite, gypsum and wollastonite, with specific gravities of 2·72, 2·31 and 2·90 respectively, to yield a product with such a low specific gravity as thaumasite, 1·877.

Specimens were moreover sent to Lacroix for renewed

* Comptes Rendus, vol. lxxxvii, p 313, 1878.

† Öfv. Ak. Stockholm, vol. xxxv, No. 9, p 43, 1878.

‡ Bull. Soc. Min. de France, vol. iii, p. 159, 1880, and vol. iv, p. 8, 1881.

§ Geol. För. Förhandl., Stockholm, vol. v, p. 270, 1880.

optical examination, and in a letter to Nordenskiöld he states* that the material was found to be practically homogeneous, uniaxial and with negative double refraction, but whether hexagonal or tetragonal could not be determined. The uniaxial material which Bertrand had taken for calcite was in reality thaumasite, and Bertrand in a letter to Nordenskiöld† withdrew his objection. He gives also the approximate indices of refraction $\omega=1·503$, $\epsilon=1·467$, which differ from those of calcite.

In 1890 Widman‡ described specimens of thaumasite belonging to the mineral collection of the University of Upsala, which are reported to have been found at Kjölland, about thirteen miles from the original locality Åreskuta, and two analyses by Hedström quoted by him agree very closely with the ones made by Lindström. From Hedström's analyses the formula $CaSiO_3$, $CaCO_3$, $CaSO_4$, $15H_2O$ was derived, and as pointed out by Widman this slight change in the formula agrees satisfactorily with the analytical results of Lindström, who really had found over fourteen and one-half molecules of water.

It is with pleasure that the authors are able to announce the discovery of this unusually interesting mineral at Burger's quarry, West Paterson, New Jersey, the material having been first brought to our notice by Mr. Geo. L. English, of New York, who sent a specimen of it to the mineralogical laboratory of the Sheffield Scientific School for identification. The mineral occurs as an aggregate of prismatic crystals, sometimes so loosely held together that the individuals can be separated by crushing between the fingers, while more often the masses are firm and have somewhat the appearance of white alabaster. Occasionally distinct prismatic crystals were observed, averaging $0·5^{mm}$ in diameter and 2 to 4^{mm} in length, but they were poorly formed and without distinct terminations. Some of the masses showing fine prismatic crystals have a decidedly silky luster. There is a distinct prismatic cleavage. Measurements were only possible in the prismatic zone and approximated to 60°, which determine the crystallization as hexagonal. On examining fragments imbedded in Canada balsam ones can readily be found which show a uniaxial interference figure with negative double refraction. Using a polished plate, the index of refraction for the ordinary ray was determined by means of total reflection in α–mono-bromnaphthalene and found to be 1·5125 for yellow Na. By means of a prism of 32° 58′ the following values were also obtained for yellow, $\omega=1·519$

* Geol. För. Förhandl., Stockholm, vol. ix, p. 35, 1887.
† Ibid., vol. ix, p. 131, 1887.
‡ Ibid., vol. xii, p. 20, 1890.

and $\varepsilon=1{\cdot}476$. It must be stated, however, that a prism cut from a crystalline aggregate cannot yield wholly satisfactory results, as the light does not traverse a single individual, and that for example which yielded the extraordinary value above was vibrating in crystals whose vertical axes were approximately and not perfectly parallel to the edge of the prism. Levy and Lacroix* give $\omega=1{\cdot}507$ and $\varepsilon=1{\cdot}468$.

In order to be absolutely sure of the uniform character of the material for analysis, selected pieces of the mineral were crushed and sifted to a uniform grain and separated by means of methyl iodide CH_3I, which was diluted with ether. That every particle of the mineral in the separator floated at a specific gravity of 1·887 and sank at 1·875, a difference of only 0·012, is sufficient proof of the homogeneous character and great purity of the material. Lindström gives as the specific gravity of the Swedish mineral 1·877 and Widman gives 1·83.

The results of the analysis are as follows:

	I.	II.	III.	Average.		Ratio.
SiO_2	9·23	9·33	9·23	9·26	·155	·97
CO_2	6·87	6·77		6·82	·155	·97
SO_3	13·56	13·32		13·44	·168	1·05
CaO		27·08	27·19	27·13	·484	3·04
H_2O	42·81	42·72		42·77	2·377	15·00
Na_2O	·39			·39		
K_2O	·18			·18		
				99·99		

The ratio of $SiO_2 : CO_2 : SO_3 : CaO : H_2O$ is very nearly 1 : 1 : 1 : 3 : 15, demanded by the formula $CaSiO_3$, $CaCO_3$, $CaSO_4$, $15H_2O$. The analytical results are, moreover, very close to those obtained upon the Swedish mineral by Lindström and Hedström. A slight amount of alkali sulphate is probably present as impurity, therefore the alkalies have been neglected in making the above calculation. That Na_2O and K_2O are not isomorphous with CaO is shown by the following experiment: 1·1765 gram of the powdered mineral were treated in a platinum dish for over two days with cold water, the insoluble mineral was then filtered off and the soluble portion analyzed, with the following results: SiO_2, 0·39 per cent; SO_3, 0·56; CaO, 0·56; Na_2O+K_4O, 0·25. These indicate that thaumasite is slightly soluble and that the alkalies have an independent existence, for a quantity of Na_2O+K_2O equal to about one-half of that found in the original analysis was

* Les Minéraux des Roches, p. 286, 1888.

extracted, while relatively only a very small proportion of the calcium was dissolved, a result which would not have taken place if the alkalies had belonged with the thaumasite. A small quantity of alkali sulphate may, therefore, be regarded as impurity, and deducting from the analysis the alkalies and sufficient SO_3 (0·64 per cent) to convert them into sulphates, and recalculating to one hundred per cent, the following results are obtained, which agree satisfactorily with the values required by theory:

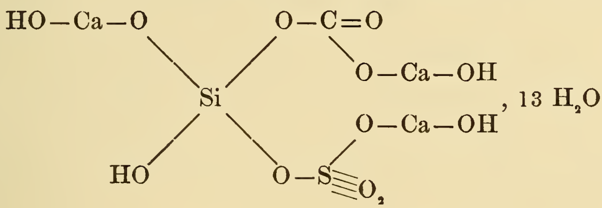
	By recalculation.	Theory.
SiO_2	9·38	9·64
CO_2	6·90	7·08
SO_3	12·95	12·86
CaO	27·47	27·01
H_2O	43·30	43·41
	100·00	100·00

Hoping to obtain data concerning the constitution of the mineral, experiments were made to determine the temperature at which the water was driven off. As determined by Lindström, the mineral slowly loses water at 100° C., and in our experiment, after heating for over ninety hours, a loss of 29·35 per cent was obtained, but the weight had not become constant. At 150° the weight soon became constant and then at 200°, 250° and 300° respectively constant weights were obtained, and in each case the heating was continued until the loss of weight during several hours did not amount to more than a few tenths of a milligram. Between 300° and 360° no loss of weight was obtained, but the material still contained water which, as seen by a closed tube experiment, was expelled at much below a red heat.

The results obtained from ·6663 grams of the air-dry mineral are as follows:

	Loss.	Proportional parts using $\frac{1}{15}$ of total H_2O as unity.
Two days in dessicator	Nothing	
Nine hours at 150°	37·41	13·13
Seven hours at 200°	1·82	0·64
Eight hours at 250°	1·41	0·50
Five hours at 300°	1·05	0·37
Below redness	1·08	0·38
Total	42·77	

It is evident from the above that 13 molecules are to be regarded as water of crystallization and two molecules, sufficient to form four hydroxyls, as constitutional. The last two molecules are, moreover, expelled at four separate temperatures, indicating the existence of four hydroxyls which play different parts or have different positions in the molecular structure. It is evident also that the $CaSiO_3$, $CaCO_3$ and $CaSO_4$, together with the water, are united in some way into a complex molecule, and probably as suggested by Groth* in some way analogous to the combination of silicate and sulphate in the haüyne-nosean group of minerals or of silicate and carbonate in cancrinite. Regarding silica as the linking non-metallic element, the following constitution may be suggested as a probable one:



The above may also be expressed as [(CaOH)CO_2] [(CaOH)SO_3] [CaOH] $HSiO_4$, 13 H_2O. The formula agrees in a very satisfactory manner with the results obtained in driving out the water, for it demands four independent and different hydroxyl molecules.

Formulæ may be written with four hydroxyls and with either carbon or sulphur as the linking element, but they do not seem to the authors so probable as the one given above.

The occurrence of thaumasite at Paterson is in the trap which has been quarried for road material. It is associated with heulandite, apophyllite, laumontite, pectolite, chabazite, scolecite and natrolite, all of which are found at the locality in beautiful crystals. Widman mentions the occurrence of apophyllite with the thaumasite at Kjölland. The thaumasite has crystallized later than the zeolites and occurs upon or surrounding them. A considerable quantity of it was found.

In closing the authors express their thanks to Messrs. Geo. L. English & Co. of New York for generously furnishing them with material for the investigation.

Mineralogical-Petrographical Laboratory,
Sheffield Scientific School, February, 1896.

* Tabellarische Uebersicht der Mineralien, p. 149, 1889.

Art. XXV.—*The Age of the Wealden;* by O. C. Marsh.

The Wealden formation of England has long been studied, and is now well known in nearly all its features. Its stratigraphical relations and its Cretaceous age are usually regarded as fully determined, and this is true, also, of the corresponding strata on the Continent.

The vertebrate fauna of the Wealden is of special interest, and has attracted much attention ever since Mantell in 1825 unearthed *Iguanodon* in the Tilgate Forest. Some of the remains, he sent, through his friend, Professor Silliman, to Yale College, where they have proved of much service. In 1865, the writer examined the same famous locality, as well as others on the south coast of England especially rich in vertebrate fossils, and at all of them secured interesting specimens. A study of these in connection with the collections at London and Brussels first made the writer question the Cretaceous age of the Wealden, and a later comparison of its reptilian fauna with allied forms found in the Rocky Mountains led him to the conclusion that both series were Jurassic in type, and should be placed in that division of the geological series.

At the meeting of the British Association, at Ipswich, in September last, the writer read a paper on European Dinosaurs, including two from the Wealden, and thus the question of their geological age came up for determination. The facts presented by the writer, based mainly upon the reptilian fauna, strongly indicated the Jurassic age of the Wealden, and he urged a re-examination of the question by English geologists.* The subject has since been taken up by Smith Woodward, with special reference to the fossil fishes. In the Geological Magazine for February, 1896, he gives the main results of his investigation, which prove that the fishes, also, of the Wealden are of Jurassic types, thus placing the geological age of this formation beyond reasonable doubt. The concluding statement of this interesting article is as follows:

"The Wealden estuary seems to have been the last refuge of the Jurassic marine fish-fauna in this part of the world, not invaded even by stragglers from the dominant race of higher fishes which characterized all the seas of the Cretaceous period. The Wealden river drained a land where a typically Jurassic flora flourished; the only two known Mammalian teeth from the Wealden resemble those of a Purbeckian genus; and now it is clear that the fishes agree both with these and the reptiles in their alliance with the life of the Jurassic era."

Yale University, February 22d, 1896.

* Report, British Association for the Advancement of Science, p. 688, 1895; and this Journal, vol. l, p. 412, November, 1895.

ART. XXVI.—*Experiments upon the Cathode Rays and their Effects;* by ARTHUR W. WRIGHT. With Plates VI–VII.

THE history of the investigations which have led to our present knowledge of the phenomena of electrical discharges in rarified gases, and especially of the actions which take place at the negative electrode in an exhausted tube, is a long one and full of interest. But while there are many memoirs of very high importance, those which most immediately relate to the subject here considered are two papers of Philipp Lenard, of the University of Bonn,* which marked a great advance in the study of the cathode rays, and the paper of Professor W. C. Röntgen,† of Würzburg, which has attracted immediate attention from the novelty and importance of the results therein announced.

In his first paper Lenard, by a series of very ingeniously contrived experiments, showed how, by the use of a small window of thin aluminium, the cathode rays could be obtained in the air outside of the vacuum-tube, and their properties studied by the use of fluorescent screens and of sensitized photographic plates. He showed that they could be traced to a distance of several centimeters in air, that they penetrated various materials in different degrees, determined in a large measure, by the circumstances under which they are originated. He proved that in air and other gases they undergo a lateral diffusion or scattering, as if by the action of a turbid medium, and this in different amounts depending upon the degree of exhaustion of the tube in which they originated. His researches led him to the conclusion that the cathode rays are phenomena of the ether. Among many experiments may be cited one in which he obtained a photographic picture, in an opaque metallic box, one side of which was made of thin aluminium. In his second paper he studies the relative absorption of the rays by different materials, showing that, broadly, the absorption is proportional to the density of the matter, and independent of its kind, but that the order of the different kinds of matter in this respect is to some extent dependent upon the character of the rays.

Prof. Röntgen's paper, which is full of most interesting results, greatly extends the range of the phenomena observed, especially as to the remarkable power of the rays to penetrate masses of matter, and brings up some very important questions as to their character. He states that as obtained outside of the vacuum-tube they are not deflected by a magnet to an appreciable extent, that they undergo neither refraction, reflec-

* Wied. Ann., li, p. 225, 1894; lvi, p. 255, 1895.

† Sitzungsberichte der Würzburger Physik-medic. Gesellschaft, 1895; translation in Nature, vol. liii, p. 274, Jan. 23, 1896.

tion nor polarization, that they do not produce perceptible heating effects, nor influence the magnetic needle. These characteristics differentiate them strongly from luminous rays, and he suggests, but with great moderation in statement, that they may be longitudinal waves in the ether. To these questions of high scientific importance, were added descriptions of results obtained in the production of photographic pictures of objects through considerable masses of matter opaque to light, thus revealing the inner structure of bodies otherwise invisible, and even showing, in the body of an animal, the bones clearly distinguished from the flesh.

These results were of such great interest that physicists were immediately incited to test their reality, and to witness the novel effects. The present paper gives an account of experiments made by the writer in the Sloane Physical Laboratory of Yale University, and, omitting many details, follows the general course of the work as it was carried out.

For the production of the cathode rays, a Crookes' tube, nearly spherical in shape, was used, of the kind often employed to exhibit the independence of the negative electrode in high vacua. It is provided with four electrodes, three of straight wire, of which two are situated at the opposite extremities of a diameter and directed radially, while the third is placed at the end of a diameter at right angles to the line of the other two. The fourth is situated a little to one side of the point opposite the third electrode just described. This disposition is advantageous, as it leaves a space of smooth thin glass opposite the third and fourth electrodes, which were the ones employed, sometimes one, sometimes the other, as the cathode. The fourth wire terminates in a slightly concave disk or cup about two centimeters in diameter. The concave disk concentrates the cathode rays, issuing normally from its surface, at a point near the opposite surface of the tube, sending them through a small area of the glass wall, which becomes strongly heated. The photographic plates show this concentration of the rays plainly. On account of the unequal distribution of the effect, however, as well as because of the inferior definition of the pictures thus obtained, the third straight wire electrode was used in preference. This gave somewhat less intense effects, making a longer exposure necessary, but the results were otherwise much more satisfactory. The induction coil used with the tube gives a spark of six or seven centimeters in air, and was actuated by four, sometimes five, secondary cells.

The first photograph obtained with this apparatus, on Jan. 27, was made upon a piece of bromide paper which had been wrapped in thick black paper. It gave very clear representations of the objects employed. In the evening of the same day a strong picture was made upon a photographic dry-plate covered with a thin, white-wood board. In some of the earlier experiments the objects to be tested were separated from the sensitive plate by a screen of wood from a centimeter to a centimeter and a half in thickness. Strong effects were produced easily, but the pictures had a blurred appearance, which was largely due to the increased distance from the plate, but in part also to the diffusing or scattering effect of the wood. Later, an ordinary photographic plate-holder was used, the objects being simply laid upon the ebonite slide, the vacuum-tube being supported directly over it at a distance of from four to six inches. In general it may be said that the pictures have the appearance of shadows, and the conditions which are necessary for the production of distinct shadows by ordinary light apply to them, especially the greater distance of the radiating source, and nearness of the object to the surface upon which it is to be projected. To secure the latter condition the best arrangement was simply to wrap the photographic plate in one or two thicknesses of black opaque paper, as a protection from ordinary light, and to lay the objects upon this. Increasing the distance of the vacuum-tube improved the pictures in the matter of sharpness, fulness of detail, and accuracy of form and dimensions, but the time of exposure was correspondingly increased. In one experiment a variety of objects was selected to test the action of the rays upon different materials. On one side of the plate were arranged four equilateral prisms, two of flint glass, one of Faraday's heavy glass, and one of quartz. Two of these were drawn out of line with the other two, so that a straight steel wire laid along them was met by the sloping surfaces from opposite sides. It was hoped that the trace of the wire upon the plate would show the presence or absence of refraction, as it was so placed that the trace would be displaced in opposite directions by alternate prisms in case of refraction. Unfortunately the prisms proved too opaque to the rays to show the desired effect. The quartz transmitted a little at the thin edges, the flint glass prisms very little, and the heavy glass still less. A block of calcite proved also to resist the passage of the rays very strongly, and where some passed through the thin edges, there was no trace of duplication of the images, showing the absence of double refraction and polarization. A metallic mirror set so as to throw a trail of rays along the plate in case of regular reflection showed no such effect whatever, nor did the polished surfaces of the prisms and of the Iceland spar. The plate showed, however, that a scattering of the rays occurred at various points where they encountered the surfaces of the objects, and this effect was noticed on many other occasions in the different experiments.

This confirms the statement of Prof. Röntgen that regular reflection does not occur, and the theoretical results announced by Jaumann in his remarkable paper, where he shows that diffuse reflection may occur but not specular reflection.* Other objects upon this plate were slips of differently colored glass, ebonite, tin-foil and thin sheet aluminium. The latter having a thickness of about $0 \cdot 1^{mm}$, transmitted the rays so freely that it shows but very faintly upon the negative, and not at all upon the prints from it. The ebonite $1 \cdot 8^{mm}$ in thickness ranked next in permeability. The slips of glass (crown) showed apparently no effect dependent upon color, the effect in stopping the rays being evidently dependent chiefly upon the thickness. The tin-foil transmitted the rays somewhat freely, and the impression shows the various little irregularities in its surface. Lead a little more than a millimeter thick was practically opaque.

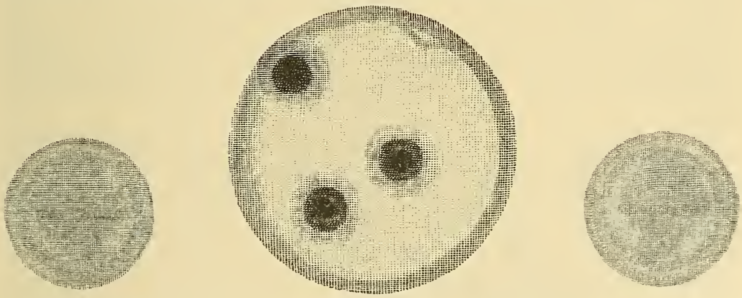
Other experiments were made upon the bodies of animals and the human hand. A rabbit, purchased in one of the markets of the city, after an exposure of one hour to the rays, left upon the plate a complete representation of the bony skeleton, the bones of the legs being very sharply and perfectly represented. The region of the lungs was more transparent than the rest of the body, and the heart still more so, being somewhat definitely outlined. The cartilages at the base of the ears left a distinct trace, the ears themselves scarcely any. Particularly interesting in this photograph were several small round spots which appeared dark in the positive print. These were at once surmised to be shot, and from the indication of their location in the print were readily found and extracted. The mode of death of the animal was not previously known. Similar results were obtained with the body of a rat, the whole skeleton being shown, with some of the tendons. Organs of the abdominal region were also discriminated to some extent.

The photograph of the hand shows the bones and their articulations very clearly and well defined. On the side of each finger the plexus of nerves and blood-vessels is distinctly shown as it divides into several branches for distribution to the ball of the finger. When the negative is held to the light the hand appears as if modeled in a translucent, luminous material, with the full appearance of roundness and solidity. It is as if it had become nearly transparent, so that the structure of the interior could be seen, not only in respect to the particulars already mentioned, but also with respect to the distribution, or relative abundance, of the blood in its different parts. It may be remarked here that this effect is noticed in many other cases. The pictures are not merely flat shadows, but the partial opac-

* Longitudinales Licht., Wied. Ann., lvii, p. 147, 1895.

ity, varying with the thickness, gives a corresponding depth of shade in the picture, thus producing an effect of perspective, which in the negative, or a negative transparency projected upon a screen, has a striking effect of relief, and a luminous solidity often of great beauty.

As in the case of tissues which are rather freely traversed by the rays the differences of shade in the impression are not very great, the development of the negative requires especial care. It is better to use a developer of less than the ordinary strength, and to use no alkaline accelerator at all, until just at the end of the process, and then very sparingly and chiefly for the purpose of intensifying the picture. This makes the process very long and tedious, but the results amply compensate for the labor of obtaining them. Aside from this it appears that the photographic plates which have been subjected to the rays are peculiarly slow, even with the ordinary mode of development. The picture is a long time in making its appearance and grows very gradually. This is perhaps in part due to the fact that the effect of the cathode rays extends through the entire thickness of the film, which must therefore be thoroughly developed to the bottom to bring out the full effect, or possibly to a specific action upon the film itself.



The results of some of the many experiments are shown in the accompanying cut, and in Plate VI. These are selected, not so much for any special interest in the objects themselves, as for the reason that they illustrate some of the characteristic features of the pictures obtained by the use of Prof. Röntgen's method. The cut, from a plate made January 30, shows a small paper box filled with cotton in which were imbedded three metallic spheres, which had been used in the laboratory as pendulums. The sphere nearest the edge was aluminium, the one nearest the center platinum, the other brass. They were all of the same size. The cover of the box was in place during the exposure. The box and its cotton filling show little hindrance to the passage of the rays, only the vertical walls showing, with an inward nick where the side was crumpled by the tight cover. The aluminium sphere appears diminished in size by the passage of the rays more freely through the lesser thickness of its periphery, and leaves a lighter trace upon the plate than the two others, which are practically opaque, and nearly alike. On either side of the box was a medal of aluminium, the head in one being uppermost, in the other beneath, the two being alike except in position. The medal is one made by Johnson Matthey & Co., some years ago, and one side, the reverse, bears the name of the firm, and the address, HATTON GARDEN, around the rim. Across the middle of the face is the word REFINERS. On the obverse is the bust of Queen Victoria, and around the rim the words VICTORIA QUEEN. The raised rim is serrated on the inside on the obverse, but is plain on the reverse. In the cathode picture, owing to the great permeability of the metal, the designs and letters upon both sides are shown, appearing as a similar medal in translucent wax would, if viewed by transmitted light. In the negative the separate letters can be distinguished, and two dots separating the name from the address, though the letters are hardly clear enough to enable one unacquainted with their import to make out the inscriptions. The gradations of light and shade in the negative are too delicate to be represented adequately in any process print, but are fairly well shown in the wood-cut. The position of each medal can be determined from the greater distinctness of that side which was nearest the photographic plate.

The plate, VI, represents a portion of a picture obtained Feb. 1. The handles of the saw and awl are of cherry wood. This appears very transparent, but gives a shading proportional to the thickness of the wood. The tang of the awl is clearly seen, and that of the saw also, extending entirely through the wooden handle, and expanded or riveted at the end to prevent it from being pulled out in use. The eye-glasses in their leathern case show minute details of form, and the varying thickness of the lenses is indicated by corresponding depth of shade. The same effect is shown still more strikingly by the figure of the pocket lens in its ebonite mounting, where no effect of refraction can be traced, the lenses simply showing the greater thickness at the center by the deeper shading. The sides of thin ebonite are separated by thicker pieces of the same material at the ends, and are held together by two brass rivets which are plainly depicted.

With a view to study the character of the rays outside of the vacuum-tube the following experiments were made: A flat, rectangular plate of copper, $1{\cdot}8^{mm}$ in thickness, $25{\cdot}5^{cm}$ long, and $21{\cdot}5^{cm}$ wide was used, and in the center of this two straight, parallel slits $1{\cdot}5^{mm}$ wide and 35^{mm} long were cut through the metal. Their inner edges were 5·6^{mm} apart, and they were parallel to the shorter dimension of the plate. On one side of the copper plate was soldered a strip of thinner sheet copper at right angles to the length of the slits, and about three millimeters from their ends. One side of the strip was turned up at right angles to the copper plate and formed a ledge for the end of the sensitive plate to rest upon, and to serve as a guide in placing it in position. The copper plate was placed in a horizontal position beneath the vacuum-tube and distant from it about one decimeter (97^{mm}), the cathode being carefully brought directly above the slits and pointing towards them. In the first experiment, the results of which are illustrated in Pl. VII, the distance of the nearest part of the tube was greater, being 132^{mm}. The sensitized photographic plate, wrapped in a single thickness of black paper, was placed beneath the copper plate, with its upper end resting against the guide ledge at the inner end of the slits, and inclined at such an angle that its lower end was beyond the vertical line through the outer end of the slits. The streams of cathode rays passing through the slits were thus intercepted by the dry plate, upon which they left their trace throughout its length. The experiment was carried out as follows:—The dry-plate was first placed so that the slits were at the middle of its upper edge. One of the slits was covered with a strip of thick copper plate and an exposure of 30 minutes made, after which it was uncovered, the copper strip transferred to the other slit, and a second exposure of equal length made. This was for the purpose of fixing upon the plate the position of the cathode stream from each slit uninfluenced by the presence of the other. The sensitive plate was now moved along in its own plane, both slits were uncovered, and a new exposure of the same length as before was made. This was to detect any repulsion such as occurs under similar circumstances within a vacuum-tube. Finally the photographic plate was moved in the opposite direction, bringing the slits over a point nearly midway between the center and the edge, and a powerful Jamin magnet so placed, that if any effect upon the cathode streams were produced, such as is seen in a vacuum-tube, they would be deflected away from the center of the plate. The consecutive positions of the slits relatively to the plate are indicated by the numbers 1, 2, 3 in the illustration, Pl. VII.

Development of this plate showed some interesting results. Opposite each position of a slit is a trail extending nearly across the length of the plate, of the same breadth as the slit where the latter met the upper end of the plate, and spreading out in a fan-like shape at an angle of very nearly 15°. The sides of each trail, near the origin, are well defined, and rectilinear, or nearly so, but at a distance of a centimeter, or a little more, from it, they show an outward curvature, which increases with the distance, and their edges become blurred and diffuse, like the rays shown in Lenard's first paper, already quoted, but in a much less degree. Traces of curvature produced by the magnet, appear to be faintly indicated, but if real are very slight. Mutual repulsion of the two streams produced simultaneously appears to be shown, but the effect is very little. To the eye the three pairs of streams appear to be nearly alike, and even a careful measurement of the angular dimensions of the trails shows but a minute difference, too small to be made the basis for any positive conclusion.

Within the tube the cathode rays are accompanied by metallic matter derived from the substance of the electrode, and the minute portions of the metal, whether in the form of vapor or fine dust, have been shown by various investigators to be negatively electrified. The electrostatic repulsion of these would be a cause for the mutual repulsion of two cathode streams, as shown in a well-known form of Crookes' tube, while the motion of the electrified masses, causing them to act like an electrical current, as was proved by Rowland,* would render them susceptible to magnetic attractions or repulsions. This also is a familiar observation in respect to cathode streams. Now the glass walls of the tube do not suffer the metallic matter to pass through them, and the metal is deposited upon them, in the form of a sooty coating, or under proper condition, of a mirror-like film of brilliant luster.† Naturally, then, the rays outside of the tube being freed from the metallic matter would show the effect of mutual repulsion and magnetic deviation in a less degree, or not at all. If, however, it were possible to make them pass through a metal which would be volatilized by them to some extent, the effects might be expected to reappear.

To test this point the previous experiment was repeated with this modification: The slits were covered with two layers of ordinary gold leaf, thin enough to transmit light readily, two being used to lessen the chance of small rifts permitting the rays to pass unimpeded and to interfere with the result. To compensate for the lessened effect of the rays, caused by the gold leaf, the vacuum-tube was brought a little nearer the slit-plate, to a distance of 97^{mm}. Otherwise the arrangement and adjustment were exactly as before, and the exposures were made in the same manner, but were slightly longer, 40 minutes each. Gold was selected for this experiment for the reason that it had been found, in earlier experiments by the writer,‡

* This Journal, III, xii, p. 390, 1876; xv, p. 30, 1878.
† This Journal, III, vol. xiii, Jan. 1876, p. 49; vol. xiv, Sept. 1877, p. 169.
‡ This Journal, loc. cit.

to be volatilized with great facility when used as a cathode. It was thought that the passage of the cathode rays through it would cause the liberation of the metal in their path, in the same manner as within the tube, and thus cause them again to become susceptible to mutual repulsion, and to deviation by a magnet.

This expectation appeared to be justified by the character of the trails upon the developed photographic plate, although the changes were not great. The angles were determined by measurement, in most cases by pricking the outlines of the streams with a fine needle on a positive print, and then tracing the lines of direction of the perforations with a straight-edge upon paper. The angular spread of the streams was greater than in the previous experiment, being now about 18°. The effect of the magnet was shown by a small deviation, in the direction expected. The measurements of its amount were difficult to make, but all agreed in showing a positive effect, of something like half a degree. The mutual repulsion of the two streams was also clearly shown, the angle between the axes of the pencils being increased a little more than half a degree. It was also evidenced by the fact that when the axes were prolonged they were found to meet at a point nearer the slits than those of the pencils produced singly.

A third experiment, in which a sheet of aluminium, $0{\cdot}26^{mm}$ in thickness, replaced the gold leaf, was now made under the same conditions as before. As this metal, though readily permeable by the cathode rays, is very slightly affected when used as an electrode, it was not to be expected that it would modify the stream of cathode rays to the same extent as the gold. This the developed plate confirmed. The magnetic deviation could not be detected with certainty, but the mutual repulsion of the two streams was somewhat greater than before.

An attempt to discover the point of departure of the rays was made by tracing the axes of the trails or pencils until they met upon the plot. In the case of the first two experiments, they were found to come together at a point very near the center of the spherical body of the vacuum-tube, thus indicating that they left the surface of the glass nearly normally. The third case showed the point of meeting nearer the cathode, but the results of the three pairs of pencils varied much from each other.

While it is doubtless premature, in the present state of our knowledge to formulate a conclusion as to the nature of the rays which produce these remarkable results, we may derive some useful suggestions from a consideration of the circumstances of their production. If the cause of the excitation is an ordinary induction coil, the resistance of the circuit of the secondary is so great that the oscillations in this circuit at each opening or closing of the primary circuit will be rapidly extinguished, and the mode of discharge will approximate closely to a simple discharge at each movement of the interrupter, producing at the terminal of the electrode within the tube an unsymmetrical rise and fall of the electrostatic potential. This must give rise to the passage of inductive actions through the space surrounding the electrode both within and without the tube. The period or duration and phase of these inductive pulses will be essentially the same as those of the variations of potential at the surface of the electrode, and as these are not a continuous sequence like the elements of a train of waves, the inductive actions in space may be regarded as very probably occurring in the form of isolated or unsystematic pulses, succeeding one another at intervals long compared with their own duration, and more or less irregular with most forms of interrupters used with the coil, from the variations in their action. As to the mode of propagation of these pulses the most natural view would be to regard them as analogous to longitudinal compression waves in an elastic medium, but of an unsystematic character.

It may be of interest to recall the fact that appearances similar to these pictures produced by the rays from the cathode of a vacuum-tube, and not unlikely due to a similar cause, have been observed before. In a paper published by the writer in 1870,* it was shown that, under certain conditions, when the silent discharge took place between the terminals of a static electrical machine, a minute point-like brush appeared upon the negative terminal, and a glow upon the positive, in which appeared the figures of objects brought into the path of the discharge. When a piece of wire gauze was interposed, "the shadows were formed with striking distinctness. . . . Every peculiarity of texture was faithfully represented, the irregularities in the wires, breaks in the gauze, and the like, being accurately reproduced, and moving with the gauze, just as in the case of true optical shadows." In a subsequent paper† attention was called to the fact, that many cases of images formed upon the bodies of persons killed by lightning, which had been reported by reputable observers, might be explained by supposing that the objects represented were so situated as to interrupt the lines of electrical action. These facts suggest the probability that every electrical discharge, which is not simply a flow of potential along a conductor, may produce effects of a similar kind, though much inferior in accuracy of form and dimensions to those produced by the agency of the cathode rays from a high vacuum-tube.

Sloane Physical Laboratory, Yale University,
February 22, 1896.

* This Journal, II, vol. xlix, May, 1870, p. 381.
† Ibid., III, vol. i, June, 1871, p. 437. Also vol. x, Oct. 1875, p. 317.

ART. XXVII.—*Triangulation by means of the Cathode Photography;* by JOHN TROWBRIDGE.

PHOTOGRAPHY by means of the Röntgen rays seems already to be of great importance in examining certain portions of the human body to determine the presence of metallic bodies, calcareous formations, and fragments of glass. The shadow pictures as they are taken at present, however, do not give the approximate position of the shots, for instance, embedded in the flesh. They indicate only the line in which they are situated. It occurred to me that the principles of triangulation could be applied with success to determine more exactly the position of the metallic particles. I was led to this conclusion by considering Rumford's photometer. This instrument, it is well known, consists merely of a vertical rod placed opposite a suitable screen of white paper. The two lights, the intensities of which are to be compared, are placed in a fixed position, and throw two shadows of the rod on the screen. From a measurement of the positions of the lights when shadows of equal intensity are thrown on the screen, an extinction of the brightness of the lights can be obtained. Moreover, by measuring the distance between the shadows, and by drawing lines from them to the lights, the position of the rod throwing the shadows can be determined. This position is evidently at the intersection of these lines.

I have used two Crookes' tubes with two terminals making an angle with each other, and have employed a to-and-fro excitation by means of a Tesla coil. A suitable screen of glass shielded the sensitive plate first from one cathode and then from the other. From the distance between the shadow pictures of a shot, for instance, on the back of the hand and from the position of the terminals the height of the shot above the sensitive plate could be estimated. It seems to me that this method promises to be of importance in the surgery of the extremities of the body; for the question whether to make an incision from the palm of a child's hand or from the back of the hand is an important one. Stereoscopic pictures can also be obtained.

The use of a Tesla coil in obtaining shadow pictures is advantageous in certain respects, for by changing the size of the spark gap in the primary circuit of the Tesla coil one has a great range of electrical energy at command. This range can be still further increased by putting the spark gap in a magnetic field. I have taken such pictures in less than a minute, showing the bones in the fingers. The tubes were, at first, destroyed by disruptive sparks over the surface of the tube which apparently penetrated the glass between the platinum terminals and the glass. I have lately discovered, however, that if the terminals of the tube are placed in a vessel filled with paraffine oil and if the oil is kept cool by an outside vessel filled with snow or ice, the entire energy developed by the Tesla coil can be employed, and the tubes are not destroyed.

I have tried wooden lenses, both double convex and double concave, in order to see whether the rays travel slower or faster in wood than in air, but my results are negative. A copper ring placed on a double convex lens of wood of approximately six inches focus, and one also on a concave lens of the same radius as the surfaces of the double convex lens, gave shadow pictures of the ring which were of the same size and character as those of an equal copper ring placed in air at the same distance from the sensitive plate.

We naturally turn to Maxwell's great treatise on Electricity and Magnetism, to see if a hint of this new phenomenon cannot be found there: for I believe there is no manifestation of electro-magnetism since the death of Maxwell which has not been predicted or treated by him in one form or another in his remarkable book. In section 792, vol. ii of the treatise on Electricity and Magnetism he says, " Hence the combined effect of the electrostatic and the electrokinetic stresses is a pressure equal to $2p$ in the direction of the propagation of the wave. Now $2p$ also expresses the whole energy in unit of volume. Hence in a medium in which waves are propagated there is a pressure in the direction normal to the waves, and numerically equal to the energy in unit of volume. Thus, if in strong sunlight the energy of the light which falls on one square foot is 83·4 foot-pounds per second, the mean energy in one cubic foot of sunlight is about 0·0000000882 of a foot-pound, and the mean pressure on a square foot is 0·0000000882 of a pound weight. A flat body exposed to sunlight would experience this pressure on its illuminated side only, and would therefore be repelled from the side on which light falls. It is probable that a much greater energy of radiation might be obtained by means of the concentrated rays of the electric lamp. Such rays falling on a thin metallic disc, delicately suspended in a vacuum, might perhaps produce an observable mechanical effect."

Jefferson Physical Laboratory.

ART. XXVIII.—*Notes of Observations on the Röntgen rays;* by HENRY A. ROWLAND, N. R. CARMICHAEL and L. J. BRIGGS.

THE discovery of Hertz some years since that the cathode rays penetrated some opaque bodies like aluminium, has opened up a wonderful field of research, which has now culminated in the discovery by Röntgen of still other rays having even more remarkable properties. We have confirmed, in many respects, the researches of the latter on these rays and have repeated his experiment in photographing through wood, aluminium, cardboard, hard rubber and even the larger part of a millimeter of sheet copper.

Some of these photographs have been indistinct, indicating a source of these rays of considerable extent, while others have been so sharp and clear cut that the shadow of a coin at the distance of 2^{cm} from the photographic plate has no penumbra whatever, but appears perfectly sharp even with a low power microscope.

So far as yet observed the rays proceed in straight lines and all efforts to deflect them by a strong magnet either within or without the tube have failed. Likewise prisms of wood and vulcanite have no action whatever so far as seen and, contrary to Röntgen, no trace of reflection from a steel mirror at a large angle of incidence could be observed. In this latter experiment the mirror was on the side of the photographic plate next to the source of the rays and not behind it as in Röntgen's method.

We have, in the short time we have been at work, principally devoted ourselves to finding the source of the rays. For this purpose one of our tubes made for showing that electricity will not pass through a vacuum, was found to give remarkable results. This tube had the aluminium poles within 1^{mm} of each other and had such a perfect vacuum that sparks generally preferred 10^{cm} in air to passage through the tube. By using potential enough, however, the discharge from an ordinary Ruhmkorff coil could be forced through. The resistance being so high the discharge was not oscillatory as in ordinary tubes but only went in one direction.

In this tube we demonstrated conclusively that the main source of the rays was a minute point on the *anode* nearest to the cathode. At times a minute point of light appeared at this point but not always.

Added to this source the whole of the *anode* gave out a few rays. From the cathode no rays whatever came, neither were there any from the glass of the tube where the cathode rays struck it as Röntgen thought. This tube as a source of rays far exceeded all our other collection of Crookes' tubes and gave the plate a full exposure at 5 or 10^{cm} in about 5 or 10 minutes with a slow-acting coil giving only about 4 sparks per second.

The next most satisfactory tube had aluminium poles with ends about 3^{cm} apart. It was not straight but had three bulbs, the poles being in the end bulbs and the passage between them being rather wide. In this case the discharge was slightly oscillatory but more electricity went one way than the other. Here the source of rays was two points in the tube, a little on the cathode side of the narrow parts.

In the other tubes there seemed to be diffuse sources, probably due in part to the oscillatory discharge, but in no case did the cathode rays seem to have anything to do with the Röntgen rays. Judging from the first two most definite tubes the source of the rays seems to be more connected with the anode than the cathode, and in both of the tubes the rays came from where the discharge from the anode expanded itself toward the cathode, if we may roughly use such language.

As to what these rays are it is too early to even guess. That they and the cathode rays are destined to give us a far deeper insight into nature nobody can doubt.

Baltimore, Feb. 20, 1896.

SCIENTIFIC INTELLIGENCE.

I. Miscellaneous Scientific Intelligence.

1. *Longitudinal Light.* — The experiments of Lenard and Röntgen have awakened great interest in the question whether the cathode rays indicate a periodic movement in the direction of the propagation of the electro-magnetic waves sent out from the cathode. G. Jaumann states that he is the first to maintain that the manifestations of cathode rays support the hypothesis of longitudinal waves. He calculates that the order of magnitude of the time of swing of the cathode rays is from 10^{-8} to 10^{-9} seconds. E. Wiedemann, on the supposition that the cathode rays are a manifestation of ultra violet light, attributes to them a time of vibration of from 10^{-15} to 10^{-16} seconds. Lenard attributes to the rays wave lengths of the order of magnitude of molecules. Jaumann reviews the experimental evidence in favor of the hypothesis of longitudinal waves and finds it of great weight. He then turns to the equations which express Maxwell's electro-magnetic theory of light, and points out that the longitudinal wave, in the direction of the movement of the wave-point, is not expressed by these equations, and that they do not embrace the phenomena which are observed in rarified gases. On the supposition, however, that the dielectric constant and the magnetic permeability of the medium change in value during the instant of propagation, he is enabled to embrace in these equations the hypothesis of longitudinal waves. The paper is of much interest in view of the late development of the subject of cathode rays. —*Ann. der Physik und Chemie*, No. 1, 1896, pp. 147–148.

J. T.

2. *The Natural History of Aquatic Insects*; by L. C. Miall. (London and New York, 1895. Macmillan & Co.) — Professor Miall here gives us an excellent example of a kind of work too rarely seen, the popular and yet strictly scientific treatise on natural history. The short introductory chapter treats briefly of some essential matters relating to aquatic insects in general, such as the dominance of insects, their invasion of the waters, adaptation to aquatic conditions, the surface-film of water, etc. The rest of the book is devoted to descriptions of the structure, transformations, and habits of a series of typical species well apportioned among the different groups of insects. Although the species described are European, they are so closely related to North American forms that the work will serve as a guide for the American student almost as well as for the European. The numerous illustrations are excellent. S. I. S.

3. *Huxley Memorial.*—It is gratifying to learn that the movement to establish a permanent memorial to the late Professor Huxley has met with marked success. The committee announced in a circular dated Dec. 21, 1895, that the subscriptions up to

that time amounted to £1535. It is to be hoped that the scientific men of this country may not be backward in doing their share. Donations may be sent to the treasurer, Sir J. Lubbock, or the bankers, Messrs. Robarts, Lubbock & Co. (15 Lombard street, London, E. C.), or to the honorary secretary, Prof. G. B. Howes (Royal College of Science, South Kensington, S. W.). It has been decided that the memorial shall take the form of a statue, to be placed in the British Museum of Natural History, and a medal in connection with the Royal College of Science, and that the surplus be devoted to the furtherance of biological science in some manner to be hereafter determined by the committee, dependent upon the amount collected.

OBITUARY.

Charles Wachsmuth died in Burlington, Iowa, on February 7th, aged sixty-seven. Dr. Wachsmuth has for many years been working on the classification of the fossil and recent Crinoidea and is well known to all paleontologists by the admirable "Revision of the Palæocrinoidea" prepared by himself and his constant friend and collaborateur, Mr. Frank Springer of Las Vegas, New Mexico. This work was issued in parts in the Proceedings of the Academy of Natural Sciences in Philadelphia; Part I appearing in 1879, Part II in 1881 and Part III, "A discussion of the Classification and relations of the Brachiate Crinoids and conclusion of the generic descriptions," in 1885 and 1886. At the time of his death the authors had in press an illustrated monograph on "The North American Fossil Crinoidea Camerata," which is being published by the Museum of Comparative Zoology, Cambridge, Mass. In a letter from Mr. Springer we are advised that all correspondence connected with the publication of this monograph should be addressed to Mr. Frank Springer, East Las Vegas, New Mexico, U. S. A.

ERRATA.

In the article by Prof. A. M. Mayer in the February number, 1896.

Page 83, line 13 from top, for 2·12 read 2·35.
Page 84, line 2 from top, for modulus increased, read modulus *at* 20° increased.
Page 84 and 85, for Keyser read *Kayser*.
Page 85, line 4 from bottom, for the vibrations read the *longitudinal* vibrations.
Page 93, line 14 from top, for 2135×10^6 read 2131×10^6.
Page 94, for moduls of glass at 40° read 748511034.
Page 94, under St. Gobain glass for 99·88, 99·76, 99·53, 99·30 read 99·76, 99·53, 99·30, 99·07
Page 103, line 22 from bottom, for renders read *render*.
Page 103, line 19 from bottom, for would have given read *gives*.
Page 103, line 12 from bottom, for equal intensity, read equal *initial* intensity.
Page 104, line 13 from bottom, for rest read *rests*.
Page 105, lines 19 and 21 from bottom, for from read *between*.
Page 105, line 17 from bottom, for Fig. 4 read *Figure* (3).

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FOURTH SERIES.

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PLATE VIII.

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[FOURTH SERIES.]

Art. XXIX.—*The Morphology of Triarthrus*; by C. E. Beecher. (With Plate VIII.)

Most of the recent advances in the knowledge of trilobite structure have come from the study of *Triarthrus*. Since Valiant's discovery of the antennæ, and its announcement by Matthew in 1893, the writer has published a series of papers on the detailed structure of this trilobite. Much time has also been spent in carefully working out the numerous specimens from the abundant material in the Yale Museum. Altogether upwards of five hundred individuals with appendages more or less complete have been investigated; and at the present time, it may safely be said that the important exoskeletal features have been seen and described.*

Notwithstanding the amount of information regarding the details of the various organs, very little has been shown illustrating the general appearance of the animal with the appendages in a natural and lifelike position, and it is one object of the present article to supply this deficiency.

Several specimens have been lately developed which preserve not only the appendages in great perfection, but also show them extended and disposed in a very lifelike manner. No new structural points are here brought out, yet the representation of the complete animal serves as a summary of present knowledge, and also gives a definite picture of great assistance in forming a conception of general trilobite morphology.

* The more important literature relating to the structure of the genus *Triarthrus* is given at the end of the present article; numbers in the text refer to this.

The dorsal view represented on Plate VIII is from a camera drawing based upon three specimens of about the same size. One gives the entire series of legs down to the ninth free segment, with the exception of the exopodites of the head, which are supplied from a second individual. In the third specimen, the anterior appendages are bent and irregularly arranged, while from the ninth backward to the end of the pygidium they are complete and uniformly extended. The figure is, therefore, a restoration only in so far as representing the best portions of three individuals.

The ventral view, Plate VIII, is based mainly upon two very excellent specimens. One was figured on Plate IV, vol. xv, of the *American Geologist*, and another, since found, nearly completes the ventral aspect. The under side of the head and pygidium was carefully compared with all the available material, and no attempt was made to supply any characters except as to the exact number of joints in the endopodial cephalic elements and the precise form of the cephalic exopodites, which from every character observed, and from analogy with similar structures elsewhere, were as represented.

So many specimens preserve the appendages in the position shown in the figures, that this must be recognized as natural and one likely to have been assumed by the living animal when extended. Few, however, show the details of the limbs with sufficient clearness to enable one to make out all their joints, and more minute characters.

In comparison with what is now known of the appendages of several other genera of trilobites, especially *Trinucleus*,* those of *Triarthrus* seem to have been exceptionally long. On this point Bernard, in a letter to the writer, suggests that "*Triarthrus* must have been a sort of 'Daddy longlegs' among the Trilobites, as *Scutigera* is among the Myriapoda." The entire length of a thoracic leg, including the coxal joint, is nearly equal to the width of the body at that point, and about half the length projects beyond the pleura.

The limbs of the head diminish in length forwards until the anterior pair scarcely extends beyond the border of the cephalon. The anterior thoracic legs are the longest, and there is a gradual shortening backward in the series, especially noticeable after passing the fifth, those at the extremity of the pygidium being about one-ninth the length of the first thoracic leg. Their position is also of interest. At the posterior extremity they point almost directly backwards, while those on the head are directed more or less forwards. Between these two extremes, all the intermediate positions occur in regular order.

* Structure and Appendages of Trinucleus, C. E. Beecher. This Journal, vol. xlix, April, 1895.

The gnathobases, or coxopodites, become more and more specialized anteriorly, growing broader and having their inner edge denticulate, until on the head they function as true manducatory organs. The second pair, however, corresponding to the mandibles of higher crustacea, has not become clearly differentiated from the rest of the series, and apparently has not lost the exo- and endopodial branches.

Few changes of importance can be traced in the exopodites, though the latter are considerably reduced in size on the cephalon. Over the anterior half of the thorax, they functioned as vigorous paddles, and on the pygidium their length and compact arrangement made them overlap each other, thus producing two broad flaps, or fin-like organs. The conclusion cannot be avoided that *Triarthrus* must have been an active creature, and with its rows of endopodites and exopodites it was as fully equipped as the bireme in classic navigation. The form of the animal and the multiplicity of locomotor organs were well adapted for rapid motion either along the sea-bottom or through the water.

The youngest and most immature limbs are on the pygidium, and in a young trilobite they are very much like those in the larval *Apus*[4] and are typically phyllopodiform. According to the law of morphogenesis, these limbs may be taken as of phylogenetic value and indicative of the primitive type of limb structure.

The whole series of endopodites anterior to the last two or three show modifications from the phyllopodous type, the change involving progressively from one to all of the endites. The endopodites of the pygidium have a true phyllopodiform structure, and are composed of broad leaf-like joints, wider than long. This character is gradually lost in passing anteriorly, the distal endites being the ones first affected. By the time the anterior pygidial limb is reached, the three distal joints are longitudinally cylindrical. The ninth thoracic endopodite shows a fourth endite becoming cylindrical, and on the first and second thoracic legs even the proximal ones are thus modified, making all the endites of these limbs slender in form.

This gradual modification of a phyllopodiform swimming member into a long, jointed, cylindrical, crawling leg deserves more than passing notice, for here, probably, better than in any known recent form can the process and its significance be studied. No living type of crustacean more nearly conforms to the theoretical archetype of the class than do the trilobites, and as *Triarthrus* belongs to an ancient Cambrian family, it may be expected to retain very primitive characters.

In this genus several causes evidently influenced the modification of the appendages. First may be mentioned the specialization into oral organs of the gnathobases of the head, which would tend toward a reduction of the other portions of the limbs. Next, the assumption of a walking habit would gradually lead to a corresponding adaptation of the anterior thoracic endopodites, this region of the body being naturally the place where they would be most operative. Lastly, any tendency to change the form of the anterior limbs would be accelerated through the greater number of moults they undergo as compared with the abdominal appendages.

Since the anal segment of crustacea contains the formative elements out of which all the trunk segments are successively developed, it may be considered as the same segment in all crustacea, no matter how many nor what kinds of segments may intervene between it and the head. The youngest segment, therefore, is always in the budding zone, just in front of the telson, or terminal somite, and those further anterior and more differentiated are older. This sequential order in the age of the segments and appendages may be greatly obscured in higher forms, so that, as in the Thoracostraca, the last pair of pleopods, forming with the telson the caudal fin, appears at an early stage of the ontogeny. In such cases, as Lang says, "the grade of development and physiological importance of a section of the body or of a pair of limbs in the adult animal may be recognized by the earlier or later appearance of their rudiments."*

In *Triarthrus*, these disturbing factors are hardly to be recognized, for no pair of limbs had an excessive physiological importance over any other pair or series of pairs, and increase progressed regularly by the addition of new members in front of the anal segment. The pygidium being formed of fused segments accommodated itself to this kind of growth by pushing forward the series of limbs and by the formation of a new free segment at the posterior end of the thorax. This process of metameric growth continued from the protaspis stage with no free thoracic segments, and successively added segment after segment with corresponding moults, until the full complement was reached, after which the moulting resulted mainly in increase in size. The repetition of moults afforded the chief means by which modifications in the appendages could be brought about.

The earliest protaspis stage shows, from the segmentation of the axis, that there were present five pairs of appendages on the head and two on the pygidium.[6] The adult animal has thirteen or fourteen free thoracic segments and six pygidial.†

* Text-Book of Comparative Anatomy, English edition (Bernard), p. 410.

† A few individuals of this species (*T. Becki*) have been observed with one or two additional thoracic segments. Walcott.[11]

Now, so far as is known of trilobite ontogeny, there was never more than one segment added at a single moult, though there is no evidence that there may not have been more moults than segments between the protaspis stage and the finished segmentation. In *Triarthrus*, the average full number of segments was attained by the time the animal reached a length of about 7^{mm}. So that the limbs of the anterior thoracic segment in an individual 7^{mm} in length, and containing the full complement of fourteen free and six pygidial segments, must have undergone at least seventeen moults. The second thoracic segment, therefore, at this stage of growth would have been moulted sixteen times, the fifth thirteen times, the tenth eight times, and the fourteenth four times. The length of full-grown individuals is from 25 to 40^{mm}, and to have reached this size a considerable number of additional moults must have occurred, in which all the segments participated alike.

Some mention should be made of the probable method of respiration of *Triarthrus.* No traces of any special organs for this purpose have been found in this genus, and their former existence is very doubtful, especially in view of the perfection of details preserved in various parts of the animal.

The delicacy of the appendages and ventral membrane of trilobites and their rarity of preservation are sufficient demonstration that these portions of the outer integument were of extreme thinness, and therefore perfectly capable of performing the function of respiration. Similar conditions occur in most of the Ostracoda and Copepoda, and also in many of the Cladocera and Cirrepedia, where no special respiratory organs are developed.

The fringes on the exopodites in *Triarthrus* and *Trinucleus* are made up of narrow, oblique, lamellar elements becoming filiform at the ends. Thus, they presented a large surface to the external medium, and partook of the nature of gills. But, as Gegenbaur says, " the functions of respiration and of locomotion are often so closely united that it is difficult to say whether certain forms of these appendages should be regarded as gills, or feet, or both combined."* For purposes of locomotion, the limbs of the cephalon and pygidium were of feeble assistance compared with those on the thorax, and in the higher crustacea, these two regions are the ones where the greatest branchial specialization takes place.

Yale Museum, New Haven, Ct., February 24th, 1896.

* Elements of Comparative Anatomy, English edition (Bell and Lankester), p. 241.

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3. ——— 1894.—On the mode of occurrence, and the structure and development of Triarthrus Becki. American Geologist, vol. xiii, pp. 38–43, Pl. III, January. Abstract of a paper "On the Structure and Development of Trilobites," read before the National Academy of Sciences, November 8th, 1893.
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Explanation of Plate.

Figure 1.—*Triarthrus Becki* Green; dorsal view; showing character and extent of antennules and limbs beyond the carapace. × 2½.

Figure 2.—*Triarthrus Becki* Green; ventral view; showing entire series of appendages, together with hypostoma, metastoma, and anal opening. × 2½.

Utica Slate, Ordovician, near Rome, New York.

ART. XXX.—*An examination of the arguments given by* NEUMAYR *for the existence of climatic zones in Jurassic times;* by ARNOLD E. ORTMANN.

IN a recent publication (Principles of marine Zoogeography)* the present writer incidentally indicated the reasons why Neumayr's theory of climatic zones in the Jurassic period cannot be accepted as correct. It may be allowed to enter into details in the present article, since my views differ so widely from these of Neumayr, and especially since many prominent geologists have adopted his views more or less completely.

It is very important to examine closely the arguments of Neumayr himself and his defense against the objections made by other scientists. Although the arguments are collected in a special paper (1883), the detailed palæontological investigations and the conclusions derived from particular cases are scattered through a large number of publications, and therefore it would be perhaps desirable to give here a list of the papers referred to.

1871. Jurastudien, 5. Der penninische Klippenzug.—Jahrb. K. K. Geol. Reichsanstalt, vol. xxi, p. 503–526.
1876. Die Ornatenthone von Tschulkowo und die Stellung des russischen Jura.—Benecke's geogn. palæont. Beitræge II.
1877. Bemerkungen über den russischen Jura.—Neues Jahrb. Min. Geol. Pal. 1877.
1883. Ueber Klimatische Zonen wæhrend der Jura—und Kreideperiode.—Denkschr. K. K. Akad. Wiss. Wien., vol. xlvii.
1885. Die geographische Verbreitung der Juraformation.—ibid., vol. l.
1887. Ueber die Beziehungen zwirchen der russichen und westeuropäischen Juraformation.—Neues Jahrb. etc. 1887, 1.†
1890. Kritische Bemerkungen ueber die Verbreitung des Jura.—ibid. 1890, 1.
1890. Erdgeschichte, vol. II.

The supposition, that in the Jurassic time climatic zones were developed on the earth, was first made by Marcou, but it attracted no attention until Neumayr attempted to prove this theory by palæontological and geological evidence. The demonstration given by him proceeds in the following manner.

He investigated the different faunas, especially of the middle and upper Jura in the different localities of Europe, and

* Grundzüge der marinen Tiergeographie, Jena, 1896, p. 62, 63.

† This is a reply to a paper under the same heading published by Nikitin in 1886 in the same periodical.

discovered, mostly in the groups of cephalopods, certain peculiarities of distribution, consisting chiefly in the presence of certain genera (*Phylloceras*, *Lytoceras*, *Simoceras*) in the southern European deposits, but wanting or represented only rarely in the deposits of the other parts of Europe. The northern boundary of this southern province, the Mediterranean, follows, generally speaking, the course of the Alps and Carpathian mountains. In the other parts of Europe, the Jurassic deposits of England, France, Germany, Poland, show further differences from those of Russia; the former, the Middle-European province, possesses peculiar cephalopod-genera, such as *Oppelia*, *Aspidoceras*, while in the latter, the Russian province, these are nearly wanting and other animals are here abundantly developed, such as species of the group of *Belemnites excentricus*, and of the Lamellibranchiate-genus *Aucella*.

Neumayr resolved to investigate the causes of these apparent faunistic differences of strata formed at the same times, and his considerations are the following. Such differences may be due either to topographical causes, such as separation of the relative basins by land, or as differences of facies or depth of the sea; or they may be due to climatic causes. Believing further, to have demonstrated the impossibility of the action of such topographical causes as named, he concludes that the only remaining way for explaining the existing differences is by supposing that climatic differences of the sea are responsible for them. This supposition is strengthened, according to him, by the situation of these "provinces," being limited each to a circumpolar zone around the earth.

An investigation of Neumayr's views is therefore divided conveniently into three separate parts: 1. An examination, whether differences of the faunas are really present; 2. An examination, whether the proofs given for the impossibility of the action of topographical causes are sufficient; 3. An examination, whether the circumpolar zones are confirmed in a satisfactory manner.

But, before this, we have to decide a preliminary question: whether the groups of animals investigated by Neumayr give us a guarantee that their distribution is able at all to indicate climatic differences. Further, in conclusion, we will demonstrate that many additional objections can be made to the climatic zones of the Jura, even if their existence is supposed to be granted.

I. The group of animals, the fossil remains of which are most especially studied by Neumayr, and from the distribution of which his arguments are taken, is that of the Ammonites. This group is extinct in the recent seas; the now living

Nautilus only is in some way related to it, but we have reason to suppose that the habits of the Ammonites were generally the same as in Nautilus. From the latter animal recently J. Walther * has inferred a peculiar fact in regard to the Ammonites, namely that the living animals were restricted in their distribution to narrow limits within the littoral district of the sea, but that after the death of the animal the empty shell, provided with air chambers, rose to the surface of the sea and was transported by wind and currents. Thus the shells were dispersed all over the earth and were deposited as fossils in parts where the living animal did not exist. According to this peculiarity, he says that the Ammonites are true "characteristic fossils," as they are to be found in all the deposits of the same time on the whole earth.

This supposition is without any proper foundation, even in case the Ammonites possessed the same habits as Nautilus. The living Nautilus is *not restricted* to a limited range, as supposed by Walther (l. c. p. 513.) It is true, the living animal has been found up to the present time only in a few localities, but even these localities, scattered in the Pacific Ocean,† indicate a more extensive distribution within this area, and I may add, that I have ample reason for believing that the living Nautilus is also an inhabitant of the eastern coast of Africa.‡ This distribution would not be strange; on the contrary, the range of Nautilus would be in accordance with that of the other animals belonging to the littoral Indo-Pacific fauna. Further, the empty shells of Nautilus occur only in the Indo-Pacific Ocean, the statement made by Walther (l. c. p. 513), that their distribution is an universal one, being incorrect, and thus the distribution of the shells does not occupy a wider area than that of the living animal. On the

* Einleitung in die Geologie als historische Wissenschaft II. Lebensweise der Meerestiere 1893, p. 509ff.

† For instance: Amboina, New Guinea, New Hebrides, New Caledonia, Fiji Islands.

‡ During my stay on the east coast of Africa I collected positive information about the existence of living Nautilus near the harbor of Dar-es-Salaam. I was shown two very fresh specimens of the shell, and the owner of one of them told me, without being asked, that he found the shell on the beach after a high tide with an animal inside, which he had much difficulty in extracting. Hearing from me that the animal was a very valuable one, he was sorry not to have preserved it, and farther on, he spent his leisure time in search for another specimen, and that without my knowledge, apparently intending to sell it to me if possible. He was not successful. I trust wholly in the correctness of his information, as I received others from him regarding zoölogical objects which proved to be trustworthy. Later on I found out that the animal is generally known among the negro fishermen living on the beach. According to their own words, it lives "kisiwani," ("among the islands," situated off the coast), and in "maji mingi" ("deep water," for the coast-negro 10 to 20 fathoms are "deep water"). The animal is not rarely captured by them, but it is always thrown away as of no use for them.

other hand, if the alleged transportation of the empty shells of the Ammonites over the seas should be correct, we ought to observe actually a world-wide distribution of the fossil Ammonite-species, but this is not the case. Some species indeed are found in the same zone all over the European Jura, and some of them are found even in extra-European localities, but this fact can never be a proof of the universal distribution of the Ammonites in general. On the contrary, most of the species are found only in limited localities and almost every locality has its peculiar species. Whoever is occupied in determining the different species of Ammonites and is familiar with the systematic diversity of this group, ought to know the local restriction of most of the species.*

Neumayr, on the contrary, is inclined to regard the Ammonites as animals swimming on the surface of the sea, as belonging to the pelagic fauna (see Erdgeschichte, 1890, p. 270). It seems that he was not aware that this supposition is very dangerous to his theory. I do not want to deny that the possibility must be granted, that perhaps some species or genera of Ammonites belonged to the pelagic fauna, as well as that some of them lived perhaps in abyssal depths of the sea; but by the actual distribution of these fossils I am convinced that by far the greatest number of Ammonites lived as benthonic animals in the moderate depth of the littoral, and in this point I agree with Walther (l. c. p. 515). But further I am convinced that they lived even in these places where now their shells are found in the fossil state. It may be that the empty shells could be transported in the manner mentioned, but such a transportation could not take place over large tracts of the seas, and could not be the normal condition of things; otherwise the actual distribution of the species of Ammonites would be entirely different.

From the foregoing considerations we have to conclude that the Ammonites can furnish us with sure evidence for the existence of faunistic differences, as Neumayr has indicated.

I have still to make some remarks on the Reef-corals alluded to now and then by Neumayr. Contrary to the Ammonites, he tries to abate the value of the proof given by the Reef-corals in regard to the former climatic conditions. Generally we are wont to conclude from the recent exclusive distribution of the Reef-corals in the tropical seas, that the fossil Reef-corals also lived in seas of a tropical climate. Neumayr, however, urges on several occasions that we have no sufficient reason for so doing, since Reef-corals may have

* Already Tornquist (Fragmente einer Oxford fauna von Mtaru.—Jahrb. Hamb. Wiss. Anst. X. 2, 1893, p. 24) calls Walther's hypothesis an "incomprehensible" one.

lived in former times in cooler water. In this point, I believe, Neumayr's view is incorrect. We are justified in supposing that animals living in cooler water are to be traced back to such ones living in the tropics in former times, that is to say, the adaptation to a cooler climate is a more recent acquisition. But it is very improbable that animals living originally in cooler water migrated back into the tropics, because they would find there a most dangerous concurrence in the struggle of life by the well adapted tropical fauna, while they themselves were not so well fitted for the tropical conditions. Therefore the stenotherm Reef-corals living nowadays exclusively in the tropics and showing no traces of existence in the cooler seas, were most probably stenotherm tropical animals also in former times. If in any groups of animals, we have surely in the Reef-corals sufficient reason for arguing from the recent conditions to the former ones; especially is this the case in the Mesozoic corals, since these are the direct ancestors of the Tertiary and recent corals.

II. The palæontological foundations of Neumayr's theory, taken principally from the Ammonites, are the following: The Mediterranean province is characterized by the most general and frequent presence of the genera *Phylloceras*, *Lytoceras*, and *Simoceras* in all the cephalopod-beds, and a very peculiar deposit of this province are the Aptychus-beds. Both the genera just mentioned and the Aptychus-beds are either very rare or wholly wanting in the Middle-European province. The latter, however, shows often a local development of Sponge-fields and Coral-reefs, connected with the abundance of certain gasteropods, such as *Nerinea.* On the other hand the genera *Oppelia*, *Peltoceras*, *Aspidoceras*, very frequent in middle Europe, are very rare in the Russian province and the same is the case in the Reef-corals. In the latter province again the genus *Cardioceras*, the group of *Belemnites excentricus*, and certain bivalves, such as *Aucella* (Aucella-beds), prevail.

These differences cannot be overlooked. Nikitin, indeed, attempted to reduce these differences for the Russian Jura, and in some instances, for example as regards the genus *Cardioceras*, he is right (l. c. 1886, p. 232); but his statement, that there prevails an equal fauna throughout the Russian and West-European Jura is at least an exaggeration. According to the lists of fossils given by him, the differences mentioned by Neumayr are certainly present. On the other hand, Nikitin proved the existence of Reef-corals in the Russian province, and although these corals occur only in a few localities, and although Neumayr does not notice properly this point in his reply to Nitikin's objections, regarding the presence of these animals as not conclusive, we must regard this point as very important, as we shall see below.

III. Neumayr continues in his argument by attempting to prove that these faunistic differences cannot be due to *topographical* causes. First he says that these three provinces could not be separated from each other by land. This relates especially to the limits between the Mediterranean and Middle-European provinces, while for the Middle-European and Russian provinces it was only partially the case. In the latter, at the formation of the Callovien-beds, first there was an open communication of the seas, later, after the Oxford-group, the Russian basin was closed on the west. We make no objection to this part of Neumayr's views.

Further Neumayr says that a second cause of a separation can be found in the different depths of the respective seas. Between the Middle-European and the Russian seas such differences are out of the question, because both were seas of shallow water. Between the Middle-European and Mediterranean provinces, however, differences of depth were certainly present. At least as regards the *Aptychus*-limestones, it is sure and generally accepted, that these peculiar deposits were formed in deep water, and further, Neumayr himself concedes that such a supposition has a "certain probability" (1871, p. 523) also for the subcarpathian and subalpine localities showing the peculiar Cephalopod-beds of the Mediterranean Jura, since the situation of the latter is an intermediate one between the Aptychus-beds on the one side and the Middle-European deposits on the other "formed in considerably shallower water." In spite of this, he believes that this supposition is not justified, since in some localities on the northern border of the Mediterranean province, especially near Stramberg in Moravia, where the Coral-reef facies prevails, among the Ammonites the typical Mediterranean genera, *Phylloceras* and *Lytoceras*, predominate. Therefore he concludes (1871, p. 524): because on certain localities on the northern border of the Mediterranean province corals are found in Cephalopod-beds, differences in depth of the sea cannot be the cause of the faunistic differences of the Mediterranean and Middle-European Cephalopod-beds.

This conclusion is incorrect. From the condition of the Stramberg-strata we learn only, that there is a mixture of the Coral-facies and the Mediterranean Cephalopod-facies.* Neu-

* Mojsisovics stated once (Verhandl. K. K. geol. Reichsanst, 1867, p. 187, 1868, p. 127 and 438) that even in this locality the Cephalopod-beds and the Sponge and Coral-beds are not mixed up, but that the former underlie the latter. But

mayr gives no explanation of this peculiar mixture. Regarding, however, the local position of these beds, quoted by himself, on the narrow limits between the Middle-European and Mediterranean Jura, that is to say, between the deposits formed in shallow water and those formed in deeper water (Aptychus-beds), we must assume undeniably that in this region in question the precipice of the sea bottom must have been situated : *a Jurassic Continental border* must have been present there! Then there are only three cases possible. Either the Mediterranean Cephalopod-facies is present there in shallow water, as Neumayr seems to suppose. Or the Coral-reefs grew there in deep water, which is very hard to believe. Or there was present a third condition, namely, the Cephalopod-beds of Stramberg were deposited like the other Cephalopod-beds of the Mediterranean province in deep water, but the corals and other fossils indicating shallow water did not live there, but were transported thither. Such an occurrence can be imagined the easier, since these beds are situated on the continental border, and if the precipice of the sea bottom was a steep one, Coral-fragments from the Coral-reefs living in an upper level, and specimens of the other shallow-water-fauna could roll down to the bottom situated in a lower level and could be deposited in the Cephalopod-beds formed there. That such conditions were actually present in that locality is confirmed by the petrographic nature of the Stramberg-limestone, as described by Böhm (l. c. 660). According to him this limestone often may be called a breccia, and, indeed, respecting one place he says: "Angular, larger or smaller fragments of a light gray limestone are embedded here in a dark gray to pitch black matrix. *The light gray limestone is filled with Corals,*" ("ist von Korallen fœrmlich durchspickt.") *

We need no more evidence for the supposition made here. The conditions of the Stramberg-beds, quoted by Neumayr as adverse to the theory of a formation of the Middle-European and Mediterranean Cephalopod-deposits in different depths of the sea, prove to be a support of this theory when we consider the situation of these beds and their petrographic character.

Besides there is a third topographical cause, which may be held responsible for differences of faunas deposited at the same time: the different characters of the facies. Neumayr alludes to this point only incidentally, and generally he passes over it without giving it due consideration. Concerning the Mediterranean and Middle European provinces he says

this fact lacks confirmation. According to Böhm (Die Bivalven der Stramberger Schichten.—Palæontographica, Suppl. II. 4. 1883 p. 660-662) the different faunas are really found in the same rocks.

* The italics are mine.

directly (1871, p. 521), that there are present palæontological differences between deposits of both "with the development of facies and conditions of formation apparently in complete agreement" ("bei offenbar ganz übereinstimmender Facies-entwicklung und Bildungsverhältnissen"). The facies of these two provinces are, according to him, "apparently" the same, but he does not give any proof for it. It is true, limestone-facies prevail in both, and it may be that Neumayr thought of this fact. There is, however, no doubt that all the known limestone-deposits were not formed under the same conditions; the Coral-limestones and the Cephalopod-limestones of the Middle-European province are certainly different facies; the Aptychus-limestone of the Mediterranean province is characterized by its petrographic nature (Hornstone limestone) due to the presence of silicious matter, and the Cephalopod-limestones of the latter province are also probably different. It is well known that all these deposits are different petrographically, and after a more close, especially microscopical examination, we will be, perhaps, enabled to find out the causes of their differences.

Yet we do not need much to urge these differences in these two provinces, as we saw above that the main differences are given by the different depths of the respective seas. To distinguish the Middle-European and Russian provinces, however, we have to direct more attention to the facies. The differences of the facies in the two latter provinces are wholly neglected by Neumayr, although they were pointed out most vigorously by Lahusen * and Nikitin.

It was a well known fact, even to Neumayr, that in the Middle-European province limestones prevail, especially if we consider the upper strata (1890, p. 316), while in the Russian Jura "more soft clays and sands" (p. 326), and only "in an inferior degree limestones" (p. 327) are found. This prevalence of sandstones, especially in the Aucella beds, is stated by Lahusen several times (l. c. p. 486, p. 491, p. 492), and Nikitin (l. c. 1886, p. 211, p. 237) even holds this peculiarity of the facies responsible for the faunistic differences. It is further a very interesting fact given by Nikitin (p. 217, p. 234, p. 236), that corals are found in some places of the Russian Jura, and these are true Reef-corals belonging to the *Thamnastrœidœ.* Neumayr refers (1887, p. 72) to this statement only by saying, that the occurrence of corals in Russia is "very rare," and that (p. 73) against the view that conditions of the facies play part here "grave doubts exist" ("schwere Beden-

* Uber die jurassichen Bildungen im südwestlichen Teile des Gouvernements Rjäsan.—Neues Jahrb. Min. Geol. Pal. 1877.

ken gegenüberstehen").* The statement of Nikitin, however (p. 232), that calcareous deposits are almost absent in the Russian Jura, but that where such are exposed corals are found, induces us to accept a causal connection between the two facts. The occurrences of corals is connected with a calcareous development of the facies, and in the Russian Jura, according to the prevailing sandy nature of the deposits, only local formation of Coral-reefs and limestone-deposits was possible.

The fact that the Aucella-beds are mostly sandy deposits strengthens this supposition so much more, as these beds are wanting in the limestone-facies of Middle-Europe. Thus we are amply justified in looking at the differences in the character of the facies as the cause producing the faunistic differences of the Middle-European and Russian provinces even in the Ammonite-fauna.

By these considerations, I think, I have proved that the argument given by Neumayr for the non-existence or non-action of topographical differences upon the distribution of the Jurassic faunas is a complete failure. Only one point may be granted, that a separation by land was not present in an extensive manner. On the other hand we have learned that it is in the highest degree probable, that on the one side differences of depth of the seas, on the other differences of the facies, are the laws governing the faunistic differences. The first cause applies especially to the distinction of the Mediterranean and Middle-European provinces, the second to that of the Middle-European and Russian (Boreal) provinces.

IV. We have still to examine the third point in Neumayr's argument. As a corroboration of the climatic nature of the differences of the Jurassic faunas, he points to the distribution of the different provinces on the earth, which he alleges to be generally parallel to the equator all around the earth, thus forming circumpolar zones. This is the weakest part in Neumayr's view, especially because most of the extra European Jurassic deposits are very unsatisfactorily known, and because Neumayr himself was already acquainted with some localities contradicting his theory.

Neumayr attributes some significance to the supposed fact, that in South Africa and South America Jurassic deposits are said to be present, corresponding in their characters to the

*In his latest rejoinder to Nitikin (N. J. M. G. P. 1890, 1, p. 142) Neumayr refers to his former paper (1887) as having shown that differences of this kind were not to be held responsible for the faunistic differences. But he did not even attempt to prove this assertion in that paper.

Middle-European features, thus indicating a similar (temperate) zone on the southern hemisphere. But he himself gives different opinions concerning these localities: once (1890, p. 330) he says, that the so-called Uitenhaage-formation, near Port Elizabeth, Cape Colony, has a fauna of Middle-European "habitus," and again (p. 333) he says, that the same formation has relation neither to the tropical African localities nor to those in Europe, while relations to some localities in East India (!) and South America (in the Andes of Chili) are apparent. All we know of the latter locality* is that there are present species of *Phylloceras*, *Lytoceras*, and *Simoceras*, thus showing a more likely relation to the Mediterranean than to the Middle-European Jura, as supposed by Neumayr. At present, indeed, we may better disregard all these localities, as our knowledge of them is very incomplete.

Further, Neumayr himself concedes the Middle-European character of the Jurassic deposits of the Hermon, Syria. This occurrence, so absolutely opposed to his theory of climatic zones, he tries to explain in a very forced manner, supposing arbitrarily a southern local extension of the Middle-European Jura into the equatorial zone. We may add here that the Jura of Cutch, India, is regarded by Waagen as Middle-European, while Neumayr claims it as Mediterranean.

In this respect a recent paper of Tornquist,† treating a Jurassic locality on the eastern coast of Africa, near the equator, is very interesting. Tornquist says (p. 23): "As far as we know the fauna of Mtaru, it must be regarded surely as being of Middle-European character." Thus we would have there, near the equator, a Jurassic fauna, which, according to Neumayr, can only be found in much higher geographical latitude. As the fauna of Mombassa, situated in the neighborhood of Mtaru, shows relations to the East Indian localities, which are according to Neumayr Mediterranean, we have there, on the eastern coast of Africa, Jurassic deposits of either character closely approaching. Further, if we consider that Tornquist makes mention (p. 7, p. 25) of a peculiar facies of the strata of Mtaru, suggestive of the so called "terrain à chailles" in Middle-Europe (limestone-concretions in marl-deposits), we are again led to the opinion that differences of the facies take part in making up the faunistic differences.‡

*See Gottsche, Ueber jurassische Versteinerungen aus der argentinischen Cordillere.—Palæontographica, Suppl. III. 1878.

† Fragmente einer Oxfordfauna von Mtaru.—Jahrb. Hamburg, Wiss. Anst. X. 2, 1893.

‡ We may quote here the following interesting remark of Tornquist (p. 25): "It seems that there is repeated the fact which is known in the Jura of the different countries and which is always equally astonishing, namely, that even over great distances a faunistic agreement of the different zones of the Jura can be accompanied by a lithological one."

The tracing of the different Jurassic zones around the other parts of the earth, especially across the American continent, is so problematic, that it is not worth while to go more into details here.*

The instances, however, given above are wholly sufficient to conclude, that a circumpolar arrangement of the different Jurassic faunas is not yet proved ; on the contrary, that some facts are known wholly dangerous to that theory.

V. But even in the case, that it may be granted, that it is neither proved nor refuted, whether the differences of the Jurassic faunas are due to topographical or to climatic causes, and even if we suppose that the action of the latter may have been possible, we will find that such a supposition meets difficulties hard to solve.

1. As we have seen above, Nikitin recognized the presence of Reef-corals in the Russian Jura, that is to say, in Neumayr's *Boreal* zone. Neumayr indeed denies the value of the Reef-corals as evidence for forming an opinion as regards the temperature of the sea water, but as I pointed out above, the Reef-corals are the only group of animals allowing a somewhat sure conclusion as to the former climatic conditions, and I can not strongly enough emphasize that I differ in this respect entirely from Neumayr. Therefore, I am convinced, that the presence of Reef-corals indicates a warm, and especially an equally warm temperature of the seas inhabited, such as now prevails in the tropical seas. If such a temperature was present in the *boreal* Russian basin, we have to ask : what kind of temperature-conditions prevailed in the *temperate* and *equatorial* zones of the Jurassic time? Then we would be induced to believe, that the equatorial seas of the Jura possessed a degree of heat which, compared with the recent conditions, would not have permitted at all the existence of animal life!

2. If we compare the temperature zones of the recent seas † with the supposed temperature zones of Jurassic age as constructed by Neumayr (1890, p. 336), we shall find that the latter are nearly the same as the former, at least as regards their distance from the equator. Even in some cases in Neumayr's map such places belong to a cooler zone, which are nowadays warmer. For instance, New Zealand and Port Elizabeth are situated in his map distinctly in the temperate

* The occurrence of Aucella-beds like the Russian is indicated by Nikitin (Neues Jahrb. Min. Geol. Pal. 1890, II. p. 273) in tropical America, near St. Luis Potosi, Mexico. If this fact should be confirmed, it would prove an additional argument against Neumayr's theory.

† See the map accompanying my book : Grundzüge der marinen Tiergeographie.

zone, while they lie now, if not within the tropical zone, at least on the border of it. An arctic zone can be distinguished in the present seas only with difficulty from the temperate zone: Neumayr's *boreal* zone extends so far southward, that it is hard to believe that it existed at all.

According to our knowledge of the climatic conditions of former times, especially of the Tertiary age, there was a gradual decreasing of the temperature of the earth, beginning at the poles, and we are accustomed to believe that the climatic conditions now prevailing form the most extreme degree of cooling ever present on the earth. Then it would be impossible, that at any time in the past a climate existed which was cooler or was more differentiated than the present climate.* Especially, we can not make such a supposition for the Jurassic age, passed by long ago, and the climatic conditions of Neumayr's map agreeing with the recent ones are utterly impossible. This striking improbability is the more conspicuous as we compare the supposed Jurassic climate of Neumayr with that of the older Tertiary times, as I have already done elsewhere.†

In the passage just referred to I remarked, that Neumayr perhaps intended to express no judgment of the actual temperatures at Jurassic times, but that he had in mind only that a *difference* in temperature was present. But then we would be induced to accept for his boreal zone a climate like that of the recent tropics, and we would be confronted with the same difficulty as discussed under No. 1.

3. Remembering the climatic conditions of the recent times we find, that climatic limits generally are not very sharp, but that there are zones of transition interposed. The limits of Neumayr's Mediterranean and Middle-European provinces are very sharp, so that we can not expect that there prevailed normal conditions. Neumayr himself is aware that these limits are unusually sharp ones, and he explains this fact by supposing that there was a current of warm water present. This supposition, however, is a pure imagination, supported absolutely by nothing.

4. But we will examine this current-theory more closely. Neumayr says (1871, p. 525), that this current coming from the South-West reached in the neighborhood of Cracow its most northern point, and curved then in a south-easterly direction—or the course of this current was in the opposite direc-

* Perhaps one would refer to the conditions of the "ice age" as representing the most extreme cooling: but I remark explicitly, that I regard the so called "ice age" as a local feature of the subrecent time, which is not at all related to the general cooling of the earth.

† Grundzüge der marinen Tiergeographie, 1896, p. 62, 63.

tion. Such a current is according to his map hardly possible. The course in the direction first mentioned is impossible, because no conditions in the configuration of land and sea were present there which could effect a current in this direction (like the Kuro-Siwo and Florida current of recent time). The alleged curve of the current at its most northern point would be also astonishing: why does this current not carry its warm water farther northward into the Russian province? If it went in the opposite direction, we must ask: where did it come from, and what was the cause producing such an abnormal movement of water in a direction never displayed by any important current of the recent seas? And a current effecting such striking and sharp differences of temperatures must necessarily have been an important one!

I think, however, there is no profit in trying to construct the ocean currents of Jurassic age. But if we adopt the configuration of land and sea given in Neumayr's map, there can be no doubt, I believe, that only *one* kind of movement of the surface water of the sea was possible in all these parts under discussion, namely a general current running from East or North-East to the West or South-West. Then from the Russian basin a cool current would run into the Middle-European and Mediterranian provinces, and the course of the northern limits of these two provinces should be very different from that given by Neumayr. These limits could not show a convexity toward the North just opposite the main opening, through which the cool water was discharged, but we should expect a southward curve of these lines.

Under such conditions of things, since it is at present utterly impossible to get an approximate idea of the Jurassic currents, it would be profitable to have recourse to such theories only in the most desperate cases, where no other explanation is possible.

The results obtained by these considerations may be summed up as follows. The differences observed in the faunas of the Jurassic deposits are not caused by climatic differences. The arguments of Neumayr for the non-action of the topographical conditions are partly incomplete, partly they fail to convince. On the contrary, I have shown, that even conditions of the latter kind, differences of depth of the seas and differences of the facies play the chief part in influencing the distribution of the Jurassic fauna, and that the existence of climatic zones in the Jurassic seas is not only not proved, but extremely improbable. Therefore it would be well to abandon entirely Neumayr's theory of climatic zones in Jurassic time,* and it would

* In order to prevent any misunderstanding, I wish to say expressly, that I do not deny the existence of changes in temperature and differences in climate in

be more profitable to examine closely the differences of the facies of this time, especially the question, how the different facies are deposited, and how the different groups of animals are influenced by the facies. There is no doubt that for this purpose we have to compare the fossil deposits with those formed in the recent seas. This latter method is the way outlined by J. Walther in his work: "Einleitung in die Geologie als historische Wissenschaft," and it would be very advantageous to direct more attention to this subject in subsequent geological studies.

Princeton, N. J., January, 1896.

pre-Tertiary times. But such changes and differences of the *ocean-waters* were only slight ones, not differing from those present nowadays within the tropical seas, and not influencing the distribution of animals. On the other hand, the *air-temperatures of the continents* changed even in pre-Tertiary times in proportion to the size of the continental masses to the elevation and to the geographical latitude. Perhaps they did so in a lesser degree than at present, but this difference of the oceanic and the continental conditions of temperatures was almost as striking as it is nowadays between the temperatures of the recent tropical seas and those of the high mountain-chains and table-lands of the tropical parts of the recent continents.

ART. XXXI.—*On an Occurrence of Theralite in Costa Rica, Central America;* by J. E. WOLFF.

AMONG a series of rocks collected by Prof. R. T. Hill in 1895 in a reconnaissance of the Isthmus of Panama and Costa Rica made in coöperation with Mr. Alexander Agassiz, was one small specimen occurring as an intrusion through the Tertiary rocks of the Atlantic slope of the Costa Rican volcanic plateau. Of this specimen Mr. Hill says: "The rock is pushed up through the Upper Oligocene strata [limestone] and hence its age is Miocene or later." According to his diagram, it occurs as a large mass cutting across the bedding of the limestone.

The rock has the typical spotted dark gray color of the Montana theralite with distinct crystals of augite, biotite and rounded areas of radiating zeolites.

In thin section the rock is composed of augite, triclinic feldspar, sanidine, nepheline, a mineral of the sodalite group, olivine, biotite, magnetite, apatite, and abundant zeolites. The augite occurs in imperfect prisms with both pinacoids and terminal planes; it has a pale yellowish-green color with marked zonal structure and an extinction of 43° on the clinopinacoid. In a large section cut across the prism the inner lighter green core has the orthopinacoidal cleavage alone developed, while the outer zones have the usual double prismatic cleavage alone developed, showing an apparent relation between the development of these cleavages and the chemical composition. Ægirine as an outer border or separate from the augite is entirely wanting. The few imperfect crystals of olivine are entirely serpentinized. The biotite occurs in hexagonal plates; the apatite and magnetite require no special description.

The feldspar is the most striking constituent in comparison with the Montana theralite, for the larger part shows multiple twinning on the albite law, with rarely a pericline lamella; even apparent Carlsbad twins are found by optical study to be on the albite law analogous to the well-known occurrence of albite itself in the crystalline schists, and the Carlsbad law seems to be wanting. By means of the Federow universal stage a number of these feldspar sections were brought into the zone of optical symmetry and by revolution on the second horizontal axis the maximum negative extinction of this zone determined at between 26° and 27°*; the feldspar is therefore a labrado-

* The use of this instrument is especially helpful in such cases where the use of the excellent methods of Michel-Lévy (combination of the albite and Carlsbad laws) or of Fouqué (bisectrix sections) is impracticable. Prof. Fedorow has rendered a service to petrographers comparable to that of Goldschmidt, himself and others to crystallography in the invention of the theodolite goniometer.

rite of the composition Ab^1An^1. A few sections of untwinned feldspar have an index of refraction inferior to that of the balsam, a small axial angle, and are therefore probably orthoclase.

The mineral of the sodalite group occurs exactly as in the Montana rock in little crystals enclosed in the feldspar, with a dirty blue color, isotropic character and characteristic square or hexagonal outlines. The nepheline is in small stout square prisms, generally in clusters or enclosed in the feldspar—the usual fibrous decomposition has obscured the original optical properties, but its entire identity in form and characters with the nepheline of the weathered specimens of the Montana rock, leaves no doubt as to its identification. Zeolitization has spread from the nepheline to a large part of the feldspar; most of the zeolites are of the radiating prismatic type, which was not further determined, but there are some patches of analcite.

The main differences from the Montana type are in the absence of ægirine, the distinctly basic soda-lime feldspar and the small amount of sanidine; it probably represents a type poorer in alkalies, but a chemical analysis was considered unremunerative on account of the small amount of material and considerable alteration of the rock. It represents the purest type yet described of theralite as defined by Rosenbusch, namely a soda-lime feldspar-nepheline, plutonic rock.

From the point of view of there lationship of rock magmas this occurrence is extremely interesting, representing as it does a peculiar and rare rock type occurring some three thousand miles from the Montana region, but in a somewhat analogous position both as regards Tertiary age, and location some distance east of the main continental divide. It may be that other occurrences will be found in the future in the intervening region; the nearest representative to theralite known to me in the intermediate distance is the nepheline rock described by Zirkel (in the "Microscopical Petrography of the 40th Parallel") from Fortification Rampart, Elkhead Mts., Colorado, of which more will be said in the forthcoming monograph on the Crazy Mts.

The lack of a chemical analysis makes a comparison from the point of view of identity or difference of rock magmas of less value and weakens the argument which could be based on this occurrence against the localization of rock magmas, while on the other hand it points to a possible southern continuation of the zone of alkaline rocks occurring in the northwestern United States in the east border of the Rocky Mountains.

University Museum, Cambridge, Mass., February, 1896.

ART. XXXII.—*Metamorphism of a Gabbro occurring in St. Lawrence County, N. Y.;* by C. H. SMYTH, JR.

IN the course of a reconnoissance of the crystalline rocks of St. Lawrence County, carried on, during the past summer, for Dr. James Hall, State geologist, the writer examined an area of gabbro which seems of sufficient interest to merit description. The rock affords another indication of the widespread occurrence of gabbro in the Adirondack region, to which attention has been called in a previous paper,* and also shows striking variations in composition and structure, in part primary, but chiefly secondary.

The locality is in the town of Russell, about four miles southwest of the village of the same name, and one-half mile east of the well known danburite locality. The prevailing rock of the vicinity is a massive gneiss, generally with a decided red color. This rock probably bounds the gabbro on all sides, although the limits of the latter were found only on the east and west. The extent in this direction is hardly more than one-eighth of a mile.

It will be convenient to describe, first, the phenomena observed in the field, and then, to consider the petrographic details of the various phases of the rock.

The gabbro and associated gneiss form a short steep ridge, with an elevation of fifty to seventy-five feet, just north of the highway. Even in a rapid examination of the region the gabbro could scarcely be overlooked on account of the marked contrast between its coarser portions and the prevailing country rock. These very coarse parts have a decidedly mottled aspect on weathered surfaces, due to imperfect porphyritic structure, with phenocrysts of feldspar ranging up to three inches in length, surrounded by dark green or black material. A more abundant variety has feldspars seldom extending one-half inch in length, and the porphyritic structure is replaced by a more or less perfect ophitic structure. This phase of the rock may become finer, and may assume a nearly granular structure. At the same time there are variations in the relative proportions of feldspar and ferro-magnesian minerals, with corresponding changes of color. These variations in the rock are all primary and may be summarized as a range in grain from very coarse to moderately fine; in structure from porphyritic to ophitic, and to nearly granular; in color from nearly black to gray. These changes in character take place very suddenly, and

* C. H. Smyth, Jr.—On Gabbros in the Southwest Adirondack Region, this Journal, III, xlviii, p. 54.

the different phases are most irregularly distributed, seeming to conform to no law. The prevailing variety is that having the coarse ophitic structure. In spite of this structure, the rock is classed with the gabbros, rather than with the diabases, on account of its coarseness, the character of its component minerals, and its affinity with other rocks of the region which are undoubted gabbros.

The primary variations in the rock suffice to give considerable diversity to different portions, within a limited area, but this diversity is greatly intensified by certain secondary modifications of structure and composition. As a result of the combined effect of primary and secondary variations, it would be easy to collect, within an area of a few square rods, a half dozen or more specimens whose appearance, even in thin section, would scarcely suggest that they had any connection with one another.

The secondary changes are of two kinds. The first might be classed as degradational in nature, the mineral constituents decomposing, with the formation of reddish masses, blotched with green. These masses are scattered through the unchanged rock very abundantly, and, at first sight, look like inclusions of red gneiss, but on closer inspection they show a less crystalline aspect than the gneiss, being rather inclined to an earthy surface, and they, further, pass by gradual transitions into the gabbro.

The second modification is mainly structural, so far as the megascopic aspect is concerned, but is accompanied by certain peculiar transformations in the minerals of the rock. In this instance the gabbro loses its massive character and passes over into a well developed gneiss, sometimes almost a schist. As the normal structure gives place to a parallel arrangement the constituent minerals assume a more or less rounded contour, and the resultant gneiss is, in consequence, decidedly granulitic. The passage from coarse, massive gabbro into fine, granulitic gneiss, and back into gabbro, is repeated over and over again, and takes place within a few feet. Specimens of the extreme types differ greatly in appearance from each other, and, in the absence of the intermediate phases, would scarcely be suspected of having a common origin.

At several points this gneissoid gabbro shows still another modification of a somewhat peculiar character. This consists principally in the development of platey masses of hornblende, which cut across the foliation of the gneiss at a high angle, approximating, as a rule, a right angle. These plates of hornblende range in thickness up to about half an inch, and extend, interruptedly, for several feet in a horizontal direction. There are no sections to show their vertical extent, but it doubtless corresponds to the lateral. The plates are parallel with each other, are from one to six inches apart, and occur over areas of several square yards. Wherever this structure is developed, the gneiss has a very peculiar surface. The rock immediately adjacent to the hornblende has been rendered particularly liable to weathering, so that the plates all occupy shallow grooves, separated by corresponding ridges. As a result, the surface of the rock presents an appearance which may be described as similar to that of corrugated roofing. The distance between the grooves corresponds to that between the hornblende plates, their depth reaches an inch or more. As a rule, the plates of hornblende, on account of their resistant character, project slightly above the bottom of the groove.

The grooves, following the hornblende plates, often curve considerably, and when the curves become sharp they commonly pass into small shear zones. In other cases, instead of finding relief along distinct zones, the pressure has crushed masses of the rock into a rather fine breccia.

It is evident that this development of hornblende plates is, like the foliation, a secondary phenomenon. For, not only would it be very difficult to explain as a case of primary banding, but the plates occur only in the gneissoid portion of the rock, showing that their formation has some connection with the gneissoid character. While so much is clear, the precise relation between the platey structure and the foliation is not so evident. The hornblende plates occur in a distinctly gneissoid rock, and make a high angle with the foliation, but they are not themselves affected by this foliation, rather cutting across and interrupting it. The intimate connection between foliation and platey structure, however, indicates that they should be regarded as phases of one period of metamorphism, rather than as resulting from two distinct periods with different conditions.

It may be worth while, in passing, to note the resemblance presented by this phase of the gabbro to a metamorphosed sedimentary rock. In the absence of the massive and transitional portions, the platey structure, with attendant grooving of weathered surfaces, might well be regarded as representing original bedding, crossed at high angles by secondary foliation. There is afforded here an instance of the apocryphal nature of parallel structures in crystalline rocks.

Petrographic Description.

In specimens of the normal gabbro the feldspar is pale gray or purplish, altering to green. The ferro-magnesian constituents are dark green to black, often green in the center with black margins.

Thin sections always show some alteration in the minerals, and this is usually considerable. Where there is an approximation to the original character of the rock, the minerals are plagioclase, pyroxene, magnetite, and titanite as primary constituents, together with a variety of secondary products. Of the two chief constituents, the feldspar is the older, tending to assume a lath shape. It is well twinned, and the lamellæ extinguish at about 25° as a maximum, indicating labradorite. Twinning on the pericline law is often present, in addition to that on the albite law. The feldspar is filled with the fine dust-like inclusions so common in the feldspar of gabbros. It is always largely altered, and is often entirely replaced by secondary products. The most conspicuous of these is scapolite. This mineral generally begins to form on the margin of the feldspar, gradually extending inward until the latter is wholly replaced. On account of this mode of growth, the clouded feldspar individuals are often separated from the pyroxene by a clear zone of scapolite. The mineral is readily recognized by its parallel extinction, strong double refraction, uniaxial figure in convergent light, and negative optical character.

Where the rock shows no effects of crushing, the scapolite is in rather large plates, but in cases where cataclastic structure is present, it is, like the other minerals, reduced to small grains, indicating that it was formed prior to the crushing.

The second product of change in the feldspar is a fine-grained semi-opaque aggregate. This is possibly saussuritic in its nature, but the opacity and extreme fineness combine to render a determination of its constituents impracticable. This method of alteration becomes most conspicuous in the reddish, earthy portions of the rock referred to above.

The pyroxene is colorless, and often contains abundant fine, dark inclusions. The maximum extinction angle observed is 44°. It forms large plates, filling the spaces between the feldspars. It is always more or less changed into deep-green hornblende, usually in irregularly oriented scales. This change begins on the exterior of the pyroxene and extends toward the center. The inward growth may be very regular, showing a central area of nearly pure pyroxene, surrounded by a well defined zone of hornblende. Or, on the other hand, the hornblende may penetrate the pyroxene very irregularly, yielding a network of the former mineral inclosing residual grains of the latter. Usually, a considerable part of the hornblende is oriented parallel with the pyroxene, but there is always an abundance of scales irregularly arranged, and these are not uncommonly in excess. There is invariably some of the hornblende present and it increases at the expense of the pyroxene, up to almost entire replacement of the latter. The amount of hornblende seems to bear a somewhat peculiar relation to the structure of the rock. Always fairly abundant, even in the most massive specimens, it increases as the rock takes on a cataclastic structure, but as this passes into a distinctly gneissoid structure, the relative amount of hornblende, as compared with pyroxene, decreases.

The other constituents of the normal gabbro, such as magnetite surrounded by secondary biotite, titanite, and rare tourmaline, are of minor importance, and demand no special description.

Of the modifications of the gabbro, only the gneissoid variety requires consideration. While the passage from gabbro to gneiss is gradual, as seen on a large scale in the field, it appears quite abrupt in the microscopic sections, the original structure breaking down rapidly and giving place to the secondary structure. Two types of this secondary structure appear, which, though closely connected, present much difference in thin sections. In the first type, the rock as a whole retains its original structure, the outlines of the different minerals being slightly changed, but all of the constituents are, at the same time, reduced to fine grains, giving a cataclastic structure. As the crushing becomes more intense, the mineral outlines change, and a more or less pronounced parallel structure results. In this stage the rock is a massive gneiss made up of very fine grains of pyroxene, hornblende, feldspar and scapolite. The grains of the two dark and of the two light minerals are aggregated in large masses, so that the rock appears much coarser than it really is.

In the other type of secondary structure, the rock is a well defined gneiss. It is apparently much finer grained than the previous variety, but in reality is coarser, the individual grains being many times larger than in the cataclastic rock, but not aggregated in large patches. The pyroxene and the hornblende do, however, form fairly large masses, but quite different from those described above, being elongated in the direction of the foliation, and often passing around and enclosing the feldspar grains. This rock is composed of feldspar, with pyroxene or hornblende, or, more generally, both. Between this phase of the rock and that with cataclastic structure intermediate phases occur, showing that the development of cataclastic structure is the first step in the process of converting the gabbro into gneiss. The changes which have taken place in the completed process become apparent upon comparing the minerals of the gneiss with those of the original rock.

The feldspar of the gneiss is in equidimensional grains, instead of lath-shaped, and is quite free from the dusty inclusions of the original gabbro feldspar, being water-clear, except when kaolinized. While, in the gabbro, the feldspar is always well twinned, in the gneiss there are abundant grains, often more than half of the total feldspar, showing no twinning, and, in general, when twin lamellæ are present, they are much broader and less frequent than in the original rock. While some of the grains show extinction angles almost as large as in the gabbro, in most it is from 5° to 15° lower. Adjacent feldspar grains are distinct individuals and evidently not mere fragments of larger individuals.

For these facts, but one explanation seems acceptable: the feldspar of the original rock has been entirely recrystallized, forming again plagioclase, but most of it more acid, while the abundance of untwinned grains points, almost with certainty, to the production of much orthoclase. Moreover, while in the cataclastic variety crushed scapolite is abundant, in the present type this mineral is generally absent. Evidently, metamorphism has changed it back into feldspar, from which it was originally derived.

The pyroxene of the gneiss differs from that of the gabbro in being free from the black inclusions, and in having a deep green color, with faint pleochroism. A difference in form is necessitated by the structure of the rock, and, as above stated, it often builds elongated grains, united to irregular spindles, commonly with parallel orientation over a considerable area. The pyroxene is moulded upon and often encloses the feldspar.

Here again the change in character and in form can be explained only by recrystallization.

The hornblende occurs precisely as does the pyroxene; has lost its scaly form, is often bounded by its cleavage planes, and sometimes by crystal faces, and is rather browner than in the gabbro, with more intense pleochroism. It appears to be the result of recrystallization of the scaly secondary hornblende of the gabbro, this having entirely disappeared.

The gneiss further contains many grains of titanite, the amount of this mineral being much greater than in the unchanged gabbro, where it is a scanty accessory. Two sections show a few grains of epidote. These minerals doubtless formed from materials separated out in the process of recrystallization.

The foregoing facts lead to the conclusion that the extreme effect of metamorphism on the gabbro has been to produce complete recrystallization, yielding a granulitic structure. But in spite of this recrystallization, the mineralogical composition is not greatly changed—feldspar yielding feldspar, pyroxene yielding pyroxene, and hornblende, itself secondary after pyroxene, yielding again hornblende, and some pyroxene. Yet in each case the recrystallization has produced not only changes in external form of the minerals, but also modification of internal structure and of composition.

The relations of hornblende and scapolite to the history of the rock present some points for further consideration. As has been stated, both occur abundantly in the most massive portion of the rock, while the hornblende seems still more abundant in the somewhat crushed portions, decreasing again in the gneiss. The scapolite remains about the same in quantity in the massive and crushed portions, but disappears almost entirely in the gneiss, having been found in only one specimen. In the case of the hornblende it is possible, though not probable, that the relations stated are only apparent, resulting accidentally from the particular set of specimens examined. But as to the scapolite there seems to be no doubt. These phenomena lead to the conclusion that the formation of the scaly hornblende and the scapolite took place under conditions different from those required for the production of the gneiss. The latter is a clear case of dynamic metamorphism, with development of a pronounced parallel structure, and complete recrystallization, the previously formed scaly hornblende crystallizing into larger masses of the same mineral and, partly, into pyroxene as well; while the scapolite is changed back into feldspar. In other words, in the case of these minerals intense dynamic metamorphism has brought about a direct reversal of the earlier process which led to their formation. It is evident that the different varieties of the rock represent different stages of metamorphism, and that the work of the earliest stage is, to a large extent, undone by the latest stage.

The first stage is marked by the formation of scapolite and some scaly hornblende, with little or no sign of crushing, the probable agents of change being pressure, heat and solutions. The latter factor is of importance in connection with the possible addition of chlorine in the conversion of feldspar into scapolite. The familiar theory of Judd* to account for this alteration certainly cannot be applied to the present case, whatever value it may have elsewhere. In the gefleckter gabbro, or dipyre diorite of Norway other writers have pointed out the connection between the alteration of feldspar to scapolite and the apatite veins. The probable derivation of chlorine from the vein-filling solutions has been pointed out, and has been recently accentuated by Vogt† in a lucid manner. In the case under consideration there is an absence of any distinct conduit for chlorine-bearing solutions, and yet it seems possible that chlorine from a deep source may have been carried into the rock by the gradual passage of water under heavy pressure,

* J. W. Judd: On the processes by which a plagioclase feldspar is converted into scapolite, Min. Mag., viii, 1891.

† J. H. L. Vogt: Beiträge zur genetischen Classification der durch magmatische Differentiationsprocesse und der durch Pneumatolyse entstandenen Erzvorkommen, Zeits. f. prakt. Geol., 1895, p. 456.

and probably at a high temperature. The whole question is, however, an obscure one, on which the case under consideration throws no light. At the same time that the scapolite was forming, the conversion of pyroxene into hornblende began. From such a process there would result, ultimately, a rock composed of hornblende and scapolite, which would be massive, but there could not be formed a granulitic pyroxene-hornblende gneiss.

In the second stage, the effects of crushing are pronounced. All of the constituents are granulated, and the rock becomes more or less gneissoid. At the same time the scaly hornblende increases in quantity, seeming to reach its maximum in this phase of the rock.

Finally, in the third stage, the rock undergoes complete recrystallization, the new formed constituents being arranged normal to the pressure that has crushed the rock, and thus producing a pronounced gneissoid structure. In this final product of metamorphism the recrystallization has removed all trace of cataclastic structure. This is a point of some importance in its bearing upon the question of the origin of gneisses, for it shows the uncertainty of one of the criteria which have been used in dealing with this problem. In his valuable paper on the Laurentian of Canada, Dr. Adams* has stated that the gneisses with cataclastic structure are probably igneous, while those lacking this structure have resulted from the crystallization of sediments. While he gives abundant evidence to substantiate this view for the Canadian rocks, the case under consideration shows that this criterion must be used with caution. For here is an example of a gneiss derived from an igneous rock, and yet without a trace of cataclastic structure. There can be no doubt, moreover, that the converse is often true, as there is no reason why the constituents of a rock formed by crystallization of sedimentary material should not be crushed by subsequent pressure, yielding cataclastic structure.

That there have been three such stages of metamorphism, with the results outlined above, seems to follow clearly from the facts observed. As to the scapolite, the history is plain, but in the case of the hornblende the writer accepts with some hesitation the recrystallization into pyroxene, as this is a direct reversal of the common alteration. Still, that such a change has taken place is strongly indicated, and can be doubted only by accepting a remarkable coincidence in the specimens studied.

On comparing the normal gabbro with other rocks of the family in the Adirondack region, it appears to be most closely connected with a gabbro occurring in Pitcairn, St. Lawrence

* F. D. Adams: A Further Contribution to our Knowledge of the Laurentian, this Journal, l, p. 58.

County, which has been briefly described by the writer.* In composition, and in the methods of alteration of feldspar and pyroxene, there is a close resemblance, but a marked difference appears in the fact that the pyroxene of the Pitcairn rock is distinctly older than the feldspar, approaching a prismatic form; and, further, the feldspar is free of inclusions.

In the ophitic structure, and in the abundant inclusions in the feldspar, the gabbro resembles that of Lake Champlain described by Kemp,† but differs from the latter in the absence of olivine with its attendant reaction rims.

The Russell rock is much more closely connected with both of these gabbros than with any of the diabases of the region, which, with its extreme coarseness and non-ophitic phases, justifies its classification as a gabbro, rather than as a diabase.

But it is in its gneissoid phases that the relations of the rock are of most importance, as they may throw some light upon the question of the origin of the Adirondack gneisses. Light colored, granulitic, pyroxene and hornblende gneisses are quite common in the region, and in seeking their origin the possibility of their being metamorphosed gabbros was early entertained by the writer; but definite facts bearing upon the question have been difficult to procure. These gneisses are closely similar to the gneissoid phases of the rock above described, and while this fact affords no proof of the origin of the pyroxene gneisses in general, it is, to say the least, suggestive, and may well help in further investigation.

Hamilton College, Clinton, N. Y., January, 1896.

Art. XXXIII.—*Notes on Glacial Gravels, in the Lower Susquehanna Valley;* by Harvey B. Bashore.

In this Journal for February, 1894, in describing the Harrisburg Terraces, I mentioned that no evidence of flooded-river action had been observed above the highest gravels then reported at that place, i. e. about 130 feet above the river; and observations since carried on, go far to prove that assertion. It is intended to map out completely the flooded river of glacial times from the southern ice limit to tide water, and to obtain all the facts available in regard to the Lafayette, Columbia and Trenton gravels in this valley, but the rapid approach of cold weather cut short the work for this season.

In view of the vast amount of drainage down the Juniatta from glacial Lake Lesley, considerable work was expended at

* C. H. Smyth, Jr.: Crystalline Limestone and Associated Rocks of the Northwestern Adirondack Region, Bull. Geol. Soc. Am., vi, p. 263.

† J. F. Kemp: Gabbros on the Western Shore of Lake Champlain, Bull. Geol. Soc. Am., v, p. 213.

the mouth of that river. On the left side where it skirts hills several hundred feet high, we found water-worn bowlders about 125 feet above the stream, but no higher.

At the mouth of Losch's run there were gravels and some bowlders on all the adjoining hills up to the height of 125 or 130 feet, but on the land above this altitude there was no trace of flood action. North of this point Dicks Hill—a mountain ridge, 1000 feet high—crosses the valley of the Juniatta and thence continues over the country to the Susquehanna: consequently on this triangular tongue of land extending downward from the mountain, between, and to the junction of the two rivers, we would most readily find the highest flood limit—however high it might be—provided the flood left any record, which it was very likely to do in the still water formed behind the intersection of two such streams. In descending from the mountain, where, it is almost needless to say, we found no "shore lines," we came upon a broad plateau some 250 feet above the river, upon which we found one small bowlder at exactly 200 feet, but it was probably carried there by other means than the action of a flooded river, for nothing more came into sight until we reached a somewhat lower point, where we found a line of bowlders, mostly of Pococo sandstone and conglomerates, stretching from river to river—just about 130 feet above the present channel (341 + 130 = 471 A. T.): here then, most likely, in this ancient "shore line," was left the highest record of the great glacial floods: and a very distinct and remarkable record it is.*

On the Susquehanna, observation was made at the mouth of Clarks Creek and adjoining country—about 30 miles above Harrisburg—but nothing was found above 140 feet, which corroborates the observations which Prof. Wright made several years ago. Investigation has been made concerning all reports of any higher gravels and in every case the gravels were found to be due to other than glacial floods.

The following case is interesting: I was told of presumably high gravels on certain hills west of Harrisburg, in York County, some six miles back of the river.

I visited the place and there, true enough, were the gravels covering almost every field, and the barometer registered 400 feet above the river: but these were not *glacial* gravels.

The bed rock in this locality is a red Trias sandstone, which in some places is literally filled with gravel and small bowlders: to the disintegration of this stone, these gravels were due, although just at that exact locality there was no surface exposure.

One important fact which I have noted in tramping over many miles in this locality is the abrupt termination of all distinct evidence of flooded-river action, at a point about 130 or 140 feet above the present channel.

* In all the high gravel deposits in this locality there occurs some granite—showing glacial origin.

ART. XXXIV.—*The Bearpaw Mountains, Montana.** *First Paper;* by WALTER HARVEY WEED and LOUIS V. PIRSSON.

Introduction.—The present paper gives an account of the prominent features of a mountain group in northern Montana. It consists of a cluster of dissected volcanoes whose breccias, tuffs, and flows compose a large part of the area, especially the marginal region; while cores of massive rock and associated dikes and bosses are found cutting soft Cretaceous shales in the central parts of the mountainous tract. The rocks present interesting examples of the differentiation of an alkaline magma, and consist of various types of the syenite family of igneous rocks, together with highly differentiated basic forms that accompany them. The only mention of the geology of the region that we have been able to discover is a brief note by Dr. Waldemar Lindgren,† who examined some specimens of rocks, mostly altered, collected from the southern foot hills by Dr. C. A. White in 1882.

The Bearpaw Mountains form one of the isolated mountain areas that rise abruptly above the grassy plains of central Montana. They consist of a group of peaks and are not a true mountain range, and lie between the meridians of 109° and 110° west, and parallels of 48° and 48° 50′ north. They are situated far to the east of the Rocky Mountain front, and north of the swift flowing Missouri River. The region is readily accessible by a mail stage from Chinook, a town of some size situated upon the main trans-continental line of the Great Northern Railway. The valley lands of the eastern part of the mountains are settled, and there are three post offices in this portion of the region. The western and most highly accidented part lies within the limits of the Fort Assiniboine military reservation.

Topography.—In scenery there is a strong contrast between the billowy, rolling surface of the plains covered with glacial drift and the abrupt slopes and crag crowned summits of the mountainous tract. Several isolated buttes rising above the plain far out from the mountains are genetically connected with them, but will not be considered here.

Seen from the level plains, the mountains present a skyline of more or less conical peaks, in part connected with one another, in part as separate elevations of nearly equal height,

* By permission of the Director of the U. S. Geological Survey. The present paper is based upon notes and collections made by one of the authors (W. H. W.) during a brief visit to the region in October, 1895.

† This Journal, vol. xlv, April, 1893, p. 287.

with one prominent higher point. In reality the mountains do not constitute a chain of hills but an elevated tract 40 miles long and 20 miles broad, dominated by high, prominent peaks, few of which are named. The highest point, known as Bearpaw Peak, reaches an elevation of 7,040 feet above the sea, rising high above the neighboring summits, none of which exceed 6,200 feet in height. Among the Indians this central peak is called Heart Mountain, or literally the Heart of the Mountains. The name of the mountain group is itself derived from the Indian designation for Black Butte near Fort Assiniboine, called by them the Bear's Paw. The mountains of course became known as the Mountains of the Bear's Paw. From Bearpaw Peak the streams radiate in every direction—Clear Creek and Beaver Creek on the east and north, Big Sandy Creek to the west, and Eagle Creek, which runs to the Missouri, on the south, the other streams being tributary to the Milk River. Even the highest and most rugged parts of the region are easily traversed and offer none of the usual risks of mountain exploration.

The mountainous tract is formed of a central group of hills and ridges, coalescing in the western part of the area where they attain their greatest elevation. The eastern half of the mountain area is relatively low in altitude and consists of two chains of hills running east and separated by the broad open valley of Peoples Creek. This valley, which is 3 to 6 miles wide, is a smooth, grassy, alluvial plain sloping very gently from the base of the hills to the stream channel, and is a terrace but little cut by lateral gullies. It is eroded in soft Cretaceous shales, in which there are numerous igneous intrusions. The old outlet of the valley was unquestionably through a wide, flat gap on the southeast side, where the flat terrace level abruptly divides the southern line of hills. The creek meanders quietly through an open bottom with occasional patches of low rose bush, but without trees or even the common willow brush. The mountains on either side are smooth, grassy, somewhat irregular and broken, and show slopes with occasional masses of black or gray volcanic rock projecting above them, conspicuous because of the contrast but not large in amount.

The central part is encircled by a hilly region of much less altitude, whose slopes rise abruptly from the dimpled plain and undulating ridges of moraine covered country, and its northern slopes are covered by forests of pine. Groves of aspen occur also in the highest valleys, and cottonwoods along a few of the streams. Elsewhere the slopes are smooth and covered by a carpet of grass that conceals the rocks, making rapid geological observations impossible.

In topographic features the mountains present a good example of simple sculpture, in which the dendritic system of drainage is but little altered by the marked diversity of rock structure. The region is well watered, but the streams are mostly of small volume and head in perennial springs. With one or two exceptions, they flow rapidly in quiet, meandering courses through grassy bottoms or groves of low willows, show little evidence of spring floods, and are doing but little cutting at the present time. None of them are of the normal torrential type so common in the western mountains.

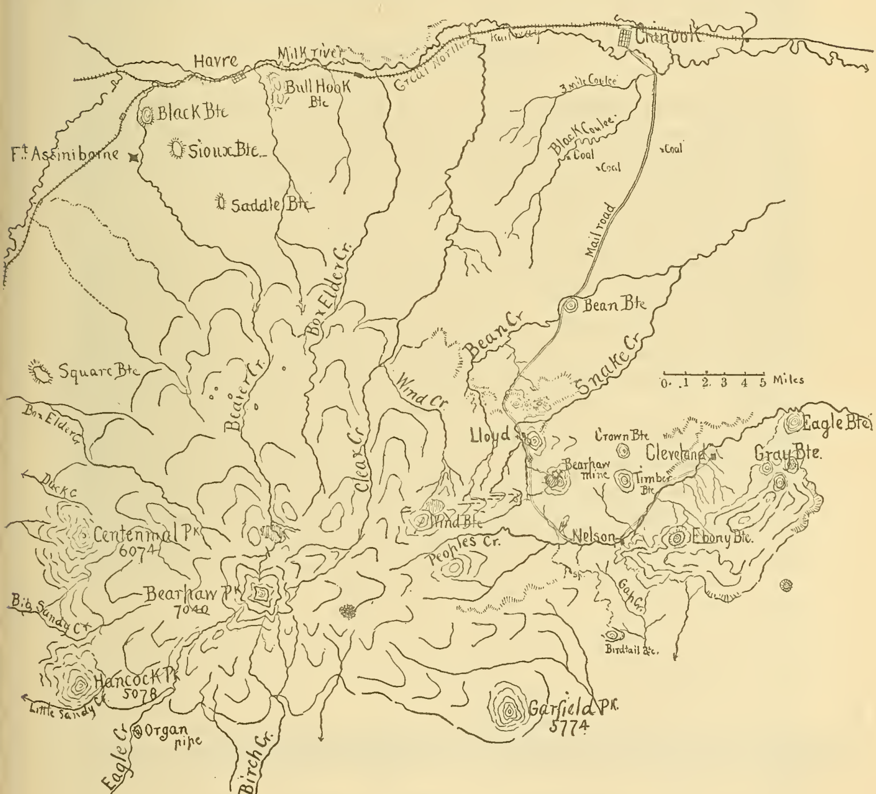

FIG. 1.—Sketch map of the Bearpaw Mts.

Outside of the military reservation the region is settled wherever there are level tracts suitable for cultivation or for the cutting of hay. The heavy growth of grass and the gentle, open nature of the country have been found especially suitable for stock raising.

The highest western point of the mountains is known as Centennial Butte, and the isolated, conical elevation standing at the extreme east end is called Eagle Butte. A few other names in common use among the settlers are given upon the accompanying sketch map.

The mountains have never been surveyed. They appear on most maps of the State, but only the merest approximation to the drainage is given, and the intervening space is filled with meaningless hachures. The accompanying sketch map, compiled from various sources and our own notes, is the best obtainable.

General Geology.

The Bearpaw Mountains are the dissected remains of a group of volcanoes of Tertiary age. Denudation has laid bare the central cores or necks of the old vents, surrounded by altered sedimentary rocks through which the conduits were made. Radial dikes traverse the sedimentary foundation, and accumulations of scoria and various fragmentary volcanic rocks and lava flows form the outer part of the mountain region and also a portion of the central area. The accompanying figure represents a diagrammatic cross-section through the range, showing the stock of granular rock exposed on Beaver Creek and the relations of the effusive rocks to the basal platform of Cretaceous shales. The geology is interesting, not only from these features, which have their counterpart in the neighboring Highwood Mountains, but also on account of the character of the eruptive rocks and the bearing of their occurrence upon the broad problems of petrology. The mountains have not been glaciated, although the confluent terminal moraines of the two great continental ice sheets skirt the flanks on all but the southern sides.

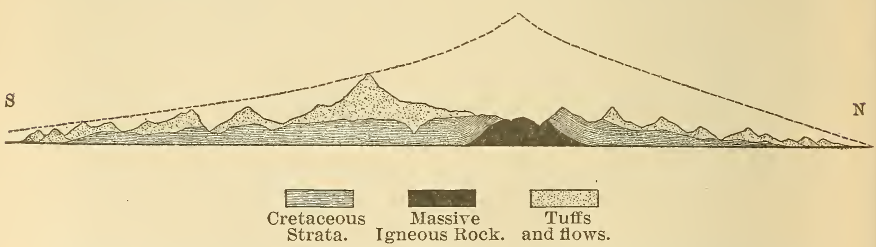

Fig. 2.—North and South section of Bearpaw Mountains through Bearpaw Peak and Beaver Creek Core.

The sedimentary rocks are Cretaceous, and in part at least of Laramie age. They consist of a thickness of 2,000 to 3,000 feet of dark-colored shales, with interbedded sandstones and occasional lenticular intercalations of impure limestones. So far as observed, the rocks have proved nearly barren of fossils, but as a coal-bearing series occurring along Milk River is also exposed beneath the drift along the stream courses north of the mountains, fossils will probably be found upon a close examination of the beds.* Older Cretaceous strata also occur to the north, near Havre, where they have been identified by Mr. T. W. Stanton, and in the bad lands of the Missouri River, where they have been studied by one of the authors (W. H. W.). About the cores of granular igneous rocks the sedimentary beds are generally highly metamorphosed, more especially where the eruptives are of basic types. In such cases the original character is obscured, and the shales and sandstones are converted into dense, hard hornstones and quartzites of those light-colored, compact and flinty rocks of various shades of lavender, gray, green, and of adinole-like character, which so often characterize the contact zones of igneous intrusions. These baked rocks possess a marked cubical jointing, which causes them to break into small angular fragments, so that imposing exposures are seldom seen. As, however, they often resist erosion better than the granular rocks of the volcanic cores, the contact ring generally stands in bold relief, forming ridges about the igneous centers. Where dikes occur thickly clustered, as is the case on the ridge at the head of Snake Creek, the sedimentary rocks are also much indurated and altered.

From what has already been stated, it is evident that the chief interest in the region lies in the igneous rocks. The unusual character of the types represented make their study of importance, for which reason the field occurrence and the petrographic character are described somewhat in detail.

Extrusive Rocks.

The extrusive rocks are most abundant, forming the highest peaks and many of the lesser summits of the region; they are the usual rocks of the foot-hills, where their richly-colored, rough outcrops form crags and oddly shaped castellated masses in strong contrast to the smooth and grassy slopes about them. They consist of dark-colored basaltic tuffs, breccias and lava flows, which are parts of the former volcanic cones. The finer tufaceous varieties are often washed down and form dark-colored, sandy soils, generally well grassed, while the vesicular slaggy rocks and coarser breccias form

* We have been informed by Prof. O. C. Marsh that the remains of a Dinosaur *Hadrosaurus breviceps* Marsh) described by him (this Jour., vol. xxxvii, p. 335, 1889, also ibid, vol. xxxix, p. 423, 1890), are stated by the collector to have been obtained in the Bearpaw Mountains.

rough masses standing above these slopes. The rugged hills forming the eastern end of the range are largely covered by these crags, whose creamy tints of purple, red, brown, and gray are a striking feature of the scenery.

Within the mountain area the effusive fragmental rocks are quite irregularly distributed. In general they rest upon a formerly eroded surface that was hilly in nature; so that the exposures occur both as cappings to hills and in masses at lower altitudes; no definite bedding is recognizable. The irregular disposition of these masses is well shown in the accidented region between Clear and Beaver Creeks, where the effusive rocks and sedimentary beds are exposed at various altitudes and without apparent order. The rocks of this part of the mountains are, in part at least, more acidic than those generally prevailing, the breccias including fragments of trachytic rocks. The hills in this interior part are smoothly contoured, well grassed, and show the black patches of gravelly debris so characteristic of these basaltic accumulations and which accentuate and bring into strong relief the grassy ridges and intervening hollows. The rocks here also frequently form rough, craggy exposures, almost invariably found upon the southern side of the hills.

In the effusive rocks the breccias predominate, with associated tuff beds and lava flows. The rocks vary from compact, dense basalts showing no porphyritical crystals, to open porous forms which pass into scorias. They have a wide range of colors, red, brown, gray, in warm rich tones, more rarely green and buff. Though varying in appearance they consist almost wholly of leucite basalts; many varieties have no megascopic phenocrysts, but most of them show a dark ground-mass peppered with small white specks of altered leucite, while occasionally crystals of augite are seen, and more rarely olivine. Sometimes the breccias contain blocks of a dense, black rock with large phenocrysts of altered mica. The tuffs vary from pale-buff or dull-green to dark red, brown, or gray in color, and are largely altered.

A specimen selected for examination representing a common variety seen throughout the mountains but coming from Bull Hook Butte, is typical of the rock forming the larger blocks and fragments in the breccias. The rock is of a very dark-gray color, rather compact on the whole, though on jointing surfaces it seems rather porous, and this is probably due to the weathering out of an iron-bearing component; on a completely weathered surface it becomes of a leather-brown color.

On fresh surfaces one readily detects yellowish grains of olivine, passing at times into a chestnut-red color and 1 or 2^{mm}

long, black prisms of augite of about the same size or larger, and round white or very pale greenish grains of leucite, which thickly pepper the dark ground-mass and which vary in size from mere white dots up to 0·5^{mm} across. The rock strongly recalls certain of the south Italian leucite rocks in which the leucite phenocrysts are very small. In thin section the rock is composed of the above minerals thickly crowded, so that there is little base.

The *augite* is of the usual character in rocks of this class; in section it becomes very pale in color and of a brownish rather than greenish tone and has a strong zonal structure, is very idiomorphic, frequently twinned on a(100), has a wide angle of extinction up to 40° or more, shows excellent cleavage and is very fresh.

The *olivine* is generally idiomorphic though occurring at times in polysomatic groups; the large crystals are fresh and clear; the smaller ones frequently changed into a deep-brown or reddish-brown colored substance, which appears to be similar to alterations of olivine seen in other occurrences,* in this change the smaller crystals are completely altered, larger ones only partially, and in the largest the alteration appears only as red-brown bands following cleavage planes. We believe this to be due to a change in the iron oxide in the mineral, and that it is especially iron-rich olivines which are liable to it.

The *leucites* under the microscope are seen to be very thickly crowded, composing the bulk of the rock. They are of all sizes, from very minute individuals up to those previously mentioned. They are of rounded forms though not generally bounded by an absolutely sharp, definite line, but fade out into the ground-mass in a rather ragged indefinite way. They do not contain any of the inclusions zonally arranged which are so frequently seen in this mineral, but are, like the larger leucite phenocrysts in the leucitic rocks, entirely free from them; like these larger phenocrysts they are frequently cracked or appear in grouped polysomatic forms. They are not colorless and limpid like the leucites of the fresh Italian rocks, but are of a light-brown color and appear with a low power very like a kaolinized orthoclase in character; they are perfectly isotropic between crossed nicols. Studied with high powers they appear filled with excessively fine granules, shreds and leaves of some substance so fine that they can barely be discriminated; this material is unevenly distributed through them and does not act on polarized light. It is possi-

* Rosenbusch, N. Jahrb., 1872, p. 59, Phys. d. Min., 1892, p. 472; Michel Lèvy, Bull. Geol. Soc. France, 3d Ser. xviii, 1890, p. 831; Iddings, Geol. Eureka Dist., Mon. xx., U. S., Geol. Surv., Appendix B, pp. 388–390; Pirsson, this Journal, vol. xlv, 1893, p. 381; Lawson, Geol. Carmelo Bay, Bull. Univ. Cal., vol i, 1893, p. 31.

ble that it may be original and represents extremely fine inclusions, which, had they been gathered into larger grains, might have arranged themselves zonally. We believe, however, that they really represent a stage of alteration and that the leucites, since they appear so exactly like kaolinized orthoclase, are in fact partially kaolinized. That some alteration has taken place seems possible from the fact that the rock contains over 3·5 per cent. of water, though this in part may well come from the including base. Qualitative tests showed the absence of SO_3 and Cl, and the mineral is therefore not hauyn, nosean, nor sodalite.

The rock appears closely related to the analcite basalts of the Highwood Mountains which have been described by Lindgren,* who showed that in the material studied by him the mineral resembling leucite was really analcite, and from the freshness of the other components he was inclined to regard it as of primary origin. In the course of our own work in the Highwood Mountains we have gathered a large and varied collection of these leucite-like rocks and have found them to consist of several types, and we hope that the investigation which we are now making of them will throw some light on the character and origin of the leucite-analcite minerals. The discussion of these similar Bearpaw types is deferred in consequence until our publication upon this material, which will appear at a later date.

The ground-mass in which the other minerals lie is very small in amount and consists mainly of minute black grains of magnetite, with tiny microlites of augite imbedded in what appears to be a colorless glass.

The composition of the rock from the foregoing is thus shown to be a very simple one—magnetite, augite, olivine, and probably altered leucite. There are no signs of any feldspar present, and the rock is thus a leucite basalt. The occurrence of leucite in this locality we shall have occasion to mention later, in connection with its presence in some remarkably fresh, unaltered, and interesting lavas from Bearpaw Peak.

Intrusive Rocks.

Eagle Butte.—The eastern end of the mountains, near Cleveland, is formed of the sedimentary rocks tilted near the postoffice at angles of 15° to 20° to the southeast, while the prominent buttes seen near by are formed of igneous intrusions of basaltic rocks. The extreme easterly point of the mountains is an isolated conical hill of considerable elevation, called Eagle Butte on the map. It shows a cap of black debris

* 10th Census U. S., vol. xv, p. 719. Proc. Cal. Acad. Sci., Ser. 2, vol. iii., p. 51.

extending downward in tongues cutting the grassy middle slopes. The base of the butte is formed of rough outcrops of purplish, reddish, and steel-colored rocks, with fragments of a light-colored variety which seemed to form a dike or intrusive mass, as seen from the summit of Gray Butte.

The rock is a *mica-trachyte*, having a medium gray color, is of fine grain and filled with many very small glittering black tablets of biotite and with small whitish spots and specks. Under the microscope it appears very badly altered, much more so than the megascopic appearance would suggest. The mica is fresh and recalls that of minettes; there is, moreover, a great deal of it, and it is strongly pleochroic and very idiomorphic.

The rock is filled with masses of calcite, which appears due to the decomposition of augite; some may possibly have been introduced. Secondary quartz also appears filling cavities. There are a number of phenocrysts of feldspar generally showing both albite and carlsbad twinning; one of these, oriented in the zone 001 on 100 perpendicular to 010, gave extinction angles with the Bertrand ocular for the albite twins $a = 19°$ $a' = 19$, the carlsbad twin gave 9°, and hence the plagioclase is andesine. The ground-mass is made up of lath-shaped feldspars, which are so much altered that it cannot be safely told whether a plagioclase which is present or alkali feldspar predominates. The alkali feldspar appears, however, to predominate. It is certainly present, as a little interstitial quartz permits the recognition by Becke's method that some less altered, unstriated granules, have in all positions less refraction than the quartz. The rock appears, therefore, to be a transition form between a *mica-andesite* and a *mica-trachyte* so far as can be told.

Gray Butte is the most western of the isolated group of three elevations, which forms such a prominent feature of the east end of the mountains. Unlike its neighbors it is rugged in appearance, showing bold exposures of massive rock with talus of large blocks covering the slopes below. The lower part for 200 to 300 feet above the base is a steep slope cut in soft black shales that show no fossils and are apparently horizontal. The shaly beds are cut at the southwestern base by a dike of decomposed, hornblendic trachyte. The butte above is formed of an intrusive mass of massive, alkali *quartz-syenite-porphyry*, breaking up through the shales in a boss a half mile wide. The gray color of the outcrops and debris piles which gives the name to the butte is due to lichens, as the rock is a pale-green on fresh fracture, becoming pink on weathered surfaces. The shales are slightly altered for a few yards distant from the contact. The rock occurs in place on the summit of the butte, where it forms a massively jointed wall extending north and south along its crest, while below large talus blocks cover a steep slope extending down to the top of bold cliffs of the same rock. The cliffs, seen from the surrounding country, form the most noticeable feature of the butte. On three sides they form an almost insurmountable wall, over a hundred feet in height. In these cliffs the syenite-porphyry has a massive, platy structure, the lamination being parallel to the outer surface of the cliffs, dipping on all sides away from the butte at 30° to 45°. Though the rock sometimes breaks along these planes and forms a smooth rock slope, the exposed face of the cliffs is generally much steeper and corresponds to a jointing of the rock. The debris consists of blocks, often 8 feet in diameter, with very little material less than a foot across.

The weathered rock has a botryoidal surface that is rather characteristic. No difference is recognizable between the rock forming these cliffs and that of the summit of the butte, either in the nature or relative amounts of the component minerals, or in the granularity or physical structure. It appears probable, however, that erosion has as yet only exposed the outer part of the boss, and that both summit and side show only the outer portion of the intruded mass.

On a surface of fresh fracture the rock is a very pale-gray color mottled with very pale-pink; on a somewhat weathered surface these contrasts of coloring are accentuated. Upon closer examination the rock is seen to be chiefly composed of large, thickly crowded crystals of feldspar, held in a dense pale-green ground-mass that is speckled with small black augite crystals. The pale-pink tone of the rock is due to these thickly crowded phenocrysts of feldspar. The black augites which occur plentifully scattered through the ground-mass rarely attain a length of 2^{mm}. The feldspar phenocrysts are stout in habit and vary in size from one to one-half centimeter in length. They usually possess the orthoclase habit, are very rarely clear glassy and sanidine-like, and are developed in short, stout, columnar forms on the clino axis; they are apt to be more or less rounded and anhedral.* When idiomorphic they show the common planes $m(110)$, $b(010)$, and $c(001)$. They are frequently carlsbad, less often baveno twins. A few sporadic grains of quartz have also been observed, though they do not appear to be at all common.

* A term suggested for rounded formless masses which do not show outward crystal form. See report of the winter meeting of the Geol. Soc. Am. 1895, in its proceedings, also abstracts in this Journal, p. 150, vol. i, 1896; Jour. Geol. vol. iv, 1896, p. 128. It has been suggested that the terms anhedron and anhedral conflict with allotriomorphic; this is by no means the case, since allotriomorphic is a term of *structure* denoting a formal relation of parts, while anhedron is individual and used in a crystallographic sense.

Under the microscope the rock is found to be composed of *apatite*, *ægirite-augite*, *alkali feldspars* and *quartz*.

The *ægirite-augite* has the usual characters of this mineral; a clear light grass-green color, pleochroism, though not strong, into tones of yellow, an excellent cleavage, and is usually quite idiomorphic. It is zonally built, increasing in the ægirite molecule towards the periphery, and has in these parts a corresponding decrease in the angle of extinction. It has in many cases a pronounced dispersion of the optic axes, which is probably owing to the presence of titanium.

Since the mineral composition of the rock is, as indicated above, so simple, we may reckon out of the bulk rock analysis the chemical composition of this augite, which then has approximately the following composition:

SiO_2	Fe_2O_3	FeO	MgO	CaO	Na_2O
45·3	22·1	1·8	8·6	13·6	8·6=100·0

corresponding in round numbers to two molecules of diopside to one of ægirite.

The *apatite* has been seen only in a very few, rather large, scattered grains; the small amount of it is indicated in the minute quantity of phosphoric anhydride shown in the analysis.

The large *feldspar* phenocrysts between crossed nicols appear homogeneous and in general untwinned, except an occasional carlsbad. In some places areas of kaolinization occur, otherwise they are quite fresh. The cleavages parallel to *b* (010) and *c* (001) are both excellent and furnish good plates for optical examination: such plates parallel to *c* (001) extinguish at about one degree from the trace of *b* (010) while plates parallel to *b* (010) extinguish positively at 10° 30′ to 11° 30′ from the trace of *c* (001) and show in convergent light a positive bisectrix nearly centered in the field. The feldspar is, therefore, not orthoclase but *anorthoclase*, as must indeed be expected from the rock analysis. It seems to be closely related to the cryptoperthite described by Brogger.* A noticeable feature of these phenocrysts is that they contain certain quantities of slender microlites of a striated feldspar. While these are apt to be scattered through the phenocrysts they are especially found arranged in a zone around the edge and projected vertically from the plane faces inward, as illustrated in fig. 3, which shows the phenocrysts and the character of the rock in a diagrammatic way. The great majority of these slender feldspar microlites, no matter how twinned, extinguish parallel to the plane of the nicols or nearly so, and Becke's

*Mineralien der Syenit-pegmatit Gänge, Zeit. für Kryst, vol. xiv, p. 524, 1889.

method shows that they have a higher index of refraction than the anorthoclase in which they lie. They are, therefore, *oligoclase.* Others much more rarely extinguish at angles which reach a maximum of 16° (in sections perpendicular to 010); one of these that gave this maximum showed the exit of a negative bisectrix, and the plane of the optic axes stood at 74° to the trace of 010; the section showed both carlsbad and albite twinning, and both sets extinguish and illuminate nearly simultaneously. This is consequently albite, and Becke's method shows its refraction to be higher than the *anorthoclase.* Thus these microlites vary in composition from albite to oligoclase, the majority being the latter. A closely related occurrence with albite microlites is described by Brogger.* It is thought, in the present case, that the phenocrysts having originally formed at considerable depth were afterwards mostly resorbed, as some of them plainly show by their rounded and corroded forms. An example is to be seen in fig. 3. In the later process of crystallization these were restored and a simultaneous crystallization of the oligoclase took place, the two arranging themselves as seen in the figure.

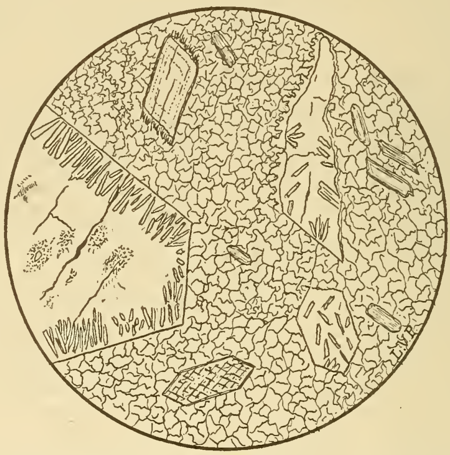

FIG 3.—Syenite Porphyry of Gray Butte, × 14, actual field 4 mm.

The *ground-mass* consists of very small allotriomorphic grains of feldspar with occasional ones of pyroxene. The small feldspar grains are pretty turbid from kaolinization; they do not show any twinning, but with very high powers between crossed nicols they show a mottled, zoned, or flamed appearance in tones of gray and white. Becke's process shows that their refraction is always less than that of quartz, and hence

* Grorudit-Tinguait Serie, p. 17, 1894.

they are various mixtures of alkali feldspars, which agrees with the rock analysis. Nothing definite concerning them could be made out by examination in convergent light.

The *quartz* is clear and limpid and occupies minute irregular areas between the feldspars; a few larger grains were seen. It is small in amount and it does not appear very evenly distributed, some areas being much richer in it than others.

Au occasional small *zircon* and one or two scattering *biotite* leaves complete the list of minerals. The rock, with the exception of the slight kaolinization mentioned, is very fresh. An analysis of it, made for us by Dr. H. N. Stokes, in the laboratory of the U. S. Geol. Survey, resulted as follows:

	I.	II.	III.	IV.
SiO_3	66·22	65·54	66·13	64·63
Al_2O_3	16·22	17.81	17·40	18·15
Fe_2O_3	1·98	·74	2·19 (Fe₂O₃ + FeO)	3·05
FeO	·16	1·15		
MgO	·77	·98	·04	·50
CaO	1·32	1·92	·81	1·54
Na_2O	6·49	5·55	5·28	5·80
K_2O	5·76	5·58	5·66	4·76
H_2O above 110°	·24	·54 (above + below 110°)	1·22	1·08
H_2O below 110°	·08			
MnO	trace	trace	·13	1·00
TiO_2	·22	·11	·74	?
P_2O_5	·10	trace	?	?
BaO	·29	not det.	----	----
SrO	·06	not det.	----	----
SO_3	·02	----	----	----
Cl	·04	----	----	----
Fl	trace	----	----	----
Li_2O	trace	trace	----	----
	99·97	99·92	99·54	100·54
O=Cl	·01			
	99.96			

I. Quartz-syenite-porphyry, Gray Butte, Bearpaw Mountains, Montana. H. N. Stokes, anal.

II. Quartz-syenite, Highwood Peak, Highwood Mountains, Montana. L. V. Pirsson and W. L. Mitchell, anal.

III. Porphyritic quartz-syenite, near Thinghoug, So. Norway, G. Särnström, anal. (Brögger Min. Syenit pegmatit gänge, 1889, p. 46.)

IV. Quartz-syenite (dike), Fourche Mountains, Ark. R. N. Brackett, anal. (Igneous Rocks of Ark., J. F. Williams, Rep. State Surv., 1890, vol. ii, p. 96.)

This analysis shows very clearly the alkaline character of the rock and its low lime, iron and magnesia. The chlorine and fluorine are in the small amount of apatite. The sulphur shown must come from the traces of sulphide ores present; the titanic oxide is probably mostly present in the augite; a little titanite may be present, but has not been seen. The barium and strontium are probably present in the feldspars. The small amount of water shows the freshness of the rock. Its simple mineral composition permits us to calculate from the analysis the proportion of the different mineral molecules which compose it as follows:

Ægirine augite	8·9
Orthoclase	34·4
Albite	48·5
Anorthite	1·7
Quartz	6·5
	100·0

The amount of the anorthite molecule is a trifle too large, the small quantity of lime required to form the apatite not having been deducted. The augite would have the composition previously given.

For purposes of comparison some analyses of quartz syenites from other parts of the world have been quoted. (The one quoted from Highwood Peak is from a report in preparation by the authors on the mountain group of that name.) These are all quartz-alkali syenitic rocks and they belong to Brogger's Åkerite group.

The contact form of this Gray Butte syenite is fine-grained and resembles the dike rocks of the district. The actual contact was not observed owing to the great amount of talus, but the contact form and the flinty, hardened shales showed its proximity. The rock from the contact is very fine-grained and dense; it appears exactly like the ground-mass of the main type and has the same pale grayish-green color. The most noticeable feature is the almost entire lack of the large feldspar phenocrysts which in the main type are so thickly crowded together and which make so characteristic a feature of the main rock. Occasional feldspar phenocrysts occur, but they are rare, mostly quite small in size, and do not present very sharp boundaries. The little black prisms of augite are the same in size as before, but somewhat less in quantity.

Under the microscope the contact form is precisely like the main type previously described; it consists of the same minerals—ægirine-augite, alkali feldspars, and quartz. The structure is the same only the grain is somewhat finer. The only noticeable difference is that which is so striking megascopically, the lack of large phenocrysts; a few indeed do occur and they are similar to those previously described but are comparatively very small.

The most interesting feature then of this contact form is the sharp contrast between its almost total lack of feldspar phenocrysts, with the main type in which they occur in such great size and profusion. *It shows clearly that these phenocrysts are not of intratelluric formation*, since in that case they should occur in both forms alike, but that on the contrary they have developed by far the greatest part of their bulk during the final period of consolidation, and thus confirm the ideas concerning their formation previously expressed. Such facts are of great importance to a proper understanding of the porphyritic structure, and the present case is a confirmation of the observations of Cross,* who has thoroughly discussed the bearing of such facts on theoretical petrology.

Cleveland Butte.—The summits south of Cleveland are probably formed mainly of the effusive basaltic rocks, as is shown by the character of the stream drift from their slopes, but massive rocks also occur. The summit forming the eastern end of the range of hills south of Cleveland shows an intrusive rock that differs from those described.

The rock is a *trachyte* of a medium gray color, with a somewhat waxy greenish tone. It is thickly spotted with small prisms of black hornblende of varying size; they are rather slender and average 1 to 3^{mm} in length; occasionally they are much larger, and exceptional individuals a centimeter or so long are sometimes seen; quite rarely irregular or stellate aggregations of them occur. Feldspar phenocrysts are rare; they are 1 or 2^{mm} in diameter. The dense, greenish-gray, feldspathic ground-mass and the hornblendes give the rock its prevailing character. It weathers with a brownish crust.

In the section the *hornblende* is found to be generally idiomorphic but always more or less resorbed and coated with borders of black opacite grains; in some cases this process has gone so far that nothing is left of the original crystal but a mass consisting of black ore grains, shreds of brown biotite and granules of diopside mixed with fibres and masses of the original hornblende. The mineral is of the usual olive-green character with pleochroism into yellowish tones; it has the small angle of extinction and rather low birefraction so commonly found in rocks of this class.

The other prominent ferro-magnesian mineral is a pale-green *diopside*, which is pretty freely sprinkled through the ground-

* Laccolitic Mountain Groups, etc., 14th Ann. Rep. U. S. Geol. Surv. for 1892–1893, p. 228 et seq. Washington, 1895.

mass in well formed crystals which average a smaller size than the hornblende. Unlike the latter it is always fresh and unaltered.

The phenocrysts of *feldspar* are too small and occasional to furnish good material for optical study. In the section they are unstriated, untwinned, and have the mottled, varied appearance between crossed nicols so often seen in anorthoclase. One section of the few that were found was cut near to the face *b*(010), the feldspar was not zonal in its growth but full of irregular areas having varying birefraction and different extinction angles; the direction of the base *c*(001) unfortunately could not be determined, but contacts with quartz show that generally quartz has a higher index of refraction; in one or two areas it did not. We cannot say positively what the character of the feldspar is, but we believe it to be anorthoclase with included areas of an untwinned lime-soda variety.

The phenocrysts lie in a very fine-grained *ground-mass* of alkali feldspar in allotriomorphic interlocking grains, with here and there a very little quartz. It is plentifully dotted through with minute ore grains, and the feldspar is somewhat turbid from kaolinization.

The small feldspar grains of this ground-mass show characters similar to the larger phenocrysts; they have the same patchy, mottled appearance and are untwinned, save for an occasional example after the carlsbad law. They offer only confused images in convergent light, and it was found impossible to orient and determine them. The contacts with quartz, however, show that their refraction is that of the alkaline feldspars, and they are undoubtedly varying mixtures of the albite and orthoclase molecules.

Nelson intrusives.—Near Nelson P. O. there are two buttes which form prominent land marks of the mountains. To the south Ebony Butte is a conical summit with a black cap of debris, while to the north Timber Butte rises high above the valley slopes. This hill is surrounded by an annular ridge with intervening hollows. The debris from the ridge shows it to be a decomposed trachytic rock. A dike of what seems to be the same rock forms a wall exposed on both sides of the creek. The rock is a *trachyte* of a pale brownish-gray color; it is thickly speckled with rusty phenocrysts of a more or less decomposed ferro-magnesian mineral, and occasional large tabular plates of biotite.

The thin section shows numerous phenocrysts of *augite*, *mica*, *oligoclase*, and *orthoclase* in a very fine ground-mass of alkali felkspar with a little quartz. The phenocrysts of augite and biotite are almost entirely altered by decay into serpentine, calcite, chlorite, and ferruginous products, probably mostly limonite. The augite, indeed, has not been actually seen, but its former presence is inferred from the shape of pseudomorphs consisting of serpentine and calcite. The feldspars are much fresher but have also been attacked by decay, and are pretty turbid from kaolin leaves. The oligoclase whose presence is inferred from the constant practically parallel extinction of albite and Carlsbad twins in the zone 100 on 010 perpendicular to 010, is not very common and appears only as a phenocryst. The orthoclase phenocrysts are much more common and they appear to contain an admixture of the soda molecule, as is usual in these rocks.

The ground-mass in which the above lie is extremely fine-grained, allotriomorphic, and with the exception of a little residual quartz wholly of feldspar, which is untwinned and an alkali feldspar and not an untwinned plagioclase, the presence of the quartz permitting its determination by Becke's method.

People's Creek Basin.—Just above Nelson, People's Creek has cut through a sheet of dark-colored minette-like rock, whose grotesque erosion forms of 3 to 4 feet in height are seen standing in relief upon the grassy bench. This rock contains a large amount of mica, making it a readily recognizable type, but it yields quickly to atmospheric agencies and crumbles to a fine sandy debris. Fresh, unaltered material is very hard to obtain, and although the rock is a common one in the mountains good exposures of fresh rock are very rarely seen.

In the center of People's Creek basin there is a short but very striking dike-like ridge, standing abruptly above the gentle, grassy, gravelly terrace slopes. The rock weathers in huge blocks of pinkish or flesh color, resembling granite from a distance. It is much decomposed, and the blocks are covered by a thick decomposition crust so that fresh material could not be obtained for examination, but it is seen to be a feldspathic rock in which biotite is the only prominent phenocryst.

Galena Butte (*Bearpaw mine*).—Northwest of Nelson is the low divide in the northern chain of hills, through which the mail road from Lloyd has been built. East of this divide there is a high summit, whose grassy open slopes crowned by a log shaft house make it a conspicuous object in the landscape. The building has been erected over an ore body of argentiferous galena, in which a prospect shaft has been sunk. The ore body occurs near the margin of an intrusive mass of trachyte, which, as is commonly the case in these mountains, has been deeply cut by the drainage, while the contact zone with its denser rock and rim of hardened sediments stands out in relief, forming the summit of the butte and its most prominent westerly spurs. The main mass of the rock is a trachyte, generally much altered, in which large crystals of white feldspar occur in a reddish-yellow ground-mass. Good exposures of the intrusive mass are rare even where the slopes are deeply cut by drainage channels, for the prevalent covering of grass, everywhere a feature of the mountains, often conceals even the debris. The rock is a *trachyte* or syenite-porphyry which is too greatly altered and decomposed to be of value for petrographic study. It consists of a brownish, earthy, feldspathic, ground-mass filled with limonite and with hollow cavities caused by the weathering and decay of a former iron-bearing mineral. This is thickly filled with feldspar phenocrysts of a thick tabular or short columnar habit about 1^{cm} in greatest length. Its determination as a rock of the alkali class rests upon the character of its contact form.

The contact form of the trachyte is a dark greenish-gray rock thickly crowded with small idiomorphic feldspar phenocrysts of thick tabular form. There is a sprinkling of rather dull, inconspicuous black dots which are either pyroxene or micas.

In the section the great quantity of feldspar phenocrysts is very evident. The great majority are clear and homogeneous, while some show microperthite intergrowths with albite lamellæ. In a section parallel to $b(010)$ shown by its outline, high birefraction and the exit of a positive obtuse bisectrix, the angle β was measured 65° and the extinction was 8° 30′ plus in the obtuse angle β. A section perpendicular to the acute bisectrix a was examined in convergent light, but the hyperbolas were too vague and shadowy for accurate measurement —it was estimated that 2E was over 60° and under 75°. All these facts show clearly that the feldspar is an alkali one, not of the lime-soda group. No albite twinning occurs, but Carlsbad and more rarely Baveno twins were seen. The measurements would point to the orthoclase nature of the feldspar, but it unquestionably contains the albite molecule to some extent as shown by the extinction angle on $b(010)$.

The dark-colored minerals are occasional small tablets of a greenish lepidomelane-like mica and prisms of a colorless augite of a wide extinction-angle. This latter is partly changed in some places to serpentine and in others into a fibrous green mineral that is believed to be hornblende. Occasional apatite and iron ore occur.

These lie in an excessively fine-grained ground-mass that appears to be composed of fine feldspar granules. It is so fine as to be almost cryptocrystalline, and even with very high powers little can be learned save that it appears holocrystalline, of untwinned feldspar, and is filled with fine ore grains and microlites of an extremely pale-green mineral occurring in slender needles, and which is thought to be pyroxene. This dense ground-mass when treated with acid is found to yield a small quantity of gelatinous silica, and as no other mineral appears to be present which could yield it, it is probable that this comes from a small quantity of nephelite not otherwise to be detected.

This rock belongs then very plainly in the alkali syenite series, and is a porphyry with a somewhat trachytic habit. The contrast between the size of the feldspar phenocrysts in the main type and in the contact form indicates that they were formed in place and not brought up from below, which idea is favored by the vastly greater number of them in the contact type. This is analogous to the facts shown at Gray Butte and mentioned elsewhere in this paper.

The shaft of the mine has been sunk upon a mass of *shonkinite*, a dark, basic, micaceous rock which appears to form a dike cutting transversely across both the periphery of the trachyte intrusion and its marginal zone of hardened, baked sedimentary rocks. This rock is of a moderately coarse grain, and is filled with stringers and thin seams of pyrite. It consists of iron ore, apatite, augite, biotite, and soda orthoclase feldspar. It is moderately coarse-granular and the augite and biotite which are the chief ferro-magnesian minerals are enclosed poikilitically by the alkali feldspar in broad plates. The structure is hypidiomorphic and the rock is identical with a similar one from an intrusive center on Beaver Creek, and to avoid repetition further details are deferred to the more complete petrographic description of the type occurring at the latter locality.

Its association, however, with the syenite is a matter of great interest, and shows that it is here the complementary rock to that type. The complementary relation between syenite and shonkinite we have already shown on two occasions,* and the present example will be included in the second part of this paper, where we will present further cases in the Bearpaw Mountains with more complete description and a fuller discussion.

The gangue of the ore body is a brecciated and much altered trachyte or syenite-porphyry. The fragments composing it are angular, of varying size, color, and character, and the rock shows considerable pyrite scattered throughout its mass. Examined under the microscope, the thin section shows untwinned feldspar phenocrysts, biotite, and iron ore in a feldspathic ground-mass consisting apparently of singly or untwinned alkali feldspars. It is now so greatly altered by leaching solutions, filled with calcite which exists everywhere in thin films, and the feldspar is so changed into sericite, that it would not be safe to assert more than this about it.

* Bull. Geol. Soc. Am., vol. vi, p. 400, 1895; this Jour., vol. 50, p. 467, 1895.

ART. XXXV.—*Pleistocene Marine Shore-Lines on the South Side of the St. Lawrence Valley;* by ROBERT CHALMERS, of the Geological Survey of Canada.

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ALTHOUGH it has been known for many years that a considerable rise of the land took place in the St. Lawrence Valley in the later Pleistocene period, the facts on which this conclusion was based have been few and disconnected. Sir J. W. Dawson first showed that marine deposits of Pleistocene age, containing fossils, occur on Mount Royal, at Montreal, 470 feet above the sea.* Later, the same author found evidences of ancient shore-lines at the same place at a height of 550 feet;† and Adams and de Geer discovered beaches there also at an elevation of 600 feet and upwards. Along the lower St. Lawrence, between Sainte Flavie and Rivière du Loup, marine shore-lines were observed by the writer in 1885 at heights varying from 345 to 375 feet. During the seasons of 1894 and 1895, however, an opportunity was afforded me of examining the evidences of the Pleistocene upheaval along the south side of the St. Lawrence in much greater detail than has heretofore been done, and data have been obtained showing the extent of a differential uplift there with some approach to accuracy. The observations referred to, it may be stated, are in continuation and extension of those relating to changes of level made in New Brunswick, Nova Scotia, Prince Edward Island and the Gaspé peninsula, the results of which have appeared from time to time in the reports of the Geological Survey of Canada and are shown on the maps accompanying them.‡ In a report recently issued,§ the whole of the work relating to this subject in the eastern maritime provinces is summarized, and it will be seen that the highest Pleistocene marine shore-lines have been traced continuously along the coast from the International boundary between the State of Maine and New Brunswick northward to the mouth of the St. Lawrence River, also around Prince Edward Island and the Magdalen Islands. On the maps accompanying this report these shore-lines are laid down, and in the text their elevations are tabulated and the differential movements they indicate described. This investigation is now in progress along the south side of the

* The Post-Pliocene Geology of Canada, Can. Naturalist, vol. vi, 1872.

† The Canadian Ice Age, p. 63.

‡ Annual Report Geol. Survey Can., vol. ii, 1886, Part M; ibid., vol. iii, 1887, Part N; ibid., vol. iv, 1888–89, Part N, with accompanying maps.

§ Annual Report Geol. Survey Can., vol. vii, 1895, Part M, with accompanying maps.

St. Lawrence Valley, as stated, and will, if possible, be continued until the International boundary is again reached in the neighborhood of Lake Champlain. The following notes on the salient features of these high-level shore-lines, though incomplete, are offered meantime in the hope that they may be of interest to students of Pleistocene geology.

Topographic features of the region on the south side of the St. Lawrence River.—The border of the highlands or mountainous country called the Notre Dame Range, extending from the extremity of the Gaspé peninsula to the International boundary in the State of Vermont, runs close to the St. Lawrence as far west as Kamouraska. Thence it gradually recedes from the river as we proceed westward and near Lake Champlain is not less than forty or fifty miles distant from the St. Lawrence River. The elevation of these mountains is from 1,500 feet to 2,000 or 2,500 feet, the central range being of course the highest. Though intersected in a few places by rivers, as, for example, by the Ste. Anne des Monts, the Chaudière and St. Francis, the mountains, nevertheless, present a gradually ascending slope, rising from the marine plain of the St. Lawrence Valley, of almost unbroken continuity throughout their whole length. Along the foot of the range lower ridges extend parallel thereto, especially below Quebec, which, however, become more and more broken and of less altitude as we leave the higher grounds and approach the shore of the river. Above Quebec a considerable breadth of low-lying country intervenes between the mountains and the St. Lawrence, described below, in which few elevations occur.

The marine plain on the south side of the St. Lawrence Valley.—A large portion of the great marine plain of the St. Lawrence Valley lies on the south side of the St. Lawrence River, i. e. between it and the northern base of the Notre Dame Range (the low-lying country referred to above being a part of it). This part of the plain extends continuously along the whole valley, with hills and ridges, often isolated, rising here and there which relieve the monotony. Along the lower St. Lawrence it is comparatively narrow, in some places forming merely benches; but it widens as we ascend the valley. At Kamouraska it is from half a mile to two or three miles in width; at Montmagny from two to five miles; at Lévis it is not less than fifteen miles wide; at Ste. Henedine and the mouth of the Chaudière River the width is about twenty miles, and at Ste. Julie and Somerset stations, Grand Trunk Railway, twenty-five miles or upwards. Between South Somerset and the International boundary it is from forty to fifty miles in width. The deposits constituting the plain are Saxicava sand, Leda clay and bowlder-clay with some residuary material beneath in places. The height of its surface above the sea varies from a few feet to five hundred feet or more; but the average height does not exceed two hundred and fifty to three hundred feet. As stated already, it is traversed by ridges, especially near the base of the Notre Dame Range, where the plain is usually highest. To the southeast of Ste. Julie and Somerset stations, Grand Trunk Railway, the border of the marine plain, at the foot of the mountains, was found to be about 600 feet in height. From this point it slopes away gently to the northeast, north and northwest, and it would seem as if the margin here must have received a somewhat greater differential uplift than other parts in the vicinity. A number of facts, which cannot be given in detail, lend support to the view that this local uplift, the axis of which is, perhaps, transverse to the general trend of the mountain range, i. e. approximately in a southeast and northwest direction, was of slightly greater extent here than to the eastward. But the forces producing the general Pleistocene upheaval seem also to have effected similar local deformations in other places in the region on the south side of the St. Lawrence River.

From the foregoing facts, therefore, it will be seen that the topographical and physical features of the region described are such as would be likely to favor the formation of terraces or beaches along the shore of the Pleistocene sea which occupied the St. Lawrence Valley.

Along the inner border of the marine plain the terraces and beaches representing the upper limit of the subsidence, and showing the extent of the subsequent upheaval, are to be found. In most places they consist of a series of two, three, or more, and are usually formed of stratified, water-worn materials with bowlder-clay beneath. Sometimes they retain their original outlines continuously for considerable distances; in other cases they are broken and denuded. The lower terraces are always best preserved. Occasionally we find a terrace or water-line cut into the bowlder-clay; but as a rule the beaches partake largely of the character of those formed along the coasts at the present day.

Highest Pleistocene Shore-lines.—Commencing with the beach at Gaspé Bay, we shall proceed westward along the south side of the St. Lawrence River. A considerable gap lies between Gaspé and Ste. Flavie, where I have not yet been able to make the necessary levellings. With this exception the observations form a connected series along the north side of the Notre Dame Range as far west as Somerset station, Grand Trunk Railway. From Somerset or Arthabaska westward to the International boundary the beaches have not yet been traced along the north side of the mountains.

The heights given are from aneroid readings based on the levels of railway stations, and are all referred to mean sea level. Those along the Chaudière valley are only approximate, the shore lines being some distance from railway stations; elsewhere they lie near railways, and the heights may, therefore, be assumed as accurate within a small limit of error:

1.	At Gaspé Bay (Ann. Report Geol. Survey Can., vol. vii, p. 22 M)	225 to 230 feet.
2.	Near Ste. Flavie station, Intercolonial Railway, three terraces or beaches, viz: at 246 to 250 feet, at 300 feet and at	340 to 345 "
3.	At Rimouski, three beaches also, viz: one at 260 feet, another at 330 feet and a third at	367 "
4.	South of St. Simon station, I.C.R.	345 and 375 "
5.	In rear of Trois Pistoles station, I.C.R.	345 and 375 "
6.	South of Rivière du Loup station, I.C.R., along the Temiscouata Ry., two shore lines at	350 and 420 "
7.	Near St. Gervais, southeast of St. Charles Jct. I.C.R., two levels at 510 ft. and	540 to 550 "
8.	At St. Anselme Mountain, 15 miles southeast of Levis, several terraces, height	540 and 555 "
9.	A wide terrace forming part of the marine plain occurs on the west side of the Etchemin River above St. Anselme station, Quebec Central Railway	575 "
10.	Between Etchemin River and Ste. Henedine station, Q.C.R., west of No. 9	620 "
11.	On road going southeastward from Ste. Henedine station, Q.C.R., to Ste. Marguerite village, half a mile from Ste. Henedine	715 "
	Further up hill on south side of a valley	750 "
12.	On the east side of the Chaudière valley at Ste. Marie	740 to 750 "
13.	On the west side of the Chaudière valley, opposite the same place	760 "
14.	Westward near the head of Beaurivage River, on road from Ste. Marie to St. Sylvester	835 "
15.	On road from Ste. Julie station, Grand Trunk Railway, to Inverness, at northern base of mountains, terraces at 850, 865 and	895 "
16.	On a road farther west leading from Ste. Julie or Somerset station, G.T.R., towards St. Joseph and Williams lakes, terraces also at northern base of mountains, at the following levels: 720 feet, 755 to 765 feet, well defined, and a third, which is somewhat denuded and abuts against an escarpment at	860 "
	Gravel hills and mounds here rise to 885 and	890 "

The shore-lines above described face the open St. Lawrence valley, either where it is now occupied by the sea, or has been occupied by it during the Pleistocene period.

No fossils have yet been detected in the terraces, though they have been found in a number of places in the marine plain of which the terraces or shore-lines form the margin. Very little search for fossils has, however, been made in them.

The Chaudière and St. Francis rivers intersect the mountain range, along the north side of which the shore-lines have been traced, by valleys as low as the marine plain along the St. Lawrence River. During the Pleistocene subsidence the sea invaded these valleys, and shore-lines are, therefore, found along the banks at the present day. Not only the main valleys of the Chaudière and St. Francis have been thus occupied by the sea, but a wide extent of country to the southeast of the mountains referred to was also overflowed (unless the relative levels were wholly different then from what they are now), and apparently formed estuaries in which thick deposits of stratified sand, gravel and clay were laid down.

Following the valley of the Chaudière southward from Ste. Marie we find shore-lines in numerous places—one of these on the west side opposite the village of St. Francois, being at a height of 870 to 875 feet. Another occurs seven or eight miles above the confluence of the Du Loup and Chaudière rivers. Here an extensive terrace spreads out in the valley of the latter river which I was informed extended across the country to the Du Loup valley. Prof. J. W. Spencer and I examined this terrace together. In the valley of the Chaudière it is 870 to 875 feet high; in the Du Loup valley near St. Come it is slightly higher, being 890 to 900 feet.

In the drainage basin of the St. Francis River, terraces were observed which seem to be related to the shore-lines on the northwest side of the intervening mountains and correspond with them in altitude. One of these stretches along the southeastern base of Dudswell Mountain for five or six miles, facing a great valley to the south, through which the St. Francis River flows. Its height is from 840 to 850 feet.

At the north end of Lake Memphremagog, and extending towards the base of Orford Mountain, terraces occur composed of gravel, sand and clay, resembling the Saxicava sand and Leda clay of the St. Lawrence Valley. Fossils have not yet been found in these deposits, but no thorough search has been made for them. The height of the terraces is from 860 to 865 feet. A valley of considerable width extends from the north end of Lake Memphremagog along the course of its outlet—the Magog River—by Little Magog Lake, thence to the main valley of the St. Francis River. Through this valley the sea could easily have reached the basin of Lake Memphremagog during the later Pleistocene subsidence, if the relative levels then were not entirely different from what they are at the present day. Thick deposits of stratified sand, gravel and clay occur along this valley; but I have not had time yet to examine them for fossils. Many years ago fragments of shells were found in this valley near Little Magog Lake which were reported on by Dr. T. Sterry Hunt as follows: "It is worthy of record that on Lot 6, Range XIV, of Ascot, Mr. A. Michel detected shells in clay beds which were too imperfect to be preserved, but from a drawing made on the spot appear to be a species of *Mya*."*

Terraces and plains occupying higher levels than those described were observed along the Quebec Central Railway about the headwaters of St. Francis River, also on the divide between these and the Chaudière waters. Between Tring and Robertson stations one was seen at a height of about 1040 feet. At the west end of Lake Aylmer another occurs at about 1075 feet. These were at first supposed to be lacustrine, but there seem to be no barriers which could have held in lakes at these levels. The terrace at Lake Aylmer is apparently continuous with other terraces or plains surrounding several of the lakes in this vicinity. If these terraces are marine they indicate a greater differential uplift of this portion of the country—a theory which was broached on a previous page,—but in the absence of fossils and of detailed examination no positive conclusion can be reached concerning them.

In the valley of the Coaticooke River high-level terraces were also observed. These appear, however, to be bounded by the sides of the valley and enclosed in longitudinal basins, narrow at both ends, and sometimes end on to each other. The height of one at Coaticooke station, Grand Trunk Railway, is about 1210 feet, and of another at Norton Mills is not less than 1250 feet.

In regard to the highest marine shore-line along the north side of the Notre Dame Mountains, which has been traced from the Gulf of St. Lawrence as far west as South Somerset, Quebec, the question arises whether it is likely to continue further to the west at or near the height reached where we left it and merge into the Iroquois beach? The last mentioned beach has been traced along the south side of Lake Ontario by G. K. Gilbert from Lewiston, N. Y., where it is 385 feet high, eastward to Watertown, N. Y., where the height is 730 feet. Thence it was followed by J. W. Spencer, who contends that it is of marine origin, to Fine, where the height attained is

* Report of Progress, Geol. Survey Can., 1863–66, p. 87.

972 feet.* Prof. Spencer extended his levellings still farther to the east, along the northern base of the Adirondacks, finding what he regarded as beaches at different levels up to 1200 and 1350 feet. The evidence as to these was, however, disputed by Prof. Gilbert.†

Mr. F. B. Taylor, who has examined a number of the beaches in the region of the Great Lakes, regards the Iroquois as coinciding with other beaches to the west, and reports some evidence of marine shore-lines from the Lake Champlain basin. On this point he argues thus: "But if the sea filled the Hudson-Champlain trough, attaining a height of 700 feet or more at the north end of Lake Champlain, it is impossible to avoid the inference that this was the time of the formation of the Iroquois, Chippewa and Herman beaches."‡

Baron de Geer, while in America, found a marine shore-line in the Lake Champlain valley, at St. Albans, Vermont, 658 feet high.§

The distance between the levelled points of the marine shore-line of the St. Lawrence valley and of the east end of the Iroquois beach is still so great, however, that it seems scarcely permissible to draw any inferences as to their probable relation to each other based on the levels now at hand. But if the terraces at the north end of Lake Memphremagog are really marine, and have corresponding terraces on the northwest side of the intervening mountains at or near the same height, then the two high-level beaches referred to—the St. Lawrence and the Iroquois—would thus have their levelled points brought much nearer to each other, and may, indeed, prove to be one and the same beach. In that case, as the St. Lawrence beach is certainly marine, there would be no escape from the conclusion that the Iroquois beach is also marine. But further detailed examination and levelling are required to satisfactorily determine the question.

Ottawa, February 4th, 1896.

* This Journal, vol. xl, 1890, pp. 443–451. The heights of the Iroquois beach, etc., are referred to sea level, Lake Ontario being 247 feet high, according to the U. S. Lake Survey.

† Bulletin Geol. Soc. of America, vol. iii, pp. 488–495.

‡ This Journal, vol. xlix, 1895, pp. 249–270.

§ Proc. Boston Soc. of Natural History, vol. xxv, 1892, p. 469.

Art. XXXVI.—*An Occurrence of Free Gold in Granite*; by George P. Merrill.

The specimen described below was received at the National Museum at the close of the New Orleans Exposition (1884–85). It was labelled as simply "gold ore, Sonora, Mexico," and appeared on casual inspection to be an ordinary mica-granite with small disseminated particles of free gold scattered over the surface. It was seen at once to be something worthy of investigation, although at the time it was assumed to be doubtless a case of local impregnation of the rock forming the wall of a vein. The sample was laid aside and quite forgotten until the fall of 1895, when the writer's attention was once more called to it while preparing for the Atlanta Exposition a series of specimens illustrating the occurrence of gold and silver in nature. It has now been the subject of more careful study, with the results as given below:

As above noted, the rock* appears on casual inspection to be an ordinary black-mica granite considerably weathered, somewhat brownish and quite friable. Quartz, feldspar and black mica are all conspicuous and easily determined, the feldspars occurring in crystals some 5–10^{mm} in diameter. The striking feature of the rock is, however, an abundant sprinkling of small flecks of native gold, not merely over the surface, but throughout the entire mass of the specimen, which measures some 125^{mm} × 80^{mm}, by 40^{mm} in greatest thickness.

Under a pocket lens these flecks are so abundant that in extreme cases a half dozen or more are comprised within a space of 10^{mm} square. They are very small, rarely exceeding a millimeter in diameter, and are disseminated throughout the rock, not only as interstitial flecks among the mica scales, but apparently enclosed in both the feldspar and quartz granules. To finally determine this point, a number of thin sections were prepared and submitted to microscopic examination, with results in every way confirmatory.

The rock is, as stated, apparently a normal black mica-granite, the feldspar having a pronounced microperthite structure, and being in most cases badly muddied through kaolinization. The mica has undergone a considerable amount of chloritic alteration. Quartz occurs in the customary interstitial granular forms; fluidal cavities are neither large nor abundant. Magnetite is a common accessory and more rarely apatite and sphene. No sulphides of any kind were detected. The gold occurs associated with the mica or again wholly imbedded in

* Specimen 64987 U. S. National Museum Collections.

the mass of the quartz granules and feldspars. In such cases it does not appear to have been deposited, as was at first thought probable, along fissures, as a secondary constituent, but is completely enclosed in the fresh and unfractured minerals in most beautifully perfect arborescent and extremely thin, platy forms as if deposited directly from solution. Careful search was made for indications of impregnation, by means of solutions, along preëxisting fractures or cleavage planes. But, while in some cases the metal does occur in thin platy forms in what are now fractures or minute rifts, there is nothing to indicate that these existed as such at the time the gold was deposited, but rather that they are due to the subsequent weathering of the rock. The plates do not lie in one common plane, but are scattered at haphazard at all angles with the orientation of the crystals in which they are imbedded. Moreover many of the forms are so branched, moss-like or arborescent, that it is impossible to consider them as formed in this manner. No pyrite or other sulphides or their decomposition products can be detected. There is apparently no way of accounting for the gold other than by considering it an original constituent of the rock, a product of cooling and crystallization from the original magma. This of course on the supposition that the rock is a true granite, which it in every way resembles.

This occurrence is of unusual interest, if not of importance. So far as the writer is aware, nothing quite comparable with it has been noted.

J. B. Jaquet has briefly described and figured* an occurrence of free gold in microcline, the rock in which the latter occurs consisting essentially of microcline and quartz, impregnated with hematite. He remarks that it somewhat resembles the coarsely crystalline granite found in the schists of the region. Adams and Dawson have described† the ore of the Treadwell mine, Alaska, as a hornblende granite, "much crushed, altered, and impregnated with secondary quartz, calcite and pyrite," the last named carrying the gold, a considerable portion of which is free. In the present instance, however, the granite is altered only by the ordinary processes of superficial weathering, and as above noted contains no pyrite or other sulphides. The occurrence of the gold completely imbedded in the clear glassy quartz and unfissured feldspars apparently precludes the possibility of a secondary origin. The beautiful, highly lustrous yellow metal stands out in the sections, clear and distinct, whether in quartz or feldspar,

* Geol. of the Broken Hill Lode, etc., Mem. Geological Survey of N. S. Wales, Australia, No. 5, 1894.

† Am. Geologist, Aug. 1889.

without a trace of iron staining and with no cavities left by pyritiferous decomposition (see figs. 1 and 2).

1. 2.

FIG. 1.—Free gold in feldspar.
FIG. 2—Free gold in quartz. Gold indicated in black.

The Museum has no record as to the occurrence of this ore. But if, as is apparent, it is a normal granite, the occurrence is of importance in its bearing upon the question of the origin of the gold in veins and other secondary deposits.

National Museum, Mar. 2, 1896.

SUPPLEMENTARY NOTE.—Since the above was in type the writer's attention has been called by Mr. W. Lindgren to an article by W. Möricke (Tschermak's Min. u. Petr. Mittheil. iii, 1891) on Chilean ore deposits, in which free gold is described as occurring in a quartz-trachyte. The metal is visible with the aid of the microscope and is found both in glassy (pechstein) and crystalline varieties. It is regarded by Möricke as an original constituent.

Art. XXXVII—*A Theory of the "X-Rays;"* by Albert A. Michelson.

The principal facts, which any satisfactory theory of the "X-rays" is called upon to explain, may be summarized as follows:

1. The production of the rays by electric impulse, at the cathode,* in a highly exhausted enclosure.

2. Propagation in straight lines and absence of interference, reflection, refraction and polarization.

3. The importance of density of the medium as the determining factor in the transmission of the rays.

4. The production of fluorescence and actinic effects, and the action on electrified conductors.

Two theories have been proposed to account for these remarkable phenomena: (1) the theory of longitudinal waves; (2) the theory of projected particles.

In reference to the first theory it may be said that unless it is proved that an oscillatory discharge is essential to the production of the X-rays, there can be no reason for supposing that these rays are of a periodic nature—that they are wave-motion as commonly understood. The absence of interference, reflection and refraction is also a very formidable difficulty. Attempts have been made to account for the absence of these invariable accompaniments of every known form of wave-motion, but, as I think, with very indifferent success.

The most serious difficulty in the second theory is the attempt to explain the passage of the electrified particles of the residual gas (or of the electrode) through the walls of the vacuum tube. The query at once arises, if glass is permeable to these particles in virtue of their relatively great velocity, why is it not permeable (in lesser degree) to the same particles moving with smaller velocities? That it is not, is evident from the fact that vacuum tubes retain their high degree of exhaustion unimpaired for years.

In view of these difficulties, I would propose a third theory, which may be called the "ether-vortex" theory.

Let it be supposed that the X-rays are vortices of an intermolecular medium (provisionally, the ether†). These vortices

* Even should further experiment prove that the X-rays proper originate at the first obstruction encountered by the discharge, the fact remains that this discharge originates at the cathode.

† A possible objection occurs to the formation of ether-vortices in a medium which is usually considered free from viscosity; but the fact that vibrating molecules can and do communicate their motions to the surrounding ether shows that the communication of vortex motion may also be possible.

Though not a necessary part of the theory, it may be considered that the expulsion of the ether-vortices is due to an accumulation of ether in the cathode, are produced at the surface of the cathode, by the negative charge, which forces them out from among the molecules of the cathode.

Let us now apply the tests above mentioned.

According to this theory, an oscillatory discharge, while it may be just as effective as a series of separate impulses, is not essential to the formation of the vortices. The vortices being forced outward from the surface of the cathode by the negative charge, the effect of the positive charge at the anode would be to drive them in. Hence their appearance at the cathode alone.

One of the greatest puzzles connected with the behavior of the X-rays is the fact that while they can pass almost unimpeded through air at atmospheric pressure (let alone water, glass, wood, flesh, bone, and metals) *when once outside the enclosure in which they are produced*, they cannot even reach the walls of the enclosure, except there be a very high vacuum within. This problem receives a very natural solution if it be considered that, in order that ether-vortices may result from the electrical impulse, this impulse must be communicated to them; and must not be dissipated in the interchange of molecular charges which accompanies, or rather produces, the discharge at moderate or high pressures.

As exhaustion proceeds there are fewer molecules present to effect this discharge with sufficient rapidity, and as this limit is approached there will be a division of the energy of the electric impulse between the electrified molecules and the ether-vortices, and in the end all the energy of the discharge will be confined to the latter.

The reason for the non-appearance of the rays under ordinary conditions is not that the rays cannot reach the walls of the enclosure or pass through them, but that they cannot form at all. The propagation of vortices in straight lines, the absence of interference phenomena, of reflection, refraction and polarization, follow from the properties of vortices, and from the absence of anything corresponding to a wave-front. The passage of an ether-vortex through a mass of matter may be compared with a passage of a smoke-ring through a wire gauze screen or a series of such; and as the motion of the rings is more impeded the greater the diameter and the number of wires per unit volume, so, the greater the number and the size of the molecules—that is, the greater the density—the more effective will the medium be in dissipating the energy of the ether vortices.

and this would lend support to the theory that this accumulation is not merely a result of the negative charge, but that this excess of ether is what constitutes the negative charge.

The production of fluorescence, actinic effects, and the dissipation of electric charges by light (which is an ether motion) would make it at least probable that similar (though perhaps not identical) effects would be produced by the motions of ether-vortices.

Professor J. J. Thomson has measured the velocity of cathode-rays and obtained a result so very far less than the velocity of light as to preclude entirely the idea of there being any connection between the two. If these results can be made to apply to the X-rays, the analogy with the properties of smoke-rings would lead us to expect such a result. The cathode rays have been shown by Lenard to have a considerable range in their properties, depending on the mode of their origin.* It seems likely that their velocities are to a considerable extent dependent on the potential and the suddenness of the electrical impulse; and if this were shown to be true of the X-rays, it would be to that extent a confirmation of the theory.

The foregoing evidence may be considered scarcely sufficient to entitle the proposition here advocated to the dignity of a theory, but it may at least merit consideration as a working hypothesis which may serve as a guide in future experiment.

* The distinction between the X-rays and the cathode rays appears to be somewhat artificial, and it seems probable that the X-rays are only cathode rays sifted by the various media they have traversed.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On some physical properties of argon and helium.*—LORD RAYLEIGH has made a new determination of the specific gravity of argon, using a large volume of the gas separated from atmospheric nitrogen by sparking with oxygen. The result obtained, referred to O_2 as 16, was 19·940. Professor Ramsay had previously obtained a density of 19·941 for the gas obtained by the magnesium method, so that it is evident that the products obtained by the two methods are identical. The author has also determined the refractivity of argon and helium, with the results that the refractivity of argon is 0·961, while that of helium is 0·146, compared with air as unity. The result in the case of argon is very unfavorable to the view that this gas is an allotropic form of nitrogen. The refractivity of helium is remarkably low, the lowest previously known being that of hydrogen, which is nearly 0·5 that of air. The results of determinations of viscosity were for helium 0·96 and for argon 1·21, referred to dry air. The latter number is somewhat higher than that for oxygen, which has stood at the head of the list of the principal gases in this respect. The author has found by spectroscopic examination that the gas emanating from the Bath springs contains both argon and helium, with probably less than 10 per cent. of the latter in the mixture of the two. Gas from the Buxton springs was found to contain about 2 per cent. of argon, while the presence of helium in this gas in very small quantity was probable, but not certain. The interesting question concerning the existence of helium in the atmosphere was attacked by allowing the greater part of samples of atmospheric argon to be absorbed by water and examining the residues by the spectroscope. It was expected that helium, since its solubility in water is but about one-fifth that of argon, would be concentrated in these residues if it were present. No helium could be detected in this way, and the author concludes that if helium be present in the atmosphere, it must be in very small quantity, probably much less than a ten-thousandth part.—*Chem. News*, lxxiii, 75. H. L. W.

2. *Mixed double halides of platinum and potassium.*—An investigation of the compounds represented by the formula $K_2Pt(Cl, Br)_6$, where chlorine and bromine exist in varying proportions, has been made by HERTY. He found that the products prepared under varying conditions gave no definite relation between the chlorine and bromine, and that none of these substances remained constant in composition after recrystallization. The author therefore arrives at the conclusion that the products are simply isomorphous mixtures of K_2PtCl_6 and K_2PtBr_6. The previous contrary conclusion of Pitkin and of Pigeon may be considered as unfounded in the light of Herty's careful and elaborate work.—*Jour. Am. Chem. Soc.*, xviii, 142. H. L. W.

3. *The relative atomic weights of oxygen and hydrogen.*—A new determination of this important ratio has been made by JULIUS THOMSEN. The novel feature of his method consisted in evolving hydrogen, by means of strong potash and metallic aluminium, from a weighed apparatus and determining the amount of the element used from the decrease in weight of the apparatus. The result arrived at from a series of experiments was

$$H : O = 1 : 15 \cdot 8690 \pm 0 \cdot 0022.$$

This result agrees with remarkable closeness with the results of a number of other investigators, as will be seen from the following list cited by Thomsen:

Cooke and Richards	1 : 15·869
Rayleigh and Scott	1 : 15·862
Morley	1 : 15·879
Noyes	1 : 15·886
Dittmar and Henderson	1 : 15·867
Leduc	1 : 15·881

The author believes that the ratio is now definitely settled within very close limits, and there is no doubt that most chemists will accept a ratio very close to this, especially in view of the very elaborate work of Morley.—*Zeitschr. anorg. Chem.*, xi, 14.
H. L. W.

4. *The synthesis of caffeine.*—The complete synthesis of this important alkaloid, the active principle of tea and coffee, has now been made possible by the work of EMIL FISCHER and LORENZ ACH. The important step accomplished by the authors is the conversion of γ-dimethyl uric acid, by the action of phosphorus pentachloride, into chlortheophylline. The latter, by reduction to theophylline and subsequent methylation, gives caffeine. The γ-dimethyl uric acid has been produced, in a roundabout way only, from dimethyl urea as a starting-point, and the authors therefore consider the synthesis of no practical value at present on account of the expense. They believe that their results would have a practical importance if it were possible to methyllate uric acid directly so as to place two methyl groups in the alloxan nucleus. It is their opinion that as soon as the base becomes a cheap material through artificial preparation, it may have use in the manufacture of substitutes for tea and coffee to give them the same physiological action as the natural materials. —*Berichte*, xxviii, 3135.
H. L. W.

5. *Free hydrazine.*—Curtius, who discovered and investigated hydrazine, obtained the hydrate, $N_2H_4 . H_2O$, but did not succeed in isolating the anhydrous substance. LOBRY DE BRUYN has now obtained the free base by two methods. The first method consists in treating the hydrochloride with sodium methylate, when the following reaction takes place:

$$N_2H_4 . HCl + NaOCH_3 = N_2H_4 + NaCl + HOCH_3.$$

According to the second method hydrazine hydrate is heated with barium oxide at 100° and the product is distilled under diminished pressure. Free hydrazine is a liquid which boils at 113·5° (at 761^{mm}). By cooling below 0° it solidifies, and it melts at +1·4°. Its specific gravity is about the same as that of the hydrate, 1·003 (23°). It is a very stable body and can be heated above 300° without decomposition. The halogens act upon it with great violence, and it acts upon solid sulphur at ordinary temperature with the formation of hydrogen sulphide. Oxygen attacks the base, with the liberation of nitrogen, when it is exposed to the air. The author has also made the useful observation that hydrazine hydrate can be distilled under diminished pressure from glass vessels, since under 50° it does not attack glass. Curtius, operating under atmospheric pressure, was obliged to use a special apparatus of silver for the distillation.—*Berichte*, xxviii, 3085. H. L. W.

6. *Practical Inorganic Chemistry*, by G. S. Turpin, 12mo, pp. 158, London and New York, 1895. (Macmillan & Co. Price 60 cents.)—This is a course of laboratory work for beginners in chemistry. The experiments are very simple in character, and are such as can be carried out by very youthful pupils with limited facilities. Many of the operations are of a rough quantitative nature, designed as illustrations of chemical and physical laws. While the processes are clearly described, the results, in most cases, are not mentioned, so that the student is obliged to observe them for himself. A chapter is devoted to a very simple course in qualitative analysis, covering a range of seven metals and four acids. H. L. W.

7. *Chemical Experiments, General and Analytical;* by R. P. Williams, 12mo, pp. 110, Boston, 1895 (Ginn & Company).—This book is intended for a somewhat comprehensive course of laboratory work in high schools, academies and colleges. The subject matter is condensed, abbreviated and tabulated to a large degree. It seems that more help should have been given to the student in the way of explanations. Upon the mere mention of such words molecule, affinity, stochiometry, definite proportion and the like, the pupil is expected to study these subjects "outside the laboratory," and he is expected to write chemical equations, although none are given in the book, even in some instances where the products of the reactions are not mentioned. Unfortunately the book contains a number of astonishing inaccuracies. H. L. W.

8. *A Text Book of Gas Manufacture for Students;* by John Hornby. 12 mo., pp. 261, London, 1896 (George Bell and Sons).—This little book gives an excellent account of the subject in view. The chemical and mechanical features of the processes are clearly described and the illustrations are numerous and well-chosen. H. L. W.

9. *Methods of determination of Dielectric Constants.*—W. Nernst refers to his method of measuring the dielectric constant of insulators and bad conductors (Zeitschr. f. Phys. Chem. xiv,

p. 622, 1894) and illustrates its accuracy in comparison with previous electrometer methods and with the glass trough method. Under his direction J. F. Smale has employed two electrometers of the form designed by Bjerknes, in which a needle is acted on inductively by two quadrants, which are connected to the terminals of a Ruhmkorf coil. The needle and the quadrant are immersed in the dielectrics which are to be compared. It is pointed out that the needle of the electrometer must be placed in a comparatively large mass of the dielectric, which must also fully surround the electrodes or quadrants. J. F. Smale describes an ingenious gas regulator to obtain uniform revolution of the armature of a little alternating machine which excited the transformer which was connected with the electrometers, which in turn were connected in parallel. Smale found a satisfactory agreement between the electrometric method and the bridge method employed by Nernst.—*Ann. der Physik und Chemie* No. 2, 1896, pp. 209–222. J. T.

10. *Dielectric Resistance.*—P. Drude elaborates the conception of dielectric resistance to lines of electrostatic force, analogous to the conception of magnetic resistance previously touched upon in his treatise "Physik des Aethers"; and also by Professor Nipher, of Washington University, St. Louis.—*Ann. der Physik und Chemie* No. 2, 1896, pp. 223–231. J. T.

11. *Index of refraction and reflective power of water and alcohol for Electric Waves.*—If the wave length of electric waves along two parallel wires is measured, first with air between such wires and afterwards when a portion of the space between them is filled with a dielectric, the ratio of the resulting wave lengths will give the index of refraction of the dielectric for the electric waves. A. D. Cole, working in this manner, has obtained 8·95 for the index of refraction of water at 19° C. and 5·2 for alcohol at 18° C. With the employment of mirrors to reflect the electric waves from the surfaces of water and alcohol, it was found that waves 5^{cm} long gave with reference to Fresnel's formula, both for rays polarized perpendicular to the plane of incidence and also parallel to it, the same value for the index of refraction (calculated from observed reflective power). For water $n=8{\cdot}8$ and for alcohol $n=3{\cdot}2$. With alcohol the index of refraction was much greater for long electric waves than for short.—*Ann. der Physik und Chemie* No. 2, 1896, pp. 290–310. J. T.

12. *Röntgen Rays.*—Righi, in a preliminary paper (Rendiconto delle Sessioni della R. Accademia delle Scienze di Bologna, Feb. 9, 1896), states that the Röntgen rays have the property of dispelling positive charges of electricity as well as negative. Professor J. J. Thomson has independently made the same observation. (Nature, Feb. 27, 1896.) Professor Thomson also states that when the Röntgen rays pass through any substance they make it for the time a conductor of electricity. This explains the fact that an electrified plate in air loses its charges whether it be electrified positively or negatively. The air is converted into a

conductor and the charge escapes through it. The leakage through non-conductors is due to a kind of electrolysis, the molecules being split up by the rays. Professor Thomson thinks that the rays are not all of the same kind. Crookes tubes generally improve for a time after they are sealed off from the air pump and then begin to deteriorate. Mr. A. A. C. Swinton describes a simple apparatus for determining whether a Crookes-tube is efficient. It consists of an opaque pasteboard box with a simple aperture at one end to which the eye is applied. The other end is provided with an opaque diaphragm of double black paper, upon the inner side of which is laid a piece of blotting paper impregnated with platino-cyanide of barium in a crystalline state. Shadows of objects held against the diaphragm are clearly seen. Mr. Swinton has thus seen the bones in the thick portion of his hand. This apparatus is similar to that described by Professor Salvioni of Perugia.—*Nature*, Feb. 27, 1896. J. T.

13. *Experiments with the Röntgen rays.*—Doelter has recently called attention to the fact that the X-rays of Röntgen may be used as a means of distinguishing between different gems, as also between them and their imitations. A true diamond may thus be readily told from a false one. While rock crystal, topaz, strass and spinel are opaque to the rays, the varieties of corundum (ruby, sapphire) transmit them to some extent. The usually accepted relation between the opacity of the substance to the X-rays and its density finds some exceptions, according to Doelter, among minerals. He finds sulphur (G. = 2) and realgar (G. = 3·4), quartz (G. = 2·6), fluorite (G. = 3·1), quite opaque; corundum (G. = 4·1), as stated above, transmits the rays somewhat, while diamond (G. = 3·5) and graphite (G. = 2) transmit much better. Most silicates are opaque; this is true of mica in layers of 1^{mm} in thickness. In sections of $\frac{1}{3}^{mm}$ it is possible to distinguish between the transmissive powers of amphibole, garnet, quartz, mica, feldspar.—*Private publication*, Gratz, Feb., 1896.

14. *The Elements of Physics; A College Text-book*, by E. L. Nichols and W. S. Franklin, vol. i., 228 pp., 8vo. New York, 1896 (Macmillan & Co.).—This volume forms the first of a series of three in which the authors propose to develop the fundamental principle of Physics; it embraces the subjects of Mechanics and Heat, while the other two volumes are to be devoted to Electricity and Magnetism, and Sound and Light respectively. The scope of the work and the method of treatment differ from those of many existing text-books inasmuch as the authors write for a somewhat more advanced grade of students than those which form the mass of many college classes. It has thus been possible for them to assume a knowledge of the Calculus and in general to treat the topics more concisely and from the mathematical side; long descriptions of the applications of the principles are thus avoided. For those students for whom the work is prepared, who desire to make a serious study of Physics, this excellent new text-book cannot fail to be of much value.

II. Geology and Natural History.

1. *Contributions to the Cretaceous Paleontology of the Pacific Coast: The Fauna of the Knoxville Beds*; by T. W. Stanton. (Bulletin U. S. Geological Survey, No. 133.) 132 pp., 20 plates, Washington, 1895 [issued Feb. 3, 1896]. Abstract by the author. —The Knoxville beds as described in this paper form the lowest division of the Lower Cretaceous section in California, and are found in the Coast ranges from San Luis Obispo County, Cal., (near latitude 35°) on the south to the neighborhood of Seattle, Washington, on the north, though they are not continuously exposed throughout that distance. The name was first applied in 1885 by Messrs. White and Becker to the Aucella-bearing portion of the ill-defined Shasta group. Since then the beds have been studied more in detail, especially by Mr. J. S. Diller, and a résumé of his stratigraphic results is given together with the author's observations made during portions of two field seasons spent in the most important areas.

Lithologically the beds consist of a series of dark clay shales alternating with sandstones, usually in thin beds, with local deposits of heavy conglomerate and more rarely small limestone masses. The thickness is very great, always several thousand feet and, according to one of Mr. Diller's measured sections, reaching a maximum of nearly 20,000 feet in Tehama County, Cal., where the series is best developed both faunally and lithologically.

The underlying formations have not been very definitely determined owing to the fact that they are usually unfossiliferous and frequently more or less obscured by metamorphism and by the intrusion of igneous rocks. The evidence tends to prove that the Knoxville rests on rocks varying in age from Carboniferous to probably Upper Jurassic. The Horsetown beds which rest conformably on the Knoxville are, in part at least, referable to the Gault.

The invertebrate fauna as now known consists of 77 species and varieties, of which 50 species and one genus (Cardiniopsis) are described as new. Most of these are rare, having been found at only one or two localities, but the several forms of Aucella are very abundant, often filling the rocks and occurring at many horizons. All but 7 of the species are Mollusca, including 33 species of Pelecypoda, 1 of Scaphopoda, 18 of Gastropoda, and 18 of Cephalopoda, of which 15 are Ammonoids and 3 are Belemnites. The ammonites belong to the genera Phylloceras, Lytoceras, Desmoceras, Olcostephanus and Hoplites, the last being especially well represented. The other seven species include 5 Brachiopoda and two Echinodermata.

As a result of the study of the fauna the Knoxville beds are referred to the Lower Cretaceous and are regarded as later than the Mariposa beds of the Sierra Nevada, which are also Aucella-bearing but of Jurassic age.

Beds of Knoxville age and with a similar fauna occur in British Columbia and probably in Alaska and Mexico. Correlation may also be made with an indefinite upper portion of the Aucella-bearing series in Russia, especially with the "Petschorian."

It is a peculiar fact that this fauna has nothing in common with the fauna of the Texan Comanche series, which must have been in part contemporaneous. Not only are the species distinct but even most of the genera are different, and yet the eastern sea with its Comanche fauna at one time extended as far west as Arivechi in Sonora, while the Mexican Aucella beds, which faunally seem to belong to the Pacific basin and in part comparable with the Knoxville, are much farther east in San Luis Potosi. These facts have an important bearing on the history of the continent, but their exact interpretation must await more detailed stratigraphic and faunal studies in Central Mexico.

2. *Contribution a l'étude des lapiés.*—In a paper in "*Globe, journal geographique*," Tom. xxxv, Genève, 1895, entitled *La topographie du désert de Platé* (*Haute-Savoie*), M. Emile Chaix has given a detailed description of the peculiar phenomena called "*Karrenfelder*" by Heim, Fr. Becker and others, and "*lapiés*" by Charpentier, Rollier, Duparc and LeRoyer, etc. Lapiés are barren rock surfaces, high up in the Alpine glacial regions, smoothed off in general, but crossed by shallow channels or grooves commonly in the direction of the slopes; with deeper crevasses, continued for long distances in a more or less straight line and transverse to the slopes, though sometimes crossed by others at nearly right angles and in line with the slopes of the rocks. The author has mapped with great care the direction and position of the crevasses of the Désert de Platé, and has figured typical examples of the peculiar structure in 16 photogravure plates.

After describing them in detail, and referring to the various theories offered by other geologists in their explanation, he adopts the view that the more superficial grooves and channels (*ciselures* and *rigoles*) are the result of chemical erosion; and that the deeper *crevasses* are the result of torsion, as suggested by the investigations by Duparc and LeRoyer. He concludes that these two classes of phenomena, in the case of the Désert de Platé, were produced at different times, the latter being of ancient and the former of post-glacial origin, the edges of both having been more or less rounded by later atmospheric and aqueous agencies. H. S. W.

3. *The geographical distribution of marine animals.*—In line with Walther's "Bionomie des Meeres," Dr. Arnold E. Ortmann* has contributed some interesting chapters to this rapidly crystallizing department of science, the geographical and geological

* Grundzüge der Marinen Tiergeographie. Anleitung zur Untersuchung der geographischen Verbreitung mariner Tiere, mit besonderer Berücksichtigung der Dekapodenkrebse von Dr. Arnold E. Ortmann (Princeton, N. J.), pp. 1–96, 1 chart. Jena (Gustav Fischer), 1896.

biology. Two or three points may be briefly referred to, which might be much enlarged on if our space would admit. In discussing marine regions of distribution the author reaches this significant conclusion, that the passage from the temperate to the polar climatic zones does not constitute so important a climatic boundary for the distribution of organisms as the passage from tropical to temperate. The most important climatic boundary is the line where the sum of the general fluctuations of temperature is so great that tropical organisms accustomed to an equable warm climate are unable to endure the changes; a greater reduction of mean temperature is found farther poleward, this being associated with the diminution of the amplitude of the fluctuation and is not to be regarded as a climatic limit of first rank.

In the chapter on the distribution of Decapods the conclusion is reached that the ancestors of Decapods, as well as Euphausiacea, were Nekton (open sea) animals, and as they were dependent upon the substratum they could exist only under littoral and abyssal conditions.

In an interesting chapter on the favoring and hindering means of distribution, the author emphasizes the importance of isolation, and formulates the four following as the chief factors in the formation of new species, viz: 1, Adaptation to external conditions forms variations; 2, the transmission of adaptations fixes the variations, thus occasioning groups of morphologically similar forms; 3, natural selection modifies these morphological groups causing mutation in definite directions; 4, isolation of the morphological groups produces differentiation and direction of mutation and thus the production of separate species. We hope to have, in a future number, a fuller discussion by the author of some of these points. H. S. W.

4. *Charles Lyell and modern Geology;* by Prof. T. G. Bonney. pp. 224, New York (Macmillan & Co.), 1895.—This is a brief but readable account of the life of a geologist whom all the world knows, but whose memory will be revived for the younger generation by this compilation. It is one of the Century Science Series edited by Sir Henry Roscoe, and like others of the series the brevity of the work is likely to lead earnest students to look up the original biographies of these scientific worthies who have made the present century famous.

5. *Beiträge zur Geophysik. Zeitschrift für Physikalische Erdkunde.* Herausgegeben von Prof. Dr. Georg Gerland. II Band. 2–4 Heft. pp. 197–773, Stuttgart, 1895.—This part closes the second volume of the valuable *Beiträge zur Geophysik*, edited by Professor Gerland, the first volume of which was noticed in volume xxxv (p. 344) of this Journal. Some of the papers here included are: A. Schmidt, Erdmagnetismus und Erdgestalt; E. v. Rebeur-Paschwitz, Horizontalpendel-Beobachtungen auf der Kaiserlichen Universitäts-Sternwarte zu Strassburg; E. Rudolph, Ueber submarine Erdbeben und Eruptionen; H. Wagner, Areal und mittlere Erhebung der Landflächen sowie Erdkruste.

6. *Structure-Planes of Corundum and some Massive Minerals* (*simple rocks*) *from India and Australia;* by J. W. JUDD (Min. Mag., vol. xi, No. 50).—The author, as the result of his studies, states that "corundum has at least three sets of structure-planes but that none of these can be regarded as true *cleavage*. Two of these structure-planes, those parallel to the base 0R(111) and to the prism ∞P2(10$\bar{1}$) are normal solution-planes; the third set of structure-planes, those parallel to the unit rhombohedron R(100), are gliding planes which when developed become secondary solution-planes." He also says that the partings observed "appear to be due . . . . to chemical alterations taking place along these structure-planes of the crystal."

In the second portion of the paper an account is given of some minerals which occur on so large a scale as to form veritable rock masses. Some of these are occurrences of corundum at several localities in India; also rock masses made up of quite pure tourmaline of a black color and in fibrous form. A rock composed entirely of a green garnet is mentioned as occurring in dike form cutting serpentine; associated is another dike composed of nearly pure picotite (chrome spinel). L. V. P.

7. *Remarkable phosphorescence in Wollastonite;* by W. F. HILLEBRAND. (Communicated.)—In examining a fibrous mineral recently received from New Hartford, Oneida County, N. Y., which proved to be wollastonite, although of somewhat greater hardness (about 5·5) than the limit given in text-books, a most beautiful greenish-yellow phosphorescence was observed. The color is not very conspicuous by daylight, but in a dark room the phenomenon is very strikingly shown when fragments are heated below redness, or when the somewhat coarsely powdered mineral is thrown into a hot, but not red-hot, crucible.

Professor Penfield, to whom the specimen was sent, finds that "the columnar and compact varieties from Bonaparte's Lake, Lewis Co., N. Y., New Windsor, Orange Co., N. Y., and Bucks Co., Pa., show exactly the same phenomenon. Fragments of crystals from Diana, Lewis Co., N. Y., and Dognaczka, Banat, show only a slight phosphorescence, while a few of the crystallized varieties that were tested do not show it at all. The compact edelforsite of Hisinger, which Forchhammer (Danske Videnskab. Selskabs Förhandlingar, 1867, p. 64) by means of chemical analysis has shown to be impure wollastonite, exhibits the phosphorescence beautifully."

I may add that my own tests on material in the U. S. National Museum show that different specimens from the same locality may glow with very different intensities, as those from Natural Bridge, Lewis Co., N. Y., for instance. Several Bucks Co., Pa., specimens failed to phosphoresce, at least visibly, in daylight. The beauty of the phenomenon and its novelty as regards this species seem to merit publicity.

Washington, U. S. Geological Survey.

8. *Propagation of the sugar-cane.*—Director J. H. WAKKER, of the experiment station for the study of sugar-cane, in East Java, has published an important communication relative to this matter, which is likely to stimulate further investigation in all cane-producing districts. It is well known that in practice cane is universally propagated from cuttings or their equivalents, and, furthermore, this mode of perpetuation has very naturally resulted in a loss of the power to produce good seeds. Wakker, by prosecuting extensive and exact researches, has found that the power of producing viable seeds is not wholly lost by this plant, but is capable of at least partial restoration by proper selection. Close inspection shows that although a great majority of all the flowers of the cultivated varieties of the cane are practically sterile, it is possible in some instances to find a few scattering blossoms which can be utilized for artificial pollination. At the experiment station in East Java there are between two and three hundred varieties of Saccharum under cultivation, but of these only a very few (in fact only one to any great extent) are employed in Javan agriculture. The principal variety, the so-called "Cheribon-cane," does not seed at all, and the same is true of some of the others, but diligent search was rewarded by the discovery that in some good varieties efficient pollen could be obtained, and in some others there were receptive stigmas. The pollination in an illustrative case, namely, that in which Cheribon-cane was used for the female plant, was guarded from foreign influence by the use of a paper covering around the inflorescence. In the year 1893, Wakker obtained from these crosses 669 seedlings of remarkable vigor. From all of his experiments in that year, he procured 490 which had to be subsequently rejected, but he retained 179 of high promise. Most of these possessed a higher percentage of sugar than the parent plants, and were free from disease.

It is difficult to overestimate the value of these researches. The range of bud-variation in the cane is very wide, but it has seemed to tropical cultivators an almost hopeless task to lead the product of sugar up to a much higher percentage than at present by means of selection among these varieties, whereas it has been felt that if seeds could in any way be had, the initiation of new and more productive variations might reasonably be hoped for. It is understood that no appreciable advance in the process of sugar extraction is to be expected: on the other hand, a path for the successful cultivation of new varieties is now fairly broken and may speedily give us far greater production per acre than has hitherto been thought possible. G. L. G.

9. *Systematic arrangement of Australian Fungi, together with Host-Index and List of Works on the subject*; by D. McALPINE, pp. 236, 4to (Melbourne, 1895).—The rapid development of the study of fungi in Australia is strikingly shown in the present volume by Prof. McAlpine, the government vegetable pathologist of Victoria, issued by the Department of Agriculture. Of the

311 titles given in the List nearly two-thirds are of works which have appeared in the last ten years; the greater part in fact in the last five years. Furthermore, while the works published prior to 1885 were almost entirely by a small number of British and continental mycologists, since that date the authors have been for the greater part persons living in Australia. The two hundred pages devoted to a list species of Australian fungi with habitats and notes of general characters, are followed by a list of 84 edible species. Excluding a few characteristic forms like *Cyttaria Gunnii* and *Polyporus mylittæ* or native bread, one is struck with the fact that the edible species of Australia are nearly identical with those of Europe and North America. Some interesting statistics are given which show the whole number of fungi known in Australia to be 2,284, of which the greater number, 1,266, are Hymenomycetes. Uredincœ have 90, Ustilagineæ 39 and Myxomycetes 52 species. Of the different host-plants, the species of Eucalyptus are attacked by 54 species of fungi. The species of Acacia come next with 16 parasites. The Host-Index gives an alphabetical list of hosts with their parasites, without synonymy, and a note of the organs attacked. This work by Prof. McAlpine will be of very great assistance not only to Australian mycologists but also to those of other countries, who will be able at a glance to get a practical knowledge of the distribution of Australian vegetable parasites with a facility which would otherwise be impossible. W. G. F.

10. *Der Reis-Brand und der Setaria-Brand;* by OSCAR BREFELD, Botanisches Centralblatt, lxv, 97–108, January, 1895.—In the twelfth part of his "Untersuchungen" Brefeld made mention of a smut of Oryza in which the spores did not germinate like those of other Ustilagineæ but produced a mycelial thread with spores arranged acropetally. He also described a very similar fungus on *Setaria Crus Ardeæ* from South America. Since then, having obtained abundant material of the latter fungus, he has been able to trace its development and finds that, besides the so-called smut-spores, the fungus produces a well-marked sclerotium. The sclerotia, after remaining for six months in moist sand, developed into stalked fruit-bodies much like those of *Claviceps purpurea*, the common ergot. The ascospores on germinating produced conidia like those produced by the smut-spores. Brefeld regards the sclerotium, ascoporic form and smut-spores as stages of the same fungus which he calls *Ustilaginoidea Setariæ*, and the smut of Oryza, although its development has not been traced, he places in the same genus on grounds of analogy. The genus Ustilaginoidea belongs to the Hypocreaceæ and the so-called smut-spores in this case correspond to the chlamydospores of species like *Hypomyces chrysospermus*. Brefeld ventures to predict from this case that other supposed species of Ustilagineæ will eventually be proved to be stages of Ascomycetes. It may be said, on the other hand, however, that, in his Untersuchungen, Brefeld showed that, although the Oryza-smut had been originally placed

in the Ustilagineæ, the development of the spores were in an important respect different from those of other Ustilagineæ. This being the case, one is perhaps hardly justified in predicting that, in their later development, the Ustilagineæ proper are likely to have ascorporic forms like Ustilaginoidea. It is a conceivable supposition, to say the least, that Ustilagineæ are a heterogeneous group and that when more is known of their development, they may prove to be imperfect conditions of more than one order of higher fungi. W. G. F.

11. *Die Entwickelung des Peritheciums bei Sphaerotheca Castagnei.* By R. A. HARPER (Bericht. Deutsch. Bot. Gesell., xiii, 475–481, Pl. 39).—More than twenty-five years ago DeBary advanced the opinion that the perithecium of Sphaerotheca and its allies is of sexual origin. At that time botanical technique was very different from what it is at the present day, and DeBary did not attempt to show that there was an actual union of the nuclear elements of what he considered to be the male and female organs. More recently there has been a tendency among mycologists to regard the sexuality in this case as doubtful or even disproved. In the present paper, the author, making use of the best modern manipulations, confirms the general account of the origin and nature of the antheridium and oogonium originally given by DeBary, and describes and figures the union of the nuclei of the male and female organs, adding important details with regard to the development of the perithecium from the oogonium. The fertilized nucleus of the female does not develop further until the ascogonium is surrounded by an envelope of two layers. The ascogonium then elongates and curves away from the side where the antheridium was attached. The nucleus now divides into two, and a transverse wall divides the ascogonium into two cells, the lower of which does not develop farther. The nucleus of the upper cell divides again and the process is repeated until a more or less curving row of five or six cells is formed. Each cell of this row contains a single nucleus except that next to the terminal cell, which has two nuclei and becomes the ascus. The ascus then enlarges strongly on the upper side, pushing the terminal cell sidewise and downwards until it is finally absorbed and disappears. The two nuclei of the ascus now fuse, but the author does not consider this to be a sexual act but another instance of the nuclear fusion known in asci and basidia. Finally the large nucleus divides three times and there are formed eight spores. W. G. F.

DR. JOHANN MÜLLER (known as Müller Argoniensis), died at Geneva Jan. 28, in his 68th year. He was the Director of the Jardin Botanique and Custodian of the Delessert Herbarium. He was distinguished as a Lichenologist, and also wrote the Euphorbiaceæ of DeCandolle's Prodromus.

III. Miscellaneous Scientific Intelligence.

1. *Catalogue of Scientific Papers (1874–1883). Compiled by the Royal Society of London*, vol. xi, 902 pp., 4to. London, 1896 (C. J. Clay & Sons, Cambridge University Press).—The present issue completes the series of three volumes forming the Supplement to the Royal Society's Catalogue of Scientific Papers for the years 1874–1883. The first volume (vol. ix) was noticed in vol. xxxiv (p. 170) of this Journal. The unique value of this work as a whole is too well appreciated to need commendation here. It gives under the name of the authors, arranged alphabetically, the full titles of papers wherever published, with the original references. This labor has been performed with much thoroughness and accuracy; the work should have a place in every scientific library.

2. *The Yellowstone National Park*, by Capt. H. M. Chittenden, U. S. A. 8°, 397 pp., 1895 (Clarke Co., Cincinnati).—This work will be found a most useful book of reference for the national wonderland. The history of the park and its early exploration will be found quite exhaustively treated. Other chapters treat briefly of its topography, geology, natural wonders, fauna and flora, etc. An excellent descriptive itinerary is given for travellers. The work is an excellent specimen of typographical art and is embellished by a large number of reproductions of beautiful photographs. The appended map, while very complete, is, however, a very poor specimen of typographic work and the only blemish we have noticed. L. V. P.

3. *Mechanics and Hydrostatics: an Elementary Text-Book, theoretical and practical*, by R. T. Glazebrook, M.A., F.R.S., pp. 652, Cambridge (Cambridge Natural Science Manuals); New York (Macmillan & Co.).—The crucial test of a treatise on Elementary Mechanics is the amount of vagueness and inconsistency to be found in the pages devoted to the discussion of force relations. To secure the requisite degree of simplicity without narrowness, and of logic without intricacy calls for much of the equipment of the philosopher, historian, physicist and practical teacher. Professor Glazebrook has succeeded in this, and *à fortiori* in the other parts of his work, not only because he possesses these qualifications but also because the numerous text-books on elementary mechanics which have appeared in the last ten years, though individually faulty, have collectively raised the treatment of the subject to a level where a text-book that is good throughout becomes possible.

The subject is developed experimentally and historically with an unusual fullness of discussion of difficult points and numerous detailed solutions of typical problems which will materially lighten the labor of teaching and economize the time spent in the class room. The author has judiciously avoided the use of most of the various new-coined words, such as velo, celo, and the like, of which such a prolific crop has sprung up of late years. Velocity is treated as a vector, but the distinction between speed and velocity is in several cases somewhat carelessly disregarded.

4. *The Constitution and Functions of Gases, the Nature of Radiance, and the Law of Radiation.* By SEVERINUS J. CORRIGAN. St. Paul, 1895, pp. 128, and Supplement, pp. 46.—This is a restatement and enlargement of the author's hypothesis of the constitution of matter, first given in *Astronomy and Astrophysics*, Nos. 101 and 102 (1892). Two equal atoms are assumed to revolve in a circle about the middle point of the line joining them. The orbital velocity of atmospheric atoms of normal pressure and temperature is found to be 550,521,646 miles per second. A great number of atomic couples are regarded as forming a spherical shell, or hollow ball, and this constitutes a molecule of any gas. In a normal atmospheric molecule the number of atoms is found to be $2 \cdot 8943 \times 10^{14}$. The luminiferous ether is a rarified gas. From such a hypothetical constitution of gases the author develops the laws of radiation of light and heat.

5. *Algebra for Beginners*, by H. S. HALL and S. R. KNIGHT; revised for American schools by Prof. F. L. SEVENOAK. (Macmillan & Co. Price 60 cts.)—A text-book designed to meet the wants of those who do not require a knowledge of algebra beyond quadratic equations.

6. *An Introduction to the Algebra of Quantics*, by E. B. ELLIOTT. Clarendon Press, 1895, 8°, pp. viii, 423.—The students of higher algebra will feel specially grateful to Professor Elliott for his systematized treatment of the additions made to this branch of mathematics by Cayley, Sylvester, Salmon, Clebsch, Faà de Bruno, Gordan, and others during the last fifty years. Though entitled an *Introduction*, it really calls for a considerable preliminary knowledge on the part of the reader, such as would be gained, for example, from BURNSIDE and PANTON'S *Theory of Equations.*

7. *Problems in Differential Calculus*, by W. E. BYERLY. (Ginn & Co.)—An excellent collection of problems designed to accompany Prof. Byerly's Differential Calculus, but valuable in connection with any such treatise. It includes also problems in simple integration and in mechanics.

8. *Plane and Solid Geometry*, by Professors W. W. BEMAN and D. E. SMITH. (Ginn & Co.)—The work covers the subjects in geometry taught in the best American High Schools. There is a good index, also a biographical table, and a table of etymologies.

9. *Computation Rules and Logarithms with Tables of other Useful Functions;* by SILAS W. HOLMAN; pp. xlv, and 73. (Macmillan & Co., 1896.)—The Introduction of this book gives in detail precepts for securing a required degree of accuracy in computations without unnecessary expenditure of labor. Four and five-figure tables of logarithms of numbers, of logarithmic sines, tangents, etc., follow. The arrangement is well adapted for instruction, and for subsequent use in work not requiring unusual accuracy. It is rare that six or seven-figure tables are needed in actual practice.

TEN-VOLUME INDEX.—Attention is again called to the Index to Vols. XLI–L, issued in January. Those wishing should order now, as the edition is limited; price 75 cents.

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[FOURTH SERIES.]

Art. XXXVIII.—*Carbon and Oxygen in the Sun;* by John Trowbridge.

In 1887 Professor Hutchins of Bowdoin College and myself brought forth evidence to show that the peculiar bands of the voltaic-arc spectrum of carbon can be detected in the sun's spectrum. They are, however, almost obliterated by the overlying absorption lines of other metals, especially by the lines due to iron. In order to form an idea of the amount of iron in the atmosphere of the sun which would be necessary to obliterate the banded spectra of carbon, I have compared the spectrum of carbon with that of carbon dust and a definite proportion of iron distributed uniformly through it. The carbon dust and iron reduced by hydrogen was formed into pencils suitable for forming the voltaic arc.* Chemical analysis showed that the iron was uniformly mixed with the carbon dust. Specimens, taken from different sections of the carbons which I burned in the arc, gave twenty-eight per cent of iron and seventy-two per cent of carbon.

The method of experimenting was as follows: That portion of the spectrum of the sun which contains traces of the peculiar carbon band lying at wave length 3883·7 and which has been almost obliterated by the accompanying lines of absorption of other metals, among them those of iron, was photographed. The pure carbon banded spectrum was photographed on the same plate immediately below the solar spectrum, and the spectrum of the mixture of iron and carbon immediately below this. The sun's spectrum can be regarded as a com-

*I am indebted to Mr. John Lee of the American Bell Telephone Co. for his skill in making the carbons and for analyses of the composite carbons.

posite photograph, and the iron and carbon can also be regarded as a composite photograph. It was speedily seen that from twenty-eight to thirty per cent of iron in combination with seventy-two to seventy per cent of carbon almost completely obliterated the peculiar banded spectrum of carbon. This proportion therefore of iron in the atmosphere of the sun, were there no other vapors of metals present, would be sufficient to prevent our seeing the full spectrum of carbon.

The iron in the carbon terminals which I employed greatly increased the conductivity, as will be seen from Table I, which was obtained in the following manner.

The carbons were separated by means of a micrometer screw and the current and difference of potential were measured with different lengths of arc. Table I gives the results for pure carbon. Table II for twenty-eight per cent of iron and seventy-two per cent of carbon.

TABLE I.

Length of arc in mm.	Amperes.	Volts.
1	27	25
2	23	24
3	22·5	20
4	20	18
5	16·5	15

TABLE II.

Length of arc in mm.	Amperes.	Volts.
1	30·5	30
2	29	30
3	27·5	28
4	24	25
5	22	20
6	20	20
7	18	19
8	16	18

The length of the arc could be nearly doubled with the same current and the same voltage by the admixture of 28 per cent of iron. The light was apparently greatly increased, but the difference in color between the pure carbon light and the iron carbon light made measurements unreliable.

Moissan* has shown that the carbon in an electric oven through which powerful electric currents have flowed is free from foreign admixtures. Deslandres has confirmed this and finds only a trace of calcium present. The purification comes from a species of distillation of the volatile impurities. The purest carbon is found at the negative pole. The light of the

* Comptes Rendus, cxx, pp. 1259–1260, 1895.

electric furnace is due to the combustion of carbon. Can we conclude that the sun is also a vast electric furnace?

If the voltaic arc is formed under water its brilliancy diminishes greatly. On the other hand, an atmosphere of oxygen greatly augments its vividness. The question, therefore, whether oxygen exists in the sun is closely related to questions in regard to the presence of carbon, when we consider the temperature and light of the sun.

If suppositions also are made in regard to the magnetic condition of the atmosphere of the sun, it is of great interest to determine whether oxygen exists there, for oxygen has been shown by Faraday, and later by Professor Dewar, to be strongly magnetic.

Professor Henry Draper brought forward evidence to prove the existence of bright oxygen lines in the solar spectrum. Professor Hutchins of Bowdoin College and myself examined this evidence and, after a long study of the oxygen spectrum in comparison with the solar spectrum, came to the conclusion that the bright lines of oxygen could not be distinguished in the solar spectrum. We published our paper in 1885. I have lately studied the subject from another standpoint, having carefully examined the regions in the solar spectrum where the bright lines of oxygen should occur if they manifest themselves, in order to see if any of the fine absorption lines of iron in the spectrum of iron were absent, for it is reasonable to suppose that the bright nebulous lines of oxygen would obliterate the faintest lines of iron.

The method adopted by Draper for obtaining the spectrum of oxygen consisted in the employment of a powerful spark in ordinary air. To obtain this spark the current from a dynamo running through the primary of a Ruhmkorf coil was suitably interrupted. By the use of an alternating machine and a step-up transformer, powerful sparks can be more readily obtained. Since the time of exposure with a grating of large dispersion is long, considerable heat is developed in the transformer from the powerful currents which are necessary to produce a spark of sufficient brilliancy. I have therefore modified the method in the following manner. The spark gap is enclosed in a suitable chamber, which can be exhausted. When the exhaustion is pushed to a certain point, the length of the spark can be increased ten or twenty times over its length in air, and a suitable spark for photographic purposes can therefore be obtained by the employment of far less energy in the transformer. A pressure of eight to ten inches of mercury in the exhausted vessel is sufficient. A quartz lens inserted in the wells of the exhausted chamber serves to focus the light of the spark on the slit of the spectroscope.

The following table gives the oxygen lines and iron lines in the same region of the spectrum.

0	Fe in Sun.	Intensity.
4631	4629·44	1
	4730·22	4
	4630·91	1
	4361·61	1
4656	4654·7	
	4657·71	
4683	4683·04	1
	4683·93	2
4601·5	4600·09	1*n*
	4601·8	1
	4602·11	4
4007	4604·84	1*n*
	4605·52	1
	4606·34	
	4607·79	6
4613	4611·38	8
	4613·35	4
	4614·29	1
4693·5	4691·52	6
	4696·97	1

The faintest iron lines are therefore not obliterated in the spaces where the oxygen lines should occur. If we examine the great absorption region about the K line, we find that between wave lengths 3930·29 and 3938·55 Rowland, it gives 8 lines which coincide with iron lines.

From the table of wave lengths of iron lines in the arc spectrum given in the report of the British Association for 1891, I find the following lines given between these limits.

3930·37*
3931·22*
3932·71*
3933·01*
3933·75
3934·47
3934 81*
3935·40*
3935·92*
3937·42*
2938·16
3938·59

The starred lines are probably the iron lines given by Rowland in his list of standard solar lines. The iron lines that are not starred apparently are obliterated in the great absorption band near the calcium line K.

Lord Salisbury, in his address before the British Association at Oxford, 1894, remarks: "Oxygen constitutes the largest portion of the solid and liquid substances of our planet, so far as we know it; and nitrogen is very far the predominant constituent of our atmosphere. If the earth is a detached bit, whirled off the mass, leaving the sun we cleaned him out so completely of his nitrogen and oxygen that not a trace of these gases remain behind to be discovered even by the sensitive vision of the spectroscope?"

Although we have not succeeded in detecting oxygen in the sun, it seems to me that the character of its light, the fact of the combustion of carbon in its mass, the conditions for the incandescence of the oxides of the rare earths which exist, would prevent the detection of oxygen in its uncombined state. Notwithstanding the negative evidence which I have brought forward, I cannot help feeling strongly that oxygen is present in the sun and that the sun's light is due to carbon vapor in an atmosphere of oxygen.

Jefferson Physical Laboratory.

Art. XXXIX.—*On the Determination of the Division Errors of a Straight Scale;* by Harold Jacoby.

1. Lying as it does at the base of all exact metrology, the above problem has received the attention of many investigators. Numerous methods have been devised and employed for its solution, the object generally sought being a result of sufficient accuracy accompanied with the minimum amount of labor. Probably the first investigation in which the highest precision was attained or even aimed at, was carried out by Hansen.* His method amounts to comparing the spaces of the scale under investigation, which we will call scale A, with a series of spaces marked upon an auxiliary scale B. This was done in such a way that every one-space of scale A was compared with an auxiliary one-space; every two-space of scale A, with an auxiliary two-space, etc. The method may of course be varied by using, instead of spaces on an auxiliary scale, a fixed interval between the two microscopes of a *comparateur*. In fact, Hansen's process really consisted in comparing *inter se* all the single spaces, two-spaces, three-spaces, etc., of scale A. The series of observations made in this way, Hansen treats by the method of least squares, giving a solution whose numerical application requires a very considerable amount of computation.

* Abh. d. math. phys. Classe der Kgl. Sächs. Gesell. d. Wissenschaften, vol. xv.

This method of Hansen appears to have received no material improvement until 1888. In that year, Gill, acting upon a suggestion made by Marth, began to determine the errors of the straight scales of the Cape heliometer. Gill employs an auxiliary scale B which is an exact duplicate of scale A. In fact, in the case of the heliometer, each of the two scales is used as an auxiliary for investigating the other. Instead of then comparing, as Hansen did, every one-space, two-space, etc., of scale A with *one* auxiliary one-space, two-space, etc., on scale B, Gill compares every one-space of scale A with every one-space of scale B; every two-space with every two-space; etc. This method must be regarded as an important extension of Hansen's. With comparatively little additional labor in the observations, it causes a considerable increase of precision in the results.

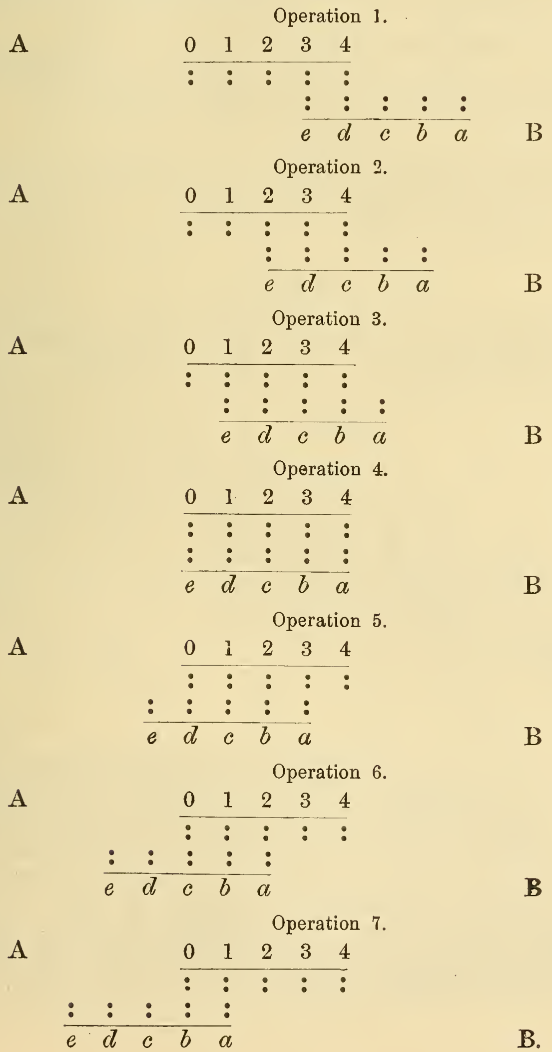
Precisely the same method of observation employed by Gill has been discussed very recently by Lorentzen,* and used in determining the errors of the Bamberg heliometer. He begins by applying the method of least squares rigidly to the reduction of the observations; but the numerical work required being very great, he concludes by recommending a slight departure from the rigid least square method of reduction. This brings him to a method which is identical with Gill's, both in the observations, and in the calculation of the division errors. They differ, however, in the calculation of the weights of the division errors determined for the several lines of the scale. Gill comes to the conclusion that all these division errors are determined with the same weight. This is not rigorously correct. Lorentzen does not come to the same conclusion; but as we shall see further on, he deduces a weight formula which is quite correct.

2. The method of Hansen, both in its original form, and as extended by Gill, in common with all other methods of determining division errors, has the defect just mentioned. The various lines are not determined with rigorously equal weight. Since, in general, there is no reason *a priori* why we should determine some of the lines more accurately than the others, a method which will produce true equality of weights for all the lines still remains a desideratum. Now the method of Gill would appear to be observationally exhaustive, since all possible combinations of spaces on the two scales have been compared. Nevertheless, the method may be observationally varied, the general weight greatly increased, and even the desired equality of weights may be produced, if we vary the precision with which the several comparisons between the two scales are effected. This need not increase the labor very

* Astronomische Nachrichten, 3134, 3236.

much, as we shall see further on. First, however, I will briefly describe Gill's method of observation and reduction. The latter admits of demonstration without resorting to extensive mathematical formulæ.

The scale under investigation, A, and the auxiliary scale, B, are supposed to be graduated as nearly alike as possible, and to be mounted so that one can be compared with the other. The observations are now effected in a series of separate operations, the diagrams given below showing how they would be arranged for a scale of four spaces.



Scale A is numbered 0, 1, 2, 3, 4; and scale B is numbered e, d, c, b, a, to avoid confusion. Operation 1 consists in placing scale B opposite scale A in such a way that division e comes opposite 3, and d opposite 4. The microscope of the *comparateur* is then brought over the divisions 3 and e, and readings are taken on each of these divisions. The microscope is then brought over the divisions 4 and d, and these are also read. The operation is then repeated in the reverse order, the scales remaining unmoved all the time. If we suppose the microscope readings to decrease as the readings of scale A increase, and if we put:

d_4 = excess of reading on division 4 over that on division d,
e_3 = excess of reading on division 3 over that on division e,

it is obvious that operation 1 furnishes the quantity:

$$e_3-d_4,$$

or the excess of the space 3, 4 of scale A over the space e, d of scale B. In exactly the same way operation 2 furnishes the quantities:

$$d_3-c_4 \text{ and } e_2-d_3,$$

or the excesses of the spaces 2, 3 and 3, 4 over e, d and d, c respectively. Proceeding in this way, we may arrange the results of all the operations as in the following table:

TABLE I.

0, 1	1, 2	2, 3	3, 4	
			(e_3-d_4)	Operation 1.
		(e_2-d_3)	(d_3-c_4)	" 2.
	(e_1-d_2)	(d_2-c_3)	(c_3-b_4)	" 3.
(e_0-d_1)	(d_1-c_2)	(c_2-b_3)	(b_3-a_4)	" 4.
(d_0-c_1)	(c_1-b_2)	(b_2-a_3)		" 5.
(c_0-b_1)	(b_1-a_2)			" 6.
(b_0-a_1)				" 7.
K_1	K_2	K_3	K_4	

It will be seen that each of the quantities in parenthesis is the excess of one of the spaces of scale A over one of the spaces of scale B. Thus the first column contains the excesses of the space 0, 1 of scale A over each of the four spaces of scale B. Similarly the other columns contain the excesses of the spaces 1, 2; 2, 3; and 3, 4. Moreover the results of each separate operation will be found in the same horizontal line of the table. The quantities K_1, K_2, K_3, K_4, are the means of the quantities above them in the columns. Thus:

$$K_1 = \tfrac{1}{4}[(e_0-d_1)+(d_0-c_1)+(c_0-b_1)+(b_0-a_1)]$$

It is evident that K_1 is the excess of the space 0, 1 over the *true fourth part* of scale B, since it is the mean of the excesses of 0, 1 over the four constituent spaces of scale B. Consequently, if we assume scale B as standard, the space 0, 1 is too large by the quantity K_1, which we may express as follows:

$$\text{Division error of line 1, scale } A_1 = K_1$$

Similarly the space 1, 2 is too large by K_2, and therefore the space 0, 2 is too large by the quantity K_1+K_2; or:

$$\text{Division error of line 2, scale } A, = K_1+K_2$$

Similarly:

$$\text{Division error of line 3, scale } A, = K_1+K_2+K_3$$
$$\text{Division error of line 4, scale } A, = K_1+K_2+K_3+K_4$$

Since we have assumed scale B as the standard, the quantity:

$$K_1+K_2+K_3+K_4$$

or the division error of line 4 of scale A, is really the difference in length of the two scales; so if we put:

$$K_0 = \tfrac{1}{4}(K_1+K_2+K_3+K_4),$$

K_0 will be the excess of the true average space of scale A over the true average space of scale B. Consequently, if we wish the division errors of scale A to be expressed in terms of that scale itself as a standard, we must write:

$$\text{Division error of line 1} = K_1-K_0$$
$$\text{Division error of line 2} = K_1+K_2-2K_0$$
$$\text{Division error of line 3} = K_1+K_2+K_3-3K_0$$
$$\text{Division error of line 4} = K_1+K_2+K_3+K_4-4K_0 = 0$$

Table I also furnishes the corresponding division errors of scale B. If we take diagonal means as follows:

$$Q_d = \tfrac{1}{4}[(e_0-d_1)+(e_1-d_2)+(e_2-d_3)+(e_3-d_4)]$$
$$Q_c = \tfrac{1}{4}[(d_0-c_1)+(d_1-c_2)+(d_2-c_3)+(d_3-c_4)]$$
$$\text{etc.} \qquad\qquad \text{etc.}$$

we have:

$$\text{Division error of line } d = -(Q_d-K_0)$$
$$\text{Division error of line } c = -(Q_d+Q_c-2K_0)$$
$$\text{Division error of line } b = -(Q_d+Q_c+Q_b-3K_0)$$
$$\text{Division error of line } a = -(Q_d+Q_c+Q_b+Q_a-4K_0) = 0$$

since, necessarily,

$$K_1+K_2+K_3+K_4 = -(Q_d+Q_c+Q_b+Q_a)$$

Generalizing these formulæ we have for the division error of the line numbered m on scale A, supposed to have $n+1$ lines, numbered from 0 to n, the following:

$$\left.\begin{aligned} K_0 &= \frac{1}{n}\sum_1^n K \\ \text{Division error of line } m &= \sum_1^m K - mK_0 \end{aligned}\right\} \quad (1)$$

And for the other scale,

$$\text{Division error of line } m = -\left(\sum_d^m Q - mK_0\right)$$

3. The above is Gill's method, substantially in the form described in the Monthly Notices (vol. xlix, p. 110); though the way in which it is presented has been somewhat modified. The formulæ (1) are the same as Lorentzen's final formulæ, given in Astr. Nach., 3336.

The next step is to calculate the weights of the division errors determined. This can be done very easily, if we notice in Table I that the sum of any number of consecutive parentheses in the same horizontal line is known with the same precision as any one parenthesis alone. Thus the quantity:

$$(e_0-d_1)+(d_1-c_2)+(c_2-b_3)$$

is known with the same precision as the equivalent quantity:

$$e_0-b_3$$

This circumstance will of course affect the sums of the K's, the mean error of

$$K_1+K_2$$

for instance, being by no means as great as

$$\sqrt{2}\,(\text{mean error of } K_1),$$

as it would be if K_1 and K_2 were independent. Now let us put:

ε = mean error of any of the observed quantities, as c_1, b_2, etc., which are supposed to be all observed with equal precision.
A_m = division error of line m on scale A.
$s_m = b_m+c_m+d_m+\ldots,$

so that s_m is the sum of all the letters except the first and last, after each has received the subscript m. Then we get at once from equations (1)

$$A_m = \frac{n-m}{n}\sum_1^m K - \frac{m}{n}\sum_{m+1}^n K$$

Also we see from Table I that

$$n\sum_1^m K = s_0-s_m+(e_0+e_1+\ \ldots\ +e_{m-1})-(a_1+a_2+\ \ldots\ +a_m)$$

$$n\sum_{m+1}^n K = s_m-s_n+(e_m+e_{m+1}+\ \ldots\ +e_{n-1})-(a_{m+1}+a_{m+2}+\ldots+a_n)$$

Substituting these values in the previous equation gives:

$$A_m = \frac{n-m}{n^2}\left[s_0 + \sum_0^{m-1} e - \sum_1^m a\right] + \frac{m}{n^2}\left[s_n - \sum_m^{n-1} e + \sum_{m+1}^n a\right] - \frac{s_m}{n}$$

This equation is not intended for calculating A_m, since equation (1) is more convenient for that purpose. But in the present equation, all the quantities are independent, so that it can be used at once for getting E, the mean error of A_m. Since ε is the mean error of any one of the observed quantities, we shall have:

$$(\text{mean error of } s_0)^2 = (n-1)\varepsilon\varepsilon$$

$$(\text{mean error of } \sum_0^{m-1} e)^2 = m\varepsilon\varepsilon$$

$$(\text{mean error of } \sum_m^{n-1} e)^2 = (n-m)\varepsilon\varepsilon$$

$$(\text{mean error of } s_m)^2 = (n-1)\varepsilon\varepsilon$$

etc. etc.

Consequently,

$$EE = \left\{\left[\frac{n-m}{n^2}\right]^2\left[n-1+m+m\right]\right\}\varepsilon\varepsilon$$

$$+\left\{\left[\frac{m}{n^2}\right]^2\left[n-1+n-m+n-m\right]+\frac{n-1}{n^2}\right\}\varepsilon\varepsilon$$

$$= 2\left[n^2(n-1)+m(n-m)\right]\frac{\varepsilon\varepsilon}{n^4}$$

If, therefore, we assume our unit of weight such that:

$$\varepsilon\varepsilon = 1$$

we shall have for computing the weight P_m of line m on scale A, the equation:

$$\frac{1}{P_m} = \frac{2(n-1)}{n^2} + \frac{2m}{n^4}(n-m) \qquad (2)$$

$\frac{1}{P_m}$ has a maximum value for:

$$m = \frac{n}{2}$$

We therefore have:

$$\frac{1}{P}\,(\text{maximum}) = \frac{2n-\frac{3}{2}}{n^2} \qquad (3)$$

The minimum value of $\frac{1}{P_m}$, subject of course to the condition that m may only vary from 1 to $n-1$, will occur when:

$$m = 1 \text{ or } m = n-1$$

In either case:

$$\frac{1}{P}\,(\text{minimum}) = \frac{2(n-1)(n^2+1)}{n^4} \qquad (4)$$

The difference, therefore, is:

$$\frac{1}{P}\,(\text{maximum}) - \frac{1}{P}\,(\text{minimum}) = \frac{\frac{1}{2}(n-2)^2}{n^4}$$

The formula obtained by Lorentzen for computing P_m is, allowing for the difference of notation (Astr. Nach., 3134, Eq. 15):

$$\frac{1}{P_m} = \frac{2}{n^2}(n-1) + \frac{2m}{n^4}\,(n-m)$$

which agrees with equation (2) just obtained. But Lorentzen's value for the weight of a quantity he calls δ, which equals the excess of the true average space of scale A over the true average space of scale B, is not quite exact. In our notation this excess is $\frac{1}{n}K_0$, and as we have seen, it is equal to:

$$\frac{1}{n^2}\ (\text{the sum of all the parentheses in Table I}).$$

We have also seen that the sum of all the parentheses in any horizontal line of Table I, has for the square of its mean error the quantity:

$$2\varepsilon\varepsilon$$

And, as there are $2n-1$ horizontal lines, the sum of the whole table has for the square of its mean error:

$$2(2n-1)\varepsilon\varepsilon$$

Therefore the square of the mean error of δ is:

$$\frac{2(2n-1)}{n^4}\,\varepsilon\varepsilon$$

and the weight of δ, $\varepsilon\varepsilon$ being taken as unity, is:

$$\frac{n^4}{2(2n-1)}$$

which may be written:

$$\frac{n^3}{4-\frac{2}{n}}$$

Lorentzen gets for the same quantity the slightly incorrect value:

$$\frac{n^3}{4}$$

In Table II, which will be given further on, are contained the maximum and minimum weights obtained in Gill's method for various values of n. The table is computed by means of equations (3) and (4). When n is an even number, the maximum weight applies to the middle line of the scale; and when

n is an uneven number, it applies to either of the two lines nearest the middle of the scale.

4. Having now described Gill's method, I shall proceed to show how it may be improved very materially. For this purpose, let us resume the equation:

$$A_m = \frac{n-m}{n^2}\left[s_0 + \sum_0^{m-1} e - \sum_1^m a\right] + \frac{m}{n^2}\left[s_n - \sum_m^{n-1} e + \sum_{+1}^{n} a\right] - \frac{s_m}{n}$$

Now let us suppose that the various observed quantities contained in Table I, have been determined with different weights as follows:

$$\text{Weight of } a_0 = \frac{1}{a'_0}$$

$$\text{Weight of } c_2 = \frac{1}{c'_2}$$

etc. etc.

In other words, let us indicate the number of times each letter is observed by the reciprocal of that letter *primed.* Then if we put:

$$s'_m = b'_m + c'_m + d'_m + \ . \ . \ .$$

following the analogy of s_m, already employed, we shall have:

$$(\text{mean error of } s_0)^2 = s'_0 \varepsilon\varepsilon$$

$$(\text{mean error of } s_m)^2 = s'_m \varepsilon\varepsilon$$

$$(\text{mean error of} \sum_0^{m-1} e)^2 = \varepsilon\varepsilon \sum_0^{m-1} e'$$

etc. etc.

Consequently we shall have for computing the square of the mean error of line m on scale A, assuming $\varepsilon\varepsilon = 1$:

$$n^4(\text{EE})_m = n^4 \frac{1}{\text{P}_m} = n^2 s'_m + (n-m)^2\left[s'_0 + \sum_0^{m-1} e' + \sum_1^m a'\right]$$

$$+ m^2\left[s'_n + \sum_m^{n-1} e' + \sum_{m+1}^{n} a'\right] \qquad (5)$$

This equation may be used in a very simple way for strengthening Gill's method. Let us put the weights of all the exterior quantities in Table I equal to each other, i. e., let us put:

$$\frac{1}{b'_0} = \frac{1}{c'_0} = \frac{1}{d'_0} = \frac{1}{e'_0} = \frac{1}{e'_1} = \frac{1}{e'_2} = \frac{1}{e'_3} = \frac{1}{d'_4} = \frac{1}{c'_4} = \frac{1}{b'_4} = \frac{1}{a'_4} = \frac{1}{a'_3} = \frac{1}{a'_2} = \frac{1}{a'_1}$$

and suppose any one of these quantities to be represented by $\frac{1}{q}$. In other words, let us observe every comparison between the two scales in which either of the four end lines appears $\frac{1}{q}$

times instead of once, and use the mean in the further computations. We then have, since $\varepsilon\varepsilon = 1$:

$$s'_m = n-1, \; s'_0 = (n-1)q, \; s'_n = (n-1)q$$

$$\sum_0^{m-1} e' = mq, \; \sum_1^m a' = mq, \; \sum_m^{n-1} e' = (n-m)q, \; \sum_{m+1}^n a' = (n-m)q,$$

So that if we put all the other weights equal to unity, equation (5) becomes:

$$\frac{1}{P_m} = \frac{1}{n^2}(n-1) + \left[\frac{1}{n^2}(n-1) + \frac{2m}{n^4}(n-m\right]q \qquad (6)$$

This equation agrees with (2) if we put unity for q.

I shall call Gill's method, when modified in the manner just explained, method 1. In Table II given below, will be found the maximum and minimum weights belonging to method 1, placed for comparison next to those belonging to Gill's method. In order to bring out more clearly the advantage of method 1, I have also put in the table the total number of observations required for carrying out Gill's method, and the additional number required for method 1. This number is:

For Gill's method, $(n+1)^2-2$

Additional for method 1, $(4n-2)\left(\frac{1}{q}-1\right)$

In computing the column "Time used" I have taken as the unit the time required to make one observation in Gill's method. I have then assumed that the additional observations of method 1 each require only one-fourth as much time, since they simply consist in additional settings after the microscope, etc., have been brought into position and adjusted. In computing the table, I have put:

$$\frac{1}{q} = 4,$$

which is equivalent to observing all the comparisons involving the end lines four times. It does not seem desirable to carry the number of observations beyond four for any one comparison, since it is doubtful if the mean of a large number of observations of this kind really possesses a weight corresponding to that number.

For the sake of comparison, I set down here the theoretical weights which would result from a rigid least square discussion of the observations in Gill's method, according to Lorentzen.

n	Weight. Max.	Weight. Min.
3	2·15	2·15
4	2·77	2·68
5	3·35	3·19
6	3·99	3·69
10	6·49	5·74

It will be seen that these weights are nearly the same as those obtained in Gill's own method of reduction.

TABLE II.

n	Gill Method. Weight. Max.	Gill Method. Weight. Min.	Method 1. Weight. Max.	Method 1. Weight. Min.	Max. Weight. / Min. Weight. Gill	Max. Weight. / Min. Weight. 1	No. of Obs. Gill	No. of Obs. addit. 1	Time used (arbitrary) unit). Gill	Time used (arbitrary) unit). 1	Min. Wt. × 10^2 / Time used. Gill	Min. Wt. × 10^2 / Time used. 1
3	2·03	2·02	3·45	3·44	1·00	1·00	14	30	14	21·5	14·3	16·0
4	2·49	2·44	4·13	4·10	1·02	1·01	23	42	23	33·5	10·5	12·2
5	3·00	2·95	4·93	4·88	1·02	1·01	34	54	34	47·5	8·5	10·2
6	3·47	3·40	5·65	5·62	1·02	1·01	47	66	47	63·5	7·1	8·8
7	4·08	4·00	6·62	6·58	1·02	1·01	62	78	62	81·5	6·4	8·1
8	4·39	4·31	7·09	7·04	1·02	1·01	79	90	79	101·5	5·6	6·9
9	5·15	5·05	8·33	8·26	1·02	1·01	98	102	98	123·5	5·1	6·7
10	5·49	5·41	8·93	8·85	1·02	1·01	119	114	119	147·5	4·3	6·0
15	8·06	7·94	12·90	12·82	1·02	1·01	254	174	254	297·5	3·2	4·3
20	10·53	10·42	16·86	16·78	1·01	1·01	439	234	439	497·5	2·4	3·4

The last two columns of Table II bring out very clearly the advantage of method 1 over Gill's. It may be objected that these columns depend upon the somewhat arbitrary assumption that the additional observations require only one-fourth the time needed for the first ones. But it should be noted that even without this assumption, these columns would show an increasing advantage for method 1, as soon as n becomes larger than 10 or 12. The same would be true even for the smaller values of n if we were to put $\frac{1}{q}$ equal to 2 or 3 instead of 4. But the assumption seems fully justified by the experience gained by Dr. Gill and others in investigating the scales of the Cape heliometer.

5. The above method 1 leaves very little to be desired on the score of variation in the weight with which the several division errors are determined. Consequently the investigation of a method which will make these weights all equal is of interest chiefly from the theoretical point of view. Still an occasion might possibly arise when it would be worth while to take the extra trouble necessary to bring about this equality of weights. This can be done by the following method, which we will call method 2. Let us resume equation (5):

$$n^4 \frac{1}{P_m} = n^2 s'_m + (n-m)^2 \left[s'_0 + \sum_0^{m-1} e' + \sum_1^m a' \right]$$
$$+ m^2 \left[s'_n + \sum_m^{n-1} e' + \sum_{m+1}^n a' \right] \qquad (5)$$

and put $m+1$ for m in it. This gives:

$$n^4 \frac{1}{P_{m+1}} = n^2 s'_{m+1} + (n-m-1)^2 \left[s'_0 + \sum_0^m e' + \sum_1^{m+1} a' \right]$$
$$+ (m+1)^2 \left[s'_n + \sum_{m+1}^{n-1} e' + \sum_{m+2}^n a' \right]$$

In order to bring about equality of weights, we have only to make:

$$n^4 \frac{1}{P_m} = n^4 \frac{1}{P_{m+1}}$$

If we do this, and let $\frac{1}{q}$ have the same signification as before, we get, after some simplification:

$$s'_m - s'_{m+1} = \frac{2q}{n^2} [n-1+2m(n-2)] \qquad (7)$$

This equation shows that the sum of the reciprocals of all the weights (except the top and bottom weights) in any column of Table I exceeds that in the following column by the quantity:

$$\frac{2q}{n^2} [n-1+2m(n-2)]$$

And if this equation be satisfied for all values of m from $m=1$ to $m=n-2$, the division errors will be determined with equal weight. If we substitute successively 1, 2, 3, . , $n-2$ for m in equation (7), we get a series of quantities in arithmetical progression. Summing this we derive:

$$s'_1 - s'_m = -\frac{2q}{n^2}(n-1) + \frac{2q}{n^2}[m(n-2)+1]m \qquad (8)$$

This equation shows that s'_1 can never exceed s'_m by a quantity greater than $2qn$; and since an inspection of Table I shows that $s'_1 - s'_m$ cannot possibly be made greater than $n-1$, it follows that $2q$ cannot be taken greater than unity, or q greater than $\frac{1}{2}$. We have already explained that it is not desirable to make q less than $\frac{1}{4}$. It will therefore be best to put as before:

$$q = \tfrac{1}{4}$$

It is obviously desirable to make:

$$s'_1 = n-1$$

or in other words, to observe once all the quantities in Table I that have the suffix 1, except the top and bottom ones e_1

and a_1. By means of equation (8) we can then find out how many times to observe the quantities having the suffix m. Of course we cannot apply equation (8) rigorously, as that would make it necessary to observe some of the quantities a fractional number of times. In fact, if we observe even one of the quantities in column m twice instead of once, we shall have made:

$$s'_1 - s'_m = \tfrac{1}{2}$$

and we cannot possibly make it less than $\frac{1}{2}$, unless we leave it zero. It will therefore be best to begin to make

$$s'_1 - s'_m = \tfrac{1}{2}$$

as soon as its theoretical value exceeds $\frac{1}{4}$, and to continue it $\frac{1}{2}$, until its theoretical value reaches $\frac{3}{4}$. We can then make it 1, until its theoretical value exceeds $\frac{5}{4}$, etc. To do this conveniently, we must solve equation (8) for m, after putting $q = \frac{1}{4}$. This gives, finally:

$$m = \frac{\sqrt{4(n-1)\,(n-2) + 8n^2(n-2)\,(s'_1 - s_m') + 1} - 1}{2(n-2)} \qquad (9)$$

We shall now apply this to an example. Suppose $n = 4$, as in Table I. Equation (9) then becomes:

$$m = \frac{\sqrt{25 + 256(s'_1 - s'_m)} - 1}{4}$$

from which we get:

for $s'_1 - s'_m = \frac{1}{4}$	$m = 2, 1$
" $s'_1 - s'_m = \frac{3}{4}$	$m = 3, 4$

We should, therefore, in Table I begin to observe one of the interior quantities twice for $m = 3$. For this purpose we might select either b_3 or c_3.

The above method 2 renders all the weights almost exactly equal. What the common weight is can be computed from equation (5). Since the weight is always the same, we may put in equation (5):

$$m = 1, \; s'_m = n - 1$$

We, therefore, also have:

$$s'_0 = (n-1)q \qquad s'_n = (n-1)q$$

$$\sum_0^{m-1} e' = q \qquad \sum_m^{n-1} e' = (n-1)q$$

$$\sum_1^m a' = q \qquad \sum_{m-1}^n a' = (n-1)q$$

Consequently:

$$\frac{1}{P} = \frac{n-1}{n^2} + \left[\frac{(n-1)\,(n^2-1)}{n^4} + \frac{3(n-1)}{n^4}\right]q$$

which does not differ very much from the weight obtained in method 1.

6. As an example of the use of method 1, I have caused two of my students, Messrs. Schlesinger and Ling, to make a determination of the non-periodic errors of one of the screws of the double microscope of the Repsold machine for measuring photographs at Columbia College Observatory. The method is admirably adapted for this purpose, and I am not aware that it has been used elsewhere for examining screws. It is merely necessary to take readings on the successive divisions of the millimeter scale of the machine, arranging them in accord with the scheme explained above. Such a set of readings is set down in Table A below, the number attached to each screw-reading being the weight of that reading, or the number of times the line of the scale was bisected at that point. The exterior quantities have been observed three times, instead of four, as recommended in this paper. This was done to save time. Table B is obtained from Table A by taking the differences of the successive numbers, and corresponds exactly to Table I given on page 336. In Table C the K's are set down, and their summation gives the corrections of the screw at the points 5, 7, 9, 11, 13, 15, revolutions. In column four of the table the necessary corrections are applied to give results in terms of the screw as a standard, instead of the scale. This is done by means of equation (1). Column five contains the corrected division errors, as determined by the observer S. Columns six and seven contain the results of the observations by L. and of a second set of observations by S. The last column gives the mean. In all these tables, unity in the fourth decimal place corresponds to one-twentieth of a micron on the scale. It will be noticed that in one case only does the difference from the mean amount to half a micron, or $\frac{1}{50000}$ of an inch on the scale. This implies that in measuring any object with this microscope, we need not fear errors of greater amount than $\frac{1}{50000}$ inch, on account of the non-periodic errors of the screw. It is to be noted also that this method gives the errors of the screw without the assumption of any law of error, while in many investigations by other methods it has been customary to assume that the non-periodic screw errors could be represented by a parabolic curve.

TABLE A.

Horizontal argument : Scale readings.

	78mm	77mm	76mm	75mm	74mm	73mm
Operation 1	13·0027 (3)	14·9983 (3)				
" 2	11·0023 (3)	13·0005 (1)	14·9960 (3)			
" 3	9·0070 (3)	11·0088 (1)	13·0075 (1)	15·0038 (3)		
" 4	7·0062 (3)	9·0075 (1)	11·0055 (1)	13·0075 (1)	15·0013 (3)	
" 5	4·9945 (3)	6·9935 (1)	8·9940 (1)	10·9985 (1)	12·9950 (1)	14·9917 (3)
" 6		5·0045 (3)	6·9995 (1)	9·0035 (1)	11·0035 (1)	13·0022 (3)
" 7			4·9970 (3)	6·9980 (1)	9·0000 (1)	10·9982 (3)
" 8				5·0013 (3)	7·0015 (1)	8·9992 (3)
" 9					5·0003 (3)	7·0002 (3)

TABLE B.

Excess of Two Revolutions of Screw over Space on Scale.

	Screw. 5–7	Screw 7–9	Screw 9–11	Screw 11–13	Screw 13–15
Scale 78–77	−·0010	+·0013	+·0018	−·0018	−·0044
" 77–76	−·0025	+·0005	−·0020	−·0013	−·0045
" 76–75	+·0010	+·0050	+·0045	+·0020	−·0037
" 75–74	+·0002	+·0020	−·0005	−·0035	−·0062
" 74–73	−·0001	−·0023	−·0018	−·0013	−·0033
Means	−·0005 K_1	+·0013 K_2	+·0004 K_3	−·0012 K_4	−·0044 K_5

TABLE C.

Screw	K	ΣK	$-mK_0$	Obs'r. S. Div. error	Obs'r. L. Div. error	Obs'r. S. 2d set Div. error	Mean
5	·0000	·0000	·0000	·0000	·0000	·0000	·0000
7	−·0005	−·0005	+·0008	+·0003	+·0016	−·0002	+·0006
9	+·0013	+·0008	+·0017	+·0025	+·0018	+·0016	+·0020
11	+·0004	+·0012	+·0025	+·0037	+·0031	+·0027	+·0032
13	−·0012	·0000	+·0036	+·0036	+·0036	+·0033	+·0035
15	−·0044	−·0044	+·0044	·0000	·0000	·0000	·0000

These division errors are to be subtracted from observed readings of the screw.

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Art. XL.—*Studies upon the Cyperaceæ*; by Theo. Holm. (With Plate IX.)

I. On the monopodial ramification in certain North-American species of *Carex*.

Two kinds of ramification are known to be represented in the genus *Carex*: the sympodial and the monopodial. The first of these is the most common, and species which exhibit this ramification show only the development of one single axis, which in its first year of growth merely develops leaves, until it finally, two or three years later, passes over into a flower-bearing stem. In this case the leaves and the flower-bearing stem are both developed from the same bud. But in the other kind of ramification, the monopodial, two special forms of buds develop, the main one of which continues to develop leaves, while the floral buds are constantly lateral. In this case there are two different axes, and species which possess such kind of ramification are, therefore, biaxial.

These two forms of ramification are easily recognized in our species of *Carex*. The sympodial shows us a central flower-bearing stem, the base of which is surrounded by more or less faded leaves from the previous year, while the monopodial shows a central leafy shoot with a number of laterally developed flower-bearing stems. The terminal shoot, when purely vegetative, can continue to grow for several years, and when it finally dies off, one or more vegetative buds develop from the axils of its leaves, which grow out and repeat the same kind of ramification. It is now interesting to note, that the monopodial ramification is only known as very rare in the genus *Carex*.

The German botanist Wydler deserves the credit for being the first one to observe it in *Carex*, and he described it as characteristic of two European species: *C. digitata* L. and *C. ornithopoda* Willd.* Some years later Alexander Braun attributed the same form of ramification to *Carex pilosa* Scop., *C. pendula* Huds. and *C. strigosa* Huds.† It is difficult to know, however, whether this statement of Braun is really correct. Doell has, at least, contradicted him so far as concerns *C. strigosa* and *C. pilosa*,‡ and he states that by examining a large number of specimens of *C. strigosa*, the flower-bearing stems were constantly found to be central, and that he was unable to detect any central vegetative shoot in *C. pilosa*.

* Ueber die Achsenzahl der Gewächse, Bot. Ztg., 1844.

† Das Individuum der Pflanze in seinem Verhältniss zur Species, Abhdlg. d. k. Acad. d. Wissensch, Berlin, 1853, p. 90.

‡ Flora von Baden, Carlsruhe, 1857.

Celakovsky, however, has supported Braun's opinion, and declared Doell's statement to be incorrect in regard to *C. pilosa*.* The flowering stems are actually lateral in this species, but the central vegetative axis dies off very soon. Only one more species has been added to these, namely *C. globularis* L., by Callmé.†

If we now consider our North-American species, it is surprising to see that the systematic authors keep perfectly silent in this matter, although Boott has illustrated it so exceedingly correct in several of his figures.‡

The monopodial ramification is very well represented in this country, and exists in several of our commonest species. It is characteristic of all the species, which Bailey§ has enumerated under the group "*Laxifloræ*" of Kunth, viz: *C. laxiflora* Lam. and its varieties, *C. Hendersoni* Bailey, *C. laxiculmis* Schw., *C. ptychocarpa* Steud., *C. digitalis* Willd., *C. Careyana* Torr., *C. plantaginea* Lam. and *C. platyphylla* Carey; besides that it, also, exists in the remarkable species *C. Fraseri* Andrews of the "*Physocephalæ*." We have examined several specimens of these species and the character appears to be constant.

The accompanying plate (IX, fig. 1) illustrates this ramification as shown in *C. platyphylla*, the specimen collected in the early spring. We see here a perennial vegetative shoot, the base of which is surrounded by a number of buds, which will develop into flower-bearing stems during the same spring. These floral buds are all developed in the axils of old leaves, which are situated on the same axis as those of the upper part of the shoot, which are now in their prime of growth. By examining the axils of the younger leaves, we find, also, buds, which will develop into floral shoots one year later. It cannot, however, be decided with any certainty how long the vegetative shoot can continue its growth, but it seems, at least in the species enumerated above, that it can persist for more than three years. *C. digitalis* forms perhaps an exception, since the vegetative shoot in most of the specimens examined did not seem to have persisted for a longer time than two years. The growth of the individual is, however, as mentioned above, secured by the development of a few lateral buds next to the floral ones. There are some other species of *Carex*, which probably are monopodial like the above mentioned. These are, e. g., *C. pubescens* Muhl., *C. oligocarpa* Schk., *C. grisea* Wahl., *C. gracillima* Schw. and *C. arctata* Boott. These

* Pflanzenmorphologische Mittheilungen, Lotos, vol. xiv, 1864, p. 20.

† Ueber zweigliedrige Sprossfolge bei den Arten der Gattung *Carex*, Berichte d. deutsch. botan. Gesellsch., vol. v, 1887.

‡ Illustrations of the genus Carex, London, 1858–67.

§ A preliminary synopsis of North-American Carices, Proceed. Am. Acad. of Arts and Sciences, April 14, 1886.

species do not show, however, any persistent central vegetative shoot, but the flower-bearing stems appear, nevertheless, as if they were lateral. We might suppose in these cases that the age of the vegetative shoot does not exceed one year. *C. gracillima* and *C. arctata* are perhaps to be compared with the above described *C. pilosa*.

A marked characteristic of these monopodial species is that the floral shoots are surrounded at their base by scale-like leaves. In the sympodial the flower-bearing stems are commonly, if not always, surrounded by proper leaves with closed sheaths and long, green blades. The monopodial ramification is, therefore, represented in this country by a number of species, most of which are common and abundantly occurring. These species are not exclusively southern forms, since several of them extend as far north as Canada, according to Macoun.* The character of being monopodial does, therefore, not seem to be favored by any special climate; we can only state that it seems to be especially well represented on this side the Atlantic, and we might perhaps feel justified to add, that it is prevalent among our sylvan forms. Purely vegetative shoots are, however, not exclusively connected with the monopodial ramification. There are among the sympodial species some, which yearly develop assimilatory shoots, which die off in the first year of their growth. Such species show, then, besides the flowering stems, a number of very densely leaved shoots, for instance *C. tribuloides* Wahl. with its varieties, *C. Muskingumensis* Schw., *C. straminea* Willd. and *C. Sartwelli* Dewey. These sterile shoots develop sometimes, as figured on our Plate IX (fig. 2, by *b*) small lateral buds in the axils of their leaves, which, however, die off at the same time as the entire shoot itself. It is, at the same time, interesting to observe the base of the shoots, both the floral and vegetative, of *C. tribuloides* and *C. Muskingumensis* (Plate IX, figs. 2 and 3). We find here distinct internodes which are not hidden within the sheaths of leaves, but which are free to quite a considerable extent. These basal internodes are even sometimes geniculate and show the nodes almost as distinct as in the *Gramineæ*. But otherwise, as it is stated in the Manuals, etc., the basal internodes in *Carex* are very short and perfectly invisible on account of the densely crowded leaves.

Washington, D. C., February, 1896.

Explanation of Plate IX.

Figure 1.—Specimen of *Carex platyphylla* at its vernal stage, showing a central vegetative shoot and a number of lateral floral ones. Natural size.

Figure 2.—Specimen of *Carex tribuloides*, showing one floral and one vegetative shoot. The base shows distinct internodes. About one-third of the natural size.

Figure 3.—Base of a floral shoot of *Carex Muskingumensis* with long internodes and distinct nodi. Natural size.

* Catalogue of Canadian plants, Part IV, Endogens, Montreal, 1888.

ART. XLI.—*The Bearpaw Mountains of Montana. First Paper*; by WALTER HARVEY WEED and LOUIS V. PIRSSON.

[Continued from p. 301.]

Beaver Creek Core.

A FEW miles north of Bearpaw Peak the deeply trenched valley of Beaver Creek cuts through an igneous center or intrusive stock of granular rock which presents a highly interesting example of an igneous mass which, intruded into sedimentary strata, has there experienced a differentiation in place, producing a gradational series of rock types. An excellent illustration of this process, already described by the authors,* occurs at Yogo Peak in the Little Belt Range, the front of the Rocky Mountain Cordillera, 120 miles to the southward, and it is interesting to find similar rock types repeated here. The brief visit made to the Beaver stock did not permit of a thorough study of the mutual relations of the different types involved, but the most basic rocks were found near the periphery of the intrusion, which is in accord with the usual occurrence of such rocks.

The locality is accessible by wagon road from Fort Assiniboine to the prospect claims located on several small metalliferous veins occurring in the stock. The tract is one of gently contoured, grassy summits trenched by abrupt and deep drainage ways. The topographic relief affords no hint of the presence of the massive rock, and the slopes are not scenically attractive. The accompanying diagram (fig. 4) represents an

FIG. 4. Section through intruded stock at the head of Beaver Creek, Bearpaw Mountains.

ideal east-and-west section through the stock. The intrusion is laccolithic in character, the sedimentary rocks dipping away from it in every direction, as shown in the figure. The exposed surface of the intrusion is about a mile across. The sedimentary rocks are highly altered and metamorphosed in the contact zone, and as usual these hardened strata resist erosive agencies better than the granular rock forming the higher

* Weed and Pirsson, Igneous Rocks of Yogo Peak, this Journal, l, 467, 1895.

ridges and crests about the stock. The rocks of the contact zone are well exposed on the south side of the core, where they form the cliffs on either side of Beaver Creek, dipping up stream and away from the stock at 20°, which becomes but 15° farther away from the core. Detached masses of the altered sedimentary rocks are in one place found resting upon the granular rock, as shown in fig. 4. On the crest of the spur showing these detached masses the line of contact is seen to be somewhat irregular, and the igneous rock breaks through the baked sedimentaries in chimney-like masses. The western border of the stock shows the best exposures of the contact zone. Above the uniform crest of a ridge of massive rock, the slopes of altered sedimentary strata rise abruptly to a high ridge forming the divide between the waters of Beaver Creek and the stream to the west. The ridge is formed of highly altered, hardened, metamorphosed shales forming adinoles of white and light creamy tones of brown, green, lavender and pink, together with sandstones altered to dense compact quartzites, the beds dipping at 20° away from the stock. The metamorphic influence of the igneous rock is noticeable in a zone about a half mile in width.

The massive rock shows considerable variation in character. A rather finely granular, even-grained, syenitic rock showing equal proportions of feldspathic and of ferromagnesian minerals, forms the main body of the mass, but this passes rapidly in some places into a dark, highly basic type, and on the northern boundary a highly feldspathic variety is seen, a syenite, which as it is the most acidic type occurring at this core will be considered first.

Beaver core syenite.—This variety occurs on the north side of a branch creek, from the east, near a miner's cabin. It forms a debris pile of rudely platy blocks, is hard and tough, ringing under the hammer, and breaking with difficulty. The blocks are lichen-covered, but the rock is quite fresh though stained with iron leachings near the surface. On a freshly fractured surface the rock is seen to be fine grained, evenly granular, and compact. The color is gray, slightly stained with iron rust. The rock is essentially feldspathic, and of somewhat aplitic aspect. Close examination shows certain feldspars developed with a tabular habit which give long cleavage planes with parallel arrangement. This and the "Schlieren" seen in the field show a rude flow-structure. Examined with the lens, it is seen to be composed mainly of light-colored feldspar, with a few inconspicuous small spots of green pyroxene.

In thin section under the microscope the following minerals are found: *alkali feldspar*, *augite*, *iron ore*, *quartz*, a very little *biotite*, *hornblende*, and *titanite*.

The *augite* is a clear green diopside. It occurs in small anhedral grains and there is very little of it. The *iron ore* is about equal in amount; of the *biotite* only a few shreds have been seen. *Titanite* is rare.

The *feldspar* forming the main constituent is entirely of the alkaline series; no plagioclase feldspars have been found. In the main it has a rude, thick, tabular habit on *b*(010), giving square or rectangular cross sections whose interstices are filled by smaller grains and quartz. It shows throughout a pronounced and beautiful microperthite structure, more developed on the boundaries and thus fringing the sections with palisade-like edges. The remaining feldspar consists also of varying mixtures of the albite and orthoclase molecules, giving spotted, cloudy effects in polarized light. At times the interlaminated lamellæ are so fine as to be seen only with high powers. The feldspars in fact present most perfectly the varying effects so well described by Brögger and by Rosenbusch in their articles on the alkali feldspars. The numerous contacts with quartz show that they have always, in all positions, a lesser index of refraction than the quartz. In a section parallel to *b*(010) an obtuse positive bisectrix emerges, and in some areas measured from the trace of the good cleavage *c*(001) the extinction-angle is 7° plus; these are of orthoclase. In other areas it rises to 19° which are albite; these are marked by a higher birefraction. Others give varying angles between them and are mixtures; on this face the albite interlaminations follow the direction of a very steep dome. In sections perpendicular to *b*(010) the albite patches show often the albite twinning whose maximum extinction-angle was measured at 15° on either side of the twinning line. We believe that these feldspars were once homogeneous anorthoclase and have split up into these variable masses through secondary processes. The average composition is given after the analysis.

The *quartz* fills small spaces left between the other components. It frequently contains vast quantities of slender hair-like interpositions which are indeterminable, but are believed to be of rutile like those found in certain granites.

The analysis of the rock by Dr. H. N. Stokes yielded the results shown on the following page.

	I.	II.	III.	I*a*.
SiO_2	68·34	66·22	65·54	1·139
Al_2O_3	15·32	16·22	17·81	·149
Fe_2O_3	1·90	1·98	·74	·012
FeO	·84	·16	1·15	·012
MgO	·54	·77	·98	·014
CaO	·92	1·32	1·92	·016
Na_2O	5·45	6·49	5·55	·089
K_2O	5·62	5·76	5·58	·060
$H_2O-110°$	·15	·08	·54	
$H_2O+110°$	·30	·24		
TiO_2	·21	·22	·11	
MnO_2	·07	trace	trace	
BaO	·08	·29	not det.	
SrO	·04	·06	not det.	
Li_2O	none	trace	trace	
P_2O_5	·13	·10	trace	
Cl	·04	·04	----	
Fl	none	trace	----	
SO_3	----	·02	----	
	99·95	99·97	99·92	
	·01	·01		
	99·94	99·96		

I. Quartz syenite, Beaver Creek stock, Bearpaw Mountains, H. N. Stokes anal.

II. Quartz syenite porphyry, Gray Butte stock, Bearpaw Mountains, H. N. Stokes anal.

III. Quartz syenite, Highwood Peak, Highwood Mountains, L. V. Pirsson and W. L. Mitchell anal.

I*a*. Molecular proportions of No. I.

The low lime, iron, and magnesia show that the rock belongs in the alkaline series. A couple of analyses are quoted for comparison from the first part of this paper. In I*a* are given the molecular proportions of the essential oxides. These show some interesting features in their mutual relations and may be computed into the minerals shown in the section as follows:

K_2O	= ·060 = 1	Orthoclase	Na_2O	= ·089 = 1	Albite	Or.	= 33·9
Al_2O_3	= ·060 = 1		Al_2O_3	= ·089 = 1		Ab.	= 47·3
SiO_2	= ·360 = 6		SiO_2	= ·534 = 6		Qtz.	= 13·2
MgO	= ·014 = 1	Pyroxene	FeO	= ·012 = 1	Magnetite	Pyr.	= 3·1
CaO	= ·014 = 1		Fe_2O_3	= ·012 = 1		Magn.	= 2·5
SiO_2	= ·028 = 2						
			SiO_2	= ·217 = free Quartz			100.0

The only deviation here is some 0·14 per cent of lime, which belongs in the minute amount of apatite and titanite present and of which no account has been taken. The rock is thus shown to consist of over 80 per cent of alkaline feldspar of varying mixtures, but whose average composition would be nearly Or_5Ab_7.

It therefore stands on the boundary in the alkali series between the granites and quartz syenites; it might be termed an augite aplite or granite or a quartz syenite. It is a noticeable fact how high a silica content purely feldspathic rocks may carry (albite with $SiO_2 = 68{\cdot}7\%$) and in this case high silica may still yield little free quartz.

Basic syenite or monzonite (*Yogoite*).—This variety constitutes the main mass of the stock. It seldom occurs in prominent exposures, but forms talus slopes whose luxuriant covering of grass conceals the angular debris blocks into which the rock breaks. This type occurs in different parts of the mass, showing identical characters. The specimen described comes from the base of the slopes east of Beaver Creek.

The rock is of a medium gray color, is evenly and moderately fine granular, the average size of grain being about 1^{mm} in diameter. It is easily seen to be composed of a white feldspathic component mixed with about equal quantities of a dark augite and biotite, the augite dominating the biotite in amount. They do not appear porphyritic in development but in grains like the feldspar; more rarely the biotite is seen in somewhat larger, ragged, poikilitic plates.

In thin section the rock is found to be composed of the following minerals: *Iron ore*, *apatite*, *diopside*, *biotite*, soda-lime feldspar varying from *labradorite* to *oligoclase*, and *orthoclase*.

The *diopside* is a pale green, and is apt to occur in short, stout prisms which have rough, rounded exteriors giving the mineral an anhedral habit.

The *biotite* is also allotriomorphic with respect to the other minerals; it has a strong pleochroism between very pale yellow and deep olive brown. Its period of formation overlaps the pyroxene but commenced later; it is very common to find the pyroxenes with an interior zone filled with biotite shreds; within this it does not occur, and this marks the commencement of the biotite crystallization. The biotite frequently surrounds grains of iron ore.

The *plagioclase* feldspar occurs in short, thick laths which are very small in size compared with the other components, and are generally quite idiomorphic. In amount it is much less than any of the other components. The small laths lie scattered around among the other components, and are enclosed in the orthoclase without orientation. It shows carlsbad, albite, and rarely pericline twinning. In composition it is somewhat variable, the interior parts being as usual more basic; the interior part is labradorite, and the outer portion varies through andesine to oligoclase. Sometimes the crystals are not zonal and these may be of labradorite. Thus a section in the zone 001 on 100 perpendicular to 010 gives for the albite twins in one carlsbad half 35°, 35°, in the other half 17° and 19°, then $\delta = 17°$, and the feldspar is a labradorite between Ab_1An_1 and Ab_3An_4. The index of refraction is also higher than the orthoclase, in which the laths lie. Its period of formation laps that of the biotite.

The *orthoclase*, which was the last mineral to crystallize, fills the interspaces and encloses the other components in a poikilitic manner over considerable areas. Its determination as orthoclase rests on the fact that in numerous sections perpendicular to an obtuse positive bisectrix the angle of extinction varied from 5 to 7 degrees from the trace of the cleavage 001 in the obtuse angle β, the section being oriented by this cleavage and by inclusions which give the direction of the vertical axis as well as a parting which appears to be parallel to the prismatic faces. Thus in such a section the angle was measured 63 and $\beta = 63° 54'$. The extinction measured with the Bertrand ocular is 7° 30′ from the trace of the good cleavage 001 in the obtuse angle. The albite molecule is surely present in it to a certain extent, and some examples contain patches of interlaminated albite.

All of the minerals are very fresh, and the structure is hypidiomorphic, typical of granular abyssal rocks. The differences in the mineral composition of this rock and the syenite just described are of the same kind as those noted between the two types described from Yogo Peak, but the contrast is even greater, as will be apparent from the chemical analysis.

An analysis of this type, made in the laboratory of the U. S. Geological Survey by Dr. H. N. Stokes, is given in the first column of the table on the next page.

Not knowing the exact proportions in which the elements enter into the various minerals present, it is not possible to calculate their relative percentages, but it is clear that the albite molecule must be largely present in the alkali feldspars.

It will be seen that the agreement between this type and the one from Yogo Peak is very satisfactory, as shown by the small differences of only about 1 per cent in SiO_2, Al_2O_3, and MgO. The mineral composition and structure are also the same.

Since our paper on Yogo Peak was published the first half of the new edition of Rosenbusch's "Mikroskopische Physiographie" has come into our hands, and almost simultaneously a notable work by Brögger chiefly on the rocks of Predazzo in Tyrol. The latter shows that the granular rocks there exposed form a transition group between the alkali feldspar and plagioclase groups with all grades from those rich in feldspar to those free from it; further, the author proposes to erect a new series coequal with the granite-syenite and diorite-gabbro series; the middle members of this series are the "monzonites" and in minerals, structure, and chemical composition they are the equivalents of our Yogoites.

	I.	II.	III.	I*a*.
SiO_2	52·81	54·42	54·20	·8801
Al_2O_3	15·66	14·28	15·73	·1520
Fe_2O_3	3·06	3·32	3·67	·0191
FeO	4·76	4·13	5·40	·0661
MgO	4·99	6·12	3·40	·1247
CaO	7·57	7·72	8·50	·1352
Na_2O	3·60	3·44	3·07	·0580
K_2O	4·84	4·22	4·42	·0513
$H_2O+110°$	·93	·38	·50	
$H_2O-110°$	·16	·22		
TiO_2	·71	·80	·40	
Fl	trace	----	----	
Cl	·07	----	----	
P_2O_5	·75	·59	·50	
SO_3	trace	----	----	
MnO	trace	·10	·70	
BaO	·24	·32	?	
SrO	·09	·13	?	
Li_2O	trace	trace	----	
	100·24	100·19	100·49	
O=Cl	·02			
	100·22			

I. Monzonite, "Yogoite," or basic syenite, Beaver Creek, Bearpaw Mountains. H. N. Stokes anal.

II. Monzonite, "Yogoite," or basic syenite, Yogo Peak, Little Belt Mountains, Montana. W. F. Hillebrand anal.

III. Monzonite (Brögger, Erupt. Gest. Predazzo, 1895, p. 24). V. Schmelck anal.

I*a*. Molecular proportions in No. I.

This is also clearly shown by analysis No. III, which is that of a typical monzonite. Rosenbusch,* however, regards these as being representatives of the basic syenites, or that member of the syenite family rich in the dark-colored components as its distinguishing characteristic. He calls it the monzoni type.

As this type of granular rock corresponds so closely in all essential features and in chemical composition with our yogoite and the name "monzonite" has priority in date, we desire to

* Mikr. Phys. Mass. Gest., 3d ed., p. 123, 1895.

withdraw the term "yogoite" and substitute "monzonite" in its place and thus avoid confusion in the nomenclature.

In connection with the associated occurrence of this monzonite and the alkali syenite previously described, it is of interest to recall the keen remark of Rosenbusch* on the probable presence of an alkaline syenite at Monzoni.

Leaving aside then for the present Brögger's radical proposal for the new group, the augite syenite family, taking into consideration the relative quantities of light and dark minerals according to our method of classification† would be as follows: *sanidinite*, *augite syenite* (åkerite and laurvikite types), *monzonite*, *shonkinite*, *pyroxenite.* This leaves out of consideration the plagioclase in the monzonite; if it is considered and Brögger's monzonite group be adopted, a gap is left to be filled by some type of hitherto undescribed alkaline syenite, rich in augite and free from plagioclase.

Gradational types between the monzonite and the more basic shonkinite were collected and their occurrence is quite what we should expect.

Shonkinite type.—The shonkinite type, the complementary rock of the acidic syenite, occurs in the outer or peripheral part of the stock. This rock crumbles readily in weathering, and good exposures do not occur. Pyritic impregnations have, however, led mining prospectors to drift into the rock, and the tunnel face and dump heaps afford quite fresh unaltered material. At the Zortman claim the rock is mottled and streaked with feldspathic material often in stringers and slender extended portions (*Schlieren*), and large irregular feldspar crystals occur. The normal rock is, however, free from these streakings, the specimen analyzed being entirely devoid of such material.

It is a very dark, basic-looking rock of a moderately coarse grain and strongly micaceous appearance from the light reflected from innumerable cleavages of biotite. In the description which follows, the type from the Bearpaw mine referred to in the first part of this paper is included, as it differs in no essential from the present occurrence.

Under the microscope it is found to consist essentially of the same minerals as the monzonite previously described, though in different proportions; they are *apatite*, *iron ore*, *diopside*, *biotite*, *alkali feldspar*, and in addition a very little *olivine* and probably a little *nephelite*.

The *apatite* is present in short, stout crystals which are clear and colorless. The *diopside* is present in rather long, slender prisms and in short, round anhedral grains; it is of a very clear

* Mikr. Phys. Mass. Gest., 3d ed., p. 124, 1895.

† See this Jour., Rocks of Yogo Peak, p. 478, vol. l, 1895.

pale green, of a wide extinction angle, good cleavage, and contains a few inclusions of glass, biotite, and iron ore.

The *biotite* is of a brown, strongly pleochroic variety, which passes at times into a green one. It has the character of a granitic biotite and is not very idiomorphic. Although so prominent megascopically, it is less in amount than the pyroxene. It frequently encloses iron ore and patches of iron ore and biotite are found which are evidently recrystallizations after a former olivine. In a few cases a little olivine remainder has been found in them. These are not like the opacite resorptions found in effusive rocks, but composed of rather coarse groupings of the minerals.

The *feldspar* is found in broad masses which yield wide plates in the section. Only in one specimen was the feldspar developed in thin, flat tables on *b* (010) with irregular boundaries. The broad fields of it enclose all the other minerals in a poikilitic manner. In its composition it is wholly anorthoclase or soda-orthoclase. This is shown by the fact that sections perpendicular to an obtuse ($2H > 115°$) positive bisectrix give extinction angles in a positive sense of 9° for the Bearpaw mine type and 12° 30′ for the Beaver Creek occurrence from the trace of the cleavage *c* (001). The orientation of the section is given by this cleavage, and the direction of the vertical axis *c* by lines of altered inclusions and by a parting which appears to be parallel to a prism face; between these the angle β was measured 63° in each case.

The feldspar, moreover, presents all the characteristics of the soda-orthoclase group, which have been so frequently mentioned in these papers and shown to be dominant in the Bearpaw rocks. It has the homogeneous appearance with low powers, and the patchy varying appearance with high ones between crossed nicols. In one or two instances plates have shown an extremely fine, delicate, scarcely perceptible twinning following the albite law. The feldspar is indeed similar to the cryptoperthite of the Norwegian alkali rocks.

No trace of any lime-soda feldspar has been found in these shonkinites. It did not occur in the original type at Square Butte and was very sparingly present in the Yogo Peak variety, a noteworthy fact when the high per cent of lime is considered. The presence of a little *nephelite* is suspected as the rock powder yields a little gelatinous silica (not due to the olivine) on treatment with very dilute acid. We have not found it in the sections and only a mere trace can be present.

The structure is the typical hypidiomorphic one characteristic of even-grained abyssal rocks.

The chemical composition of the Beaver Creek type is shown in the following analysis made for us by Dr. H. N. Stokes:

	I.	II.	III.	IV.	Ia.
SiO_2	50·00	48·98	46·73	50·43	·8333
Al_2O_3	9·87	12·29	10·05	10·21	·0958
Fe_2O_3	3·46	2·88	3·53	11·57 (Fe₂O₃ and FeO)	·0216
FeO	5·01	5·77	8·20		·0696
MgO	11·92	9·19	9·68	5·58	·2980
CaO	8·31	9·65	13·22	14·82	·1484
Na_2O	2·41	2·22	1·81	1·48	·0388
K_2O	5·02	4·96	3·76	3·70	·0532
TiO_2	·73	1·44	·78	?	
$H_2O-110°$	·17	·26	·78 (both)	·87 (both)	
$H_2O+110°$	1·16	·56			
Cr_2O_3	·11	trace	----	----	
MnO	trace	·08	·28	----	
NiO	·07	----	----	----	
BaO	·32	·43	undet.	?	
SrO	·07	·08	undet.	?	
Fl	·16	·22	----	----	
$CaCO_3$	----	----	----	·52	
Cl	·08	----	·18	----	
P_2O_5	·81	·98	1·51	·70	
SO_3	·02	----	trace	----	
CO_2	·31	----	----	----	
Li_2O	trace	trace	trace	----	
	100·01	99.99	100·97	99.88	
O=Cl & Fl	·08	·08	·04		
	99·93	99·91	100·93		

I. Shonkinite, Beaver Creek, Bearpaw Mountains, H. N. Stokes anal.

II. Shonkinite, Yogo Peak, Little Belt Mountains, Montana. W. F. Hillebrand anal.

III. Shonkinite, Square Butte, Highwood Mountains, Montana, L. V. Pirsson anal.

IV. Shonkinite, Monzoni (Lemberg, Zeitschr. d. deutsch. G. G., 1872, p. 201), Lemberg anal.

I*a*. Molecular proportions in No. I.

It will be seen in the above that the rock has all the characters of the type, high lime, iron, and magnesia and also high alkalies with potash dominating the soda. We have introduced the analyses of the previous types described by us and also one of a pyroxene-orthoclase rock from Monzoni, being indebted to Brögger* for the reference. It should evidently fall under this type.

Brögger† remarks that shonkinite is "a peculiar pyroxenite rich in plagioclase"; this is certainly true, but the same

* Eruptionsfolge eruptivgesteine Predazzo, 1895, p. 66.
† Loc. cit.

definition would apply as well to augite-syenite, or gabbro could be called a peridotite rich in plagioclase. A pyroxenite, according to our conception, is essentially a *non-feldspathic* rock, and we desire to emphasize at this point that in the shonkinites described by us the alkali feldspars are a constant and essential component, true pyroxenites, the practically non-feldspathic member of the series, never having been observed at any of the localities.

As a matter of fact, if the syenites be estimated as a series practically free from plagioclase and we adopt Brögger's monzonite group as an alkali-feldspar-plagioclase series as he defines it, then the shonkinites are the syenite equivalents of the olivine monzonites, while the pyroxenites—the end terms—are alike in each, the two series approaching as the feldspars diminish until they unite in the last term, the pyroxenites.

This makes the fourth occurrence of this rock type described by us from widely separated and distinct localities in central Montana. We have material, also, from others which we hope to describe at a future date. It is of interest to note that theralite (a plagioclase-nephelite, granular rock) which shonkinite strongly resembles in the character and abundance of the ferro-magnesian minerals, also occurs in this region, in the Crazy Mts., but appears to be a very rare type, the shonkinite being a more common and dominating one.*

Differentiation at the Beaver Creek core.—To enter into detail concerning the facts of the differentiation of igneous magmas at the Beaver Creek core and their bearing on theoretic petrology, would be merely a repetition of the discussion given in our former papers. We have thought it best, therefore, to merely present the analyses (p. 362) in comparison with those at Yogo Peak and let the figures tell their own story. The lower figure in the case of each oxide refers to the Beaver Creek, the upper one to the Yogo Peak series.

At Yogo Peak the series began with a quartz-syenite porphyry,† and next to it came the syenite. The contact, if any, between them is covered, and we cannot tell whether the quartz-syenite porphyry is a differentiation in place, as seems

* While this article was passing through the press we received a paper on "Malignite, a family of basic plutonic orthoclase rocks rich in alkalies and lime," by Prof. A. C. Lawson (Bull. Univ. California, vol. i, pp. 337–362, March, 1896). These rocks appear closely related chemically and in part mineralogically to the theralites and shonkinites, and although the author does not appear to recognize it they clearly belong in Rosenbusch's theralitic magma series (Mass. Gesteine, 3d ed., p. 385, 1895).

† The analysis of the quartz-syenite porphyry given is not that of the rock occurring at Yogo Peak but of a precisely similar type from Big Baldy Mountain, a few miles distant. It represents perfectly, however, the Yogo Peak differentiation.

most probable, or a later intrusion. In any case it is a differentiated phase of the same magma. As seen in the table below, its correspondent exists at Beaver Creek, but the one corresponding to the syenite is wanting. It probably exists, but was not observed in the hasty examination we have been able to make.

	Quartz Syenite.	Syenite.	Monzonite "Yogoite."	Shonkinite.
SiO	67·04	61·15	54·42	48·49
	68·23	----	52·81	50·00
Al_2O_3	15·25	15·07	14·28	12·29
	15·12	----	15·66	9·87
Fe_2O_3	1·69	2·03	3·32	2·88
	1·90	----	3·06	3·46
FeO	1·13	2·25	4·13	5·77
	·84	----	4·76	5·01
MgO	1·75	3·67	6·12	9·91
	·54	----	4·99	11·92
CaO	2·17	4·61	7·72	9·65
	·92	----	7·57	8·31
Na_2O	4·09	4·35	3·44	2·22
	5·30	----	3·60	2·41
K_2O	5·10	4·50	4·22	4·96
	5·57	----	4·84	5·02

The other types are clearly shown. In general a comparison of the two localities shows the Beaver core as the more alkaline of the two; and the most important difference is that at Beaver Creek; the Al_2O_3 and MgO show a much greater degree of concentration and inverse variation than at Yogo. This inverse variation is especially marked in the Beaver Creek monzonite and shonkinite, which otherwise do not greatly differ from one another. They thus furnish a most instructive example of the fact that a nearly similar silica percentage may exist in two types of rocks which differ greatly in appearance, one with high Al_2O_3 being clearly feldspathic and recalling many medium diorites in appearance, while the other, with high MgO, is dark, basic-looking, and with evidently preponderant ferromagnesian minerals.

There are a number of interesting dike rocks connected with the Beaver stock; these have been studied, and an account of them, together with some other occurrences of rare types of both intrusive and extrusive rocks in the Bearpaw Mts., will be shortly published in a second paper in this Journal.

Washington and New Haven, March, 1896.

ART. XLII.—*Röntgen Rays not Present in Sunlight;* by M. CAREY LEA.

IF Prof. Röntgen's views as to the nature of the X-rays are correct, it would seem that they ought to be found amongst the many forms of radiant energy received from the sun, and various observers have thought that they so found them. Some experiments, the most important of which will be here briefly stated, do not seem to support this opinion.

1. A very sensitive dry plate (S. 27) was placed between the leaves of a book so that 100 leaves and the red paper cover should be between the sensitive film and the sunlight. The book was then packed in a box frame to exclude all light from the sides. A large and thick lead star was then fastened on the outside of the book and the arrangement was exposed to exceptionally bright sunshine from 11 A. M. to sunset, March 7. The plate when put into a developing bath behaved as if unexposed. A prolonged development did not bring out a trace of an image of the lead star.

It will be remembered that Prof. Röntgen found that the X-rays penetrated easily through a book of 1000 printed pages. Indeed G. Moreau has recently stated that in his hands the X-rays had penetrated through "several meters" of cardboard.* So that the above experiment seems to be very significant.

2. A piece of sheet aluminium $1{\cdot}2^{mm}$ thick was accurately fitted into a frame. A very sensitive plate was placed behind it and a lead star in front. With three hours' exposure not a trace of an image could be obtained. This experiment was varied by substituting thin aluminium foil for the plate, also by using bromide paper as the sensitive surface. No images in any case were obtained.

3. The sun's rays or some portion of its radiation passes readily through wood, if the latter is not too thick. Thus through a piece of white pine $\frac{3}{16}$ of an inch thick, images that could readily be developed were obtained by three minutes exposure to afternoon sunlight. With half an hour's exposure the images were brilliant.

A panel about 12 inches square was removed from an inside shutter and replaced with a piece of white pine $\frac{1}{4}$ inch thick. When the room was thoroughly darkened, reddish light could be seen to pass through the board. So that wood of this thickness is plainly translucent to the sight.

The sun's light may be examined for X-rays also by fluorescence.

* C. R., cxxii, p. 238: quoted Chem. News, Feb. 21, 1896, p. 85, (No. 1891.)

4. The panel just described was replaced by one of stout book board. With the sun shining on this book board directly and not through glass, paper marked with a saturated solution of barium platinocyanide exhibited no indications of fluorescence when placed behind the board.

5. Three thicknesses of Bristol board were pasted together, a circle was cut out, to one side of which barium platinocyanide was applied. The circle was then placed in a pasteboard tube, (an arrangement, I believe, proposed by Prof. Magie.) When the sun was looked at through this tube the barium salt exhibited fluorescence. But the interposition between the card and the sun of very thin aluminium foil sufficed to cut off the fluorescence.

These concurrent results seem to indicate the absence of X-rays from sunlight.

Charles Henry* quotes an opinion of H. Poincaré that all bodies whose phosphorescence is sufficiently intense, emit in addition to luminous rays the X-rays of Röntgen, whatever may be the cause of their fluorescence. Henry quotes confirmatory experiments of his own made with zinc sulphide.

It seemed worth while to ascertain if this principle is of general application. A dilute solution of uranin was exposed to sunlight, using a large surface of solution so as to get the best effect. A short distance over the surface was placed a sensitive film protected by aluminium foil $\frac{1}{10}$ of a millimeter in thickness and with a lead star interposed. Two hours exposure gave no result. The experiment was repeated with acid solution of quinine, with which five hours exposure gave no result.

I have also examined the Welsbach light for X-rays. This light is usually burned under a chimney which increases the brightness but interposes glass between the source of light and the sensitive film. Even without a chimney the light is bright. The experiment was therefore made both ways. No X-rays could be detected. Nothing capable of passing through aluminium foil $\frac{1}{10}$ of a millimeter in thickness by five hours exposure to the uncovered flame.

* C. R. cxxii, 312; Chem. News, Feb. 28, 1896, p. 98.

ART. XLIII.—*The Potomac River Section of the Middle Atlantic Coast Eocene;* by WM. BULLOCK CLARK.

OUR knowledge of the Tertiary geology and paleontology of the middle Atlantic slope has been largely increased since the days of Conrad and Rogers, yet few fields afford better opportunities for continued observation, and in none is there greater need of a careful revision of results. Very divergent opinions have prevailed and to-day find expression in the different interpretations of the data.

General Features of the Formation.

The Eocene strata of the middle Atlantic slope, described by Darton* under the name of the *Pamunkey Formation*, form a belt of varying width extending from northeast to southwest somewhat to the west of the center of the coastal plain. This belt has been traced almost continuously from the southern portion of Newcastle County, Delaware, to the valley of the Nottaway river in southern Virginia, and although at times buried beneath later deposits it presents fine exposures along all the leading stream channels, while not infrequently broad expanses of the formation outcrop at the surface in the intervening country.

Lithologic Characters.—The deposits are typically glauconitic and are found in their unweathered state either as dark gray or green sands or clays. The glauconite varies in amount all the way from very nearly pure beds of that substance to deposits in which the arenaceous and argillaceous elements predominate, although the strata are generally very homogeneous for considerable thicknesses. At some horizons the shells of organisms are found commingled with the glauconitic materials in such numbers as largely to make up the beds, producing what is known as a green-sand marl. These beds are at times indurated, forming true limestone bands. This latter phase is seen typically developed both at Fort Washington, Maryland, and Aquia Creek, Virginia, interstratified with the unconsolidated green-sand layers.

When the glauconite is weathered the deposits lose their characteristic gray or green color, and generally become lighter gray with reddish or reddish-brown streaks or bands, or may become entirely of the latter color. In this condition they are often cemented into a ferruginous sandstone. This change

* Bull. Geol. Soc. Amer., vol. ii, p. 411, 1891.

particularly characterizes the Eocene deposits of Delaware and the eastern shore of Maryland as well as of Anne Arundel County on the western side of the Chesapeake. A very coarse phase of the consolidated sand-rock is seen at Mt. Misery on the Severn river.

In the less completely weathered portions of the formation the change is shown in the mottled yellow and brown character of the more superficial beds, the glauconitic grains still showing their green color when crushed. Thin iron crusts at times appear under these conditions. When the glauconite is largely or more rarely entirely absent, the deposits consist of black or grey sands or clays, the latter at times micaceous and in a few instances carbonaceous.

A pebble bed has been found at some localities at the base of the formation.

Strike, Dip and Thickness.—The strike of the Eocene deposits in Delaware and Maryland is approximately N.E. to S.W. while in Virginia the prevailing trend is more nearly N. to S. This change in the direction of strike is attained in the area between the Patuxent and Rappahannock rivers, chiefly in the Potomac basin.

The dip of the strata differs in the various portions of the area, as shown by section-lines and well-borings, from 10 to 20 feet to the mile, but along the Potomac river section, where detailed measurements were made by the writer, it is on an average about 12½ feet to the mile.

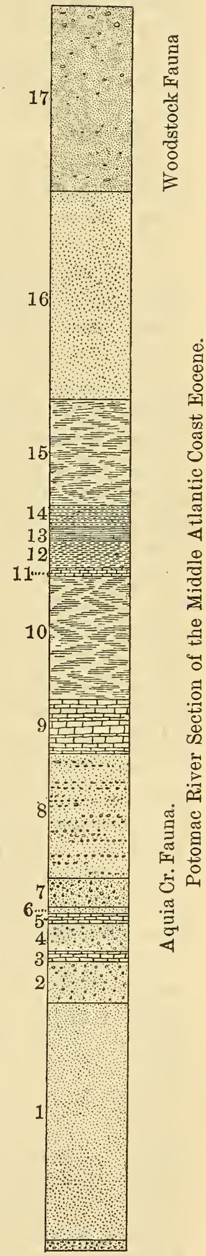
The results obtained from a study of the various section-lines and well-borings show that the average thickness of the deposits is somewhere in the vicinity of 200 feet, although estimates based upon the Potomac river section as well as upon well borings in the area to the east of Fredericksburg show that it reaches quite 300 feet in that portion of the middle Atlantic slope.

Potomac River Section.

The most extensive section of the Eocene in the middle Atlantic slope is found in the valley of the Potomac river, a nearly complete sequence of the several members of the formation being exhibited in the bluffs between Aquia Creek, Stafford County, Virginia and Pope's Creek, Charles County, Maryland.

Detailed stratigraphy.—The accompanying columnar section shows the relative thickness and character of the deposits in this area. The several members of the formation are numbered in ascending order. The full thickness is about 300 feet.

No. 1. The thickness of the Eocene beneath the basal strata of the Aquia Creek bluff, cannot fall far short of 60 feet. Some exposures are seen in the ravines to the west of the bluff, but no complete sequence of the beds has been found. The almost entire absence of fossils renders it impossible to say anything regarding the faunal relations of the strata. The deposits are typical green-sands, at times somewhat argillaceous and with a basal pebble-bed overlying the Cretaceous at several points.



No. 2. This bed is composed of dark unconsolidated green-sand packed chiefly with the shells of *Crassatella alæformis*, *Dosiniopsis lenticularis* and *Cytherea ovata*. The bed is about 12 feet in thickness at the upper end of the Aquia Creek bluff, but gradually declines in elevation until it passes below water level about half way to Marlborough Pt. The same bed appears at water level on the opposite side of the Potomac river at Clifton Beach.

No. 3. The green-sand marl composing this bed is generally indurated so as to form a firm band, 2 to 3 feet in thickness. The limestone is highly glauconitic and of dark color, and is filled with the shells, or more commonly the casts of the same species as the previous bed, together with *Ostrea compressirostra* and here and there a specimen of *Turritella mortoni*.

No. 4. This bed is a typical unconsolidated green-sand containing large numbers of the same forms as No. 3. It reaches about eight feet in thickness.

No. 5. This limestone bed is very persistent, and forms a conspicuous ledge along the face of the Aquia Creek bluff until it passes below tide level near its eastern extremity. It is commonly about two feet in thickness, and is packed with fossils among which the forms mentioned below are conspicuous, in addition to the species already mentioned as characteristic for zones 2 to 5 which still remain the most common types, viz: *Pholadomya marylandica*, *Panopæa elongata*, *Tellina virginiana*, *Pholas* (?) *petrosa*, *Fusus* sp., *Caricella* sp., etc.

No. 6. The dark characteristic green-sand overlying the limestone ledge is packed with the common species of the previous zones. In the main portion of the Aquia Creek bluff this bed is only one foot in thickness, but thickens to the eastward, and just above Marlborough Pt. contains among other forms several species of corals, including *Eupsammia elaborata*, *Turbinolia acuticostata*, and *Paracyathus* (?) *clarkeanus*.

No. 7. Overlying the preceding bed, and really a continuation of it, is a zone in which the fossils are few in number and much broken. This bed is about seven feet in thickness.

No. 8. The highly characteristic green-sands and green-sand marls of the previous zones are succeeded by a bed some thirty feet in thickness, in which the glauconitic grains have been extensively weathered, giving the strata a greenish-grey appearance which changes to a reddish-brown in the upper layers. Several irregular bands packed with *Turritella mortoni* are present both in the Aquia Creek and Potomac Creek sections, while associated with that species at both localities are *Turritella humerosa*, *Cucullæa gigantea*, *Crassatella alæformis*, *Ostrea compressirostra* and other forms. The upper portions of this bed have afforded most of the species from the Potomac Creek bluff. This zone forms the base of that bluff, while it is more than thirty feet above water level in the Aquia Creek section three miles above.

No. 9. The thick-bedded limestone layers which compose this zone are almost exclusively made up of the shells of *Turritella mortoni*, forming a true Turritella rock. Between the indurated bands are layers of unconsolidated and much-weathered green-sand which contain very few fossils of any description. Great masses of this Turritella rock strew the shore at the base of both the Aquia Creek and Potomac Creek bluffs. The bed is about ten feet in thickness in the Aquia Creek bluff, but reaches fourteen feet in places in the Potomac Creek section.

No. 10. The greenish-grey sand overlying the Turritella bed is more argillaceous than the underlying beds of the Eocene. The glauconite grains have been much weathered and nearly all trace of the shell substance removed from the few forms recognized. The casts found at the Potomac Creek bluff are chiefly those of a *Cytherea*. No fossils were found at the Aquia Creek bluff. The bed is about twenty-five feet in thickness.

No. 11. A thin highly indurated layer of argillaceous green-sand overlies No. 10 in the Potomac Creek bluff, and among several indeterminable casts a few specimens of *Venericardia planicosta* were found.

No. 12. This bed of greenish-grey argillaceous sand still shows some unweathered grains of glauconite, but is devoid of fossils so far as observed. It reaches eight feet in thickness.

No. 13. This bed consists of a light grey glauconitic sand somewhat weathered and filled with shells of *Venericardia planicosta.* It reaches three feet in thickness. This zone is very persistent and has been found outcropping in several of the ravines to the east and south of Potomac Creek, as well as in the bluff upon the river front.

No. 14. Overlying the Venericardia layer is a bed of greenish-grey argillaceous sand some four feet in thickness, which contains a great number of bands filled with gypsum crystals. No fossils were observed.

No. 15. This bed consists of greenish-grey argillaceous sand in which the glauconite grains have been extensively weathered. No fossils were found. The bed has a thickness of twenty-five feet.

No. 16. In this zone have been placed the green-sand strata intervening between the upper layers of the Eocene in the Potomac Creek section and the base of the Woodstock section.

Comparatively little is known regarding this portion of the series, as no satisfactory outcrops appear on the river bluffs, although the strata are found in an unfossiliferous condition in some of the ravines to the west of the Woodstock area. The estimated thickness of these beds is fifty feet.

No. 17. The highly glauconitic beds at Woodstock, Virginia and Pope's Creek, Maryland are grouped together in one zone, as no satisfactory separation could be made. The deposits are very homogeneous, although an inconstant indurated layer appears about six feet above the base of the Woodstock section with a band of *Venericardia planicosta* below it, while a thin bed of *Ostrea sellæformis* also occurs in the lower part of the zone, although evidently not always at the same horizon. Otherwise the fossils are the same throughout, so far as observed. The most common forms are *Protocardia virginiana*, *Cytherea subimpressa*, *Corbula nasuta*, *Corbula oniscus*, *Ostrea sellæformis*, *Pectunculus idoneus*, *Leda improcera*, *Leda parva*, *Nucula magnifica*, *Lucina dartoni*, *Lucina uhleri*, *Lucina whitei*, *Ringicula dalli* and *Cylichna venusta*.

Paleontological characteristics.—The paleontological characteristics of the several zones indicate two very distinct faunal stages in the middle Atlantic slope Eocene, the first typically developed in zones 2 to 9, and the second in zone 17. The characteristics of zone 1 and of zones 10 to 16 cannot be readily made out in the Potomac River area on account of the extensive weathering of the beds, although in some of the adjoining districts there is an intermingling of some of the forms of the two stages in the beds intervening between 9 and 17. To the two faunal divisions, the names of *Aquia Creek Stage* and *Woodstock Stage* have been already given by the writer.*

* Johns Hopkins Univ. Circulars, vol. xv, p. 3, 1895.

Aquia Creek Stage.—The most common species of the Aquia Creek stage are *Turritella mortoni* confined chiefly to zones 8 and 9, *Cytherea ovata* and *Crassatella alæformis* confined largely to zones 2 to 7, *Cucullæa gigantea* mainly found in zone 8, *Ostrea compressirostra** most common in zones 6 and 7, and *Dosiniopsis lenticularis*, for the most part limited to zones 2 to 5. Other species found in this stage are *Thecachampsa marylandica*, *Trionyx virginiana*, *Ischyrhiza* (?) *radiata*, *Myliobatis copeanus*, *Carcharodon polygurus*, *Lamna* (?) *obliqua*, *Oxyrhina hastalis*, *Odontaspis elegans*, *Galeocerdo contortus*, *Nautilus* sp., *Tornatella bella*, *Pleurotoma harrisi*, *Volutilithes* (*Athleta*) *tuomeyi*, *Volutilithes* sp., *Caricella* sp. *Mitra marylandica*, *Pyropsis* sp., *Fusus* (*Levifusus*) *trabeatus*, *Fusus* (*Strepsidura*) *perlatus*, *Fusus* sp., *Fulgur argutus*, *Lunatia marylandica*, *Natica cliftonensis*, *Turritella humerosa*, *Calyptræa trochiformis*, *Vermetus* sp., *Scala virginiana*, *Gibbula glandula*, *Solarium* sp., *Gastrochæna* sp., *Pholas* (?) *petrosa*, *Coralliophaga bryani*, *Tellina williamsi*, *Panopæa elongata*, *Pholadomya marylandica*, *Lucina aquiana*, *Venericardia planicosta*, *Crassatella aquiana*, *Leda protexta*, *Modiola potomacensis*, *Pecten johnsoni*, *Pecten* sp., *Ostrea* sp., *Serpula* sp., *Paracyathus* (?) *clarkeanus*, *Turbinolia acuticostata*, *Eupsammia elaborata*, besides many species of Foraminifera.

Woodstock stage.—The Woodstock stage is characterized by the following common species, viz: *Protocardia virginiana*, *Cytherea subimpressa*, *Corbula nasuta*, *Corbula oniscus*, *Ostrea sellæformis*, *Pectunculus idoneus*, *Leda improcera*, *Leda parva*, *Nucula magnifica*, *Lucina dartoni*, *Lucina uhleri*, *Lucina whitei*, *Venericardia planicosta*, *Ringicula dalli* and *Cylichna venusta*. Among other species found at this horizon may be mentioned *Carcharodon polygurus*, *Lamna* (?) *obliqua*, *Oxyrhina hastalis*, *Odontaspis elegans*, *Galeocerdo contortus*, *Cythere* sp. *Mangilia* (*Pleurotomella*) *bellistriata*, *Fusus* (*Levifusus*) *trabeatus*, *Lunatia marylandica*, *Cadulus bellulus*, *Teredo virginiana*, *Solemya petricoloides*, *Corbula aldrichi*, *Tellina virginiana*, *Cytherea ovata*, *Diplodonta hopkinsiensis*, *Yoldia cultelliformis*, *Modiola potomacensis*, *Pecten rogersi*, together with numerous species of Foraminifera.

Correlation of the Deposits. — By common consent the diversified and extensive Eocene deposits of the Gulf area have come to be regarded as the type for the eastern border region and the various Eocene deposits of the Atlantic coast states have been assigned to a position in this series, although very different limits have been given by the different authorities. The Eocene deposits of the middle Atlantic slope have

* Several immature oysters found at this horizon bear a strong resemblance to the young of *Ostrea sellæformis*.

been regarded by some to represent a single minor division of the Gulf section, while others have regarded them as an equivalent of a larger portion of that series. The latter conclusion seems to the writer, after a consideration of both the geological and paleontological data, to be the only tenable position. In the past too little attention has been given to the geological phenomena, while, at the same time, the knowledge of the fossils has been wholly insufficient for a proper interpretation of the faunal characteristics of the formation.

The Geological Criteria.—The lithological and stratigraphical characteristics of the Eocene in the middle Atlantic slope afford some important criteria for the correlation of the strata. To begin with, the homogeneous nature of the deposits is a characteristic feature, indicating conditions throughout the period of Eocene deposition, undisturbed by important physical changes. Again, the fact that the strata are so largely made up of secondary materials shows that the position of accumulation was in the vicinity of a coast reached by no large rivers bearing sediment, while at the same time sufficiently removed from the coast line to be unaffected by shore conditions. It is further evident that these deposits, which are so largely glauconitic, were accumulated with exceeding slowness, as has been shown in the case of the formation of greensands upon the beds of existing seas.

Now when we compare these conditions of accumulation in the middle Atlantic slope with the conditions that prevailed in the Gulf region, marked differences appear. In the latter area numerous rivers, draining the interior of the continent, discharged great quantities of material throughout much of Eocene time, making the deposits highly diversified. Instead of the green-sands and greenish and black clays of the middle Atlantic slope, which no longer to any large extent characterize the strata, are found coarser beds of sand and clay, often partly calcareous, which give every indication of more rapid accumulation. To compare, therefore, the 200 feet and more of green sands and clays of the middle Atlantic slope with one or two subdivisions of hardly equal thickness in the Gulf region would, even upon stratigraphical grounds without the aid of fossils, hardly be attempted. The strata of the Middle Atlantic slope must be represented in the Gulf by deposits many times their thickness.

The general relations of the strata, occurring as they do between the Cretaceous and Neocene along both the Atlantic and Gulf coasts, give some indications of the continental movements to which each province was subjected. Although the movements may not have been absolutely contemporaneous they afford nevertheless satisfactory criteria for the broad correlation of the deposits, their more exact parallelism being determined upon other grounds.

Paleontological Criteria.—Although life-zones are frequently of great extent and may be accepted as the most trustworthy evidence of geological contemporaniety, yet the subdivisions of a fauna recognized in one area under one set of physical conditions may not be found in another area, distant from the first, where the conditions are wholly different. It is scarcely to be expected that the vertical range of the species will be the same in the two regions, while the time occupied in migration is a factor that cannot be ignored in most classes of organisms. Forms, likewise, which, from their persistence under one set of physical conditions, may be regarded as typical, are often entirely wanting in an adjacent province. The presence also of a large number of new species is of itself evidence of change in physical surroundings, and renders it necessary to proceed with great caution when detailed correlations of the strata are attempted. Especially is this true when the areas are widely separated in latitude so that temperature differences occur.

When we come now to compare the faunal charactistics of the Eocene of the middle Atlantic slope with those of the Gulf we find first of all that the assemblage of forms is very different in the two areas. The great majority of the species is unlike, while the identical forms are mainly of wide vertical range. Most of those regarded as the same also show certain differences, as the result of the dissimilar conditions under which they lived, so that the determination of the middle Atlantic coast forms often involves certain doubts as to their identity with Gulf species. The sequence of forms is likewise different, a differentiation into the great number of subdivisions recognized in the Gulf, not occurring in Maryland and Virginia.

The Aquia Creek fauna which is typically developed in zones 2 to 9 in the Potomac area occupies, so far as can be with certainty determined, only about 70 feet of strata some 60 feet from the base of the formation and contains among other Gulf species *Turritella mortoni*, *T. humerosa*, *Tornatella bella* *Volutilithes* (*Athleta*) *tuomeyi*, *Fusus* (*Strepsidura*) *perlatus*, *Dosiniopsis lenticularis*, *Venericardia planicosta*, *Cucullœa gigantea*, and *Ostrea compressirostra*. The general aspect of this assemblage is *Lignitic*, some of the forms being found in the Gulf area in the middle, or in the middle and lower members of that division, while others range into its upper portions, and are also found at higher horizons. At the same time quite 60 feet of strata are found beneath the Aquia Creek fossiliferous beds in which as yet only a few indistinct casts of *Turritella* sp. have been observed. If the fossiliferous zones represent approximately the middle, or the middle and upper Lignitic, this lower zone (1) may he regarded in a general way as the equivalent of the lower Lignitic.

The Woodstock fauna, which is typically represented in zone 17, embraces so far as can be determined about 45 feet at the top of the series. It contains among other Gulf forms, *Fusus* (*Levifusus*) *trabeatus*, *Solemya petricoloides*, *Corbula nasuta*, *Corbula oniscus*, *Venericardia planicosta*, *Nucula magnifica* and *Ostrea sellæformis*, the latter species increasing in number toward southern Virginia and affording thick beds on the Pamunkey and James rivers. At the same time the common forms of the Aquia Creek stage are wanting. Although not possessing the number of distinctive species found in the preceding divisions, the Woodstock stage is nevertheless in all probability the representative of the *Claiborne* of the Gulf, showing a closer parallelism, perhaps, with the beds beneath the fossiliferous sands than with the upper horizon of that division.

Between the fossiliferous beds carrying the faunas of the two stages are very nearly 125 feet of strata in which few fossils have been found outside of *Venericardia planicosta*. Many of the beds seem to be wholly barren of organic remains, while in others only a few indeterminable casts appear. No satisfactory paleontological data for correlation are therefore afforded by these deposits.

If now the Aquia Creek fauna should be held to be sufficiently similar to the Bells Landing fauna of the Gulf to warrant its restriction to that sub-stage (middle Lignitic); and the *Ostrea sellæformis* bed of the Woodstock stage, the exact equivalent of the *Ostrea sellæformis* zone of the Claiborne (middle Claiborne), then we find the 600 feet between those horizons in central Alabama represented by only 125 feet in the middle Atlantic slope and perhaps by considerably less. The representatives of the Woods Bluff and Hatchetigbee stages of the Lignitic together with the Buhrstone and lower portion of the Claiborne would thus be here included. The upper beds of the Woodstock stage might then be regarded perhaps as the equivalent of the upper Claiborne, while the 60 feet below the Aquia Creek fossiliferous beds would approximately represent the earlier portions of the Lignitic. As these lower beds are much more glauconitic than the beds above the Aquia Creek stage, they doubtless accumulated more slowly.

It is apparent, however, that the sequence of organic remains in the middle Atlantic coast Eocene does not afford the necessary data for a detailed parallelism of the subdivisions of that area with the Gulf stages. It seems altogether probable that the Pamunkey formation is the equivalent in a broad way only of the lower and middle divisions of the Eocene of the Gulf, and may even represent portions of the upper division as well. Regarding the latter reference there is little paleontological evidence, but undoubtedly less change in faunal development would be produced under the stable conditions that prevailed in Eocene time in the middle Atlantic slope than in the Gulf, so that the more highly developed fauna of the upper portion of the series in the latter area may have existed contemporaneously with older forms outside the region. Without a much fuller knowledge of the characteristics of the Eocene fauna in the intermediate district, this cannot be definitely determined, although it seems highly probable.

Considering all the facts, the writer is strongly of the opinion that the Eocene deposits of the middle Atlantic slope represent the greater portion of the Eocene series of the Gulf, its upper members alone excepted. Compared with the section recognized by Prof. E. A. Smith, in the Alabama area, it undoubtedly comprises all or the major part of the Lignitic, Buhrstone and Claiborne and, possibly, also portions of higher horizons. This reference does not, however, necessarily involve the assumption that the basal beds of the Potomac section are the exact equivalent of the basal beds of the Lignitic, since deposition may have commenced in the one area somewhat earlier than in the other, although the difference was probably not great.

Conclusions.—1. The Eocene deposits of the middle Atlantic slope constitute a single geological unit already described under the name of the Pamunkey formation.

2. The deposits are remarkably homogeneous, consisting typically of glauconitic sands and clays which reach a thickness of nearly 300 feet.

3. Two clearly defined faunal zones are found, viz: the *Aquia Creek Stage* and the *Woodstock Stage.*

4. The Aquia Creek fossiliferous zone is approximately middle, or middle and upper Lignitic, the Woodstock zone middle, or middle and upper Claiborne. If restricted respectively to the Bells Landing sub-stage of the Lignitic and the Ostrea sellæformis bed of the Claiborne, as seems hardly probable for the reasons above cited, the 600 feet between those zones in the central Alabama area would then be represented by only 125 feet or perhaps considerably less in the Potomac region. The upper beds of the Woodstock stage might then perhaps represent the upper portion of the Claiborne while the beds below the Aquia Creek fossiliferous zone would stand as the approximate equivalent of the lower Lignitic, without however necessarily assuming that the basal beds of the Potomac section are the exact equivalents of the basal beds of the Lignitic.

5. The middle Atlantic slope Eocene, therefore, represents in a broad way all or the major part of the Lignitic, Buhrstone and Claiborne of Smith, and, when the physical conditions affecting range and migration of species are considered, perhaps even more. Both the geological and paleontological criteria are wholly inadequate for establishing the great number of local subdivisions recognized in the Gulf area, and in fact the sequence of forms indicates that no such differentiation of the fauna took place.

ART. XLIV.—*On some Ischian Trachytes;* by HENRY S. WASHINGTON.

IN the fall of 1894 I had occasion to visit Ischia, in the Bay of Naples, and collect the representative trachytes of the island. Most of these are too well known to need description, but some specimens from Mt. Rotaro showed a certain rather rare structure in such perfection that an account of them seems not unworthy of publication.

Mt. Rotaro is a small volcanic cone in the northeastern part of the island, some 315 meters high,* and with a well-preserved crater 107 meters deep. As far as can be seen it is composed of fragmentary material, scoriæ and blocks of trachyte and obsidian, which show stratification in places. The whole rests on marls and clays containing late Tertiary fossils.† The ridge of Mt. Tabor,‡ composed of the well known sodalite trachyte, is a lava-stream of this small volcano which has flowed to the north. According to Fuchs,§ Mt. Rotaro is the site of the great eruption of the first half of the fourth century B. C., which drove the inhabitants to the mainland.

The trachytes of Mt. Rotaro are of two kinds. One is a not very compact, light grayish-brown rock with phenocrysts of orthoclase and augite. It occurs in relatively small quantity, and under the microscope presents no features of special interest here; large phenocrysts lying in a typically trachytic holocrystalline groundmass, which shows a marked flow-structure among its component feldspar laths. Corresponding to this is a light brown obsidian, extremely brittle and somewhat vesicular, showing some orthoclase phenocrysts. Under the microscope it presents a clear, light brown glass, with rare green biotite and augite, and glassy sanidine phenocrysts, with a few feldspar microlites. Many air cavities are present.

The black trachytes and obsidians are of greater interest. For reasons which will be seen we shall begin their description with the obsidians. No. 524 ‖ is coal black, with a vitreous luster, very brittle, and shows numerous stout phenocrysts of glassy sanidine. An analysis by Fuchs¶ of a similar black obsidian from Mt. Rotaro is here inserted:

* This is the height given on the Government Topographical Maps; Fuchs gives 301·4, and Fonseca 277·4.

† Fonseca, Geologia dell'Isola d'Ischia, Florence 1870, 25.

‡ vom Rath, Zeitschr. d. d geol. Gesellsch. xviii, 628, 1866.

§ Fuchs, Isola d'Ischia. Florence 1873, 47; also, Tsch. Min. Mitth., 1872, 237.

‖ The numbers are those of specimens in my collection.

¶ Fuchs, op. cit., 40.

SiO_2	60·77
Al_2O_3	19·83
Fe_2O_3	4·14
FeO	2·43
MnO	Trace.
CaO	1·63
MgO	0·34
Na_2O	4·90
K_2O	6·27
P_2O_5	0·002
Ignit.	0·24
	100·55

Under the microscope the largely predominating, clear glass basis shows a rather light coffee color. The phenocrysts of sanidine are clear and not generally twinned. Inclusions are uncommon and consist of glass, magnetite and an occasional biotite, zircon or apatite. They are quite constantly surrounded by a narrow zone of deep brown glass, in which lie small prismatic microlites of orthoclase, generally at right angles to the domal and basal planes of the crystal. Besides these large feldspars are seen a few smaller phenocrysts of magnetite, green augite and biotite.

Scattered through the basis, often sporadically, but generally in clusters or irregular streaks, are small prismatic orthoclase crystals, which seldom exceed $0·05^{mm}$ in length, and are generally only $0·02^{mm}$ long. These are usually simple, twinning not having been seen, and only rare cases of forked forms or those brushy at the end.

They also are surrounded by a border of darker substance, or lie in large irregular patches or long streaks of this, where they occur together. This substance has no appreciable action on polarized light and shows but few signs of definite structure, though a tendency toward the formation of small spheroidal masses is noticeable under high powers, and is rendered more evident by the presence of a little globulitic dust.

When we examine the next less glassy specimen (No. 553) we find that, while the phenocrysts remain similar in general characters, the narrow dark border has disappeared and the feldspar needles have increased in number, giving rise to a fringe of fine orthoclase needles, separated from each other by extremely minute trichites and globulites. This fine narrow fringe is especially prominent on the ends of crystal sections, cut perpendicular to the plane of symmetry, the sides, as a rule, showing no such borders, but ending cleanly against the groundmass. In one case a rather small and narrow sanidine crystal has been cracked across and slightly bent, and from the broken edges have grown minute needles, prolonging the edges and crossing each other (fig. 1, *a*).

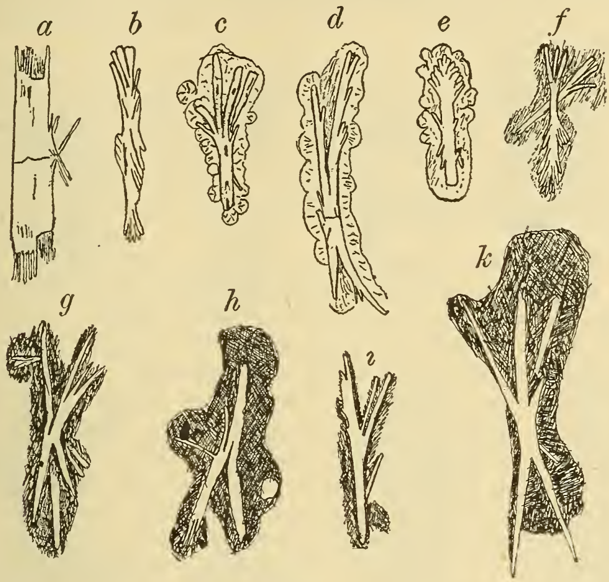


Fig. 1.

The groundmass crystals (almost solely of orthoclase), which show a decided flow-structure, have increased greatly, not only in number but in size (attaining lengths of 0·3^{mm}) and in complexity. They are seen on examination to be elongated parallel to the $\breve{a}$ axis. No twinned forms were seen, but almost all the small prisms show more or less forked forms, some of which are shown in fig. 1, *b—k*. The forms are irregular, and are rather tree or twig-like, than sheaf-like, in habit, as they do not show much tendency toward equal development of the two ends. A number of stubby brush forms are to be observed among the smallest of them (fig. 1, *e*, *f*,); and among these especially are noticed forms which are more highly developed and which resemble closely those to be described presently.

The basis proper is a clear glass, of a pale *café au lait* color, showing here and there an air vesicle. Surrounding the small forked crystals is a darker brown, slightly granular substance, which exerts some action on polarized light, as is evidenced by a very feeble aggregate double refraction. This substance also occurs in isolated spots and irregular anastomosing streaks not inclosing crystals. A fine globulitic dust occurs in it to some extent and there is a marked tendency toward spherulitic or axiolitic forms, with a faintly developed radiated structure. This gives rise to rather mammillary or botryoidal borders around the feldspars, of which it has been attempted to give an idea in fig. 1, *c*, *d*, *e*.

The last Mt. Rotaro specimen to be described (No. 523) is properly a trachyte, not an obsidian, and it may be mentioned here that the majority of the blocks of Mt. Rotaro are of this rock or the black obsidian. It is dark-brownish black in color, of a dull luster and quite compact. There are very many white glassy sanidine phenocrysts, varying in diameter from 5 to 10^{mm}.

Under the microscope the phenocrysts are seen to be the same as in the preceding types, though augite, biotite and magnetite are rather more rare. The sanidine phenocrysts show a much greater development of the fringed borders than in the last case, and the fringe not infrequently reaches a depth of $0{\cdot}5^{mm}$, being usually the deeper the smaller the crystal. In some a horn is seen on each side, being a narrow continuation of the feldspar substance, with the fringe of bright needles and interstitial trichites and dust between them. These horns are sometimes slightly bent, diverging outward, and give the crystal the appearance of a shark's egg-sac ("sea-purse"). The sides also show occasionally a narrow border of fine needles and trichites, the needles lying parallel or nearly so to the crystal edge.

The groundmass consists of a colorless glass basis quite thickly sprinkled with small black grains and globulites. Its most striking feature is the great abundance of small sheaves of orthoclase needles, a development of the forms just described. These sheaves show a well marked flow-structure, in a given area, the long axes lying approximately parallel.

In length they vary from 0·2 to $0{\cdot}5^{mm}$, comparatively few being either longer or shorter, and their width at the widest part is about half their length. While varying considerably in details, yet the general structure is much the same. Some typical forms are shown in fig. 2, *a–h*, though the great delicacy and complexity in most cases is only roughly given.

These sheaves are composed in general of a single, straight, untwinned crystal; which at its center is narrow, but which at the ends is split up, the split portions diverging but preserving their continuity with the main body. The fission and divergence have gone on, as a rule, approximately equally at both ends, and in all directions around the axis, producing quite symmetrical forms. Besides the diverging needles which are obviously connected with the waist or main crystal, are others which seem to be detached. Closer examination shows that most of these (if not all) are in reality of one substance with the main group, the connection being either masked by trichitic matter, or having been destroyed by the position of the plane of the section.

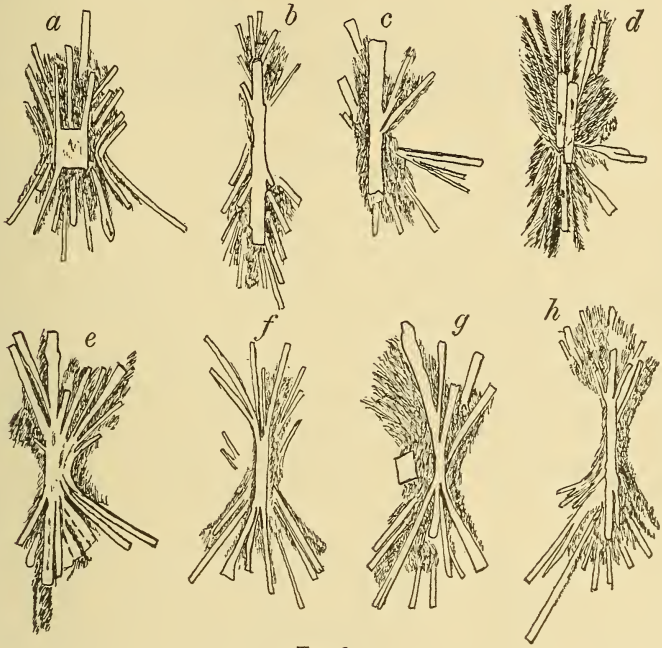


Fig. 2.

All these needles diverge at generally not large angles (up to about 30°) from the nucleus or from each other; though here and there some are seen which form angles up to 90° with the main prism. Though usually straight, or nearly so, many show marked curvature, the concavity being always outward. In some cases needles along the side form curves which are quite hyperbolic in character (fig. 2, *a*, *e*, *f*).

Between the needles lies a colorless, or very faintly brown, isotropic substance, which is very thickly sprinkled with minute globulites and curved black trichites. These bring out the structure very plainly, the colorless needles standing out bright against the dark background.

Examination with the mica plate shows that in both the nuclear prisms and the divergent needles the axis of greatest elasticity $\mathfrak{a}$, lies parallel to the length, and that hence the crystals are elongated in the direction of the *à* axis—the usual habit.

For such divergent crystal forms, which, as will presently be seen, are due to the ramification and growth of a single individual, and which correspond to the *sphærokrystalle* of Lehmann and Rosenbusch, I would propose the name *keraunoid* (Gr. *κεραυνός*, a thunderbolt). This word, which may seem somewhat fanciful, is chosen on account of the narrow waist and divergent, equally developed ends, with symmetry about an axis which give them a striking resemblance to ancient Greek representations of the thunderbolt of Olympian Zeus. It must be understood that the mode of formation is connoted with the term.

Besides these well-defined forms are seen in smaller number oblong spots of about the same size, of a dark gray color and dusty appearance, showing a very fine indistinct structure of parallel or slightly divergent lines. Under high powers these are resolved into bundles of colorless orthoclase needles, less clearly cut than the others, and with such a large proportion of interstitial trichitic basis that their true character is masked. It is probable that these are less well developed forms, as they show a great resemblance to the fringes at the ends of the sanidine phenocrysts. A few small clusters of needles radiating from a point are also seen—evidently sections cut through the ends of keraunoids at large angles with the axis.

The extinction of the needles is parallel or only slightly inclined, so that as the stage is revolved a rather broad dark band swings across the keraunoids, with occasionally, in the thicker ones, a short bar at right angles. In consequence of the approximate parallelism of the keraunoids due to flow-structure, the field under crossed nicols has an appearance simulating that of many spherulitic groundmasses, being sprinkled with short, thick, black bands lying parallel to one another, with here and there a thick elongated cross.

An examination of all the other Ischian slides in my possession (about seventy-five) revealed the presence of the keraunoids in only two of the blocks of black trachyte from the tufas of the Scanella Cliff, on the southwest coast, where fine sections of interstratified tufa and lava beds are exposed by wave action. One of these shows scarcely any phenocrysts, and the colorless glass basis is rather dusty. The keraunoids here are made up of much finer needles, and with more interstitial trichitic basis than in the Mt. Rotaro specimens, but the structure is quite the same. The other is much more like a normal trachyte in its groundmass, which is almost holocrystalline. True keraunoids are wanting, but many of the groundmass orthoclase crystals show divergent forms; and this may be held to be a type representative of the holocrystalline development of the glassy trachytes described above. Some small forked orthoclase crystals were also seen in the groundmass of a black glassy obsidian from the tufa of Monte di Procida, near Cuma; and Rosenbusch* speaks of similar forms in obsidian from Ponza, though I could find none in my specimens.

In regard to the origin of these peculiar forms, it will have been evident that they are most certainly not due to twinning, and also that they cannot be referred to skeleton forms consequent upon growth along certain crystallographic axes or interaxes. They must be either an aggregation of individuals about a common central point or axis, or else due to the continuous splitting up and growth of what would be under other circumstances a compact individual.

Many cases of such ramified crystals are described and figured by Lehmann† and all the evidence points to the Ischian keraunoids being of this character, and not of the nature of aggregate growths of separate individuals. This is clearly seen on examination of the series; passing from the most glassy obsidians with small and seldom forked crystals, through the brown glassy trachyte, with individuals which are evidently split and whose diverging needles can clearly be seen to be continuous in substance with the central crystal, to the trachytes with colorless basis, where the forms have grown quite complex but in which the continuity can be made out by careful study.

According to Lehmann, the cause of this ramification is "the existence of internal tensions which cause the crystals to split here and there at the surface, producing a discontinuity which cannot be overcome by further growth. . . . . . . The broken parts grow independently and so form ramifications from the crystal which are no longer oriented exactly parallel to the main mass." These secondary needles may also split and ramify and thus complex forms result.

That the existence of such internal tension is a sufficient proximate cause is not to be denied, and the facts as shown by Lehmann and elsewhere apparently prove that it is the true one also. It is, however, more difficult to give the cause of the existence of such tensions; or to determine whether they are inherent in the crystal during growth under certain conditions, or whether they are due to the physical action of the magma on the crystal substance.

That the conditions were extremely local in their character is to be inferred from the few instances of ramification found among the Ischian trachytes, as well as in the Hawaiian basalts to be mentioned presently. It is scarcely possible that the

* Rosenbusch. Mikr. Phys. II, 565, 1887.

† Lehmann, Molecularphysik, Leipzig, 1888, I, 378 ff.

formation of skeleton crystals is the primary cause, as Lehmann suggests (p. 390); at least in the trachytes in question no traces of skeletal growth are to be seen, and such growth is well known to be rare in the feldspars.

That fission and ramification took place after the mass had come to rest, is to be inferred from Lehmann's conclusion (p. 380) that a certain degree of viscosity and acceleration of the crystallization is necessary to the process. It is also indicated by the extreme delicacy of the forms themselves, which would hardly be able to withstand the action of a moving magma.

The existence of the easy cleavages parallel to the base and clinopinacoid probably assisted the fission materially; and, as the prisms are elongated parallel to the axis $\grave{a}$, may explain the symmetrical arrangement about an axis and not on each side of a plane.

The fringes at the ends of the sanidine phenocrysts seem to be due to the fission of feldspar substance which crystallized out of the surrounding zone and was oriented like its crystal nucleus, rather than to the fission of the phenocrysts themselves, which latter idea the sharp straight edges of the crystals decidedly disprove. The horns so often seen on either side may be due to skeletal growth, and their divergence is explained by the expansion due to fission of the enclosed feldspathic matter.

The forms just described are closely analogous to the "feather forms" assumed by augite in certain Hawaiian basalts described by E. S. Dana,* to whose kindness I am indebted for an examination of the original slides.

These augitic groups are much larger than the Ischian orthoclase keraunoids, are generally coarser, and differ as well in being much more curved and complex. Though the nuclear crystal is not, as a rule, as prominent or as constantly present in the Hawaiian forms, there cannot be much doubt but that they are due to the same cause as the Ischian—an internal tension splitting the crystal and subsequent growth enlarging it on these lines. A tendency among the augite keraunoids towards greater development at one end could be observed in many cases, which might be connected with the hemihedrism of pyroxene.†

It was also interesting to observe among these basalts, especially the finer grained ones, a tendency of the feldspars to fork and form rudimentary keraunoids somewhat resembling, though much coarser than, those seen in No. 553 of Ischia. The presence of feldspar microlites with "curved processes" apparently due to fission, and surrounded by a dark spherulitic zone, in a Hawaiian basalt glass,‡ is of great interest in this

* E. S. Dana, this Journal, xxxvii, 443, 1889.

† G. H. Williams, this Journal, xxviii, 115, 1889.

‡ Dana, op. cit., 451, fig. 5.

connection, as being very closely analogous to the Ischian forms and an evidence of the existence of internal tension in the crystals of these rocks.

Rosenbusch* mentions several cases of similar forms, and they have been described by Iddings† in a rhyolite of the Eureka District in Nevada. Analogous forms have also been noted by Herz‡ in a diabase from Guagua Pichincha, by Vogt§ in a slag, and also by H. Vogelsang.‖

It is of especial interest, however, to compare with the Ischian forms the branching feldspars observed by Iddings¶ in the Obsidian Cliff in the Yellowstone Park, and by Cross** in rhyolites of Custer Co., Colorado. The branching feldspars in these cases are orthoclase and are found as constituents of certain spherulites. Some of them are not due to fission, but are branched crystallographically and the prisms are elongated parallel to either the $\dot{c}$ or $\breve{a}$ axis in different parts of the group. Others seem from the descriptions and figures to be quite identical in nature with those of Ischia, the prisms and needles being also elongated parallel to $\breve{a}$.

The conclusions to which these two observers come regarding the structure and origin of spherulites in general are especially noteworthy. Iddings points out that we must "base the general definition of spherulitic structure on some other character than outward form," and that this fundamental characteristic is "their mode of crystallization"; spherulitic growth consisting in "the formation of radiating or diverging groups of crystals," whatever may be their outward shape, or whether the divergence takes place from one or more points or a plane.

While this definition may perhaps be thought to be in some ways too broad, (since strictly according to it we could call the radiating groups of tourmalines in granites spherulitic), yet that it applies to the larger number of true spherulites, if not all, can hardly be denied. According to this definition the Ischian (as well as the Hawaiian) keraunoids are true spherulites, though they are not groups of radiating, separate, ramified crystals, but one individual.

They are in fact, as has been said, the "*sphærokrystalle*" of Lehmann†† and Rosenbusch.‡‡ This term is not appropriate,

* Rosenbusch, Mikr. Phys., i, 36, 628; Taf. iii, fig. i; ii, 494, 548.

† Hague, Geol. of Eureka District, Mon. xx, U. S. G. S., 1892, 378, Pl. III, fig. 14.

‡ Reiss and Stubel, Reisen in S. Amer. Hochgeb. Rep. Ecuador, I, Berlin, 1892. 88.

§ Vogt. Mineralbild. in Schmelzmassen, Kristiania. 1892, 179, Pl. II, 15.

‖ Die Krystalliten, Bonn, 1875, Taf. xiv, figs. 4 and 6.

¶ Iddings, Bull. Phil. Soc., Washington, xi, 1891, 445, cf. Obsidian Cliff 7, Rep, U. S. G. S, 276 ff. 1888.

** Cross, Bull. Phil. Soc. Washington, xi, 1891, 411.

†† Lehmann, op. cit., i, 379.

‡‡ Rosenbusch, op. cit. i, 36.

as Cohen* and Cross† have pointed out; since a true, or even approximately, spherical shape is an extreme form, and one very rarely attained by the process. For this reason I suggested the use of the term *keraunoid*, which better fits the majority of the forms, and since the need of some term for this type of radiate growth seems to exist. Cross (loc. cit.) denies to such forms the right to be called spherulites, but if Iddings' definition be accepted they properly come under this head; as it is the radiate manner of growth, and not the number of individuals or the outer form which is the determining classificatory characteristic.

One can infer from the observations of these two writers, as well as from those of others and from general considerations, that true spherulites in this sense may be produced by three distinct processes. These are: by the divergence of many separate, simple, prismatic crystals from a common point or points—the most common type, especially in the smaller spherulites; by the crystallographic branching of radiating prisms, as seen in Iddings's "porous" and Cross's "hollow" spherulites; or by ramification, which may take place in only one crystal, as in the examples of Cross and Iddings. We might distinguish the two forms of this third type by the use of Tschermak's‡ terms monosomatic and polysomatic applied to meteoric chondrules. The same terms may be used for the "branched" spherulites; while those formed by the first named process are, in the nature of the case, always polysomatic. Any two, or all three, of these processes may combine, simultaneously or successively, to form complex spherulites.

In regard to the mode of growth of spherulites, Cross comes to the conclusion that, antecedent to the crystallization of the feldspar, there was a development of colloidal substance within the area of the spherulite; and that the fission of the crystals is due to the tension assumed to exist in this solidifying colloidal mass. That such a tension external to the crystal would induce strains within it, or at least aid the process of fission, seems highly probable. But apart from this an internal tension must exist in the crystal, as shown by Lehmann, and as several facts noted above (such as the curvature of the needles) go to prove.

In connection with this idea of the formation of a colloidal substance the presence of a zone of dark brown, feebly polarizing substance around individual crystals, and in patches containing many forked crystals, in the Ischian trachytes, (and in

* Cohen, Götting. gel. Anzeigen, 1886, 915.

† Cross, op. cit., 432.

‡ Cf. Cohen, Meteoritenkunde, Stuttgart, 1894, i, 260.

the Hawaiian basalt glass), is especially noteworthy.* This brown substance seems to be identical with the "supplemental spherulitic growth" of Cross (p. 424), and may be supposed to represent this colloidal substance, which in the more quickly cooled obsidian has not had time to crystalize, while in the trachyte proper (No. 523) it has entirely disappeared.

In the Colorado rhyolites Cross supposes this substance to be composed of hydrous silica and feldspar, in accordance with the chemical composition of the rock and the intimate association of quartz or tridymite with the orthoclase in the spherulites. This supposition cannot be made in the case of the Ischian trachytes, where the silica does not reach 61 per cent, and the H_2O content is less than one per cent. Here we must suppose it to have been almost entirely of feldspathic matter, with some iron which went to form the trichites.

It may be of interest to note that the ramified orthoclase crystals described in the preceding pages, as well as the Hawaiian augites, show a certain similarity to the diverging pyroxene needles forming chondrules in certain meteoric stones, as those of Montrejeau (1858), Tadjera (1867), and Tieschitz (1878), as described and shown in photographs by Meunier.† The resemblance is even greater with the artificial crystals of enstatite obtained by the same scientist and figured on page 339 of the work cited.

As I have not been able to examine sections of these falls it will not do to push the analogy far, and I can at present only call attention to their apparent resemblance, and suggest that chondrules be examined from the point of view of spherulitic growth.

* A similar brown zone may be seen about many of the spherulites in the rhyolite of the Alter Schloss, near Schemnitz, in Hungary.

† S. Meunier, Les Meteorites, Paris, 1884, 240, 242, 523.

ART. XLV.—*On numerical Relations existing between the Atomic Weights of the Elements;* by M. CAREY LEA.

IN the first part of a paper on the ions it was shown that the elements were divisible into three great classes: those whose ions were always colorless, those whose ions were always colored, and a smaller class whose ions were colored at some valencies and colorless at others.*

It was also shown that the first class, those whose ions were always colorless, could be arranged in vertical lines so that the horizontal lines contained each a natural group. Also that the elements having both colored and colorless ions were much more closely allied to these than to the group having always colored ions. This last named class does not divide into groups at all, but forms series with the atomic weights immediately following one another.

Therefore as long as an element has any colorless ions it really seems to belong to the class with the ions all colorless. So much so that when the first class is tabulated the members of this transitional class find vacant spaces into which they naturally fall. To make this clear and to elucidate what follows, I here reproduce Table II from the first part in a condensed form. (Transitionals in italics.)

I.	H 1	F 19	Cl 35·5	Br 80	J 127	----
	Li 7	Na 23	K 39·	Rb 85	Cs 132	----
II.	----	----	Ca 40	Sr 88	Ba 137	----
III.	----	----	Sc 44	Y 90	La 139	----
IV.	----	----	*Ti 48*	----	----	----
V.	----	----	*V 51*	*Nb 94*	*Ta 183*	----
VI.	----	----	----	*Mo 96*	*W 184*	----
I.	----	----	*Cu 63*	*Ag 108*	*Au 196*	----
II.	Be 9	Mg 24	Zn 65	Cd 112	Hg 200	----
III.	B 11	Al 27	Ga 69	In 114	*Tl 204*	----
IV.	C 12	Si 28	Ge 72	Sn 118	Pb 206	Th 234
V.	N 14	P 31	As 75	Sb 120	*Bi 208*	----
VI.	O 16	S 32	Se 79	Te 125	----	----

In the case of some few elements it has not been easy to find published data sufficient to determine with absolute certainty the color of the ions. Further study of this subject has led me to make a slight change in reprinting the above table. I had previously classed the metal cerium as transitional. The ceric ion is undoubtedly colored, but as to the cerous ion there is some uncertainty. Its compounds are nearly colorless, but as they exhibit a slight red tinge the ions may perhaps be colored. It, therefore, seems better in this uncertainty to place cerium

* This Journal, May, 1895; the second part will appear next month.

alongside of the other members of its group. It is, therefore, omitted from the above table. Also in the paper just referred to gold was placed amongst the elements having colored ions only. The auric ion is certainly colored, but about the aurous ion there is some doubt; the oxids and the haloids are colored but as they are insoluble they give no positive information. It appears, however, that when aurous chloride is dissolved in sodium chloride it yields a colorless solution from which colorless crystals are obtained. Various other double salts form both colorless solutions and colorless crystals. The following are examples: Ammonium aurammonium sulphite, sodium aurothiosulphate, potassium aurocyanide, etc.*

As it seems characteristic of the soluble salts to be colorless, I conclude that gold must be considered as having both colored and colorless ions. It is, therefore, a transitional element and finds its place in the above table where elements of that class appear in italics. It is, however, interesting to observe that just as these two metals cerium and gold are at the very limiting point between two classes, so there are spaces open for them in each of these classes, a circumstance that can hardly be fortuitous.

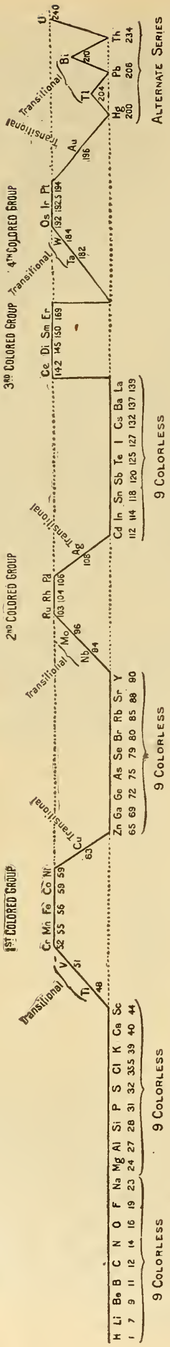
Table of Differences.

If the respective numbers of the first column in the preceding table be each subtracted from the corresponding number of the second column, the second column from the third and so on, we obtain a series of differences which are given in the table below.

18	16·5	44·5	47
16	16	46	47
----	----	48	49
----	----	45	49
----	----	44	88
----	----	----	88
----	----	45	88
15	41·3	46·7	88
16	42	45	90
16	44	46	88
17	44	45	88
16	47	46	----

It has been remarked, I think as far back as the time of Dumas that differences of 16 between the atomic weights frequently presented themselves and occasionally differences of forty-five or thereabouts. But these were scattered cases. In the above table of differences *all* the elements are represented with the exception of the comparatively small group having ions always colored. As has been already said, this

* Roscoe and Schorlemmer, 1st ed., ii, 2, pp. 380–1.



Series of all the Elements in Numerical Order.

last group of elements having nothing in common with other elements cannot be classed with them and will probably be found, when we know much more than we do now, to have a wholly different constitution.

There are several things worthy of remark in the above table. It will be seen that the differences at first approximate to 16. Then comes a long set of differences, twenty in number, beginning with 41·3 and gradually but not regularly increasing to 49. The remaining differences are all exactly 88 with one exception of 90, but as this is the difference between two metals of which comparatively little is known and whose atomic weights cannot be considered as being accurately fixed (indium and thallium), it is quite probable that this exception may hereafter disappear.

It should be remarked that when the set of differences approximating 16 is once left behind, this difference does not reappear in a single case. The same is true of the differences averaging 45: this class of differences does not once reappear when 88 is reached.

For some time past it has been believed that the oxygen group does not end with tellurium but contains still another member with a higher atomic weight. It will be observed that in both the above tables there remains a space for such an element. Its atomic weight should exceed that of tellurium by the difference 88 and should therefore be 213. Finally it may be said that the blanks in the table of differences are due to corresponding blanks in the table of atomic weights.

The change just mentioned in the classification of cerium and of gold makes a slight change in the table representing the whole range of elements in series. I therefore reproduce this table as corrected.

It will be observed that all the elements having only colorless ions appear on the base line. The elements having ions always colored appear on the upper line parallel to the base line. The transition elements appear on the inclined lines.

ART. XLVI.—*Crocoite from Tasmania*; by CHARLES PALACHE.

THROUGH the kindness of Mr. Stephen A. Douglas of San Francisco, the writer came into possession some time since of specimens of crocoite from Tasmania representing, so far as his information extends, a new or undescribed locality for this mineral. Of the two specimens available for study one is now in the mineral cabinet of the University of California, the second in the writer's possession. They consist of masses of crocoite crystals clustered upon bases of lamellar limonite, each mass measuring several inches in diameter. The mineral occurs in a silver-bearing lead deposit known as the Adelaide mine on Mt. Dundas, west coast of Tasmania; but of the nearer geological relations unfortunately no information is at hand. It is said to occur in considerable abundance, a statement borne out by the appearance of these specimens and the many others in Mr. Douglas's possession. Besides the limonite there is no trace of gangue or wall rock nor are there any other lead minerals such as might be expected to accompany the crocoite.

The crystals are of a light hyacinth red color, quite translucent and with adamantine luster. They vary in size from minutest needles to prisms of 2^{cm} length and 3^{mm} diameter. The habit is prismatic and the crystals are never doubly terminated, being attached at one end to the limonite. The larger crystals are often cavernous, giving rise to hollow prismatic forms. As is usually the case with crocoite, the crystal planes are even and brilliant, giving good reflections on the goniometer. The faces of the prism zone are, however, strongly striated parallel to the prism edges and this renders the identification of some forms doubtful.

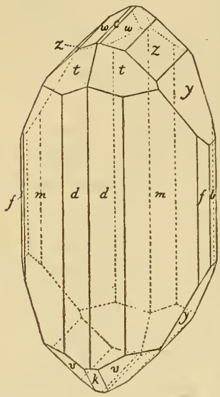
Four crystals were subjected to measurement and showed the following forms, most of which were present on each crystal. The letters used are those of Dana.

m	(110)	I	*k*	$(\bar{1}01)$	$1\text{-}\bar{i}$
f	(120)	$i\text{-}\grave{2}$	*z*	(011)	$1\text{-}\grave{i}$
d	(210)	$i\text{-}\bar{2}$	*w*	(012)	$\frac{1}{2}\text{-}\grave{i}$
*S	(10·3·0)	$i\text{-}\overline{\tfrac{10}{3}}$	*y*	(021)	$2\text{-}\grave{i}$
*T	(530)	$i\text{-}\overline{\tfrac{5}{3}}$	*t*	(111)	-1
b	(010)	$i\text{-}\grave{i}$	*v*	$(\bar{1}11)$	1
c	(001)	*o*			

The following table shows some of the measurements and the angles calculated from Dauber's elements.

		Calculated.	Average measurement.	Number of times measured.	Limits.
$m \wedge m^3$	$110 \wedge 1\bar{1}0$	86° 19′	86° 14′	14	85° 59′–86° 31′
$z \wedge z'$	$011 \wedge 0\bar{1}1$	83 37	83 38	1	
$w \wedge w'$	$012 \wedge 0\bar{1}2$	48 11	48 12	1	
$y \wedge y'$	$021 \wedge 0\bar{2}1$	121 35	121 40	1	
$k \wedge v$	$\bar{1}01 \wedge \bar{1}11$	36 9	35 41	1	
$T \wedge b$	$5·3·0 \wedge 010$	60 38	59 55	1	
$S \wedge b$	$10·3·0 \wedge 010$	74 17	74 13	3	73°–75° 15′

The two prisms (10·3·0) and (5·3·0) were represented by exceedingly indistinct faces, reflections from which were only dimly visible with the δ ocular of the Fuess instrument. On this account they are considered doubtful and are not introduced into the figure. The first form S (10·3·0), is unrecorded; the second, T (5·3·0), is enumerated among doubtful forms by Dauber.



The remaining forms are shown in the figure in about an average development; but their proportions vary widely in various crystals with either t (111), v ($\bar{1}11$) or forms of the clinodome zone predominating. This combination of forms is exceedingly like that shown by Dauber* on a crystal of crocoite from Berezov in the Ural, which is somewhat surprising considering the widely different paragenesis of the mineral in the two localities.

Mineralogical Laboratory, Harvard University, January, 1896.

* Berichte Akad. Wien., xlii, fig. 93, Pl. II, 1860.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Investigations with sulphide of nitrogen.*—In a preliminary notice, Clever and Muthmann have described a few products obtained by the action of several reagents upon this well-known explosive compound. The substances obtained are so remarkable in composition and behavior that it is evident that the authors have opened up an important field of investigation. By determining the elevation in boiling-point of the carbon disulphide solution, the authors have confirmed the recent results of Schenck, who used the depression of the freezing-point in naphthalene solution, in arriving at a molecular weight 184 for sulphide of nitrogen, corresponding to the formula N_4S_4. By the action of an excess of bromine upon a solution of nitrogen sulphide in carbon disulphide, a well crystallized, bronze-colored compound, $N_4S_4Br_4$, was obtained. By exposure to the air, the substance just mentioned loses sulphur bromide by evaporation and is changed into a yellow amorphous compound, probably having the composition $N_4S_6Br_2$. If bromine vapor is allowed to act upon dry nitrogen sulphide, it is greedily absorbed, liquefaction takes place and after some time large garnet-red crystals of a very unstable body with the composition $N_4S_4Br_6$ are formed. By exposure to the air this substance yields the previously-mentioned yellow amorphous body. The most interesting compounds, however, are those which will be now mentioned. By the action of nitrogen dioxide (NO_2) upon a solution of nitrogen sulphide in carbon disulphide, a very deliquescent, white crystalline compound, probably NSO_4, is produced. It reacts with water with the evolution of NO and the formation of sulphuric acid, probably according to the equation,

$$NSO_4 + H_2O = NO + H_2SO_4.$$

Upon acting upon the previously-mentioned substance, $N_4S_4Br_4$, while suspended in carbon disulphide, with nitrogen dioxide, a canary-yellow substance is deposited in microscopic crystals. This is free from bromine and probably has the composition represented either by the formula NSO or $N_6S_6O_4$. This compound decomposes suddenly, giving forth a brilliant light, even when a tube containing it is exposed to the heat of the hand. It dissolves in water, giving a yellow, neutral solution, which, upon warming, deposits a black substance. The latter quickly decomposes into sulphur and a gas of peculiar odor, which has not yet been investigated, but which the authors surmise to be a lower oxide of sulphur. The canary-yellow compound behaves in a different manner with alcohol, giving a dark red solution which gives off sulphur dioxide upon boiling and deposits a crystalline substance which had not yet been analyzed. Another curious

substance, probably $N_4S_3O_6$, was obtained by the action of nitrogen dioxide upon $N_4S_5Br_2$. The authors intend to complete the study of the substances that have been mentioned, and to extend the investigation to the action of chlorine, iodine and the chlorides of phosphorus upon nitrogen sulphide.—*Berichte*, xxix, 340.
H. L. W.

2. *Manganese carbide.*—MOISSAN has prepared, by means of his electric furnace, a well-characterized compound CMn_3. This result confirms that of Troost and Hautefeuille, who obtained the same substance by the use of a wind-furnace. Moissan used 200 parts of manganese protosesquioxide and 50 parts of sugar charcoal and heated the mixture in a carbon tube, closed at one end. The compound is readily attacked by various chemical agents, and the action of water upon it is especially interesting from the fact that equal volumes of marsh-gas and hydrogen are evolved. The following equation represents the reaction:

$$CMn_3 + 6H_2O = 3Mn(OH)_2 + CH_4 + H_2$$

No acetylene or ethylene is produced.—*Compt. Rend.*, cxxii, 421.
H. L. W.

3. *The preparation of pure strontium compounds.*—SÖRENSEN has made a critical study of various methods of obtaining strontium salts free from barium and calcium. The process which he recommends, after an elaborate series of experiments, is briefly as follows: The greater part of the barium is removed by adding concentrated hydrochloric acid to a solution of the chlorides until strontium chloride begins to crystallize out upon cooling. A precipitation by means of sulphuric acid is then made in the hydrochloric acid solution, whereby most of the calcium is left in solution. The sulphates are decomposed by warming with strong ammonium carbonate solution, the washed carbonates are dissolved in nitric acid, the solution is evaporated to dryness, the residue is dissolved in water and filtered, and the barium is completely removed by repeated fractional precipitations with small amounts of dilute sulphuric acid in a solution containing $\frac{1}{10}$ of its volume of 66 per cent nitric acid. This separation is not considered complete until the last precipitate of sulphate is free from barium. The nitrate solution is evaporated to a semi-solid condition, the mass is extracted with alcohol and the residue is washed with the same liquid. This residue is dissolved in water and the operation is repeated until the calcium has been completely removed. The author obtained a yield of 76–77 per cent by this method.

The author calls attention to a rule which has an important bearing upon the separation of barium, strontium and calcium compounds from each other. He considers the rule to be quite self-evident, but he believes that it has not always been taken into consideration in the preparation of chemical products. It is expressed by the statement that "Corresponding, isomorphous salts of closely-related elements are more difficult to separate than corresponding salts which are not isomorphous." As examples, the author notices that he was unable to completely separate strontium chloride from calcium chloride, although the two salts, separately, have an entirely distinct behavior when concentrated hydrochloric acid is added to their solutions. On the other hand, barium and strontium chlorides, although their behavior with concentrated hydrochloric acid is similar, can be readily separated so as to obtain pure barium chloride, because these salts are not isomorphous. Calcium nitrate, having a crystalline form which is distinct from that of barium and strontium nitrates, can be separated from the latter. The sulphates of calcium, strontium and barium are isomorphous, but although they differ considerably in their solubility, for instance in dilute hydrochloric acid, and in their stability towards the alkali-carbonates, it is nevertheless impossible to separate them when they are precipitated together, and not each by itself.—*Zeitschr. Anorg. Chem.*, xi, 305–378. H. L. W.

4. *A new class of compounds of metallic salts with ammonia.*—WIEDE and HOFMANN have described the salts $C_2S_7Co_2(NH_3)_6$, $CS_3Ni(NH_3)_3$ and $C_2S_7Fe_2(NH_3)_62H_2O$, which are evidently derivatives of thiocarbonic acid, and members of a new class of the interesting metallic-ammonia salts. The simplest method of preparing the compounds is by the action of aqueous ammonia and carbon disulphide upon the metallic hydroxides. The cobalt and iron salts are black while the nickel compound has a ruby red color, and all of them were obtained in a well crystallized condition. It is remarkable that iron forms such a compound.—*Zeitschr. Anorg. Chem.*, xi, 379. H. L. W.

5. *Influence of light on the form of discharge of a Holtz machine.*—ELSTER and GEITEL have shown that the brush and spark discharge of a Holtz machine, between a spherical anode and a disc cathode, can be made to disappear under the influence of ultra violet light. A concave disc of amalgamated sheet zinc constitute the negative poles. When sparks are passing between the sphere and the disc, they can be made to disappear by lighting a piece of magnesium ribbon in the neighborhood of the cathode. When the magnesium light no longer illuminates the cathode the sparks reappear. In this case the illumination restricts apparently the discharge instead of increasing it. Elster and Geitel return to the consideration of this phenomenon, and conclude that the brush discharge and spark of a Holtz machine is supplanted by a glow discharge when the cathode is illuminated, and that this last form of discharge carries over a less quantity of electricity than the brush and spark discharge in the dark.—*Ann. der Physik und Chemie*, No. 3, pp. 401–407, 1896. J. T.

6. *Fluorescence of Vapors.*—E. WIEDEMANN and G. C. SCHMIDT state that sodium and potassium vapor fluoresce brightly, the first green and the last red. The fluorescence spectrum of sodium vapor gives continuous and also channelled bands, together with the sodium line. Sodium and potassium vapor show also

under electrical excitation of fluorescence continuous bands in the green and also the red. Stokes' law apparently applies to the fluorescence of metallic vapor, and the fluorescence of the latter affords a means of explanation of various astrophysical phenomena. —*Ann. der Physik und Chemie*, No. 3, pp. 447–453, 1896. J. T.

7. *Interference of Electric Waves.* — VIKTOR VON LANG employs Quincke's well known double U-tube form of apparatus for showing the interference of sound waves to exhibit also the interference of electrical waves. Righi's apparatus is used to generate short electric waves. These waves are sent into the Quincke tube and by suitably changing the length of the arms of the tube, interference is produced which is detected by a species of *coherer* such as was used by Branly, and developed by Lodge. One arm of the Quincke tube was also partially filled with certain dielectrics and their index of refraction measured. The value of the latter for paraffine was $\mu = 1{\cdot}701$. Righi obtained $\mu = 1{\cdot}43$. For sulphur $\mu = 2{\cdot}333$, while Righi obtained $\mu = 1{\cdot}87$.—*Ann. der Physik und Chemie*, No. 3, pp. 430–442, 1896. J. T.

8. *Röntgen's Discovery.*—Since the last issue of this journal considerable progress has been made in the art of cathode photography. Greater detail has been obtained by what are called focus tubes, which consist in the main of a modification of that form of Crookes tube which was employed to show the convergence of the cathode rays proceeding from a concave metallic mirror, upon a thin sheet of platinum placed at its focus. When this sheet of platinum is inclined at an angle of 45° to the line connecting the cathode and the anode, it apparently serves as a center from which sharp shadows are obtained. It seems probable also that the anode reflects the cathode rays in a similar manner. Tesla, and O. N. Rood bring forward evidence to show that the cathode rays can be reflected. Tesla early stated that it was best to use one terminal of a high-frequency coil. I have found this method of great advantage in diminishing the liability to breakage of the tubes. A wire is led from one terminal of a Thomson or Tesla coil to one terminal of a Crookes tube, the other terminal of which is connected to a large metallic plate. The system should be brought into resonance. The method, however, presents this difficulty. The high electromotive force and the electrical oscillations drive out the occluded air and the tubes require to be re-exhausted. It is desirable, therefore, to have the tubes always connected with a mercury pump, or to exhaust the tubes originally by the aid of a high-frequency coil. Tubes which have been electrically excited by the ordinary Ruhmkorf coil while being exhausted soon depreciate under the action of the high-frequency coil. J. T.

9. *The Temperature of the Carbons of the Electric Arc.*—WILSON and GRAY in a paper before the Royal Society give the results of measurements of the temperature of the positive pole of the electric arc. The temperature obtained was

3600° abs. or 3300° C.

This agrees very closely with the approximate estimate given by Violle (1893), viz.: 3500° C. The method here employed is that used by the same authors in an earlier investigation on the effective temperature of the sun (Phil. Trans., A., vol. clxxxv, 361, 1894). This consisted essentially in balancing the radiation from a platinum strip against that of the carbon of the arc. Further, taking 3300° as the temperature of the crater of the positive carbon, that of the *negative* carbon is found to be about 2400°. No estimate is attempted of the temperature of the arc itself.—*Proc. Roy. Soc.*, lviii, 24.

10. *Melting points of some of the metals.*—S. W. HOLMAN, R. R. LAWRENCE and L. BARR have recently given the following determinations of the melting points of several of the metals, which they believe to be more reliable than previous data. The values are based upon 1072° C. as the melting point of gold, as given by Holborn and Wien. They are as follows:

Aluminum	660°
Silver	970°
Gold	[1072°] assumed
Copper	1095°
Platinum	1760°

All of the samples experimented upon were of a high degree of fineness except the platinum, which may have contained 0·5 p. c. of impurity. The paper, from which the above data are quoted, gives in full the method of experiment followed. Other papers by S. W. Holman, also recently published in the *Proceedings of the American Academy*, have the subjects: Calorimetry, methods of cooling correction; also Pyrometry, calibration of the Le Chatelier thermo-electric pyrometer.

II. GEOLOGY AND NATURAL HISTORY.

1. *Economic Geology of the Mercur Mining District, Utah;* by J. EDWARD SPURR, with introduction by S. F. Emmons. Six teenth Annual Report of the United States Geological Survey, Part II, pp. 343–454. (Author's abstract.)—The Oquirrh mountains are one of the parallel ranges of the Great Basin, and the first lying west of the Wasatch range and the Great Salt lake. Close to the southern end of this range the Mercur mining district is situated, in a well-marked topographical basin which has been called the Mercur basin. The rocks exposed in the Mercur basin consist of about 12,000 feet of strata, chiefly massive limestones with intercalated calcareous sandstones and occasional shale beds; fossils from various points in this series show it to be all of Carboniferous age. In the lower part there are intruded sheets of quartz porphyry of two distinct varieties. With one of these varieties, which has a distinct granophyric structure, all of the ore deposits of the district are associated. In the productive region this porphyry is reduced to three sheets, averaging

ten or fifteen feet in thickness, and within one hundred feet of each other. The lowest sheet is characterized by the presence of silver ores, to the exclusion of gold; the middle sheet by gold ores, with no silver; while the uppermost sheet, which is especially thin and intermittent, is not mineralized to any extent. The gold and silver horizon are known as the Gold and Silver Ledges respectively.

The Silver Ledge is marked by complete silification of the limestone, and by barite in irregular masses, with some stibnite and a little copper and silver. It is probable that the metals were originally deposited as sulphides, and that they were introduced into their present position, together with quartz and barite, by ascending waters; and the phenomena accord best with the idea that the mineralization was accomplished by waters excluded from the porphyry during its consolidation, and that thus the ore-deposit is a special case of contact-metamorphism.

The Gold Ledge, which is situated about one hundred feet vertically above the Silver Ledge, is characterized by a softened condition of the ores, whether in the normal condition of sulphide, or in the zone which has been bleached and altered by surface oxidation. Its most characteristic feature is realgar, which occurs in large amounts in the unoxidized ores, with frequent cinnabar and gold in small, but in certain zones nearly uniform, quantities. The gold is in extremely finely divided condition; but it is probable that it exists in the unaltered form as telluride, and that on oxidation it has become free gold. Evidence shows that the mineralization of the gold-horizon took place at a distinctly later date than that of the silver-horizon; and that the mineralizing agents were probably in a vaporous rather than in a liquid form.

2. *Catalogue of the Fossil Fishes in the British Museum, Part III, containing the Actinopterygian Teleostomi of the orders Chondrostëi (concluded), Protospondyli, Aetheospondyli, and Isospondyli (in part)*; by A. S. Woodward; pp. 1–544, pls. l–xviii. London, 1895.—Mr. Woodward's introduction, of about twenty pages, is full of important conclusions, derived from his exhaustive study of the Actinopterygian fishes, regarding the phylogenetic relations of the several families. In the arrangement of the material in the catalogue, the author has attempted to record, in as nearly a natural order as possible, the variation of each type at the time of its dominance. The origin of the Chondrostëi is obscure, but that they are later than the Crossopterygians is evident. When they first became dominant in the lower Carboniferous they exhibited a remarkable sense of modification and thereafter suffered very little essential change. The genus *Acentrophorus* of the upper Permian is the first of the sub-order Protospondyli, and it is observed to be the most generalized member of the family to which it belongs (Semionolidæ) which is also the most generalized family of its series.

The same fact is noted regarding *Ophiopsis*, the most generalized genus of the family Macrosemeidæ, and the earliest to appear.

The Pycnodontidæ, specially on account of the character of the axial skeleton and the mandible, are placed among the Protospondyli.

The author is led to place little value upon the characters of the scales for purposes of classification. The combination of thick, rhombic, firmly-articulated scales of the abdominal region with delicate, cycloidal, deeply-overlapping scales of the caudal pedicle in the interesting genus *Aetheolepis* of New South Wales, and the second case of *Tetragonolepis* having both thick and thin scales, furnish a good reason for departing from the long established usage in this respect.

Attention is also called to the interesting fact that the higher fishes, like the highest of terrestrial vertebrates, are characterized by a comparatively simple mandible. And the author remarks in this connection that, "on acquiring this simplication of the jaw, the Teleostomes seem to be infused with new vigor, vertebral centra invariably occur, at first as simple rings, then as robust amphicœlous bodies; and a still more varied series of families arises, including analogies of all the principal modifications observed among the lower races, these being superinduced upon the new and advanced type of skeletal frame." H. S. W.

3. *Catalogue of the Mesozoic Plants in the Department of Geology of the British Museum. The Wealden Flora. Part II.—Gymnospermæ;* by A. C. Seward; pp. 259, plates xx. London, 1895.—The following quotations from Mr. Seward's conclusion drawn from the study of this material will be of interest to the geologist: "The general characters of the vegetation would certainly seem to point to a tropical climate," p. 239.

"The evidence of palæobotany certainly favors the inclusion of the Wealden rocks in the Jurassic series," p. 240.

Regarding the evolution of angiospermous plants, he says: "The true Wealden vegetation would seem to have been without any examples of the highest class of plants, and may be looked upon as the last of the Mesozoic floras in which gymnosperms represented the limit of plant development. One genus, however, carries us a few steps towards the next stage in botanical evolution; the inflorescence of *Bennettites* marks a distinct advance in the differentation of reproductive structures beyond the characteristic cycadean type," p. 241.

4. *Catalogue of the Perciform Fishes in the British Museum, 2d edition, Vol. 1, containing the Centrarchidæ, Percidæ, and Serranidæ (part);* by George A. Boulenger: pp. 394, pls. xv. London, 1895.—The materials forming the basis for this second edition are the collections received by the museum since the year 1870. At the time of the publication of the first edition 29,275 specimens had been registered. The acquisitions since that time amount to 29,375 specimens. These have been obtained from all parts of the world; among the most important contributions are those brought home by the "Challenger," comprising littoral, pelagic, and bathybial forms from almost every part of the ocean

traversed by the ship. Also fresh-water specimens from out of the way places in Asia, Africa, South and North America and the isles of the seas. The author has given special attention in his revision to the study of the osteological characters, and the chief types of cranial structure are illustrated by figures in the text. Special acknowledgments are made of the assistance derived from the revisions of North American ichthyology by our countrymen Jordan, Gilbert and Eigenmann. For the families studied the report gives a thorough revision of present knowledge.

5. *Descriptive Catalogue of the Spiders of Burma, based upon the Collection made by Eugene W. Oates and preserved in the British Museum;* by T. THORELL; pp. 406. London, 1895.—This is an exhaustive descriptive catalogue, in Latin, of this unique collection containing 310 species, of which 206 are new to Burma and 153 new to science.

6. *The duration of Niagara Falls and the History of the Great Lakes;* by J. W. SPENCER; pp. 1–126, figs. 1–27, pls. i–v. (2d ed.)—This is an excellent series of papers explaining the geological features and history of Niagara Falls and environs and republished in book form under the direction of the Commissioners of the N. Y. State Reservation at Niagara and accompanying their eleventh report. The chapters, nine of them, were originally published by Dr. Spencer in this and other journals; to them are added a few full-page reproductions of photographs of the falls and river.

7. *Illinois State Museum.* Bull. No. 7.—New and interesting species of Paleozoic fossils. pp. 1–89, pls. i–v, Dec. 5, 1895. Bull. No. 8.—Descriptions of new and remarkable fossils from the Paleozoic rocks of the Mississippi valley; pp. 1–65, pls. i–v, Feb. 1896.—In these two bulletins the authors, S. A. MILLER and WM. F. E. GURLEY, have described and figured a large number of specimens of fossils, chiefly crinoids, and from Niagara, Hamilton and various Carboniferous formations, in large majority from the latter.

8. *Oblique Bedding in Limestones.*—A remarkable structural condition is described by Professor Calvin in the Le Claire limestones of Iowa.* This limestone is the second stage of the Niagara formations of that state. The author states: "In the first place it varies locally in thickness, so much so that its upper surface is exceedingly undulating, the curves in some places being very sharp and abrupt. In the second place it differs from every other limestone of Iowa in frequently exhibiting the peculiarity of being obliquely bedded on a large scale, the oblique bedding often affecting a thickness of fifteen or twenty feet. The phenomena suggest that during the deposition of the Le Claire limestone the sea covered only the southwestern part of the Niagara area, that at times the waters were comparatively shallow, and that strong currents, acting sometimes in one direction

* The Le Claire Limestone by Samuel Calvin, Bull. Lab. Nat. Sci. State Univ. Iowa, vol. iii. pp. 183–189, pls. i–ii, Mch. 16, '96.

and sometimes in another, swept the calcareous mud back and forth, piling it up in the eddies in lenticular heaps or building it up in obliquely-bedded masses over areas of considerable extent. The oblique beds observe no regularity with respect to either the angle or direction of dip. Within comparatively short distances they may be found inclining to all points of the compass."

9. *Geological History of the Chautauqua (N. Y.) Grape Belt;* by R. S. Tarr.—Under this title, Bulletin 109, of the Cornell University Agricultural Experiment Station, publishes some topographical and structural facts regarding the land bordering the eastern end of Lake Erie, which will be of interest to students of surface geology.

10. *Geological Literature.*—The assistant librarian of the London Geological Society has prepared a second pamphlet under the above title, containing a list of the geological literature added to the library during the year ending December 31, 1895. It contains a full subject index as well as list of titles of papers arranged alphabetically by authors. Although not exhaustive (157 pages), it is a convenient reference catalogue.

11. *Norges Geologiske Undersögelse.*—The following are recent publications from the Geological Survey of Norway:

No. 10. Tagskifere, heller og vekstene; af Amund Helland.

No. 11. Lagfölgen på Hardangervidda ogden såkaldte "böjfjeldskvarts;" af W. C. Brögger.

No. 12. Norges granitindustri af Carl C. Rüber.

No. 13. Gausdal. Fjeldbygningen inden rektangelkartet Gausdals omraade; af K. O. Björlykke.

No. 14. Aarbog for 1892 og '93; udgivet af Dr. Hans Reusch, undersögelsens bestyrer.

No. 15. Dunderlandsdalens jernmalmfelt (i Ranen, Nordlands amt, lidt söndenfor polarkredsen); af J. H. L. Vogt.

No. 16. Jordbunden i Jarlsberg og Larviks amt; af Amund Helland.

No. 17. Nissedalens jernmalmforekomst (i Thelemarken); af J. H. L. Vogt.

12. *Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtyrol;* von W. C. Brögger. (Vidensk. Skrift. i Math. natur. Klasse, Kristiania, 1895, 8° 183 pp.)—In this publication, which is part two of the series (part I, Grorudit-Tinguait Serie) by Prof. Brögger on the eruptive rocks of south Norway, the author mentions that having undertaken an expedition into Southern Tyrol—a region classic in geological history—for purposes of study and comparison, he has been led to publish his observations and to draw some general conclusions from them.

He first shows that "the typical rocks of Monzoni and Predazzo are not syenites, nor are they diorites (or diabases or gabbros) but *monzonites.* They form a well-characterized and particular group of rocks, which are distinguished by the fact that they occupy an intermediate position between the alkali-orthoclase rocks on the one hand and the plagioclase rocks, rich in lime and poor in alkali, on the other. The monzonites are sharply defined orthoclase-plagioclase rocks." The relations are shown in the following table, where the monzonite group is inserted between the alkali series and the lime series.

Orthoclase rocks.		Orthoclase-plagioclase. Monzonite group.		Plagioclase rocks.	
% SiO_2		% SiO_2		% SiO_2	
67–82	Granite.	67–73	Acid quartz monzonite. (*adamellite*)	66–72	Acid quartz diorite. (Tonalite.)
63–66	Quartz-Syenite. (Nordmarkite, etc.).	63–66	Medium acid quartz monzonite. (*Banatite.*)	63–65	Medium acid quartz diorite.
50–62	Syenite. (Plauenite, Laurvikite, etc.).	49–62	*Monzonite.*	48–62	Diorite.
		46–52	*Olivine-Monzonite*, etc.	44–53	Gabbros, etc.

Peripheral portions of the masses at Predazzo, composed of pyroxenites, are regarded as differentiation products in place, while dikes of camptonite and complementary feldspathic rocks (liebnerite poryhyry) are mentioned.

The order of succession of the various magmas at Monzoni and Predazzo is discussed very fully and in connection with that of the rocks of South Norway. In carrying out the discussion a notable contribution to the origin of granite and the mechanics, etc., of laccolith formation is added with illustrations drawn chiefly from the south Norwegian localities.

The author believes that in endeavoring to discover the law of succession of eruptive magmas it is wrong to confound the abyssal and effusive rocks together, since the two do not of necessity correspond. "The order of succession, basic, less basic, acid, appears in fact with abyssal rocks to occur so commonly that we must regard this succession as the normal one; the sudden recurrence to basic is known in many localities, but appears just as often to be lacking."

A very thorough digest of the literature is given and it can be truly said that in the light of the new petrology the author has cleared up and put in order a vast mass of confused and often contradictory information about this well known locality in the Tyrol. Field geologists as well as petrographers will find the work replete with fruitful and suggestive ideas. L. V. P.

13. *Mica-Peridotites in Bengal.*—In two short papers by Mr. T. H. Holland (Records Geol. Surv. India, vol. xxvii, 1894, Pt. 4, p. 139 seq.), some interesting occurrences of mica-peridotites are given; one of them, which contains over eleven per cent of apatite, appears to us of especial interest in connection with Vogt's work on apatite deposits (Zeitschr. für prakt. Geol., Nov., Dec., 1895). Several varieties of these rocks are described, some of which break up through coal-bearing strata. L. V. P.

14. *Zusammenstellung petrographischer Untersuchungsmethoden nebst Angabe der Literatur*, by E. Cohen. 3d edition, 53 pp. Stuttgart, 1896.—This little pamphlet, which contains a very full bibliography of the literature pertaining to the various methods of petrographic investigation and discrimination of rock-forming minerals, will be found a very useful addition to the working library of every mineralogist and petrographer. L. V. P.

15. *Jadeite from Thibet*, by Max Bauer, Jahrb. für Min., 1896, i, p. 85.—In studying some specimens of jadeite from an unknown locality in Thibet, Prof. Bauer has made the very interesting discovery that the mineral is a component of a rock composed of jadeite, plagioclase and nephelite; at times the jadeite predominates to the extent of practically supplanting the other components. The author remarks that if the jadeite at this locality is, as elsewhere, a member of the family of crystalline schists, then we have here an entirely new method for the occurrence of nephelite, until now restricted to eruptive rocks.

It appears to us, however, that this interesting occurrence of nephelite may prove to be of great importance in explaining the origin of jadeite, whose significance in the crystalline schists has never been understood, and it may also furnish one explanation why, among all the varieties of metamorphosed igneous rocks occurring among the crystalline schists, those containing nephelite have not been found. L. V. P.

16. *A Dictionary of the Names of Minerals including their History and Etymology;* by Albert H. Chester. 320 pp., 8vo. New York, 1896 (Wiley & Sons).—The author gives in this work, to which it is evident that he has devoted a vast amount of careful, patient labor, the most complete history of the names of mineral species that has ever been attempted. How fruitful his efforts have been will be appreciated from the fact that of nearly five thousand names included, full information with reference to the original authority, also derivation and so on, is given in the case of all but about one hundred and fifty. This work will be highly valued by all mineralogists interested in the history of their science, and will be useful to many others, including those concerned with the etymology of English words in general.

17. *Minèralogie de la France et de ses Colonies:* Description physique et chimique des Minéraux, Étude des conditions géologiques de leurs gisements; par A. Lacroix. Tome Premier (2 Partie), 723 pages. Paris, 1895 (Baudry et Cie.).—The first part of Professor Lacroix's important work was noticed nearly three years since (vol. xlvi, p. 76), and its originality in scope and method remarked upon. The part now issued concludes the first volume and carries the subject on from the micas through the pyroxenes and amphiboles. All interested will look forward with interest to the final completion of the entire work.

18. *Mineralogy;* by Frank Rutley. Eighth edition, revised and corrected, 240 pp. London, 1887 (Thomas Murby).—This little book must have been an aid to many in acquiring a knowledge of elementary mineralogy, for since its first appearance it has gone through numerous revisions and the eighth edition is now given to the public. The various subjects embraced under general mineralogy are treated concisely in the first seventy pages and the remainder of the book is given to the description of species.

19. *Determination des Feldspaths dans les plaques minces;* par A. Michel-Lévy. 2d fasc., pp. 71–108, Pls. ix–xxi, (Baudry et Cie.) Paris, 1896.—The first portion of this work which has been noticed in this Journal (vol. xlviii, p. 173, 1894) has already proved of great service to mineralogists and petrographers, and this addition will also be found extremely useful. A new additional method of determination for the plagioclase series is introduced, depending on the equal illumination (*éclairement commun*) of zonal bands. To it is added a résumé of the optical properties of microcline accompanied by a diagram. L. V. P.

20. *Allgemeine Krystallbeschreibung auf Grund einer vereinfachten Methode des Krystallzeichnens* bearbeitet und mit einer Anleitung zur Anfertigung der Krystallnetze und Krystallmonelle herausgegeben von Dr. Aug. Nies. Mit 182 Originalzeichdungen im Texte. 8vo. 176 pp. Stuttgart, 1895. (E. Schweizerbart'sche Verlagsbuchhandlung—E. Koch.)—The aim of the author in this volume is to present the elements of descriptive crystallography in simple form, and as developed by means of a new method of drawing crystalline forms which, as he states, he has used in his instruction with much success for a number of years. This method is based upon the determination of the angular points of the form, projected by means of the methods of analytical geometry, these being plotted upon sheets of paper ruled in squares of 4^{mm} on the side. The simple mathematical relations needed are explained and instructions given for the application of the method described. The symbols of Naumann are employed throughout, only modified to allow of the designation of each individual face. Numerous figures drawn by the author's method show its practical application.

III. Miscellaneous Scientific Intelligence.

1. *On the Diurnal Periodicity of Earthquakes;* by Charles Davison, M.A., F.G.S. (Abstract received from the author.)—Reference is made to the previous work of De Montessus and Ōmori, the former endeavoring to show that the diurnal periodicity of earthquakes is apparent rather than real, and the latter pointing out that a marked diurnal periodicity characterizes the after-shocks of great earthquakes in Japan. The results of twenty-six registers obtained by means of continuously recording instruments in Japan, the Philippine Islands, and Italy are subjected to harmonic analysis with the following conclusions:—

(1) The reality of the diurnal variation of earthquake-frequency seems to be proved by the approximate agreement in epoch (mean local time) of the first four components (24, 12, 8, and 6 hours) for the whole year at Tokio and Manila, and for the winter and summer halves of the year at Tokio.

(2) In ordinary earthquakes, there is in nearly every case a marked diurnal period, the maximum generally occurring between 10 A. M. and noon. The semi-diurnal period, though less promi-

nent, is also clearly marked, the maximum occurring as a rule between 9 A. M. and noon and between 9 P. M. and midnight. Other minor harmonic components are also occasionally important, the first maximum of the eight-hour component probably occurring about 6.30 A. M., and that of the six-hour component about 3 or 4 A. M.; but for these two epochs the results are not always concordant.

(3) Though the materials are insufficient for any general conclusion, the weaker shocks seem to be subject to a more marked diurnal periodicity.

(4) In the case of after-shocks of great earthquakes, the diurnal periodicity is as a rule strongly pronounced. The maximum of the diurnal period occurs within a few hours after midnight, but the epochs of the other components are subject to wide variation, possibly on account of the short intervals over which the records extend. A special feature of after-shocks is the prominence of the eight-hour and four-hour components.

The epochs of the first four components representing the diurnal variation of seismic frequency are compared in several cases with those for barometric pressure and wind velocity. While the variation of the former cannot be attributed exclusively to either of the latter phenomena, it seems not improbable that the diurnal periodicity of ordinary earthquakes may be due chiefly to that of wind velocity, and the diurnal periodicity of after-shocks chiefly to that of barometric pressure.—*Proc. Roy. Soc.*, London, vol. lx.

2. *Transactions of the American Microscopical Society;* edited by the Secretary. Eighteenth Annual Meeting held at Cornell University, Ithaca, N. Y., August 21, 22, and 23, 1895. Volume xvii, 376 pp., Buffalo, 1896 (The Wenborne–Sumner Co.).—This volume gives a full account of the Eighteenth Annual Meeting of the American Microscopical Society with the papers then read. Among these may be noted the following, all of which are illustrated by plates: Some modifications of stems and roots for purposes of respiration, by H. Schrenk; The lateral line system of sense organs in some American Amphibia and comparison with Dipnoans, and On the Spermatheca and methods of fertilization in some American newts and salamanders, by Dr. B. F. Kingsbury; Comparative Morphology of the brain of the soft-shelled Turtle and the English Sparrow, by Susanna P. Gage. The next meeting of the Society will be held at Pittsburg, Pa., August 18 and 20, 1896.

3. *Handbook of Arctic Discoveries*, by A. W. GREELY, 257 pp., 12mo. Boston, 1895 (Roberts Brothers, Columbian Knowledge Series, No. 3).—The interest and value of this little volume are quite out of proportion to its size. It deals with a subject which has not only the highest interest from the scientific side, but which perhaps more than any other tends to excite the imagination of the general public. Notwithstanding its brevity it gives a well-digested and very readable account of Arctic explorations from the earliest times. Its interest is increased in no

small degree from the fact that it has been prepared by an author who has himself a thorough acquaintance with the Arctic and whose own exploits in this field will never cease to excite admiration.

4. *James Clerk Maxwell and Modern Physics;* by R. T. GLAZEBROOK, F.R.S., 224 pp. 12mo. New York, 1896 (Macmillan & Co.—The Century Science Series).—Modern physics owes to Maxwell perhaps more than to any other of recent physicists, for his keen insight into the scientific problems in which he was interested gave a rare value and originality to all that he wrote. His Treatise on Electricity and Magnetism has been before the public for many years, but no one would venture to say that this mine has been exhausted. The present volume is written by a physicist well fitted to deal with a subject of more than usual difficulty and no one interested in the recent progress in physics, or in the personality of those to whom this progress is due, can fail to be profited by its perusal.

5. *North American Birds*, by H. NEHRLING, Part XIII, pp. 193–240, Milwaukee, Wis. (Geo. Brumder).—The thirteenth part of this interesting and handsomely illustrated work has appeared recently.

6. *Ostwald's Klassiker der exacten Wissenschaften*, (Wm. Engelmann, Leipzig).—The latest additions to Ostwald's valuable series of classic scientific memoirs are the following:

No. 67. Entwurf einer Theorie der Abel'schen Transcendenten Erster Ordnung von Dr. A. Göpel (1847).

No. 68. Das natürliche System der chemischen Elemente. Abhandlungen von Lothar Meyer (1864–1869) und D. Mendelejeff (1869-1871).

No. 69. Ueber Faraday's Kraftlinien, von James Clerk Maxwell (1855-1856).

No. 70. Magnetische Polarization der Metalle und Erze durch Temperaturdifferenz, von Th. J. Seebeck (1822-1823).

No. 71. Untersuchungen über die Reihe $1+\frac{m}{1}x+\frac{m.(m-1)}{1.2}.x^2+...$ von N. H. Abel (1826).

Nr. 72. Chemische Analyse durch Spectralbeobachtungen, von G. KIRCHHOFF und R. BUNSEN. (1860.) 74 pages.

Nr. 73. Zwei Abhandlungen über Sphärische Trigonometrie, von LEONHARD EULER. (1753 und 1779.) 65 pages.

Nr. 74. Untersuchungen über die Gesetz der Verwandschaft, von CLAUDE LOUIS BERTHOLLET. (1801.) 113 pages.

Nr. 75. Abhandlung über die Herleitung aller Krystallographischer Systeme mit ihren Unterabtheilungen aus einem einzigen Prinzipe, von AXEL GADOLIN. (1867.) 92 pages.

The Origin and History of Contract in Roman Law down to the end of the Republican Period. (Being the Yorke Prize Essay for 1893.) By W. H. BUCKLER. London: 1895. 228 pages (C. J. Clay & Sons).

Elements of Botany; by J. Y. BERGEN. 57 pp. 12mo. Boston and London, 1896 (Ginn & Company).

Las Rocas Eruptivas del Suroeste de la cuenca de Mexico, par EZEQUIEL ORDOÑEZ. (Boletin d. Inst. Geol. d. México, Num. 2), pp. 1–46. Mexico, 1895.

OUR SPRING BULLETIN

Issued during April, will be sent free on application. A glance at it will convince you that our stock is overflowing with fine minerals, indeed probably never before have so many new and really choice specimens been offered for sale in any of the markets of the world. Send for the Bulletin and then for a shipment on approval.

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[FOURTH SERIES.]

Art. XLVII.—*On the Color Relations of Atoms, Ions and Molecules*; by M. Carey Lea. Part II.

I. *Interaction of Ions.*

If a colored substance be formed by the union of a colorless kation with a colorless anion, the color belongs to the molecule only. The colorless ions have so modified each others' vibration periods that selective absorption is exercised. As soon, therefore, as the molecule is divided into ions the color must disappear. Consequently if we find a solvent which, like water, is capable of separating the ions, the resulting solution when dilute must be colorless, no matter how intense the color of the compound.

The truth of this law of interaction has been tested experimentally in a considerable number of cases. The results, which were found to be without exception confirmatory, are given below.

Alkaline metals.—These form comparatively few colored products, soluble in water, by uniting with colorless atoms. Well marked instances are, however, found in the monosulphides.

Potassium sulphide, K_2S, is in the solid form cinnabar-red. It dissolves in water to a colorless solution.* The sodium salt acts similarly. As to the alkaline selenides and tellurides, their tendency to form poly-salts is so great that it is not possible to judge of the color shown by mono-salts in solution. It is of interest, however, that hydrogen selenide and probably also the

* Graham Otto, 5th Ger. ed., vol. iii, p. 240. The reactions here described have been either found or verified by the writer except in a few instances, and in these, as in the present case, the authority on which they are stated is given.

telluride are colorless; also the oxygen acids of both are colorless. There is little doubt, therefore, that selenium and tellurium, like sulphur, have colorless ions.

Mercuric iodide affords an excellent illustration of the principle stated owing to the large variety of solvents for it.

In hot ethylic alcohol it dissolves easily. Solution absolutely colorless, gives a cloud when poured into water which settles to a red powder.

Methylic alcohol acts similarly.

In solution of calcium chloride, especially if hot, dissolves easily. Less easily in barium chloride.

In solution of potassium and sodium chlorides dissolves sparingly. All these solutions are colorless.

In solutions of potassium bromide and of iodide it dissolves abundantly. Strong solutions have a yellowish color but become colorless by moderate dilution. These two salt solutions dissolve mercuric iodide freely in the cold; the other solvents need heat.

In cold solution of mercuric nitrate, it dissolves easily to a colorless solution. In solution of mercuric chloride it is somewhat soluble; the solution is colorless.

In glycerine it dissolves pretty well with the aid of heat and does not communicate a trace of color.

Mercuric arsenite is bluish gray. It is slightly soluble in solution of sodium arsenite. The solution is colorless.

Mercuric arsenate is pale yellow. It dissolves in a solution of mercuric nitrate and also in one of sodium pyrophosphate; both solutions are colorless.

The black heavy metallic sulphides are very difficult substances to bring into solution, but it seems that when this can be done the solution is colorless when the ions are colorless. This can be shown to be the case with mercuric sulphide and with antimony tri-sulphide. According to Weber,* when mercuric chloride is precipitated with an excess of ammonium sulphide the precipitate dissolves in potash to a colorless solution.

Silver oxid is slightly soluble in water. Being very deeply colored, it would seem natural that its solution should show this color. But the solution is absolutely colorless. This is because the silver ion is colorless. Metallic oxids having colored ions carry that color into their solutions, as is seen in the case of cupric oxid in alkaline solutions and in soluble forms of ferric oxid.

Silver arsenite is lemon yellow; it is abundantly soluble in ammonia water and in mercuric nitrate. Both solutions are colorless.

* Cf. Gmelin-Kraut, iv, page 851.

Silver arsenate.—Chocolate color; dissolves in the same solvents as the last and also gives colorless solutions.

Silver phosphate.—Triargentic phosphate dissolves with facility in nitric acid, in ammonia water and in mercuric nitrate. All three solutions are colorless.

*Cuprous sulphite.**—Red; dissolves in ammonia water and in dilute hydrochloric acid, giving colorless solutions.

Stannic sulphide precipitated.—Ochre yellow, dissolves in warm potash or soda solution; the resulting solution is nearly colorless.

It also dissolves in potassium sulpharsenite to a colorless solution.

Red antimony pentasulphide dissolves in alkaline monosulphides; solutions colorless.

Orpiment (As_2S_3) dissolves easily in warm potash or soda solutions; colorless.

II. *Combinations of Ions.*

Ions may combine. A. Two or more similar colorless ions may unite to form a colored elementary molecule.

The ions of iodine and bromine are colorless as shown in solutions of HBr and KBr, HI and KI. The molecules are strongly colored. The ions of lead are colorless, as shown in solutions of lead nitrate or acetate. The molecule (or the polymer) of lead is blue. The ion of sulphur is colorless—water is not colored when saturated with sulphydric acid. The oxygen acids of sulphur are colorless. But the molecule is yellow. Selenium has a colorless ion, but a strongly colored molecule. Colorless cuprous ions unite to form red copper.

B. Two or more similar ions, colored, may unite to form a colorless (or white) molecule or polymer. The ion of platinum is yellow in Pt^{iv}, red in Pt^{ii}; in each case the ions unite to form white platinum. The nickel ion is green; these unite to form white metallic nickel.

C. Two or more similar ions, colored, may unite to form a molecule of a wholly different color. Blue copper ions may unite to form red copper.

D. Two or more dissimilar colorless ions may unite to form a colored molecule. Sulphur and nitrogen unite to form orange-colored nitrogen sulphide. Sulphur and silver to form black silver sulphide.

It is an interesting fact, and one I believe that has not been previously noticed, that no ion and, therefore, no atom, is black, but is always transparent to some portion or portions of the visible rays. In this respect atoms and ions differ absolutely

* Gmelin Handbook, Ger. ed., iv, p. 622.

from molecules. For these last are often black, and this may be the case even with elements, as for example, iodine in the solid form, platinum black, etc. The absolute difference between atoms and molecules, the entire absence of color relation between them, was mentioned in the first part of this paper; it must always be one of the most remarkable facts in chemistry.

The production of a black molecule in no way depends upon the combination of two or more atoms having different relations to light, such that one should extinguish the rays which the other or others allow to pass. This might almost be expected, but is far from being the case. Two colorless atoms may unite to form a black molecule, as in the cases just mentioned.

It seems scarcely necessary to say that these remarks relate to inorganic molecules only. For in organic molecules, chemical composition has little influence, isomeric combinations exhibit the greatest differences, and their spectra show little relation to those of their elements.*

With organic compounds, which are formed almost exclusively of colorless atoms, it is always the color of the molecule that is important. With inorganic compounds the reverse is the case, we have much less to learn from the color of the molecule; that of the atom is all important. One and the same molecule may present various colors, absolutely unlike each other. Phosphorus and sulphur may be black, red or yellow. Gold is yellow by reflected, blue or green by transmitted light, and may be red when in a state of fine division. Who shall say in either case which of these colors is characteristic? With the ion, and therefore with the atom, at any given valency, there is no such ambiguity. Its color, its absorption spectrum, are invariable; these are always highly characteristic.

III. *Acid Indicators; Theory of their Reactions.*

Acid indicators are such as show a striking change by the addition of an alkaline solution, either from one color to another, or from a colorless to a strongly colored solution. They may be considered as of the nature of weak acids. Their reactions have been explained† in this way, that the radical has as an ion a color different from that which it has in the undissociated compound.

This explanation is unsatisfactory, for two reasons:

1st. It makes the color of an acid indicator in presence of an alkali depend on dissociation. But it can be shown that

* Ostwald, Lehrbuch, 2d Ger. ed., i, 472.
† Ibid., 800.

such a colored solution may be evaporated to dryness and thoroughly desiccated at 100° without losing anything of the intensity of its color. That is, the color persists under conditions in which dissociation is impossible.

2d. It makes the color or absence of color, as the case may be, of the solution of the acid indicator when isolated depend upon the absence of dissociation. But it is a familiar fact that by sufficient dilution even the weakest acids are largely or even completely dissociated.*

Let us take litmus for example. This is a weak acid red dyestuff which in contact with an alkali becomes blue. According to the explanation here criticized, isolated red litmus has a blue ion which does not appear in solution because not dissociated. But it is certain that with sufficient dilution it must be dissociated, and according to this explanation it should then turn blue. Whereas red litmus remains red with any amount of dilution so long as any trace of color is left.

Again it is said that blue litmus owes its blue color to dissociation. But the blue solution may be evaporated and desiccated at 100° without losing its blue color. The color is, therefore, *not due to dissociation.*

With these complex and faintly acid organic substances it seems probable that some change in their constitution takes place in the presence of an alkali, such that the anion that separates from the dilute solution of the isolated substance is not the same as that which separates from the alkaline combination. That is to say, the anion which separates from red litmus is not absolutely the same as that which separates from blue. Only in this way can the various reactions of acid indicators be satisfactorily explained. The reactions of these substances have not been studied with sufficient accuracy to indicate exactly what is the change that takes place in the presence of an alkali. It may be either a re-arrangement of some of the atoms or it may depend on the taking up of one or more molecules of water.

When an alcoholic solution of phenolphthaleine is dropped into much water, the resulting solution cannot be distinguished from pure water by its color. The addition of a trace of potash brings it to a deep rose red. Phenolphthaleine acts as a very weak acid; its very dilute solution must, therefore, be dissociated, and the colorless anion of the isolated substance must differ from the colored anion which separates from the potash compound. Also, a solution of the potash compound so dilute as to leave a transparent film, has been evaporated and then desiccated for many hours at 100°, the color of the solu-

* All their molecules become active, Ostwald, Lehrb., 2d G. ed., ii, 653; Nernst, Theoret. Ch., 440.

tion still fully remaining in the dry product. Now the potash compound of phenolphthaleine is known to be anhydrous. Anhydrous substances thoroughly desiccated cannot be in a dissociated state and, therefore, the rose red-color of the potash compound is not due to dissociation.

Further, if to the potash solution a solution of a silver salt is added there is formed a silver compound having the same constitution as that of the potassium compound. This silver compound is anhydrous and insoluble, nevertheless it has the same color as the potassium compound under conditions which make dissociation to be out of the question.

Paranitrophenol.—This is another acid indicator. In a solid state it is nearly colorless; it dissolves in warm water to a nearly colorless solution which on the addition of an alkali becomes gold-yellow. A portion of this solution evaporated so as to leave a thin film exhibits the same intensity of color as the solution, which color it retains after thorough desiccation. The color of the solution is, therefore, not due to dissociation. The solution of the substance itself when largely diluted gives no indication of the dissociation of a colored ion. The behavior of phenacetoline, another acid indicator, is analogous.

It seems, therefore, that dissociation has no essential connection with the reactions of acid indicators. It is simply that these substances by combining with alkalies either have their color much intensified or in some cases change it altogether.

Such changes are not in any way confined to acid indicators so-called. Picric acid in combining with alkalies has its color much intensified; the acid itself has a pale yellow color; the sodium salt (dry) has a pure deep yellow color. Chrysammic acid affords an example of a complete change of color; the acid itself is yellow, the potash salt a deep blood red, not only in solution but in the dry state so that its color cannot be due to dissociation. It may be remarked also that the potash salt in its dry state has remarkable optical properties which were investigated by Brewster, properties not possessed by the acid.

To the reactions which have been here examined might be added those of methyl orange, rosolic acid, and other acid indicators. I have found no exception to the rule that the characteristic colors exhibited by these substances when placed in contact with alkalies, are retained after a thorough desiccation. Also, no acid indicator when dissociated by a large dilution shows any tendency to exhibit an anion similar in color to that of its alkaline compound.

IV. *Classification, continued from Part I.**

Any attempted classification of the elements is necessarily subjected to a severe test through later discoveries. If the classification is in complete accordance with nature, it must offer suitable places for such new elements as may present themselves later. If it does not do this, it must be more or less artificial.

Mendeléef's remarkable predictions and the fact that the elements next discovered found places marked out for them in advance, caused his periodic law to be received with enthusiasm, It so happened that these new elements missed the weak portions of the system. This is now much changed. Within the last year or two, several new elements have been discovered for which the periodic law affords absolutely no place.

This appears to be admitted by Mendeléef. In an article† he contends that argon must be polymerized nitrogen and after examining the possible forms that nitrogen might take, he decides in favor of N_3.

But Berthelot succeeded in combining argon with carbon disulphide or with its elements, and from this compound he has been able to regenerate argon with all its characteristic properties. This Berthelot justly calls a capital fact. It is scarcely necessary to say that it is quite fatal to the theory of polymerization just mentioned.

The impossibility of finding a place for argon in the periodic system will become evident from the following considerations. If its atomic weight should prove to be 19·9 its place will necessarily be between fluorine and sodium. Introduced into the periodic system, it would take its place at the head of the iron group. It is to be remarked that in the periodic system the iron group is a somewhat singular one. It does not include any of the metals which we commonly associate with iron, cobalt and nickel, chromium and manganese. Instead of these, iron is made to form a group with ruthenium and osmium, so that if argon should enter in the periodic system with the atomic weight of 19·9 it would form the head of a group consisting of argon, iron, ruthenium and osmium. Or of one consisting of A, Co, Rh, and Ir. Or of another, equally anomalous, A, Ni, Pd, and Pt.

But argon may prove to have for its atomic weight the number 39·8. For such an element there is absolutely no place in

* In the first part of this paper (this Journal, May, 1895) in the table at page 362, by a vexatious mistake of the printer, the groups have been dislocated so that the series is no longer in numerical order, thus wholly destroying the sense of the table. On page 361 the order is correct and the table has been correctly printed in the German translation which appeared in the Zeitschrift für Anorg. Chemie.

† Reprinted in the Chemical News for July 12th, 1895.

any periodic system. The position required is already occupied by calcium and a place cannot be made without dislocating all the following groups, a strong argument in favor of the lower figure.

Helium with an atomic weight of probably 4 offers equally great difficulties. As the old periodic system excludes hydrogen and commences with lithium with an atomic weight of 7, any element having an atomic weight less than 7 is, like hydrogen, entirely outside of a system which does not recognize the existence of such elements.

In the system which I have proposed, helium, argon with the atomic weight of 19·9, and their congeners would constitute a group of their own, taking position between the hydrogen group and the lithium group.

In the first part of this paper I endeavored to show that the relations of atoms to the visual rays of the spectrum might be made the basis of a classification of the elements composed of these atoms and that such a classification harmonized extremely well with the known properties of the elements. Not that the particular color exhibited by an atom has for this purpose any importance; the question is simply whether color is present or absent. In other words, we have to inquire whether a given atom does or does not exercise selective absorption amongst the visual rays. It was there shown that the atoms of all the elements having atomic weights below 48 did not exhibit selective absorption. After these came two elements which I call transitional because at some valencies their atoms exhibit selective absorption and at others do not. Next, elements whose atoms at all valencies exhibit selective absorption. Next came a transitional element and then more elements having colorless atoms, and so on through the entire series of elements arranged in the numerical order of their atomic weights.

It is even probable that the distinction so established between these three classes of elements may eventually prove to have a far-reaching significance and that those elements whose atoms always exercise selective absorption may prove to be differently constituted in some important way from those whose atoms always allow free passage to all the visual rays.

About the same time that the first part of this paper appeared, Julius Thomsen proposed another and a different system of classification,* to which later he added a supplement† in reference to my paper with the object of showing that the elements which I had indicated as possessing colored ions were

* Zeits. fur Anor., Ch. ix, 192. † Ibid., x, 155.

found to come together and to occupy certain distinct positions in his series. This perhaps may be taken as additional proof of the conformity of the system which I have proposed to the essential characters of the elements.

A few weeks after the first part of this paper was read before the National Academy (April, 1895), M. Lecoq de Boisbaudran brought before the French Academy a note on the subject of the relations of the elements.* At page 1100 the elements to which his system of nodes and decrements applies, are tabulated. They are thirty-one in number, with three additional elements somewhat widely separated from the rest. I observe that all these thirty-one elements, without an exception, belong to my first division and have atoms that are colorless at all valencies. The three additional elements belong to the transitional class. The elements of the third division, that is, having atoms colored at all valencies, find no place in his classification. The chances are enormously against this happening fortuitously. The indications from both this and Thomsen's classification are, therefore, confirmatory of the principle I have endeavored to establish, that is, that the presence or absence of specific absorption of a certain range of rays is a function of the atomic weight and is closely related to the constitution of the elements.

In considering the theory of ionic dissociation it is necessary to bear in mind that no rigorous proof has ever been found for it. It remains, therefore, a theory only, a fascinating theory because it affords beautiful explanations of phenomena which otherwise have none.

There is, however, an important difficulty connected with this theory. The dissociated ions are often spoken of as "free ions," which in the absence of exterior electrical agencies, static or dynamic, they do not appear to be. It is certain that after dissociation the ions continue in some way to influence and control each other. This fact appears in a great number of reactions, of which the following familiar one may be taken as typical.

If to a dilute solution of ferrous chloride we add dilute hydrochloric acid in excess, completely excluding the air, there will be a considerable dissociation and the ferrous ions will be in presence of more than enough chlorine ions, *if these were free*, to cause at least some portion of the ferrous ions to acquire additional valency and become ferric ions. No change of the sort can be detected. The chlorine ions which would bring about this change are held in check by the hydrogen

* C. R., cxx, 20 (May 20th, 1895).

ions with which they were previously combined. That this is true is shown by removing the hydrogen ions, which is easily done by the addition of nitric acid. Thereupon those chlorine ions which were previously influenced by, and influenced, the hydrogen ions, now influence the ferrous ions, converting them to ferric ions.

The facts of osmosis seem to indicate that dissociated ions are mechanically free, inasmuch as the total number of molecules appears to be increased. But the above reaction, which is one of a great number, shows that in a chemical sense they cannot be considered as free.

Those who, like Ostwald, on the contrary hold that dissociated ions are perfectly free* would perhaps explain the above reaction by the asserted principle that plurivalent ions have a tendency to lose a portion of their valency.† One of the examples given (p. 796) is that of the trivalent iron ion, which by reason of its tendency to lose valency, may act as an oxidizing agent.

This reasoning does not seem to be sound. Whatever may be the tendency of the ferric ion to lose valency, the tendency of the ferrous ion to gain it is still stronger, so that ferrous chloride acts as a powerful reducing agent by reason of the strong tendency of the ferrous ion to acquire additional valency. This tendency of the ferrous ion shows itself in other ferrous salts and a similar tendency is exhibited by cuprous and stannous salts. In fact it may be said that most of our powerful reducing agents owe their activity to the tendency of ions to acquire additional valency; consequently it cannot be admitted that an opposite tendency prevails. And when in the above mentioned reaction we find that ferrous chloride in dilute solution with hydrochloric acid does not take up additional chlorine ions actually present in spite of its strong tendency that way, we are compelled to believe that the chlorine ions of the hydrochloric acid, though mechanically dissociated, are still held in check by, and hold in check, the hydrogen ions.

In this connection I may refer to some interesting remarks made by Professor Fitzgerald in his recent Helmholtz Memorial Lecture, reported in Nature (January 30, 1896).

"It is almost impossible to explain dynamically the assumption that free electrically-charged ions wander about in a liquid in a condition at all rightly described as one of dissociation."

And again:

* Lehrbuch, 2d Ger. ed., ii, 783.
† Ib., 796 and 801.

"The term dissociation as applied to electrolytes in which this independence of the ions does not exist is obviously a misnomer. There is said to be an electrical force acting between the various oppositely charged ions into which a dissolved molecule separates, which in some way binds them. Even in dilute solutions this force is very considerable and must make the condition of charged ions moving independently in the liquid so unstable as to be dynamically impossible unless other important forces operate at the same time."

From these various considerations the following conclusions may be drawn.

1. When highly colored inorganic substances are composed of colorless ions, then if these substances can be brought into solution as electrolytes, the color wholly disappears. A number of instances are given above and no exceptions were met with. Much that is important follows from this. It is proved that the ions have become so far separated that they no longer influence each others' vibration periods. For example, antimony pentasulphide is an intensely colored substance. It dissolves easily in solution of alkaline sulphides forming absolutely colorless solutions, because the ions of antimony and of sulphur are colorless and in the act of solution they separate sufficiently to no longer change each others' vibration periods, without however passing out of each others' sphere of influence. The ion theory is the only one capable of explaining this loss of color, and on the other hand the reactions are so exactly conformable to that theory that they constitute a new proof of its correctness: perhaps the best proof yet presented.

2. The union of ions colored and colorless gives rise to the most surprising changes of color. Two similar colored ions may unite to form a colorless element. Two similar colorless ions may unite to form a strongly colored element. No black ion is known. There is absolutely no relation traceable between the color of an ion and that of the element which it aids to form.

3. The change of color of an acid indicator placed in contact with an alkali in no way depends upon dissociation. Dissociation may result, but the change of color is independent of it.

4. Selective absorption of the visual rays by an element can never constitute a basis for classification, but the relation of ions to the visual rays leads to a classification which is in absolute harmony with the chemical characteristics of the elements. Quite recently two chemists, Thomsen and deBoisbaudran, have proposed new systems of classification, in both of which

it appeared subsequently that the elements having colorless ions had come together. And in Thomsen's system the same was also true of the elements having colored ions.

5. While there is good reason for believing that in solution the ions are separated so as to no longer affect each others' vibrations (see sec. 1, supra), it is also certain that they remain within each others' range of influence, so that they cannot be considered as free. Fitzgerald has shown that this conclusion is in conformity with theory and experimental evidence has been given above, proving that it is also in conformity with fact.

Art. XLVIII.—*The Gravimetric Determination of Selenium;* by A. W. Peirce.

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

The method generally in use for the gravimetric determination of selenious acid is to precipitate the selenium with sulphurous acid in presence of hydrochloric acid and to weigh the elementary selenium. Precipitation by this method, however, is slow and incomplete in many cases, so that it is always necessary to treat the filtrate a second time with sulphurous acid and to digest for some time. To obviate the necessary delay in this process, I have tried the effect of substituting potassium iodide as the reducer instead of the sulphurous acid, adopting the idea from several recent volumetric methods for the determination of selenium* in which an iodide in acid solution is used to reduce the selenious acid, and in which the liberated iodine, caught in various ways, is titrated and taken as a measure of the selenium.

Varying amounts of selenium dioxide prepared according to the method described in former articles, by dissolving pure selenium in nitric acid, removing any selenic acid formed by barium hydroxide, and subliming in a current of dry oxygen, were dissolved in Erlenmeyer flasks, and the solution was acidified with hydrochloric acid. Potassium iodide was added and the selenium was precipitated in the form of a red powder. Boiling for ten minutes served to remove most of the liberated iodine and to change the selenium into the black modification, which was collected upon an asbestos felt, washed, dried at 100° to a constant weight, and weighed. Early experiments

* Muthman and Schaefer, Ber. d. d. chem. Gesell., xxvi, 1008; Gooch and Reynolds, this Jour., l, 254; Gooch and Peirce, this Jour., fourth series, i, 31.

showed that for small amounts the process gave accurate results, but that for large amounts the errors came far too high:

	Se taken grm.	Se found grm.	KI grm.	Volume cm^3	Error grm.
(1)	0·0355	0·0356	1	100	0·0001 +
(2)	0·0355	0·0355	1	"	0·0000
(3)	0·0355	0·0356	1	"	0·0001 +
(4)	0·2968	0·3883	4	75	0·0915 +
(5)	0·2033	0·2475	4	100	0·0442 +
(6)	0·3058	0·3495	10	100	0·0437 +

When the selenium amounted to less than a tenth of a gram the results came out well. When the amount was larger the selenium assumed on boiling a pasty molten condition which made filtering and washing impossible. This condition was observed in the work already referred to, and the mass seemed to consist of selenium with included iodine, as it gave up iodine slowly to water on standing and more rapidly to a solution of potassium iodide.

It has been found in the work to be described that if an excess of potassium iodide be used considerably above the amount necessary for precipitation, the pasty condition of the selenium does not occur, the iodine evidently being held in solution by the excess of the potassium iodide. This would seem to indicate the total release of the iodine, and would make possible the determination of quantities larger than the two-tenths of a gram set in the former work as a limit for the range of the process. Several determinations, which resulted very satisfactorily, were made according to the volumetric method thus modified, and at the same time the selenium which was precipitated was weighed. By the former method, in which the iodine evolved was estimated, the results were too low, and by the latter method, in which the residue was weighed, too high; but there appeared to be no definite relation between the errors of the two processes, as there would be if the retention of iodine were the only difficulty. Digestion of the selenium in the crucible with hot water removed a small amount of potassium iodide and reduced the error considerably; so that it was apparent that the increase in weight was due to the fact that the precipitated selenium included potassium iodide from the concentrated solution.

	SeO_2 taken grm.	SeO_2 found grm.	KI grm.	Volume cm^3	Error grm.	Se taken as SeO_2 grm.	Se found grm.	Error grm.
(7)	0·4870	0·4868	7	60	0·0002 –	0·3467	0·3507	0·0040 +
(8)	0·4980	0·4971	10	"	0·0009 –	0·3545	0·3575	0·0030 +
(9)	0·7323	0·7310	10	75	0·0013 –	0·5214	0·5312	0·0098 +

Later experiments under similar conditions, excepting that the volume of the liquid in which the precipitation took place was very much increased, so that the tendency on the part of the selenium to include the iodide might be diminished, gave errors entirely within satisfactory limits though always positive.

	Se, taken as SeO_2 grm.	Se found grm.	KI grm.	Volume cm^3.	Error grm.
(10)	0·2853	0·2861	7	900	0·0008 +
(11)	0·3189	0·3192	8	400	0·0003 +
(12)	0·3318	0·3324	7	500	0·0006 +
(13)	0·3798	0·3805	7	500	0·0007 +
(14)	0·4252	0·4259	7	350	0·0007 +
(15)	0·4430	0·4434	10	450	0·0004 +

It is sufficient to dilute to 400 cm^3 before acidifying with hydrochloric acid and adding potassium iodide to an amount about three grams in excess of that actually required. Boiling for 10 to 20 minutes will change the selenium to the black modification and remove most of the iodine. The process of precipitation and filtering can be completed in half an hour. The selenium is dried at 100° to a constant weight.

When the selenium occurs in the higher form of oxidation the reduction follows the same course, though iodine is not liberated until the solution is quite warm; but at the end of the usual time of boiling the action is complete. The following shows the results obtained by acting in the manner described on selenic acid.

SeO_3 taken grm.	Se taken grm.	Se found grm.	KI grm.	Volume cm^3.	Error. grm.
0·1709	0·1063	0·1065	5	500	0·0002 +
0·1709	0·1063	0·1062	5	375	0·0001 —
0·3231	0·2010	0·2017	5	350	0·0007 +
0·5005	0·3115	0·3126	6	500	0·0011 +

Evidently this method will not distinguish between selenious and selenic acids, but it will be found of much value in point of time saved in the determination of either separately, or of the total selenium in case both occur together.

The kindly advice and suggestions of Prof. F. A. Gooch are gratefully acknowledged.

ART. XLIX.—*The Extinct Felidæ of North America;* by GEO. I. ADAMS, Fellow of Princeton College. (With Plates X, XI, XII.)

THE following paper is a result of studies by the author in the Department of Palæontology of Princeton. It is an attempt to summarize the literature on the extinct Felidæ, to add such new points of knowledge as it has been possible to discover and to propose a classification for the family. I wish here to express my thanks for privileges of study kindly extended by Prof. H. F. Osborn and Dr. J. L. Wortman of the American Museum, to Prof. Cope for suggestions and use of material, and to Mr. Dixon and Dr. Nolan of the Philadelphia Academy for assistance in examining specimens and literature in that institution. I wish also to acknowledge my special indebtedness to Prof. W. B. Scott, whose valuable criticism and kindly interest have been an inspiration to me in my work, and to Mr. J. B. Hatcher, from whom I have received much information and assistance. The illustrations are by Mr. Rudolph Weber and their excellence is due to his care and skill.

Osteology of Hoplophoneus Primævus.

Hoplophoneus primævus is at present known from a short description of the type skull by Leidy (Geol. Sur. Wis., Iowa, Minn. and Neb. 1852), and later from a description of a specimen nearly agreeing with the type along with a second larger skull which belongs to a different species (Extinct Fauna of Dak. and Neb.) A restoration and brief description has been published by Scott (Bull. Mus. Comp. Zoology, Harvard, 1887). The material here described consists of a nearly complete skeleton, which is well preserved (No. 10741, Princeton Collection) and a skull somewhat crushed (No. 11013). In addition there is in the same collection a skeleton (No. 10934) not very complete but having associated with it the anterior and posterior portions of the skull which agree very closely with the above mentioned specimen and is supplemented by another lacking the occiput (No. 10540.) This latter specimen is slightly smaller but is a young skull just losing the deciduous canines. The principal material is that which was referred by the writer to *H. primævus* in the American Naturalist for January, '96, and corresponds with the original type.

This species of *Hoplophoneus* is of special interest inasmuch as it agrees very closely in size with *Dinictis felina*, the osteology of which is known from the description by Dr.

Scott (Proc. Phila. Acad., 1889). In describing it I shall make comparisons with the lynx (*Lynx canadensis*) and occasionally with the lion, since the bones of the lynx, although they are nearly the same size, do not express the feline characters so well as do those of the lion. I shall not attempt to quote from previous descriptions or give minute descriptions where the characters agree with those of recent felines. The osteology is illustrated by Plate X.

In general *Hoplophoneus primævus* is comparable in size with the lynx, although having a longer head, the distal portions of the limbs relatively much shorter and the tail long.

The skull.—The skull is one-fourth longer from the condyles to the premaxillary border than that of the lynx. This is due to a greater proportionate length of the face and palate. In *H. primævus* the distance from the condyles to the line of the upper molars is nearly the same as from that line to the premaxillary border. While in the lynx the first measurement is about the same as that of *H. primævus*, the latter is only about one-half as great. The brain case is not quite so large as that of the lynx and the post-orbital constriction is much more marked. The face is not only proportionately longer but wider, the width at the canines being as great as the width of the brain case at the parieto-temporal suture. The zygomata are expanded about as much as in the lynx in proportion to the length of the skull, but the space enclosed is proportionately longer and much wider because of the constriction of the brain case and the smaller size of the orbit. The orbit is considerably smaller than that of the lynx and is horizontally oval. The post orbital processes of the frontals and malar are short and rather stout.

The face is strongly arched transversely; seen from the side the angle it makes with the posterior portion of the skull is about the same as in the panther or lion, but it is straighter and the frontal region not so full.

The bones of the skull are much thicker than those of the lynx and the processes and borders much more massive. This is seen in the inion and post-tympanic process. The latter is trihedral and truncated distally. It is directed slightly towards the post-glenoid as if tending to approach it. The zygomatic process is strong and drooping with its glenoid portion looking slightly inward. The lambdoidal and sagittal crests are rather high and thick. The fronto-temporal ridges diverge at the fronto-parietal suture.

The sutures of the skull are very similar to those of recent felines. The nasal processes of the frontals do not extend so far anteriorly, being separated by a considerable space from the ascending rami of the premaxillaries. The nasals are long and inserted well into the anterior border of the frontals, their posterior borders being broadly rounded. The bullæ are seldom preserved, but judging from a cast of one they are moderately expanded.

The foramina of the skull present peculiarly primitive characters, as has already been recognized. The condylar and carotid are distinct from the foramen lacerum posterius. There is a post glenoid foramen. The foramen ovale enters the outer end of a deep transverse groove situated in the base of the zygomatic process. There is an ali-sphenoid canal, the posterior opening of which is in the inner portion of the above mentioned groove and its anterior opening is just back of the anterior lacerated foramen. The opening of the foramen rotundum is concealed within the alisphenoid canal. The optic foramen is in the same relation to the anterior lacerated as in the cats. There is also an ethmoidal foramen present. The palatal foramina need no special description. There is a post-parietal foramen and sometimes two. The infra-orbital is large and vertically oval.

The mandible.—The mandible is quite characteristic of the Machærodonts. Its anterior portion consists of two vertical nearly plane surfaces meeting at a wide angle at the symphysis. The lateral face of the mandible is separated from the anterior by nearly a right angle marked by a distinct ridge, posterior to which is a shallow fossa for the superior canine. At this place the lower border of the mandible is produced into a moderate flange on the surface of which the fossa is continued. The symphysis is lower than the ramus and abuts against the flange on its inner side. The ramus is long and quite straight, being heaviest at the sectorial. The condyle is on a line with the alveolar border and is semi-conical. The coronoid is small and evenly rounded. The masseteric fossa is deep, the angle being well out from the plane of the coronoid. The dental and mental foramina are as in the modern cats. On the anterior or symphysial surface there are two foramina on either ramus.

Dentition.—There are three stout subconical incisors which are slightly recurved and are placed in nearly a semicircle. Their posterior surface, which is a little over one-third the circumference of the tooth, is slightly flattened and separated from the anterior by a sharp line which is slightly denticulate in an unworn tooth. They increase in size outward, the external being largest. The superior canines are long, compressed and slightly recurved. They are implanted by a strong fang which reaches well up to the frontal bone. Their anterior and posterior cutting borders are denticulate. When the mouth is closed the canines rest in the fossæ of the mandible, extending nearly as low as the flange. There is a small space anterior to the canine and one about twice as great posterior to it. There are three superior premolars; the anterior one (p^2) is considerably the smallest and may lack distinct anterior and posterior cusps. The second (p^3) is well developed but may not have a distinct anterior cusp. The third (p^4) is the sectorial. This tooth is different from that of the lynx or lion in not possessing an internal cusp; the inner root, however, supports a convex buttress which descends from the principal cusp. There is also an anterior basal cusp which is rather incipient and situated high on the principal cusp. The posterior cusp is a long cutting heel. The upper molar is rather better developed than in the modern cats and is inserted as in the lion by two roots in a transverse line. The incisors of the lower jaw along with the canines form a regularly curved series, the canines being not much larger than the external incisors. The internal incisors are much compressed and in some specimens are hardly more than rudiments. They are slightly divergent and have the same general structure as the upper ones. The canine is curved slightly backward and has a rather stronger posterior border. Its greatest diameter is nearly in an antero-posterior line. It is also denticulate when unworn, but the border soon becomes smooth. Back of the canine there is a diastema about twice as great as in the upper jaw. There are two well developed premolars, the anterior being, however, considerably the smaller. The inferior molar is a sectorial and differs from that of the modern cats in having a low heel and a somewhat variable postero-internal cusp. The teeth of the molar series differ from those of the modern cats in being more compressed and in having sharper borders which when unworn are feebly crenulated.

The vertebræ.—There are sixteen presacral vertebræ of one specimen, all of which are considerably mutilated so that it is possible to judge only of the relative size and length of the centra. They indicate a much stronger vertebral column than that of the lynx and one which is proportionately shorter in the lumbar region. Five lumbar vertebræ measure considerably less than any five of same region of the lynx. On the other hand, the cervicals are longer than those of the lynx and the axis particularly so. The thoracic vertebræ are, as near as can be judged from comparison with those at hand, a little longer and, proportionately to the other vertebræ, also more massive. From what I know of other representatives of the genus I think it safe to say that the processes were stout and well developed. The sacrum, as would be expected, is heavier and wider than that of the lynx and its centrum is not so much depressed. The caudals are not preserved in the specimens of this species, but from the other species it is evident that the tail was long like that of the recent cats.

The pelvis.—I have only fragments of the pelvis, but they give an idea of its relative size and strength. The acetabulum is one-fifth greater in diameter than that of the lynx. As a whole the pelvis is more massive and considerably longer. At the sciatic notch, however, the ischium has about the same diameter as that of the lynx.

The scapula.—The distal portion of the scapula is considerably larger than in the lynx, the glenoid cavity being about one-fifth larger. There is a short stout coracoid much the same as in the modern cats. No other features are preserved in the specimens which are at hand.

The fore-limb.—The humerus of *H. primævus* is the same length as that of the lynx, but fully one-half more massive. The head presents a large articular surface which is very similar in shape to that of the cats. The great tuberosity is particularly prominent and rises considerably above the head and is well set off from it. The smaller tuberosity is low but rugose and the bicipital groove quite broad. The prominent character of the bone is the bold deltoid ridge which has a straight sharp border on the internal side extending to the great tuberosity.

On the outer side, the lower portion has a similar border which runs slightly divergent from the inner border, but farther up curves toward the smaller tuberosity and becomes a mere line on the convex surface. The prominence of the deltoid ridge makes the antero-posterior diameter of the humerus at its middle portion twice as great as the lateral diameter, a feature which is not met with in the Felidæ even in the lion. Below the deltoid ridge the anterior surface retreats rapidly as it descends, becoming an even convex surface. The supinator ridge is also very bold and is in fact a thin prominent border as far up as the lower portion of the deltoid ridge. Above it, extending in the same line but not connected with it, is a line for muscular attachment, extending to the base of the head. The ent-epi-condylar foramen is large and formed by a free arch, being but slightly depressed into the body of the bone. The trochlea is very similar to that of the lynx but slightly more oblique. The anconeal fossa is deep and large, but not perforated.

The ulna is practically of the same length as the humerus. Its olecranon is proportionately much longer than in the lynx and lion, being one-fifth the entire length, while in the lynx it is not quite one-eighth, and in the lion a little over one-seventh. The sigmoid cavity is long and defined much as in the cats. Except as to proportions, the ulna presents no especial peculiarities.

The radius is three-fourths the length of the humerus and is a short bone compared with that of the modern cats. Its head presents a distinct notch on the dorsal margin. The bone has sharp lines and the lower portion is quite rugose. The styloid portion is heavy and the process short. The scapho-lunar articular surface is rather smaller than would be expected.

The manus.—The manus is particularly short and the digits divergent. The scapho-lunar, although not much different from that of the lynx in general structure, is wider and has a better developed tubercle. The line of union of its two elements is visible on its distal surface in the facet for the magnum. The pyramidal is very seldom preserved with a specimen, but is fortunately retained in this case. It presents a concave surface for articulation with the unciform. On its external surface are two facets, the proximal for the pisiform and the other for the styloid process of the ulna. It also articulates slightly with the fifth metacarpal. The pisiform is well developed, articulating as in the Felidæ with the pyramidal and ulna. The unciform and magnum need no special description. In the specimen which I have the trapezium and trapezoid are absent. They are present in specimens of *Hoplophoneus insolens.* The trapezoid in them nearly excludes the second metacarpal from lateral contact with the magnum. In the specimen which I am describing the relation of the metacarpals is such as to indicate the same position. In this respect the carpus differs from that of the modern cats, in the lion the articulation being very large. The metacarpals are surprisingly short, being only about two-thirds as long as those of the lynx. The first metacarpal is about as much reduced as in the lynx or lion. The phalanges are large and the unguals have well developed hoods which are usually preserved.

The hind-limb.—The femur is the same in length as that of the lynx, but of course much heavier, and its extremities are rather larger in proportion to the strength of the shaft. The head is presented slightly more inward and forward. It presents about the same relative articular surface as the lynx and has a deep pit for the round ligament. The great trochanter is separated from the head by a more distinct notch, which is deepest at the neck. The digital fossa is deep and the posterior border of the great trochanter is reflected over it fully as much as in the lynx. The second trochanter is very prominent and its position is quite different from what it is in the modern cats. It is relatively farther below the head and not as much removed from the inner border of the femur. When the bone is viewed directly from in front a considerable portion of it is seen, while in the recent cats it is concealed by the shaft. The femur also differs from that of the recent cats in having a distinct third trochanter which is connected above by a ridge with the great trochanter and is continuous below with the linea aspera externa. The shaft is more rugose than in the lynx and is not quite as straight. The patellar surface is broad and shallow and the condyles large.

The tibia is absolutely and relatively shorter than in the lynx, being not quite four-fifths as long as the femur, while in the lynx they are of the same length. In the lion the tibia is five-sixths the length of the femur. The condylar surfaces are large and are separated only by a low spine. The shaft of the tibia is compressed laterally and the cnemial crest is high. The anterior tuberosity is rather far from the condyles. The distal portion is quite different from that of the lynx or lion, inasmuch as the articular surface is very oblique and the astragalar groove only slightly indicated. The malleolus is heavy and straight. A distinct ridge rises on its anterior surface and extends a short distance up the shaft.

The fibula needs no special description. It is quite stout and has sharp lines for muscular attachment and is free the whole length of the shaft. Its distal end presents a large articular surface for the calcaneum.

The pes.—The calcaneum is slightly shorter than that of the lynx owing to its tubercle being not quite so long. The sustentacular portion is situated rather farther distally and the facet is presented more nearly upward. There is no facet to support the head of the astragalus as in the lynx. This last mentioned bone extends much farther distally than in the lynx although the neck is not proportionately longer. The astragalus of *Hoplophoneus* is larger, particularly the body portion. Its trochlear surface is only slightly grooved and its outer border very oblique. It is in these two respects very primitive. The cuboid is somewhat larger than that of the lynx, while the navicular is considerably wider and the tubercle not so much reflected upon the head of the astragalus. Its distal surface presents three distinct facets for the cuneiforms. In these bones the relationship as regards the articulation with the metatarsals is similar to that of the trapezoid and magnum in the manus, the second metatarsal being nearly excluded from any lateral articulation with the ectocuneiform. In the modern cats this wedging in of the second metatarsal is a very great element of strength. The ento-cuneiform is not so much reduced as in the lynx since the first metatarsal is not so rudimental. The length of the metatarsals is proportionately even shorter than the metacarpals, being only four-sevenths as long as those of the lynx. The first digit is not much reduced and carries an ungual.

Summary.

H. primævus differs from the recent Felidæ and the lynx in particular, in the following points:

The skull is Machærodont, is large in proportion to the body and long anteriorly.

The brain case is relatively much less expanded and the post orbital constriction is very marked.

The mandible has a distinct vertical anterior face and a moderate flange.

The post-tympanic is large, sub-cylindrical and shows a tendency to approach the post-glenoid process. The zygomatic processes are drooping.

There are distinct carotid, condyloid, post-glenoid and post-parietal foramina and an alisphenoid canal.

The dentition is $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{2}M\frac{1}{1}$. The superior canine is very long, recurved, compressed and when the mouth is closed extends nearly as low as the flange of the mandible, resting in a slight fossa. The superior sectorial has an anterior basal cusp but no internal, the internal root supporting instead a convex buttress which descends from the principal cusp. The inferior sectorial has a small postero-internal cusp and a low heel. The incisors are subconical and slightly divergent. The inferior canine is not much larger than the external incisor. All the teeth when unworn are denticulated or feebly crenulated and the superior canines are permanently so.

The skeleton is about the size of the lynx but more massive as in the lion. The cervical region is rather long and the lumbar short as compared with the lynx. The tail is long as in the lion.

The humerus has a strong massive deltoid ridge, the femur a third trochanter.

The ulna and radius and the tibia are proportionately much shorter than in the recent Felidæ.

The pes and manus are very short and broad. The astragalus is only slightly grooved and its tibial surface is oblique. The scapho-lunar shows the line of union of its two elements. The second metacarpal is nearly excluded from lateral articulation with the magnum and the second metatarsal from lateral articulation with the ecto-cuneiform.

The unguals have heavy hoods and were retractile.

The position of the feet was as in the modern cats.

A comparison with Dinictis felina.

The osteology of this species of *Dinictis*, as has already been stated, has been described by Scott. In addition to the material which was known at that time, the Princeton Museum contains besides duplicate portions of the skeleton, a humerus and a few bones of the carpus. These need no special description for my purpose here. The genus *Dinictis* stands ancestral to the genus *Hoplophoneus* and the species *felina* agreeing so closely in size with *H. primævus* makes a comparison very interesting. I shall state here the points in which *D. felina* differs, although many minor points which would be apparent to the eye are necessarily omitted.

The skull is slightly larger and is higher in the frontal region.

The mandible has a smaller flange.

The glenoid process is not so low and the post-tympanic does not show a tendency to approach the post glenoid.

The dentition is $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{2}$. The incisors are small, spatulate and in an even transverse row. The outer one is considerably larger than the others. The canine is larger at the base and not quite so long. The superior sectorial has an inner cusp but no anterior basal. The inferior sectorial has a better developed heel. The second lower molar is much reduced but constant.

The foramina are the same.

The skeleton is of nearly the same size but not so massive.

The limb bones have more slender shafts and not quite so large extremities.

The ulna and radius and the tibia are not so short in proportion to the lengths of the humerus and femur, which are almost identical in length with those of *H. primævus*.

The manus and pes are narrower and longer.

The unguals have weak hoods but were retractile, although perhaps not perfectly so.

The generic distinctions are to be found in the structure of the sectorials, the character of the incisors and the unguals, although in distinguishing the two the other points above mentioned can be relied upon.

Measurements.

	H. primævus.	D. felina.
Length of skull condyles to premaxillary border	148	154mm
Length of cranium to anterior rim of orbit	99	108
Length of bony palate	79	72
Breadth of bony palate at sectorials	61	69
Breadth of skull at canines	47	50
Breadth of skull at post-orbital constriction,	35	33
Length of mandible from condyle to lateral incisor	112	119

		H. primævus.	D. felina.
Length of	humerus	160	172
	ulna	163	---
	radius	122	---
	femur	185	190
	tibia	143	168
	calcaneum	43	43
	metatarsal IV	37	53
	metacarpal IV	38	--

The Hoplophoneus Series.

Hoplophoneus primævus Leidy and Owen.

This species was the first Machærodont found in North America and was described as *Machœrodus primævus* and later as *Drepanodon primævus.* The establishment of the genus *Hoplophoneus* Cope, removed it to that group. In Leidy's description in the Ancient Fauna of Dakota and Nebraska a skull is referred to this species which is considerably larger than the original type and quite different from it. The species as here used is as limited by the writer in the American Naturalist, January, 1896. The description of the osteology preceding this makes further mention of it here unnecessary. Dental formula $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{2}M\frac{1}{1}$.

Hoplophoneus robustus Adams.

This species was proposed as representative of the larger skull, which was referred by Leidy to *H. primævus.* As compared with that species, it shows an increase in size and the skeleton is more massive. The skull is relatively large and the first superior premolar (pm^2) more reduced and in old specimens may be absent. To this species should be referred the specimen determined by Osborn and Wortman as *H. primævus* (Bull. Amer. Mus., 1894, p. 228). The figure of the skull and the measurements here given are from that specimen. $I\frac{3}{3}C\frac{1}{1}Pm\frac{2-3}{2}M\frac{1}{1}$.

Length of skull, condyles to premaxillary border,		180^{mm}
"	humerus	170
"	ulna	163
"	femur	195
"	tibia	160

Hoplophoneus occidentalis Leidy.

This is the largest species of the series. It was first proposed by Leidy on a fragment of a mandible (Extinct Fauna of Dakota and Nebraska). It is best known from a fine skull and nearly complete skeleton described by Williston (Kansas University Quarterly, June, '95), as *Dinotomius atrox*, which name, as has been shown by the writer, is a synonym (Amer. Nat., January, '96). The dentition is $I\frac{3}{3}C\frac{1}{1}Pm\frac{2}{2}M\frac{1}{1}$. The inferior sectorial is very strong and thick at the base, the postero-internal cusp is wanting and the heel is reduced.

Length of the skull, inion to premaxillary border,	260mm
" humerus	240
" tibia	237

Hoplophoneus insolens Adams.

The determination of the skeletal characters of *H. occidentalis* made it apparent that the specimen determined as such by Osborn and Wortman (Bull. Amer. Mus., 1894) is a quite distinct species, and it together with material in the Princeton collection was the basis of this species intermediate between *H. robustus* and *H. occidentalis*. As compared with *H. robustus* the skeleton is much larger, the limb bones being longer but not much heavier, the extremities being relatively smaller. The dental formula is $I\frac{3}{3}C\frac{1}{1}Pm\frac{2}{2}M\frac{1}{1}$.

Length of skull, condyles to premaxillary border,	190mm
" humerus	200
" ulna	212
" femur	250
" tibia	188

Hoplophoneus oreodontis Cope.

This species is the type of the genus. It was first described by Cope under the genus *Machærodus*, but better material enabled him to separate from that genus. The specimen figured in the series is interesting as supplementing the material already known. This skull (number 10515 in the Princeton collection) differs from that described by Cope in showing the roots of a much reduced pm^2, thus changing the dental formula of the species $I\frac{3}{3}C\frac{1}{1}Pm\frac{2-3}{2}$ $M.\frac{1}{1}$. It is the smallest species known from the White River.

Length of skull, condyles to premaxillary border, 135mm

Hoplophoneus cerebralis Cope.

This is the smallest species and the most peculiar. It is the only representative of the genus thus far found in the John Day. It is peculiar in showing a short temporal space, a very convex profile, and a nearly vertical and abrupt occiput. The superior sectorial has a better developed anterior basal cusp than the other species; in this respect it approaches *Machærodus*, as has been noted by Cope. Dentition $I^3/C^1/Pm^2M^1/$. The species is known only from a skull.

Length of skull, condyles to premaxillary border, 120mm

There are thus six species of *Hoplophoneus* disregarding, *H. strigidens* Cope, which being known only from a fragment of a canine which presents an unusual form, is not characterized by any features which refer it to that genus rather than any other. The series of skulls figured in Plate XI show a great variation in size and a study of the skeletons shows a like variation.

The Dinictis Series.

Dinictis felina Leidy.

This is the type species of the genus and is well known from the original description by Leidy, and the osteology by Scott. A summary of its essential differences from *Hoplophoneus* is given in this paper, consequently no further discussion will be given here. The skull figured is a well preserved specimen in the Princeton Museum (number 10972). Dental formulæ $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{2}$.

Length of	skull, condyles to premaxillary border,	163mm
"	humerus	172
"	femur	190
"	tibia	168

Dinictis squalidens Cope.

This species was first described from a portion of a deciduous superior canine and a fragment of a mandible supporting the deciduous dentition. Later a mandible containing the permanent dentition was referred to it. The skull figured in the series (number 11379 in the Princeton Museum) contains the permanent dentition except the superior canines, which are just on the point of being replaced. Its reference to *D. squalidens* from the character of the mandible is not to be doubted. The specimen although immature is considerably smaller than *D. felina* and differs from it sufficiently to warrant its reference to a distinct species.

Length of skull, condyles to premaxillary border, 140mm

Dinictis fortis Adams.

This species was described principally from a skeleton. *D. bombifrons*, which, was described from a skull, has since been determined to be a synonym of the former (Amer. Nat., January, '96, p. 50, foot-note). Further material has shown *D. fortis* to be quite distinct from *D. felina*, and now that the skull is known the species may be considered as established. The skull here figured is the one originally described as *D. bombifrons.*

Length of	skull, condyles to premaxillary border,	185mm
"	humerus	192
"	ulna	191
"	femur	205
"	tibia	186

D. cyclops Cope.

With this species we take up the John Day forms. The outline drawing here given is from the type skull figured by Cope. The striking features of it are its convex profile, the round orbit and the short temporal space. In a general way it is comparable with *Hoplophoneus cerebralis*, also from the John Day.

Length of the skull condyles to premaxillary border, 150mm

Dinictis brachyops (*Pogonodon brachyops* Cope).

As will be further pointed out in this paper, *Pogonodon* must be considered as a synonym of *Dinictis*. The tooth structure is identical and the dentition differs only in the absence of the second inferior molar, the reduction of which is indicated in other species of *Dinictis*. The figure given in the series is from the fragments of the skull described by Cope. The posterior portion of the skull is reversed and the restoration of the outline is conjectural. The skeleton is in part known and is very Dinictis-like. This species is from the John Day.

Dinictis platycopis (*Pogonodon platycopis* Cope).

This is the largest of the series and with it is probably reached the culmination of the *Dinictis* type as regards size. The profile of the skull was probably more convex than is indicated in the figure, which is taken from Cope's Tertiary Vertebrates, since the specimen is slightly crushed. It is comparable with *H. occidentalis* although exceeding it in size. The skeleton is not known. The type specimen is from the John Day.

Length of skull, condyles to premaxillary border, 235^{mm}

The foregoing series of *Dinictis* species, of which the skulls are figured in Plate XII, although less perfectly known than the *Hoplophoneus* series, is comparable with it. The genus *Dinictis* stands ancestral to the genus *Hoplophoneus* and, from what we know, seems to have been more conservative. In both there is a striking gradation in size. *Hoplophoneus* is greatly diversified in the White River. *Dinictis* remains are not so abundant and three of the six species are known only from the John Day, while only one species of *Hoplophoneus* is known from that formation. The range of the species in so far as I can report them is expressed in the following table.

	White River.			John Day.
	Titanotherium Beds.	Oreodon Beds.	Protoceras Beds.	
Dinictis fortis	×	×		
" felina		×	×	
" squalidens		×		
" brachyops				×
" platycopis				×
" cyclops				×
Hoplophoneus primævus		×		
" oreodontis		×		
" robustus		×		
" insolens		×	×	
" occidentalis		×		
" cerebralis				×

Nomenclature and Synonyms.

The following short account of the history of the genus *Machærodus* may not be out of place here, since this genus gives its name to a subfamily and its priority seems to be somewhat questioned.

Isolated teeth were first noticed by Cuvier in 1824, to whom specimens discovered in the Vald' Arno were exhibited by Nesti. From evidence relative to their association with remains of *Ursus*, Cuvier was induced to refer them to that genus under the name *Ursus cultridens* (Supplement to Ossamens Fossiles, vol. v, Pt. ii, p. 517). The first description is due to Nesti, according to M. de Blainville, who cites his "Lettera terza dei alcune ossa fossile non peranco descritte al Sogn. Prof. Pali Savi, Pisa, 1826," in which the name *Ursus trepanodon* is used, whence later the genus *Drepanodon*, from the species name *trepanodon*, was evidently made. Later M. Bravard described *Felis meganteron* (now known as *Machærodus meganteron*) and conjecturally restored a portion of a skull by adding to it a canine of the character previously described as *Ursus cultridens*, referring it to the genus *Felis* under the specific name *cultridens* proposed by Cuvier (Monograph de deux Felis, p. 143, 1828). Kaup in Description d'Ossemens fossiles der Muséum de Darmstadt, 1833, laid stress on the differences which the falciform canines present as compared with known bears and felines, pointing out their differences from the teeth of other carnivores in the curved form and denticulate margins and proposed a distinct genus, *Machærodus.* An associated incisor he referred to a new genus *Agnotherium*, not recognizing that it probably belonged to the same individual. The real affinities had been recognized by Bravard, but Kaup was the first to propose a generic name for this type of dentition.

In De Blainville's Osteographie, under a description of *Felis meganteron* (*Machærodus meganteron*), a very full discussion is given in which he presses Bravard's claims. Pomel has also sought to substitute the species name *meganteron* for Kaup's *Machærodus.* Finally Bronn in *Lethea Geonostica* has attempted to combine *Smilodon* Lund, and *Machærodus* Kaup under the generic name *Drepanodon*, using Nestis' species name.

The first Machærodont fossil found in North America was described by Leidy and Owen as *Machærodus primævus.* Later Leidy used for this species the generic name *Drepanodon.* Likewise Cope first described species under this genus *Machærodus.* Later, however, he removed them all to new genera. In referring to European species he used the genus *Drepanodon* with *Machærodus* as a synonym, but retained *Smilodon* as a distinct genus (Extinct Cats of North America, Amer. Nat., 1880).

It has not been definitely shown as yet that there are any representatives of the genus *Machærodus* in North America. In the American Naturalist, 1887, Cope proposed *M. catacopis* on the anterior portion of a mandible having a moderate flange and containing the roots of the incisors and a canine with a posterior denticulate border. It is not distinguishable from *Hoplophoneus* however. Cragin in Science, 1892, proposed *M. crassidens* on feline remains from the same beds and Williston has since (Kansas University Quarterly, 1895) referred other bones from the same locality to this species. None of the species can be said to be established as belonging to the genus *Machærodus* since the generic characters of dental formula, structure of the molar series and the basi-cranial foramina are not determinable in the specimens thus far found in the Loup Fork.

Smilodon is distinctively an American genus. It was established by Lund, 1842, on a specimen from Brazil (*S. neogaeus* K. Danske Vid. Selsk. Copenhagen). Leidy described a fragment of a maxilla containing a sectorial under the name *Trucifelis fatalis*. In structure the tooth agrees with *Smilodon* and a second specimen induced Cope to refer it to that genus. *Smilodon floridanus* Leidy is known from a well preserved skull from which the teeth have been lost.

The genus *Eusmilus* was established by Gervais (*E. perarmatus*, Journal de Zoologie, 1875). Previously Filhol had described *M. bidentatus*, which is synonymous, consequently Gervais genus and Filhols species are accepted.

Dinobastis Cope, although founded on very limited material, will probably prove to represent the latest development of the Machærodont type in North America. The genus is based upon the absence of the internal root of the superior sectorial.

The genus *Dinictis* has remained well defined since first proposed by Leidy. To it, however, should be referred the two species of *Pogonodon* described by Cope. The genus *Pogonodon* as proposed by Cope does not differ from *Dinictis* as regards tooth structure, and the absence of the second inferior molar, which in *Dinictis* is much reduced, is not sufficient grounds for retaining it as a distinct genus, since in several specimens of *Dinictis* it is variable in size and in one is absent from one side. The genus *Dinictis* as thus constituted shows the reduction of this tooth, just as *Hoplophoneus* shows the reduction of the superior premolar.

The genus *Hoplophoneus* proposed by Cope embraces, besides new species, others previously described under the generic names *Machærodus* and *Drepanodon.* *Dinotomius atrox* Williston is a synonym of *H. occidentalis*, as has been shown by the writer (Amer. Nat., January, 1896).

The genera *Archælurus* and *Nimravus* have remained as first defined.

Our knowledge of North American fossil forms of the true Felinæ is very limited. Leidy has described *Pseudælurus intrepidus*, referring it to the European genus established by Gervais. There are several imperfectly known species of *Felis.* Leidy has described *F. atrox* and *F. augustus.* *Felis imperialis* Leidy is not sufficiently characterized to be retained. Scott has described ? *F. maxima* from a humerus found in the Loup Fork of Kansas. It will be remembered that remains from that deposit have been described under the genus *Machærodus*, and it is not probable that this humerus belongs to a different genus although further material must be found before the affinities of these forms can be determined. The genus *Uncia* Gray cannot be distinguished with certainty in fossil forms and is here included in *Felis.*

The Dentition of the Felidæ.

The modifications of the dentition of the Felidæ consist, on the whole, of the reduction of the number of teeth until almost the entire function of the molar series is performed by a single large sectorial in each jaw and, accompanying the reduction in number, an increase in size and complexity of structure whereby the individual teeth become more perfect-cutting instruments.*

The specialization of one tooth as a sectorial to the exclusion of the others appears to be due to the following causes. It is to be observed that when a cat devours a carcass it cuts off masses by a shearing action of the jaws. In so doing the part to be divided is brought to the canthus or angle of the soft wall of the mouth, which is just at the front of the masseter muscle, at which point the greatest amount of force is gained, since the weight is brought immediately to the power. The first inferior molar situated at this point can be most effectively used and has developed into a sectorial. Inasmuch as the inferior and superior teeth do not directly oppose each other but form an alternate series, the first inferior molar more nearly opposes the last upper premolar and this tooth has become the superior sectorial. The shortening of the jaw which accompanied the reduction of the molar series has brought the canines nearer to the powerful muscles of mastication and they are as a result more effective weapons in the Felidæ than in other carnivores.

* Origin of Specialized Teeth of the Carnivora, Cope, Amer. Nat., p. 171, 1879; Mechanical Genesis of Tooth-forms, Ryder, Proc. Acad. Nat. Sci., 1878.

The cause of the reduction of the molar series seems to lie in the following facts. If the jaws of one of the primitive Felidæ are examined it will be found that when they are closed the teeth which first come in contact are the sectorials, because of their elevated crowns. The premolars being further from the condyles are the last to come in contact. The function of seizing and holding is performed by the greatly developed canines and the function of cutting by the sectorials, hence no important function devolves upon the anterior pre-molars and posterior molars. Inasmuch as the lower series bite in front of the upper, it will be seen that the last inferior molar and the first superior premolar are only partially opposed by the teeth of the opposite series, consequently they are less functional and are the first to disappear.

The most primitive form of superior sectorial among the Felidæ consists of a principal, posterior, and antero-internal cusps, as is seen in *Dinictis*. To this form there is added in *Hoplophoneus* an incipient anterior basal cusp which in *Machœrodus* is well developed. In *Smilodon* there is a second anterior basal cusp. The internal cusp present in *Dinictis* disappears in later genera, where it is represented only by a convex buttress, which descends from the principal cusp, and, as a more perfect shearing action is developed, this becomes less prominent until in *Dinobastis* it is absent and the internal root which supported it is lost.

The inferior sectorial in the most primitive genera consists of a principal, anterior, posterior and postero-internal cusps. The fate of the internal cusp is similar to that of the internal of the superior sectorial. Since it meets with no opposing cusp it is soon lost. The posterior cusp or heel is reduced in genera in which the superior molar is rudimental and does not oppose it. In *Eusmilus dakotensis*, it becomes a mere sharp line on the posterior border of the principal cusp. The function of the inferior sectorial devolves chiefly upon the principal and anterior cusps, which are well developed.

As the number of teeth was reduced the individual teeth become larger and the premolars developed posterior basal cusps by the elevation of the cingulum, as is seen in *Felis*. The incisors also became more robust in the Machærodont genera. In *Dinictis* they are small and form an even series. In *Hoplophoneus* they are more robust, and in *Dinobastis* we see their most specialized form. In this genus they have minute basal cusps and their margins are crenulated.

The development of saber-like canines characteristic of the Machærodont type is easily traced in *Archœlurus*, in which the inferior and superior canines are sub-equal; in *Ælurogale*, where the posterior border is denticulate, and then in *Dinictis*, where both the anterior and posterior borders are denticulate.

With the higher genera they attained an enormous development, such as would seem to have been a positive hindrance in biting and seizing. In the true cats the canines remained sub-equal although developing to a great size.

The development of a flange on the anterior inferior portion of the mandible is to be correlated with the lengthening of the superior canines. Its function seems to have been to protect these teeth, but in the latter genera the length of the flange evidently was not as great and the canines extending below the mandible were effective weapons when the mouth was closed. The most primitive forms probably possessed no flange since the canines were short and sub-equal. In *Archælurus* we see the first indication of a developing flange in the obtuse angle of the mandible and the shallow fossa in which the superior canine rests.

The evolution of the Felidæ is best indicated in the characters of the dentition. It is upon the dental formulæ and dental structure that generic distinctions rest, and a careful study of these points will reveal the genetic and phylogenetic relationships of the family.

The Succession of Genera.

There are two distinct types of development among the Felidæ. Of these the Machærodont type seems to have had its origin in America, since with the exception of *Ælurogale* and possibly *Machærodus* all the genera have been found here. The Old World was probably the home of the true cats, as it seems to be to-day. The only representative of them in America previous to Pliocene times was *Pseudælurus*, of which genus only one specimen has thus far been found. This genus may have been acquired through Oligocene intermigration, and the genera *Ælurogale* and *Machairodus* are probably European descendants of American forms.

Any attempt at a phylogenetic arrangement of the Felidæ must coincide with the occurrence in time, the order of reduction of the dental series, and the development of the individual teeth, particularly the sectorials. It is proposed herein to show that there is a succession of genera of the two types above mentioned which meets these requirements.

Of the Machærodont type the somewhat problematical form from the Bridger described by Wortman as ? *Patriofelis leidyanus* is the most primitive. From it *Dinictis** is derivable, through the reduction of the size of the postero-internal

* *D. fortis* has been described as having the second lower molar very rudimental. In a specimen in the American Museum this tooth is absent from one side. In *D. paucidens* described by Mr. Riggs in the Kansas University Quarterly, April, 1896, it is absent from both sides. The dental formula of *D. fortis* is thus M $\frac{1}{2-1}$, *D. paucidens* probably being a synonym.

cusp of the inferior sectorial and a modification of the heel. Thus is reached the most primitive species of the genus. Within the limits we can trace the reduction of the second inferior molar from a small two-rooted tooth to a mere tubercle and finally find it entirely absent in *D. platycopis*. The genus *Hoplophoneus* is well separated from *Dinictis* through the development of an anterior basal cusp on the superior sectorial and the loss of the internal cusp. The internal cusp had already shown some signs of reduction in certain specimens of *Dinictis* in that it had become lower and less distinct. Moreover, *Hoplophoneus* has lost the second inferior premolar and within the genus we can trace the reduction and final disappearance of the second superior premolar. The postero-internal cusp of the inferior sectorial, which had shown signs of variation in *Dinictis*, is absent in the higher species of *Hoplophoneus*. The rapidly diminishing dental series reaches its maximum reduction in *Eusmilus*. Of this only the inferior dentition is known. It differs from *Hoplophoneus occidentalis* in the loss of an incisor, the reduction of the heel of the sectorial in *E. bidentatus* and its absence in *E. dakotensis*. This is the only genus in which the incisors have suffered a reduction in number, although in some specimens of *Hoplophoneus* the internal ones are much reduced.

With the formula $I\frac{3}{3}C\frac{1}{1}Pm\frac{2}{2}M\frac{1}{1}$ the most stable form of Machærodont dentition seems to have been reached, since it has given rise through the addition of basal cutting lobes to genera which persisted until Pleistocene times. The genus *Machærodus* differs from the genus *Smilodon* in having a second basal lobe developed on the molar series. They are further distinguished by the fact that in *Smilodon* the post-glenoid and post-tympanic are coössified. The absence of the entepicondylar foramen in the specimen of *S. necator* figured by Cope* cannot be considered of generic importance since Burmeister has shown that it is present in three specimens which he has described.† Its absence in the case above mentioned is probably due to individual variation. The most specialized genus as regards the structure of the teeth is *Dinobastis*. In *Hoplophoneus* the internal cusp of the superior sectorial has disappeared and the root supports a convex buttress. This is also the case in *Machærodus* and *Smilodon*, but in *Dinobastis* even the internal root has disappeared. The incisors also present a peculiarity, which is seen in some specimens of *Machærodus* and *Smilodon*, in the possession of minute basal cusps and crenulate margins. With this genus the Machærodonts culminated in specialization of tooth structure as they did in

* Amer. Nat., 1880, p. 857.

† Description physique de la Republique Argentine, Text in Atlas, p. 106.

Eusmilus in the reduction of the dental series, and with this form they become extinct although it is probable, judging from fossil remains, that the dominant genus in Pleistocene times was *Smilodon.*

The genera *Archælurus*, *Ælurogale* and *Nimravus* seem to represent specialized forms of more primitive genera, forming a side line of development. Of these *Archælurus* is most primitive. It is not directly derivable from any known form nor does it stand ancestral to the genera of Machærodonts previously discussed. The superior sectorial consists of a principal and a posterior cusp. There is a slight convexity in the position occupied by the anterior basal cusp in *Hoplophoneus.* The same thing is seen in *Nimravus*, but it does not develop into a true cusp. The principal cusp has a convex internal buttress as in *Hoplophoneus.* The inferior sectorial consists of an anterior, principal and posterior cusp or heel. From this genus *Ælurogale* could be derived by the loss of the first superior premolar. There is also a different development of the canine, the tooth becoming longer, recurved and acquiring a posterior denticulate margin. *Nimravus* differs in dental formula from *Ælurogale* in the loss of the second inferior premolar. The canine, however, is the most striking feature of this genus: it is nearly straight and spike-shaped, a form which is seemingly not derivable from *Ælurogale* but rather from *Archælurus.* *Ælurogale* is a European genus and although indicative of the order of reduction of the teeth in this small and seemingly aberrant group, it cannot be said to occupy an intermediate position between the other two genera. These three genera differ from other Machærodonts in the order of reduction of the teeth, all having retained the second inferior molar. This tooth is, however, on the point of disappearing in *Nimravus*, as is indicated by its absence on one side in a second specimen of *N. gomphodus.* *Archælurus* exhibits a peculiarity which should not be overlooked, in the strange deflection or exostosis of the border of the mandible posterior to the molar series. Of this a trace is seen in *Nimravus.*

Of the true cats there is but one genus which is known only as an extinct form, namely *Pseudælurus.* *Felis*, *Lynx* and *Cynælurus*, however, are known as fossils. *Pseudælurus* presents the most primitive dental formula and one which can be compared with *Dinictis* as regards tooth structure, but it differs in the absence of the second inferior molar. *Pseudælurus* probably gave origin to *Felis* through the loss of the second inferior premolar. *Cynælurus* differs from *Felis* in the absence of the internal cusp of the superior sectorial and the somewhat imperfect retractility of the claws. It forms a side development from the main line of descent. In the genus *Felis* there is a tendency to the loss of the second superior premolar, it frequently being absent in old individuals. and thus is indicated the probable derivation of the genus *Lynx.* This genus occasionally loses the superior molar and so in exceptional cases we arrive at a dentition comparable with that of *Eusmilus*, the extreme reduction, however, taking place in the other jaw. In several species of *Felis* posterior cutting lobes are added to the premolars and an anterior basal cusp is indicated on the superior sectorial. Comparing the dentition with that of *Machærodus* or *Smilodon*, it differs in the retention of the internal cusp of the superior sectorial and the presence of an additional superior premolar.

Phylogeny of the Felidæ.

Present systems of classification.

Cope, in his publication on the "Extinct Cats of North America,"* has based his classification upon the basi-cranial foramina, making two families, the Felidæ and Nimravidæ, according to the following definitions.

Felidæ.—No distinct carotid foramen nor alisphenoid canal, condylar foramen entering the foramen lacerum posterius. No post-parietal and generally no post-glenoid foramina.

Nimravidæ.—Carotid and condylar foramina entirely distinct from the foramen lacerum posterius; an ali-sphenoid canal and post-glenoid and post-parietal foramina.

This classification includes Machærodont members in each family. *Procælurus* is considered as the genus from which the true Felidæ may have been derived through *Pseudælurus*, if indeed these two genera are not the primitive members of that family. The Machærodont members of the Nimravidæ are suggested as the ancestors of the Felidæ. It should be remarked here that Cope's classification, based upon structural characters, does not permit of a phyletic interpretation, since the families as constituted by him are of polyphyletic origin as I interpret his meaning.

Zittel† establishes three subfamilies, the Proælurinæ, Machærodinæ, and Felinæ, defining them as follows:

Proælurinæ.—Dental formula $\frac{3}{3}$, $\frac{1}{1}$, $\frac{4}{4}$, $\frac{1}{2}$, lower carnassial with strong cutting talon skull elongated. Lower jaw slender, small in front with curved lower border; long-legged, fore and hind feet semi-digitigrade and pentadactyl.

Machærodinæ.—Dental formula $\frac{3}{3-2}\ \frac{1}{1}\ \frac{4-2}{3-1}\ \frac{1}{1}$. Upper canine large and powerful, saber-shaped, compressed with anterior and posterior cutting edges. Front pms more or less reduced.

*Cope, Amer. Nat, 1880, p. 834.

† Handbuch der Paleontologie, 1893.

Upper carnassial with or without anterior basal cusp. Lower carnassial with talon. Lower jaw flattened at symphysis and separated from the lateral face by an angle. Lower border straight, more or less flared down in front. Femur frequently with third trochanter.

Felinæ.—Dental formula $\frac{3}{3}$ $\frac{1}{1}$ $\frac{2-3}{2-3}$ $\frac{1}{1}$. Canine conical, upper and lower of about the same size; the two anterior pms lost. Upper carnassial with strong anterior basal cusp. Lower carnassial without talon. Upper molar reduced, lower one lost. Lateral surface of mandible not separated from the symphysis by an angle.

The Proælurinæ include *Proœlurus* Fil. and *Pseudœlurus* Gerv., but some doubt is expressed concerning the relations of *Proœlurus*. From the creodont *Palæonictis* he derives the Machærodinæ, using Wortman's* suggestion in this respect, while from an independent source in the Creodontia he derives the Cryptoprocta and Felinæ through *Proœlurus*.

Schlosser† in Affen Lemuren, u. s., in criticising Filhol, expresses the opinion that *Pseudœlurus edwardsi* is a true cat, while *Proœlurus*, *Pseudœlurus intermedius* and the problematical Cryptoprocta belong to another line. He points out clearly the Viverine relationships of *Proœlurus* and rejects it as a probable cat ancestor; otherwise he accepts Cope's classification of the Felidæ.

Proposed phylogeny.

As will be seen, these authors mutually criticise each other. The determination of the relationships of Proælurus removes the possibility of its being the ancestor of Pseudælurus and the true cats, as has been suggested by Cope, and also destroys the subfamily Proailurinæ as established by Zittel. The unusual method of classification employed by Cope and accepted by Schlosser in this family, whereby Machærodont genera are grouped with the true cats, is avoided by Zittel's subfamilies Machærodinæ and Felinæ. These two subfamilies are the equivalents of the Machærodontinæ and Felinæ proposed by Gill‡ and his classification is here accepted, since it has the priority, however referring *Cynœlurus* to the Felinæ, inasmuch as the separation into a distinct subfamily Guepardinæ cannot be maintained. The points upon which the Guepardinæ was established are the non-retractility of the claws and the absence of the inner cusp of the superior sectorial. The claws are retractile although less perfectly so than in other

* Wortman, Ancestry of the Felidæ, Bull. Ann. Mus., vol. iv, p. 94.

† Schlosser, Affen Lemuren, u. s., 1887, p. 420.

‡ Theodore Gill, Smithsonian Miscellaneous Collection, 230, Arrangement of the Families of Mammals, 1872.

Felidæ, and the absence of the cusp is not of sufficient importance, as would be judged by the absence of the same character in certain of the Machærodontinæ.

The subfamilies may be defined as follows, slightly modifying Gill's definitions:

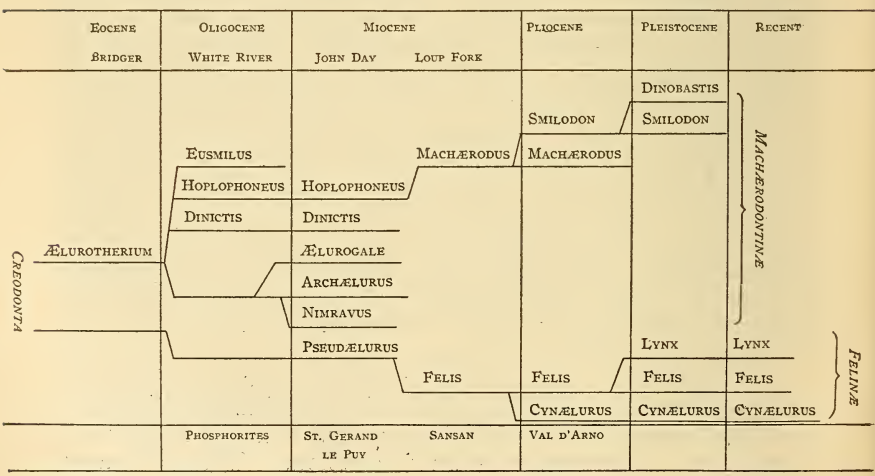
Machærodontinæ; superior canines large and powerful, usually saber-shaped with posterior and anterior denticulate borders, the inferior canine not greatly exceeding the outer incisor. Symphysial portion of the mandible separated from the lateral surface by an angle, the anterior inferior border of the ramus produced into a flange or making an obtuse angle with the symphysial portion.

Felinæ.—Canines sub-conical and sub-equal, inferior and lateral faces of ramus continuous with the symphysial.

The Machærodontinæ as thus constituted include a group which is in some respects intermediate between the two subfamilies but which do not stand ancestral to any genera of either of them and are not derivable from them. They are *Archælurus*, the European genus *Ælurogale* and the peculiar *Nimravus*. *Archælurus* and *Nimravus* have been called by Cope the "false-sabre-tooths." *Archælurus* in general appearance is very suggestive as to what was the probable ancestor of the Machærodontinæ, but its late appearance and specialized tooth structure show that it could not have given rise to any known form outside of the genera above mentioned. On the removal of the matrix from one of the specimens I found that the internal cusp of the superior sectorial is wanting in *Archælurus*. The same also proved to be true in *Nimravus*, although reported as present in each by Cope. Moreover the postero-internal cusp of the inferior sectorial is wanting in *Nimravus* and probably in *Archælurus*. Thus there is found to be the same tooth-structure in these two genera that is seen in *Ælurogale*. It is therefore demonstrated that although the dentitions of these genera are more primitive as regards numbers, they could not have given rise to other Machærodonts or to the Felinæ. These three genera are related in the order of the reduction of the dental series, the character of the mandible and the structure of the canines. The canines of *Archælurus* have a convex anterior border and a posterior cutting edge, but in its present state of preservation shows no signs of denticulations. The canine of *Ælurogale* has the posterior border denticulate. The peculiar spike-shaped canine of *Nimravus* is very suggestive that this genus marks the end of an aberrant phylum.

The subfamilies stand entirely distinct from each other and well separated from the Creodonts. In the subfamily Machærodontinæ there is, as has just been shown, a small group which stands in a peculiarly isolated position. There is, however, a specimen which may be considered as a probable ancestral form of all the Machærodontinæ and brings them a step nearer the Creodonts. It is the jaw fragment from the Bridger Eocene (number 11375 in the Princeton Collections) which Wortman has described as ? *Patriofelis leidyanus* (Am. Mus. Nat. Hist. Bull., 1892) as a probable connecting link between the Creodont *Paleonictis* and the Felidæ. A further knowledge of *Patriofelis* induced him to remove it from that genus (ibid., 1894). For the sake of reference I propose the generic name *Ælurotherium. Ælurotherium leidyanum*, following the description given by Wortman, consists of a jaw fragment containing the third and fourth premolars and the first molar or sectorial. It also bears a distinct trace of the alveolus for the canine, the position of which is such as to preclude the possibility of there being more than three premolars. The sectorial, as will be seen from a comparison with *Dinictis*, presents the same elements as that genus but has a much better developed postero-internal cusp and heel, thus fulfilling the requirement of an ancestral form. From what can be judged from the wear of the cusps and the relation of the teeth in the Felidæ it seems probable that it possessed the dental formula P$\frac{4}{3}$M$\frac{1}{2}$ as was inferred by Wortman, thus exceeding the dental formula of *Dinictis* by a premolar. It will be noted that the dental formula of *Ælurotherium* was probably more primitive than that of Archælurus, thus not precluding the possibility of its being ancestral to that genus also, although probably quite removed from it.

The following arrangement according to subfamilies expresses the probable line of descent of each as well as the occurrence in time of the various genera.



There is a point of difference among the two sub-families which should be discussed here. It is the character of the basi-cranial foramina which was made by Cope a basis of classification. The arrangement of the foramina and the presence of the alisphenoid canal as found in those genera which he made to constitute the Nimravidæ is such as is found in primitive forms. It is not unnatural that the higher forms should have paralleled each other in the loss of the alisphenoid canal and the disposition of the foramina, so that in *Smilodon* and *Felis* we find the same conditions although the two genera represent the most specialized forms of the phyla in which the basi-cranial characters are known. The two subfamilies exhibit a most remarkable parallelism in development. The point of divergence from a common ancestor is quite removed from the position by the most primitive of the well known genera. Indeed it is not impossible that the Felidæ may have had a separate origin from the Creodonts, but our knowledge of their early relationships is too meagre to justify any definite conclusions on this point. As we know them the phyla are distinct.

The following key for determining the genera of the Felidæ is submitted. *Ælurotherium* not being well known is contrasted with *Dinictis*, which it most resembles in the characters known. *Eusmilus*, being known only from the lower dentition, is contrasted with *Hoplophoneus*.

I. Superior canines large and powerful, usually saber-shaped with posterior and anterior denticulate borders. Inferior canine not greatly exceeding the outer incisor. Mandible with the symphysial portion separated from the lateral by an angle, the anterior inferior border of the ramus with a flange or making an obtuse angle with the symphysial portion.

MACHÆRODONTINÆ.

A. Anterior inferior border of mandible with an obtuse angle.

a. Superior sectorial without internal cusp.

a.a. Superior canine recurved posterior border, not denticulate.

1. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{4}{3}M\frac{1}{2}$ *Archælurus.*

b.b. Superior canine recurved posterior border, denticulate.

2. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{2}$ *Ælurogale.*

c.c. Superior canine spike shaped.

3. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{2}M\frac{1}{2}$ *Nimravus.*

B. Anterior inferior border of mandible with a flange.

b. Superior sectorial with internal cusp.

d.d. Inferior sectorial with strong postero-internal cusp and talon.

4. Dentition ? $I\frac{3}{3}C\frac{1}{1}Pm\frac{4}{3}M\frac{1}{2}$ *Ælurotherium.*

e.e. Inferior sectorial with small postero-internal cusp, talon reduced.

5. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{2-1}$ *Dinictis.*

c. Superior sectorial without internal cusp.

ff. Anterior basal cusp of superior sectorial, incipient premolars without basal cusps.

6. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3-2}{2}M\frac{1}{1}$ *Hoplophoneus.*

7. Dentition I/2C/1Pm/1M/1 *Eusmilus.*

d. Anterior basal cusp of superior sectorial well-developed, no internal cusp, premolars with basal lobes.

gg. Superior sectorial with single anterior basal cusp, post-glenoid and post-tympanic processes distinct.

8. Dentition $I\frac{3}{3}C\frac{1}{1}\ \frac{2}{2}M\frac{1}{1}$ *Machærodus.*

hh. Superior sectorial with a second anterior basal cusp, post-glenoid and post-tympanis processes coössified.

9. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{2}{2-1}M\frac{1}{1}$ *Smilodon.*

ii. Superior sectorial without internal root.

10. Dentition probably like *Smilodon*, *Dinobastis.*

II. Canines sub-conical and sub-equal, inferior and lateral faces of ramus continuous with symphysial.

Felinæ.

B. Anterior and inferior borders of mandible continuous.

e. Superior sectorial with internal cusp.

11. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{1}$ *Pseudælurus.*

12. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3-2}{3}M\frac{1}{1}$ *Felis.*

13. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{2}{2}M\frac{1-0}{1}$ *Lynx.*

f. Superior sectorial without internal cusp.

14. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{2}M\frac{1}{1}$ *Cynælurus.*

EXPLANATION OF PLATES.

Plate X.

Hoplophoneus primævus, all × ½.

Figure 1.—Skull (number 11013 Princeton Museum restored from number 10540.)
Figure 2.—Manus (number 10741 Princeton Museum.)
Figure 3.—Pes "
Figure 4.—Femur "
Figure 5.—Ulna and radius "
Figure 6.—Tibia and fibula "
Figure 7.—Humerus "

Plate XI.

Hoplophoneus series, all × ½.

Figure 1.—Hoplophoneus cerebralis (after Cope.)
Figure 2.— " oreodontis (10515 Princeton Museum.)
Figure 3.— " primævus (11013 Princeton Museum.)
Figure 4.— " robustus (650 American Museum.)
Figure 5.— " insolens (11022 Princeton Museum.)
Figure 6.— " occidentalis (after Williston.)

Plate XII.

Dinictis series, all × ½.

Figure 1.—Dinictis squalidens (11379 Princeton Museum.)
Figure 2.— " cyclops (after Cope.)
Figure 3.— " felina (10972) Princeton Museum.)
Figure 4.— " fortis (10502 Princeton Museum.) [reversed.)
Figure 5.— " brachyops (Cope's type, Amer. Mus., posterior portion
Figure 6.— " platycopis (after Cope.)

ART. L.—*The Age of the Igneous Rocks of the Yellowstone National Park*; by ARNOLD HAGUE, of the U. S. Geological Survey.

THE region embraced by the Yellowstone National Park and the adjoining country to the north and east, has been a center of great volcanic activity. By far the greater part of the surrounding mountains, and the entire park plateau, have been built up by the pouring out of vast accumulations of volcanic material. The region, throughout Tertiary time, was undoubtedly the most active center of eruptive energy to be found in the northern Rocky Mountains.

Under the authorization of the U. S. Geological Survey, aided by an able corps of assistants, I have carefully studied the geological history of volcanic eruptions in the Park country, and the order of succession of the different masses of lavas which make up this enormous body of igneous rocks. To a proper understanding of the geological relations of these volcanic lavas to the earlier crystalline and sedimentary rocks, as well as their relations to the pre-existing mountain ranges, a brief sketch of the geology of the country seems necessary.

In all the mountain ranges which surround and shut in the park, at least a nucleus of highly crystalline rocks of Archean age is exposed. The Tetons, to the south, consist mainly of an Archean mass, which towers high above all later rock formations. In the Absaroka range, stretching along the entire east side of the park and formed mainly of igneous rocks, granites and schists are exposed at the northern end, which soon pass between the later lavas. The Snowy range, which shuts in the park on the north, is largely made up of Archean schists, gneisses and granites, associated with the more recent outbursts of lava. In the Gallatin range, on the west, a body of crumpled gneisses and schists form the nucleus around which have been built up a complex mountain structure, in which the volcanic rocks play an important part in the structural features of the mountains. Resting unconformably upon these Archean bodies, which formed either a broad continental mass, or a group of closely related islands, occurs a great thickness of sedimentary beds, made up in greater part of material derived by the slow processes of denudation of the earlier continental land surfaces. These sediments, thus slowly deposited, built up during Paleozoic and Mesozoic times a series of sandstones, limestones, and shales conformable from base to summit. The basal beds, resting directly upon the Archean rocks, consist largely of siliceous material, passing gradually over into a shaly limestone, carrying a fauna characteristic of the Middle Cambrian period. These beds have been designated the Flathead formation. Above these beds, in their regular order of succession, come the Upper Cambrian, Silurian, Devonian, Carboniferous, Trias, Jura, and every grand division of the Cretaceous recognized in central Montana and northern Wyoming, including the Dakota, Colorado, Montana, and the Laramie sandstone at the top.

The Montana formation exhibits throughout its entire development a singularly uniform sandstone epoch, the argillaceous beds of the Pierre shales being poorly represented other than by a great thickness of arenaceous deposits. The overlying Laramie, on the other hand, although essentially a sandstone-making epoch, indicates frequent and abrupt changes in its sedimentation. Constantly changing beds of shales, clays, and impure standstones, afford abundant evidence in their mode of occurrence, that the material forming the beds was deposited in a shallow sea. With the close of the Laramie sandstones, the conformable Paleozoic and Mesozoic strata came to an end. The entire region was again elevated above the sea. The sedimentary beds were everywhere uplifted, and very large areas tilted up at high angles. A profound orographic movement took place and the region became one of mountain building on a grand scale, accompanied by plication, folding, and faulting. It was this movement that blocked out the mountains which surround the Yellowstone Park plateau, and indeed all ranges of the northern Rocky mountains. It has been designated the post-Laramie movement. This orographic disturbance was doubtless coincident with the similar movements described by Mr. S. F. Emmons as clearly defined in Colorado, though in the northern country no unconformities such as have been noted to the southward, have as yet been definitely recognized between the Middle Cambrian and the Laramie, as described by Mr. Emmons.* This limitation of the Laramie formation to the beds at the top of the upturned conformable series of sediments, is the line of demarcation first proposed by Mr. Clarence King.† It is in accord with the great physical break which played so important a part in the building up of the northern Rocky Mountains, and brought to a close a period of a distinctly marine or brackish fauna.

In this region there are no evidences that igneous rocks played any part during Paleozoic and Mesozoic times, prior to the post-Laramie movement. There are no intrusive masses nor interbedded flows contemporaneous with the deposition of

* Orographic Movement in the Rocky Mountains, S. F. Emmons, Bull. Geol. Soc. Amer., vol. i, 1890.

† U. S. Exploration of the 40th Parallel, Systematic Geology, vol. i, p. 357.

sediments, nor are there any beds derived wholly, or in part, from volcanic material of later age other than the eruptive masses of the Archean. On the other hand, as will be shown later, closely following and possibly coincident with the Laramie uplift, came the first outpouring of igneous rocks, which, beginning in late Cretaceous time, continued throughout a long period, lasting till near the close of Tertiary time. With the blocking out of the mountains, which accompanied the post-Laramie movement, a largely increased continental land area was formed. Coincident with this elevation of the land, denudation of the continental mass began, and deposition of fresh sediments uncomformable to the uplifted Laramie took place. Within the park region such sediments, if deposited, were either carried away by erosion or buried beneath outflows of later igneous rocks.

Along the northern slopes of the Snowy range, about 45 miles north of the park, these post-Laramie sediments were deposited several thousand feet in thickness under conditions singularly favorable for their preservation.

The lowest rocks resting directly upon these upturned sedimentary beds, are largely composed of friable sandstones derived from the degradation of the Laramie strata. They are soon followed by sands, conglomerates, clays, and grits, varying greatly in texture in different localities, and consisting mainly of material derived from the disintegration of igneous rocks. In places, they consist almost wholly of coarse, acid, andesitic agglomerates, which attain a development of nearly 2,000 feet in thickness.

The volcanic nature of the great body of this material was recognized by Mr. Walter H. Weed,* who first carefully studied it, and this view has been generally accepted by all geologists who have since visited the region. According to Mr. Weed, the beds reach a maximum development of nearly 7,000 feet. He has proposed to designate them as the Livingston formation, after the town on the Yellowstone river where they are well exposed.

Since their deposition the Livingston beds have been uplifted and now lie inclined, dipping away from the mountains, having taken part in subsequent orographic movements which elevated the Rocky Mountains. The limited invertebrate fauna obtained from these beds is as yet too restricted to be of any special value in determining the geological position of the terrane. As regards the flora, however, the collections which have been made from time to time, are more satisfactory and definite as regards specific characters, and Prof. F. H. Knowl-

* The Laramie and Overlying Livingston Formation in Montana, U. S. Geol. Survey Bull., 105.

ton has been able to determine a distinct Livingston flora higher than the Laramie, but far more closely allied to a Cretaceous than a Tertiary flora. The importance of the Livingston formation in the geological history of the region can hardly be over-estimated, from the fact already pointed out that it is the earliest occurrence of an accumulation, either wholly or in part, of volcanic material following the uplift of the Paleozoic and Mesozoic beds.

To the east and north of the Livingston formation, but farther removed from the mountains, occurs a still later series of beds made up of the disintegrated sediments of the earlier rocks, including those of the Livingston formation. Apparently they are identical in age with similar deposits found near the junction of the Missouri and Yellowstone rivers, where they in all probability lie upon the Laramie sandstones without the intervention of any beds referable to the Livingston formation; at least, the latter have not as yet been recognized in this locality. These beds along the Missouri and Yellowstone rivers have long been designated as the Fort Union formation, and have also been of special interest on account of their varied fossil flora, first carefully described by the late Prof. J. S. Newberry. This Fort Union flora is now generally regarded as of Eocene age.

Returning to the immediate region of the Yellowstone Park, the Laramie sandstones are found at a number of localities, but neither the Livingston nor Fort Union beds are exposed, and if ever deposited, have been removed by erosion or buried beneath later igneous outflows. Subsequent to the post-Laramie movement and after a very considerable erosion of the uplifted sandstones, volcanic action broke out with great energy in the Park country. From numerous centers of eruption lavas were thrown out, submerging broad areas of country. Volcanoes of great size surrounded the Park on the east, north, and northwest. The Absaroka Range was built up by the pouring forth of vast accumulations of volcanic ejectamenta, burying the greater part of the earlier range beneath many thousands of feet of accumulated lavas. These volcanoes followed the lines of orographic movement which took place at the close of the Laramie, along what are now the Absaroka, Snowy, and Gallatin ranges. To-day, this ancient center of eruption lies in the interior of the continent just eastward of the continental watershed which separates the waters of the Atlantic from those of the Pacific, but at the time this vast body of lavas was ejected, they built up a remarkable chain of coast volcanoes along the western shore-line of a gradually retreating ocean.

This volcanic energy continued throughout a long period of time with intervals of comparative rest, as shown by the evidences of erosion of the ejected material, and followed by renewed activity in the outpouring of fresh lavas. In many localities in the world the age of volcanic flows has been more or less definitely determined by the fortunate preservation of a fauna or flora in some lake beds formed in a depression or basin in the volcanic rocks, and these again preserved by beds of later compact lava or mud flows. These in a number of instances determine the age of the underlying and overlying flows, but are of slight value in determining the relative age of other eruptions in the adjoining regions. It is doubtful if any region in the world furnishes a more complete geological record of volcanic eruption from beginning to end throughout so long a period of time as the Yellowstone Park and the adjoining mountains.

As regards the problem connected with the relative age of the different masses of igneous rocks, the prosecution of the work has been greatly advanced by the field study of the so-called fossil forests and the many localities where a varied flora has been well preserved in the tuffs and waterlain deposits. The mode of occurrence of the beds carrying a fossil flora has been carefully examined and large collections made from time to time. Prof. Lester F. Ward and Prof. F. H. Knowlton passed the season of 1887 in the Park. In the following year, Professor Knowlton accompanied me to the field for the purpose of collecting from all the known localities, adding largely to the store of material previously obtained. All these collections were submitted to him for study, and his results when published will form an important chapter in the monograph upon the Yellowstone Park, soon to be published by the U. S. Geological Survey.

All references in this paper to the genera and species found here are based upon the identifications of Professor Knowlton.

The oldest extrusive flows recognized in the Park are a series of light-colored coarse breccias and fine tuffs composed of hornblende-andesite, and hornblende-mica-andesite, varying greatly in texture and physical habit, but grouped together under the general description of early acid breccias and flows. It is evident that they were thrown out from different centers of eruption, and in every instance, so far as can be told, they were the earliest eruptions from those recognized centers. In general, these early acid breccias occur as relatively small isolated bodies exposed by erosion of the later rocks. In this way they occupy the bottom of the deep valley of Cache Creek in the Absaroka Range, they are found in the deeper gorges of Tower Creek basin, and are found as far westward as Sepulchre Mountain. They are, however, best exposed in the northwest corner of the Park on both sides of the Yellowstone River, where the overlying lavas have undergone the greatest amount of denudation. Here they rest directly upon the Archean rocks of the Snowy Range, and in sharp contrast to the later lavas carry a large amount of crystalline gneisses and schists imbedded in the breccias. On Crescent Hill, just south of the Yellowstone River, these early acid breccias are well shown over 1,000 feet in height, in a steep slope facing northward. The finer tuffs, ashes, and mud flows have afforded exceptionally favorable conditions for the growth and preservation of a rich and varied flora. At Crescent Hill, Elk Creek, and on both banks of the Yellowstone River, below the mouth of Elk Creek, large collections of plant remains were obtained, which have since been studied by Professor Knowlton. From this abundant flora he has identified 79 species, of which 42 species are either new to science or now specifically determined. Of the remaining 37 species that have been found elsewhere, 17, or nearly one-half of them, are already known in beds belonging to the Fort Union formation. Of the remaining species, 5 come up from the Laramie, 5 are found in the Livingston and Denver beds, and 11 species are also common to the Auriferous Gravels of California. This flora from the acid breccias is otherwise so closely allied to early Tertiary forms that Professor Knowlton has no hesitation in referring the entire group to the Eocene period, and correlating it with the Fort Union horizon.

The following characteristic species have been determined from the acid breccias: *Sapindus offinis*, *Cornus acuminata*, *Populus speciosa*, *Sequoia couttsiæ*, *Asplenium magnum*, *Taxites ulriki*, *Populus daphnogenoides*, *Populus xantholitheusis*, *Betula iddingsii*, *Fagus undulata*, *Aralia notata*. This reference to the Eocene is in accord with the geological evidence which makes these andesitic lavas carrying the flora younger than the Livingston formation, and among the earliest of the extrusive rocks of the Park.

Overlying this group of early acid breccias comes a great accumulation, in places several thousand feet in thickness, of volcanic ejectamenta, and also like the earlier rocks, made up of coarse and fine material presenting great differences in texture and physical habit, whose character is determined in great part by their mode of occurrence and the distance from their sources of eruption. Like the early acid breccias, they have been grouped together into one series representing a distinct phase of the volcanic phenomena of the region. Unlike the earlier breccias, however, they are distinctly basic in composition and consist mainly of hornblende-pyroxene-andesites, pyroxene-andesites, and basalts.

By far the greater part of this erupted material is formed of coarse agglomerates, somber in color, with interbedded sheets of compact basalt varying in extent, and of greater or less thickness. These basic breccias cover large areas of country, extending from the Gallatin Range westward across the Snowy Range, along the nothern border of the Park. They constitute nearly all the northern portion of the Absaroka Range. Indeed, they may be said to cover the greater part of the northwest corner of the Park. Over this extensive area the basic breccias are only seen in a few localities resting directly upon the earlier acid rocks, but where exposed, they are for the most part easily recognized by their sharp contrast in color, texture, and mineral composition. In places along their contact the acid breccias show evidence of considerable erosion before the pouring out of basic flows, but in other localities they exhibit a transition from one series of rocks to the other and occasionally a mingling of both groups.

On the ridge about one mile south of Yanceys Station and within a short distance of Elk Creek, and again near Lost Creek, these basic rocks lie directly upon the acid rocks in a series of fine agglomerates and mud flows. The acid rocks present a very hilly and uneven surface, with the basic rocks frequently lying at a lower level and occupying depressions in the older lava.

Possibly in some instances erosion washed down the softer material from both series of rocks, causing a mingling of both acid and basic lavas, and rendering it impossible to discriminate between beds. Apparently similar conditions prevailed on the opposite side of the Yellowstone River along the northern escarpment of Specimen Ridge, extending eastward as far as Crystal Creek, where both series of rocks are again seen together. It is evident that the belt of country including the localities mentioned was at one time favorable to a vigorous and varied vegetable growth.

At a number of localities the same flora occurs, carrying well preserved leaf impressions, together with silicified trunks of trees still standing firmly planted in the muds and breccias.

The flora from this limited area contains 30 species, of which 18 are new to science. Only 2 of the new species are found in the acid breccias, and only 3 have been collected from the basic breccias. Nine of the species identified are common to both acid and basic breccias. Of the species previously described as occurring elsewhere than in the Park, most of them have a wide geological and geographical distribution, ranging from the Laramie well up through the Miocene. The following species may be mentioned as characteristic of this horizon: *Platanus montana*, *Quercus yanceyi*, *Laurinoxylon amethystenium*, *Populoxylon wardii.*

For the present this group of plant remains has been provisionally designated the intermediate flora, as according to Professor Knowlton, it possesses many distinct features of its own, yet appears as a transition flora between that of the acid rocks and the flora of the basic breccia which is of later age. This flora has been referred to the Lower Miocene.

Directly to the south of the region where both types of rock occur together, the acid breccias suddenly disappear, and later flows bury everything beneath an enormous mass of basic lava. In the deep ravines cut in the abrupt escarpments along the south and west side of Lamar Valley, lies the famous Fossil Forest of the Yellowstone Park. The ravines or gorges expose to view vertical sections nearly 2,000 feet in thickness across the bedded agglomerates, mud flows, and basalt sheets of these early basic breccias. From the base of the breccias as exposed along the valley, nearly to their summit on the top of Specimen Ridge the beds carry abundant evidences of an extinct fossil flora. They have so far yielded 70 species, more than one-half being new to science and described by Professor Knowlton for the first time. Those species that are identified as belonging to both the acid and basic breccias are mainly such species as have a wide geological distribution.

This flora Professor Knowlton regards as distinctly different from that of the acid breccias, and of much later age. In the identification of species and in its affinities it bears a close resemblance to the flora of the Auriferous Gravels of California. It has been referred to the Upper Miocene period, and named the Lamar flora. The following species are selected as characteristic of the Lamar horizon: *Platanus guillelmæ*, *Laurus californica*, *Magnolia spectabilis*, *Planera longifolia*, *Magnolia culveri*, *Aralia whitneyi.*

The flora presents many of the same general characteristics throughout the 2,000 feet of beds, which were derived wholly from eruptive material. It has been found impossible as yet to discriminate between the flora of the lowest beds and those at the top. This would indicate much the same climatic and physical conditions during the entire time required for the accumulation of such a mass of volcanic material with its accompanying flora buried beneath successive layers of tuffs and muds. That there were long periods of rest during the piling up of this material is evident from the great size of the trees, whose trunks are still standing at different elevations in the lavas.

On both sides of the Yellowstone, stretching from Crescent Hill to Junction Butte, occur several isolated exposures of an acid lava, remnants of a much more extensive body, the greater part of which has been carried away by erosion. Along the Yellowstone Valley denudation of the overlying material has been so excessive that the relations of these acid rocks to other igneous rocks are somewhat obscure. In many instances it would be impossible to make out their geological position, as they lie completely isolated from other lavas. In some instances they have been preserved from erosion by cappings of basalt, but the age of these basalt flows is by no means identical. They have been grouped together and designated trachytic-rhyolite, from certain resemblances in mineral composition to both these types of igneous rocks, although it can not be stated definitely that they all belong to the same period. For the present they have been correlated as being contemporaneous in age, and are regarded by the writer as of later age than the series of early acid and basic breccias.

As regards their geological relations to other eruptive masses and the general sequence of lavas, they play an unimportant part, and for the purposes of the present paper, which deals more especially with the age and duration of volcanic energy in this region, they are of slight interest, being limited in amount, covering small areas, and carrying no evidences of a fossil flora.

Resting directly upon the irregular surfaces of the early basic breccias comes a succession of distinctly bedded basalt flows, which in places have attained an aggregate thickness of nearly 1,000 feet. They cap several of the higher ridges of the Absaroka Range, and on the west side of the Lamar Valley west of the Range, they present a grand escarpment forming the abrupt wall of Mirror plateau. From this plateau the basalts stretch southward and eastward, sharply defining the series of early acid and basic breccias from later accumulations of igneous rocks. These basalts have been designated early basalt flows, as they mark a distinct period in the geological history of the volcanic eruptions, although flows of basalt frequently occur in the older breccias.

Following these early basalts comes a second series of acid and basic breccias similar in mode of occurrence, mineral composition, and in the varying manifestations of the different phases of eruptive energy. Apparently the centers of volcanic action moved southward and the later series of acid and basic breccias built up the western portion of the southern half of the Absaroka Range. Unlike the early acid breccias, the late acid breccias are not so deeply buried beneath the more recent lavas, but form the tops of several high peaks, and cover large areas along the summit of the range. The late basic breccias buried in great part the late acid breccias, and in turn built up the extreme southern end of the Absaroka Range, or at least that portion lying within the limits of the Yellowstone Park. The basic breccias stretch southward far beyond the boundaries of the park, and constitute the top of the Wind River plateau, which serves to unite the Wind River and Absaroka Ranges. In places the late basic breccias are shown in precipitous cliffs, exposing a thickness of over 2,000 feet of volcanic material. Unlike the early acid and basic breccias, neither the late acid nor basic breccias have as yet yielded any valuable contribution to our knowledge of an extinct flora. Fragments of silicified wood are common enough, but as yet no bed of tuffs or fragmental material has been found to carry a well-preserved flora. Occasionally fragmental impressions of stems, twigs, and leaves have been collected, but they are too poor for specific identification and of no special significance for comparative purposes. It may be said that the Absaroka Range has nowhere as yet afforded any important plant-bearing beds, the localities furnishing the material lying to the westward of the range.

Penetrating both the late acid and basic breccias, and consequently of later age, occurred extensive outflows of hornblende-mica-andesite. As these dense rocks withstand atmospheric agencies better than the underlying breccias, they often form the summit of isolated peaks in the more elevated portions of the range. These hornblende-mica-andesite flows denote a distinct period in the phases of volcanic phenomena in the Absaroka Range.

After the cessation of volcanic energy which built up the vast pile of andesitic and basaltic breccias and flows, a long period of erosion followed. An enormous amount of material was swept away. Broad valleys and deep canyons were carved out and the present mountains outlined somewhat as they appear to-day. Then with renewed activity volcanic eruption again broke out and immense masses of rhyolite were ejected. These rhyolite flows changed the depressed basin lying between the mountains which surround the Park into an elevated plateau, the lavas accumulating to a thickness of nearly 2,000 feet. The appellation of Park Plateau has been given to this striking physical feature which embraces an area not less than 50 miles in length and 40 miles in width. On all sides the lower slopes of the pre-existing ranges were buried beneath rhyolite, and in some instances the deeply eroded valleys in the andesitic breccias of the Absaroka range were partially filled by the later rock. Underlying the rhyolite at one or two localities occur limited flows of basalt and again thin interbedded sheets of basalt are found in the upper portion of the rhyolite, but in general the great body of rock presents a singularly uniform mass over the entire plateau. Nowhere have any aqueous deposits or accumulations of detrital material between successive flows been recognized. Neither have any marked evidences of erosion or long intervals of comparative rest been observed during the pouring out of these rhyolites. Although no plant remains or invertebrate fossils have as yet been obtained associated with the rhyolites of the park, they have been referred on other evidence to the Pliocene period.

Along the abrupt wall of the grand canyon of the Yellowstone, just north of Tower Creek, occurs a bed of coarse conglomerate, made up of Archean and andesitic material. On the west side of the canyon the conglomerates rest directly upon andesitic breccias. On both sides of the canyon the conglomerate is overlain by basaltic flows in which columnar structure is well developed. In the conglomerate on the west wall, and directly beneath the overlying basalt, a few vertebrate remains have been collected, which, though fragmentary, were sufficient to enable Prof. O. C. Marsh to determine them as belonging to the skeleton of a fossil horse of Pliocene time. A careful search of the canyon conglomerate failed to find any pebbles of rhyolite mingled with the other material, showing conclusively that none was present in the immediate region when the conglomerate was deposited, as the configuration of the drainage basin is such that had any rhyolite been present, evidences of it would have been detected in the waterlain material. The basalt on both sides of the canyon is covered by rhyolite, a portion of the great rhyolite field in all probability belonging to the earlier flows of this period.

After the cessation of the rhyolite came the final phase of volcanic activity, the pouring out of the recent basalts. They occur along the northern and western boundaries of the Park, skirting the outer edges of the rhyolite mass, where in broad, but comparatively thin, sheets they overlie the former rock. They are admirably shown in the region of Bunsen Peak and Gardiner River but are best developed in Falls River basin, stretching far westward into Idaho in somber, monotonous beds. Occasionally dikes of basalt penetrate the rhyolite, as shown in the escarpment of Madison canyon, but in the broad central portion of the Park plateau outflows of basalt are entirely wanting, even near such a powerful center of eruption as the Sheriden volcano. Upon the cessation of these recent basaltic outflows, after a long period of activity, eruptions of igneous rock in this region came to an end. That this activity lasted throughout the greater part of Pliocene time seems well established, but there is no evidence of its continuance into the Pleistocene. Slight outbursts of lava may have reached the surface at different times after the coming in of the Pleistocene, but there is no direct evidence that such was the case. If they did break out they were limited in extent and were only evidences of continued internal heat, such as is shown by the hydrothermal phenomena for which this region is still so celebrated.

The facts brought together here clearly demonstrate that the pouring out of igneous rocks began with the post-Laramie uplift or closely followed it, and from the time of the first appearance of these rocks, volcanic eruptions continued with greater or less energy throughout Tertiary time. It is evident that from the time of the post-Laramie uplift there was, as shown in the geological history of the region, a succession of events of great importance in the development of the Rocky Mountains, and that each period of this history was characterized by distinct phases of volcanic phenomena. The great value of paleobotany as an aid in determining the age of the geological formations is singularly well illustrated in the region under discussion. At least five distinct and important geological periods are defined by their fossil flora, and four of them are exposed in the Park within a few miles of each other. Along the abrupt west wall of Mt. Everts, the Laramie sandstones contain several species of plants, sufficiently characteristic to determine the Laramie age of the beds. It has been shown that the Livingston formation resting unconformably upon the Laramie carries a distinct flora, well defined from the Laramie below and the Fort Union above.

About ten miles east of Mt. Everts the early acid andesitic breccias contain a varied Eocene flora, referred to the Fort Union formation. At a number of localities within a few miles of Crescent Hill, the breccias afford a special grouping of fossil plants designated as the Intermediate flora, and regarded as more closely related to the Lamar than to the Fort Union flora. They have been referred to the Lower Miocene.

Above these latter beds in a great development of basic breccias occurs a flora referred to the Upper Miocene period. It has been named the Lamar flora, and correlated with the Auriferous Gravels of California, with which it is closely allied.

The following table may serve to bring out more clearly the relationships between the different geological formations and the floras which characterize them :

Formation.	Flora.	Age.
Basic breccia.	Lamar.	Upper Miocene.
Intermediate breccias.	Intermediate flora.	Lower Miocene.
Acid breccia.	Fort Union.	Eocene.
Agglomerates, Waterlain igneous material.	Livingston.	Cretaceous.
Sandstone.	Laramie.	Cretaceous.

In a thin bed of conglomerate exposed by the cutting of the grand canyon of the Yellowstone, vertebrate remains of a fossil horse were discovered, sufficient to determine the Pliocene age of the deposit. Upon this conglomerate rests the great body of rhyolite and the still later basalt. Soon after the dying out of these recent basalts climatic conditions changed and the Yellowstone Park was covered by glacial ice which distinctly marked the coming in of Pleistocene time.

ART. LI.—*On the Occurrence of Pollucite, Mangano-Columbite and Microlite at Rumford, Maine*; by H. W. FOOTE.

DURING the spring of 1885, Mr. E. M. Bailey of Andover, Maine, sent to Prof. S. L. Penfield for identification some specimens from Black Mountain, Rumford, Me. Among these, one which had the appearance of ordinary white quartz or beryl proved to be the very rare and interesting mineral pollucite. The following summer, the locality was visited by Professor Penfield accompanied by Mr. Bailey and a supply of pollucite and its associated minerals was obtained.

The minerals occur in a ledge of coarse pegmatite which has been worked without success for gem tourmalines, but the locality is of unusual mineralogical interest and the work has been continued to some extent for specimens. In addition to quartz, feldspar and muscovite, which are crystallized on a large scale, there were found pink, green and white tourmalines in imbedded crystals, pink lepidolite, both granular and in crystals, with hexagonal outline, spodumene occasionally in crystals but usually only in cleavage masses, amblygonite rather abundant and in cleavage masses only, beryl not very common, cassiterite rather abundant as irregular masses and rarely in small but distinct crystals, black columbite, pollucite and, very rarely, mangano-columbite and microlite.

Pollucite.

Pollucite has previously been found in the United States at Hebron, Me., where it was discovered by Mr. Loren B. Merrill while mining for gem tourmalines. A full description of this occurrence together with an analysis and a discussion of the chemical composition of the mineral has been given by Prof. H. L. Wells.* The material at Hebron was all found as loose pieces in two cavities, while at Rumford, which is about thirty miles north of Hebron, it is found intimately associated with quartz, albite, muscovite, tourmaline, lepidolite and spodumene. The specimens are not very attractive in appearance as neither the pollucite nor the associated minerals, with the exception of tourmaline, occur well crystallized. The irregular masses of pollucite are sometimes quite large, so that, for example, for a distance of ten centimeters there will be continuous pollucite. Small particles of the mineral are colorless and perfectly transparent, but the masses look as if they had been crushed and the appearance is therefore white. The quartz at the locality is mostly smoky so that it is readily told from the pollucite at a glance, but some of it is quite white, and then it is almost impossible without physical or chemical tests to distinguish the two minerals apart. A great deal of credit is due to Mr. Bailey for having observed that the pollucite was something different from quartz, which needed investigation.

Although occurring in masses of considerable size, the pollucite is not very abundant, but it is hoped, now that the mineral has been identified, that it will be more carefully looked for and saved. It is possible and even quite probable that pollucite is not at all a rare mineral at the tourmaline and lepidolite localities in Maine, but has been overlooked as it resembles quartz so closely and does not occur in characteristic crystals.

Material for a chemical analysis was separated in a very pure condition by means of the potassium mercuric iodide solution. That which was used for the analysis ranged in specific gravity between 3·029 and 2·938, a difference of 0·091. Wells gives 2·986 and 2·976 for the mineral from Hebron. The method of analysis was as follows:

The substance was digested with strong hydrochloric acid for several hours until completely decomposed. The silica and alumnia were then determined in the usual manner. The filtrate from the alumnia precipitation was evaporated to dryness and ammonium salts driven off with extreme caution. The chlorides of the alkalies were dissolved in very little hydrochloric acid and enough lead chloride added to combine with all the cæsium to form the salt Cs_2PbCl_6.† Chlorine was then passed into the hot solution which was

* This Jour. III. xli, p. 213, 1891.
† Ibid., xlvi, p. 186, 1893.

gradually cooled, finally with ice. This operation removed nearly all the cæsium, which was filtered on a Gooch crucible, washed with hydrochloric acid saturated with chlorine, dried at 100° and weighed as Cs_2PbCl_6. The filtrate was evaporated to dryness, the residue taken up in water, the lead removed with hydrogen sulphide and the potassium and remaining cæsium precipitated and weighed as platinum chlorides. The platinum was then determined, from which the potassium and cæsium were calculated. Lithium and sodium were freed from platinum and separated with amyl alcohol. Only a trace of rubidium could be detected by the spectroscope.

Water was determined by strong ignition of the substance over a powerful blast lamp.

Following are the results of the analyses, together with the analysis of the mineral from Hebron, by Wells :

	I.	II.	Average.	Ratio.			Hebron.
SiO_2	43·75	43·54	43·64		·727	9·00	43·51
Al_2O_3	16·77	16·90	16·84		·165	2·03	16·30
Cs_2O	36·25	36·03	36·14	·128			36·10
K_2O	0·33	0·42	·037	·004	·168	2·07	·48
Na_2O	2·06	2·11	2·09	·033			1·68
Li_2O	0·03	0·13	0·08	·003			·05
H_2O	1·57	1·59	1·58		·082	1·01	1·50
							CaO=0·22
	100·76	100·72	100·74				99·84

The results of the analyses are remarkably close to those obtained by Professor Wells and the ratio which is nearly 9 : 2 : 2 : 1 gives the formula $H_2Cs_4Al_4(SiO_3)_9$ as deduced by him.

In a recent article, "On the Constitution of the Silicates,"* Clarke has discussed the constitution of pollucite and considered two formulæ, one, $H_2Cs_2Al_2Si_5O_{15}$, deduced from the analysis of the mineral from Elba by Rammelsberg, the other that of Wells, The latter had shown, however, very conclusively that his formula was correct and that it agreed better with the results of the earlier analysis than did that of Rammelsberg, and this new analysis fully substantiates his view.

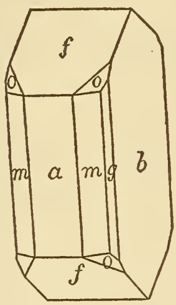
Many thanks are due Professor Wells for his many helpful suggestions as to methods of analysis.

* Bull U. S. Geolog. Survey, No. 125, p. 31, 1895.

Mangano-Columbite.

This mineral is found in imbedded crystals which are seldom over 10^{mm} long. The color is a dark reddish brown, very closely resembling that of rutile. The available material was not sufficient for a quantitative analysis, but a qualitative examination showed the the presence of manganese, tantalum and niobium. A specific gravity determination on $0{\cdot}3242^{gr}$ of material taken very carefully on a chemical balance gave 6·44, which would indicate a chemical composition about midway between a niobate and tantalate and near that of the mangano-columbite from Branchville, analyzed by Comstock.*

1.



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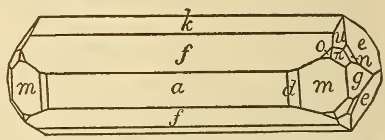


The crystals show a considerable variation in habit, being usually prismatic in the direction of the *c* axis, fig. 1, sometimes lengthened parallel to *a*, fig. 2, while occasionally they are about equally developed in all directions. They show a very good cleavage parallel to *b*, 010. The forms which were observed are similar to those found on columbite and are as follows:

a, 100	*m*, 110	*f*, 102	*u*, 133
b, 010	*g*, 130	*e*, 021	*π*, 121
d, 730	*k*, 103	*o*, 111	*n*, 163

They gave a few excellent reflections which served to establish the lengths of the crystallographic axes. The values are given below, together with the axes for columbite as determined by E. S. Dana.†

	Mangano-Columbite.	Columbite.
$m \wedge m$,	$110 \wedge 1\bar{1}0 = 79°\ 47'$	$79°\ 17'$
$f \wedge f$,	$102 \wedge \bar{1}02 = 55\ \ 40$	$56\ \ 28$
$\breve{a} : \bar{b} : \dot{c}$	$= 0{\cdot}8359 : 1 : 0{\cdot}8817$	$0{\cdot}8285 : 1 : 0{\cdot}8898$

The variation in the ratios is undoubtedly due to a change of both acid and base, the measurement by Dana having been

* This Journal, xix p. 131, 1880. † Zeitschr. Kryst. xii, p. 266, 1886.

made on columbite from Standish, Me., having a specific gravity of 5·65, and which according to the analysis of Allen* contains only a little tantalum and manganese.

Several forms gave rather unsatisfactory reflections. Some of the measured and calculated angles are as follows:

		Calculated.	Measured.	Calculated for Columbite.
$f \wedge f'$,	$102 \wedge \bar{1}02 =$	55° 40′	55° 40′*	56° 28′
$k \wedge k'$,	$103 \wedge \bar{1}03 =$	38 47	38 52	39 23
$d \wedge d'''$,	$730 \wedge 7\bar{3}0 =$	39 25	39 56	39 6
$m \wedge m'''$,	$110 \wedge 1\bar{1}0 =$	79 47	79 47*	79 17
$g \wedge g'''$,	$130 \wedge 1\bar{3}0 =$	136 31	136 51	136 10
$g \wedge g'$,	$130 \wedge \bar{1}30 =$	43 29	44 5	43 50
$e \wedge e'$,	$021 \wedge 0\bar{2}1 =$	120 57		121 20
$m \wedge o$,	$110 \wedge 111 =$	36 0¼	35 55	35 38
$o \wedge o'$,	$111 \wedge \bar{1}11 =$	76 44		77 29
$o \wedge o'''$,	$111 \wedge 1\bar{1}1 =$	62 30½		62 27½
$\pi \wedge \pi'$,	$121 \wedge \bar{1}21 =$	55 0	55 3	55 30
$\pi \wedge \pi'''$,	$121 \wedge 1\bar{2}1 =$	101 2		100 59
$n \wedge n'$,	$163 \wedge \bar{1}63 =$	19 42		19 54
$n \wedge n'''$,	$163 \wedge 1\bar{6}3 =$	118 0		118 20
$u \wedge u'''$,	$133 \wedge 1\bar{3}3 =$	79 32		

One variation from columbite shown by the habit of these crystals is that the form *f*, which is the predominating one at the termination of all of the crystals, is of rare occurrence and has previously been observed only with slight development on columbite.

Microlite.

Very beautiful crystals of microlite averaging 2^{mm} in diameter of a honey-yellow color and high luster are found sparingly at the locality. The prevailing form is the octahedron, modified by the dodecahedron and sometimes by the icositetrahedron, 113. The habit is then very much like that of the pyrochlore figured on page 762 of the sixth edition of Dana's Mineralogy. The specific gravity, taken by Professor Penfield on 0·2642 gr. of material was found to be 5·17, which is somewhat low for microlite and due probably to the presence of a little more niobium than usual. A qualitative analysis indicated the presence of calcium and of tantalum in considerable excess over niobium.

In closing, I wish to express my thanks to Professor Penfield for his kind assistance during the entire investigation and to Mr. Bailey for a generous supply of the rare and interesting minerals from this locality.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, November, 1895.

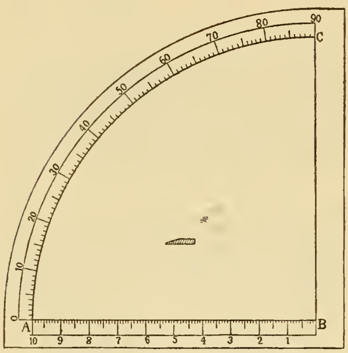
* Zeitschr. Kryst., xii, p. 272, 1886.

Art. LII.—*A Device for Simplifying the Drawing of Crystal Forms;* by A. J. Moses.

In a former article* I described a graphic method for obtaining any axial cross from any projection of the isometric axes by use of a quadrant and scale; any axial length, sine or cosine being measured on the scale and quadrant and laid off on the vertical axis and the proportionate length obtained on any other line through the center by connecting the ends and drawing a line parallel to the connecting line from the point on the vertical axis. Necessarily the vertical axis was either the length of the radius of the quadrant or proportionate dividers were used.

The method is made still simpler by laying off all measurements upon a "scale line" drawn at will from the centre of the axial cross and of a length equal to the radius of the quadrant and by using a metal quadrant shown in fig. 1, the center of

1.



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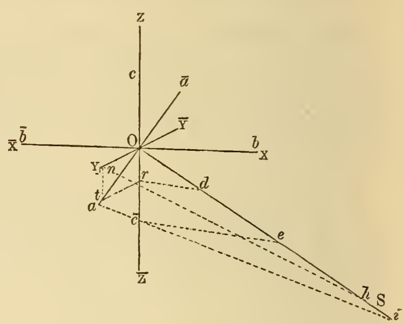


which is at B. The edge AB and the arc AC are tapered to a thin edge for greater exactness in marking. With AB ten centimeters long the results will be correct within the limits of a drawing.

Axial lengths are transferred directly from AB to the scale line approximately to the third decimal. Sines and cosines are transferred as follows. If the edge BC and the scale line are made coincident and then, by use of a triangle, the quadrant is slid along in a direction at right angles thereto (BC remaining parallel to the scale line) until the scale line cuts the arc at the given degree and approximate minute, the intercept on the scale line will be the sine. Similarly with the edge AB coincident with the scale line and a motion at right angles thereto, the intercept on the scale line will be the cosine.

* School of Mines Quarterly, xv, 214–218.

All measurements are transferred to other lines, as above described, by lines parallel to the direction between the ends of the scale line and the unit line. The device can also be used in the measurements needed in obtaining edge directions.

Fig. 2 represents the construction of the axial cross of a monoclinic crystal in which a : b : c=1·092 : 1 : 0·589 and $\beta=74° 10'$. XX $\overline{\text{YY}}$ $\overline{\text{ZZ}}$ is the isometric axial cross; OS is the scale line. O*h* is sine 74° 10′ when radius is OS and transferred to OY is O*n*; O*d* is cosine 74° 10′ when radius is OS and transferred to $\overline{\text{OZ}}$ is O*r*; by completing the parallelogram *t* and O*t* result. For the axial lengths, O*i* is 1·092 times OS and O*e* is 0·589 times OS and transferred are respectively $Oa=1{\cdot}092\times Ot$ and $O\bar{c}=0{\cdot}589\times O\bar{Z}$.

Munich, March 16, 1896.

Art. LIII.—*Concerning Crookes Tubes;* by C. C. Hutchins and F. C. Robinson.

We would offer the following contribution to the rapidly increasing literature on the X-rays of Röntgen. It has to do with a part of the subject upon which very little has been written, and for that reason may be helpful to other experimenters.

One of the chief difficulties in the way of experimenting has been the cost of the bulbs or tubes. We have proved to our own satisfaction that the making of them need not be beyond the resources of the ordinary laboratory; for within a few weeks time we have made and tested more than one hundred tubes, and have frequently made one and exhausted it and used it, all within an hour's time. All that is required is some little skill in glass-blowing and in the manipulation of the pump.

The glass.—A hard German glass, or its equivalent, free from lead, has proved the best. It gives a strong green fluorescence under the action of the current, and what is of great importance, resists without softening the heat generated by the cathode ray at its point of impact. Unfortunately it is not to be had free from bubbles, and these are the cause of the destruction of many tubes; the glass being chipped away into the bubble by the action of the current and the tube ruined. It is also rather difficult to put in the electrodes so that they will stay, and it may be necessary to use three kinds of glass,—first the tube itself, then a bit of softer glass, and upon that very soft lead glass for the seal.

Shape of the tube.—A good tube should throw shadows as sharp as possible and develop the rays as powerfully as possible. It should easily appear that the ordinary spherical form meets neither of these conditions.

To produce a sharp shadow the radiant must be small. It was found that a picture could be taken upon any side of a spherical bulb; making it probable at least that the entire surface is a source of radiation.

In the matter of strong action also, the spherical form is inferior. This is for two reasons:—first, glass more or less extinguishes the rays according to its thickness, therefore, the larger the bulb the more opaque it must be, for it must be thick enough to stand the atmospheric pressure.

Secondly: there is a comparatively large amount of radiant or conducting matter within the spherical bulb which diffuses the energy of the discharge.

Proof of the second point was obtained as follows. A moderately thick bulb about three inches in diameter was blown, and upon this a spot one inch across was blown out very thin, forming a smaller hemispherical bulb upon the first. Opposite this thin window was the concave cathode. This bulb proved better than the ordinary sort, but far inferior to tubes about to be described. A second experiment was made with a tube blown thin along one side for a space of three inches, and opposite this was the cathode in the form of a quarter cylinder. The performance of this was also inferior.

Without going into the details of many similar experiments, it will be sufficient to say that we have found that a simple straight tube from one-half to one inch in diameter, having a small and very thin bulb for a cathode window, has given the most satisfactory results. In length it may be from four to eight inches. The bulb may be blown at the bottom of the tube, the cathode placed at the top, and the anode across the tube just above the bulb. Better results are, however, produced by using a bit of platinum foil for an anode, inclining it about forty-five degrees to the cathode ray. In this case the small bulb may simply be blown out upon the side of the tube and the electrodes put in at the two ends, so that the cathode ray will be reflected into the bulb.

Shape and disposition of the electrodes.—We have made the cathode in the form of a wire, a flat plate, a convex plate and a concave plate. The concave form proves the best in every case. We have made it of varying size, up to an inch or more in diameter, and have not come to any conclusion as to which is best. It is very difficult to have other conditions sufficiently uniform to enable one to judge, where differences are small.

We have made the anode in the form of a wire of aluminum, a flattened strip of it, and, as stated above, in the form of a platinum reflector. As yet we have got our best results from the platinum. One rather interesting result obtained was, that when the anode was in the form of an aluminum disc parallel to the cathode and nearly large enough to close the tube, it gave little or no interference with the X-ray. We made one on a hinge so that it could be swung out of the path of the ray or in at pleasure, and the effect on the photographic plate was the same in either position.

Source of the rays.—Being able to construct tubes of any form, we have made many experiments as to the source of the rays, whether from the cathode or anode. One was in this way:—Two tubes were joined together parallel so that they were exhausted together. The cathode rays could be made to pass down one tube and the anode rays (if such existed) down the other, and either screened off at will. We found that the anode rays affected the plate but slightly, and that practically all the effect came from the cathode.

Intensity of effect.—We do not intend to convey the impression that these home-made tubes we have described are simply good enough for experiment and valuable from their cheapness. We believe also that they are more effective than others. We have made good negatives of bones of the hand, arm, including the elbow, foot, ankle, etc., all with remarkably short exposures; have taken impressions perfectly distinct through nine inches of wood in less than five minutes; have taken perfectly the bones of the hand through thin sheet zinc in two minutes and through the slide of the plate holder in five seconds. The ordinary coin and key impression require not over one or two seconds with our best tubes.

Remarks upon pumping.—The interest in the subject at present may make some remarks upon pumping here in place, most of all, since many have found great difficulty in this respect.

It is here supposed that the pump has a three-way cock above its bulb, opening in its two positions between the bulb and fork and the bulb and outer air; and that above this three-way cock are one or two cocks of the ordinary kind. Let the three-way cock be called A, the others B and C in order. Let the position in which A puts the bulb in communication with the fork be position 1; and that in which it puts the bulb in connection with B, C, and the outer air, position 2. The ordinary process of pumping with the use of A alone is supposed to be understood. After a greater or less number of strokes it is observed that no more air is obtained. The pump contains air, however, condensed upon the glass walls. To remove this A is put in position 2, and the mercury raised until a drop passes B. B is then shut and the mercury dropped until only a drop remains above A. A is then shut and the movable mercury tank dropped to its lowest point, when A is put in position 1. Pumping now goes on as before only with B shut, and the tank is raised only a third as high as before. After four or five strokes it is well to pass the mercury again above B.

If the highest possible degree of exhaustion is desired this process can be repeated between B and C, but this is not necessary in exhausting a Crookes tube.

As soon as the stage of pumping with B shut is reached, the tube which is being exhausted must be strongly heated, moving the lamp flame over every part of it, and after two or three strokes more the current from the coil is turned into the tube. By the combined action of the heat and current the occluded air is driven from the glass and exhaustion proceeds rapidly. It should not occupy over twenty or thirty minutes for a moderate sized tube.

Allowing the tube to cool, if short sparks can be drawn from the bulb and there is little or nothing to be seen in it except green light, the exhaustion is complete. There is danger of carrying it too far, for the vacuum very much increases during the first hour that the tube is used; but of these matters a little experience is the best teacher.

Searles Science Laboratory, Bowdoin College, May 6, 1896.

Art. LIV.—*Researches on the Röntgen Rays*; by Alfred M. Mayer.

Contents: *1. The Röntgen rays cannot be polarized by passing through herapathite. 2. The density of herapathite. 3. The formulæ of transmission of the Röntgen rays through crown glass, aluminum, platinum, green tourmaline and herapathite. 4. The actinic action of the Röntgen rays varies inversely as the square of the distance of the sensitive plate from the source of the rays.*

1. The Röntgen rays cannot be polarized by passing through herapathite.

Herapathite is an iodo-sulphate of quinine, discovered by W. B. Herapath in 1852,* and named herapathite by Haidinger. Herapath gives several formula for its production. The one which succeeded the best with me in giving crystal plates of large area is contained in Phil. Mag., Nov. 1853. It is as follows:

Bisulphate of quinine	3·24 grams.
Pyroligneous acid	56^{cc}
Alcohol (95 per cent)	56^{cc}
Solution of iodine (1 grm. in 11^{cc} alcohol)	50 drops.

The bisulphate of quinine is added to the mixture of pyroligneous acid and alcohol and heated to 55° C., and then the iodine is added drop by drop while constantly stirring the solution. The vessel containing the solution is then placed on several layers of thick felt resting on a firm support to prevent vibration, and it thus remains about 18 hours at a temperature of 8° C. At the expiration of that time large crystals will generally be seen floating on the surface of the liquid, the majority being at the bottom of the vessel. The solution gives, of herapathite, only $\frac{1}{15}$ of the weight of bisulphate of quinine.

As suggested by Herapath, a microscope cover glass is cemented to the end of a glass rod, with its plane at right angles to the rod, and is carefully brought under the floating crystal, very slowly brought up to it and the crystal is thus secured on the surface of the glass. The mother liquid is then absorbed from the glass by blotting paper. If several crystals are desired on a cover glass, a glass tube closed by the finger is brought over the crystals at the bottom of the vessel, the finger removed, then replaced and the tube taken out of the liquid. The crystals are allowed to sink into the drop at the end of the tube by holding the latter for some time in a vertical position ;

* Phil. Mag., Mar. 1852

the drop is then brought in contact with a cover glass. This is the manner in which I placed on the glass discs and blotting paper the plates of herapathite used in my experiments.

Röntgen has shown that generally the lower the density and always the thinner the substance the less it screens from a photographic plate the action of the X-rays. Herapathite is, therefore, eminently fitted as *the* substance on which to make experiments which are to decide whether the X-rays can or cannot be polarized by having traversed crystals which, like herapathite and tourmaline, transmit only one polarized beam, the other being absorbed by the crystal, for the density of herapathite is 1·557 and plates of only ·012^{mm} thick are sufficient to answer the question. When crystals of herapathite ·012^{mm} thick have their optic axes crossed at 90° these crossed portions viewed against incident light appear black, so powerful is the polarizing property of this substance. If the X-rays be polarizable these black portions should act like thick lead and completely screen the sensitive film from the action of the X-rays. The fact is that the crossed herapathites do not screen the X-rays any more than the herapathites do when superposed plates have their axes parallel. In the latter case the crystals freely transmit light with a faint olive-green tint.

The thickness of crystal plates used in the experiments varied from ·01^{mm} to ·025^{mm}, as found by focussing with a micrometer-screw a powerful objective on the top surface of the crystals and on the glass on which they rested.

Six discs of glass, ·15^{mm} thick and ·25^{mm} in diameter, were covered with herapathites in the manner described. They crossed one another at various angles; where they crossed at 90° the crossed portions were black. On a piece of yellow blotting paper, $\frac{3}{4}^{mm}$ thick, were also placed several layers of herapathites, so deep that they reflected a green metallic luster like the elytra of cantharides. These discs and the blotting paper were fastened to the slide covering the photographic plate. This slide was impervious to two hours' exposure to the actinic action of the sun's light. On the slide were also three discs of thin glass, so overlapping that the X-rays had to pass through 1, 2, 3 thicknesses of the glass before reaching the sensitive plate. These served as standards with which to compare the screening effects of the herapathites.

The slide so prepared and covering a sensitive plate was exposed to the radiations of a Crookes tube in three experiments, for $\frac{1}{2}$, 1, and $2\frac{1}{2}$ hours. On developing the plates, not the slightest trace of the presence of the herapathites was visible. The photographs of the glass discs had not the slightest mottling on their surfaces; appearing to the unaided eye and when examined through a magnifying glass with uniform illumination and grain throughout, and exactly like the photograph obtained by the X-rays passing through a similar glass disc with nothing on its surface. The herapathites used in the experiments were so thin that they did not appreciably screen the X-rays, whether the axes of the superposed crystals were parallel or crossed. But the action of the rays on the square of blotting paper proved even more conclusively that the X-rays cannot be polarized in this manner, for where this paper covered the photographic plate nothing was visible, except by careful scrutiny and with a favorable illumination, and then a mere ghost of the paper was detected, but with no traces whatever of the herapathites.

These experiments confirm in a convincing manner what Röntgen found by his experiments, viz: that the X-rays cannot be polarized. At least, they cannot be polarized by passing through herapathite, which is by far the most powerful polarizing substance known. It is unlikely that polarization will be detected by using any doubly refracting substance which transmits two beams polarized in planes at right angles to each other; for if polarization exist, the thickness of the substance required to get a measurable departure of the two rays so screens the X-rays that a very small fraction of them (at least by calcite) will be transmitted; also, Röntgen is of the opinion that if the X-rays be refrangible, the index of refraction is nearly unity even in such a highly refracting substance as ebonite, which has an index of about 1·6.* It is therefore reasonable to suppose that the difference in the refraction of the ordinary and extraordinary beams will be too small to be measurable in the faint shadowgraphs obtained by traversing doubly refracting substances.

It remains to be decided whether the X-rays can or cannot be polarized by reflection, Professor Rood having recently proved conclusively that they are reflected from platinum.

2. *The density of herapathite.*

Herapath gives 1·89, at 60° F., as the density of the very remarkable substance he discovered.† As its density is interesting to have in connection with the experiments described above, I made two determinations of it by weighing about ·3 grs. of the substance in water, and also by the displacement it gave of the water in a specific gravity flask. The mean of these two measures was 1·6. As this

* On the Physical Properties of Vulcanite, by A. M. Mayer, this Journal, Jan. 1891.

† Phil. Mag., May, 1855, p. 369.

number differs greatly from that of Herapath, I thought that the small mass I had used was the cause of the discrepancy. I then made about two grams of herapathite, freed it of its mother liquid by washing with water at 0°, and dried it at 25° in vacuo. When it had ceased to lose weight I weighed it in a specific gravity flask holding about 10 c.c., then just covered it with water, placed it in vacuo and agitated it, so that it would be freed of any air that might be contained in its mass. The flask was then nearly filled with water and again placed in vacuo, then entirely filled and weighed. I found from this carefully made experiment that the density of herapathite is 1·557 at 20° C.

3. The formulæ of transmission of the Röntgen rays through glass, aluminum, platinum, green tourmaline and herapathite.

The Röntgen rays, after their transmission through various substances, produce actinism on a photographic plate, and by the degree of this actinism we have attempted to obtain the formula of transmission peculiar to each substance. This action of the X-rays is cumulative and evidently is entirely different from the transmission of light and radiant heat where the maximum of transmission is instantly reached and under proper and controllable conditions remains constant and therefore can be accurately measured. But with the *X*-rays the amount of their action on the plate varies directly as the time of their action (see 4), depends on the distance of the sensitive plate from source of radiation, and on the energy of the source. Therefore this method of determining the constants of the formulæ of transmission of the X-rays is somewhat arbitrary; but the exact conditions in the determination of the constants having been given, these conditions can readily be obtained by other experimenters. Thus, to have the same conditions as existed in our experiments, one has only to place a pile of crown glass plates $5{\cdot}5^{mm}$ thick, at such a distance from the radiant source that on two hours exposure the X-rays will have just not visibly acted on the photographic plate. Some assumption has to be made as to the nature of the X-rays, otherwise no progress can be made in determining the constants of their formulæ of transmission. We have assumed that they are homogeneous. The formulæ, as determined, hold good till they have conclusively been shown not to be homogeneous, which is very likely to happen in the progress of research on their nature.

The method used owes whatever merit it may have to the use of the wire netting devised by Professor Rood to give accurate indications of the relative permeability of various substances to the X-rays. This wire netting he places on the slide covering the sensitive plate, and on the netting he places substances of various thickness. The netting completely screens the X-rays, and its image on the negative is the brightest possible to obtain in the given conditions. If a plate of a substance should also entirely screen the X-rays, then the image of the netting is invisible in the photograph of this substance, and as plates of substances allow more and more of the X-rays to traverse them the images of the netting in the photographs of these substances are more and more bright. If the image of the netting in the photographs of two substances should be equally bright, then these two plates transmit equal actinic action to the sensitive plate. Thus this ingenious device serves as a very delicate photometer in determining the fact just mentioned.

It occurred to me that the wire netting could also give me data with which to determine the constants of the formulæ of transmission of the X-rays through various substances. The method devised is as follows: On a wire netting with 8 meshes to the inch placed on the slide of the plate-holder, are cemented piles of glass discs, (each glass about $\frac{1}{10}^{mm}$ thick); these piles gradually increase in thickness. These piles of glass were exposed to the action of the X-rays, so that the photographic plate was 25^{cms} distant from the radiant source. In the apparatus used this distance could be accurately measured. After an exposure of two hours it was found, on developing the plate, that the netting was *just visible* in the photograph of the pile $5{\cdot}35^{mms}$ thick, and that it was not visible in the photograph of the pile $5{\cdot}5^{mm}$ thick. In this last case, though the X-rays had penetrated to the sensitive film, yet the difference in the screening effect of the netting and of the glass was not visible, because the eye cannot distinguish between the illumination of juxtaposed surfaces which differ in illumination by about $\frac{1}{100}$. Hence, through the last pile of $5{\cdot}5^{mm}$ about $\frac{1}{100}$ of the actinic intensity of the incident beam had passed.

Now the formula of transmission of rays through a substance which does not reflect these rays is $I' = Ia^t$. Where $I' =$ the intensity of the transmitted beam; $I =$ the intensity of the incident beam; $a =$ a constant depending on the substance, and t is an exponent of a, and t is the thickness of the substance. We have taken $\frac{1}{10}^{mm}$ as the unit of t.

From the conditions of the experiment $I' = Ia^t = \frac{1}{100}$, and as t is known, a is readily computed. The accuracy of the determination of a depends on the value of the least perceptible difference in illumination that the eye can distinguish in two juxtaposed surfaces. We have adopted $\frac{1}{100}$ as the most probable value.* But suppose that the fraction is not $\frac{1}{100}$ but

* Photometric Experiments, O. N. Rood, this Journal, July 1870.

$\frac{1}{113}$, or, $\frac{1}{88}$, then the departure of these fractions from $\frac{1}{100}$ will affect the constant by 4 units in the third decimal place.

These experiments, made in the conditions we have indicated, give for the formula of transmission through the glass used, a crown glass made by Chance & Co.:

$$I' = I \times \cdot 92^t$$

Having this formula as a basis, it is comparatively easy to determine the constants of another substance, by placing the substance on the netting with piles of glass of graded thickness and exposing them to the X-rays. We then see what thickness of glass gives the same illumination to the image of the netting as does the known thickness of the substance. Thus, the netting in the photograph of a disc of herapathite ·9^{mm} thick had the same brightness as in the photograph of a pile of glass ·69^{mm} thick. By the formula glass ·69^{mm} thick transmits ·5636 of the incident beam and herapathite of ·9^{mm} transmits the same. From this we compute that $I' = I \times \cdot 9382^t$ is the formula for the transmission of the X-rays through herapathite, which for $t = \cdot 69$ gives ·5636 of transmission.

In the same manner it was found that

2·05^{mm}	of	aluminum	transmits the	same as	2·44 of glass
·02	"	platinum	"	"	2·9^{mm} "
2·0	"	green tourmaline	"	"	2·0 " "
·69^{mm}	"	herapathite	"	"	·9 " "

From these determinations we have computed the formulæ of transmission of these substances:

Glass	$I' = I \times \cdot 92^t$
Aluminum	$I' = I \times \cdot 905^t$
Platinum	$I' = I \times \cdot 00063^t$
Green tourmaline	$I' = I \times \cdot 92^t$
Herapathite	$I' = I \times \cdot 938^t$

Taking the amount of transmission through aluminum of $\frac{1}{10}$^{mm} and of 1^{mm} as unity, we have, in the following table, the relative transmission through the substances experimented on.

	$t = \frac{1}{10}^{mm}$.	$t = 1^{mm}$.
Aluminum	1·	1·
Glass	1·016	1·180
Green tourmaline	1·016	1·180
Herapathite	1·036	1·435
Platinum	·000696	

Platinum ·06^{mm} thick is practically impervious to the rays from the Crookes tube used, transmitting only ·005 of incident beam.

This method of determining the transmission of the X-rays through various substances may be criticised, because in the experiments I obtain not alone the transmission through the substances placed on the slide of the plate-holder but at the same time the transmission through the slide itself. If the slide has a measurable transmission, or, screening effect, then its equivalent in thickness of the substances placed on it should be added to them. This criticism, however, is nought, because experiments have shown that if the thickness of a portion of the slide is doubled by placing on it a piece of the material of which it is made, no screening of the X-rays by this piece can be detected.

4. The actinic effect of the Röntgen rays varies inversely as the square of the distance of the sensitive plate from the radiant source.

The slide covering a photographic plate had on it the wire netting, and the plate was exposed for 30 minutes to the X-rays at a distance of 10 inches from the radiant source. Another similar plate in the same plate-holder was exposed for two hours at a distance of 20 inches from the radiant source. These distances could be accurately measured in the apparatus used. These plates were taken from the same box and developed side by side in the same tray. Indeed all the conditions were carefully made the same in the two experiments except the distance of plates from the radiant source. On developing the images on the plates they were exactly alike; the image of the netting had the same illumination on each plate, and the density of the films was the same. This experiment shows that the X-rays act on a sensitive plate according to the law of the inverse squares.

From this law it follows that the actinic power of the X-rays is not sensibly absorbed in traversing the air; also, that these rays are not sensibly diffused by radiation from the molecules of the air they traverse, the air being at ordinary barometric pressures.

These deductions, which necessarily follow from the law of the inverse square, are, however, at variance with the facts observed by Professor Pupin, who states in Science of April 10, 1896: "There was evidently a diffuse scattering of the X-rays in their passage through the air." . . . . . . "These experiments prove beyond all reasonable doubt that the Röntgen radiance is diffusely scattered through bodies, gases not excepted." These opinions of Professor Pupin are founded on experiments on the action of the X-rays on a fluorescent screen, or, rather on a "fluoroscope," not on experiments on their actinic effects. In the latter case I am confident that the X-rays act according to the law of the inverse squares, and therefore are not sensibly diffused. In the former case Professor Pupin finds that they are diffused in traversing the air, and very sensibly diffused if I understand aright his paper; but as he does not give any photometric measures, or estimates, of the intensity of the fluorescence in the geometric image of the slit, and outside of this image, one cannot form an opinion of the amount of the diffusion he describes. The facts of diffusion described by Professor Pupin are opposed to those discovered by so distinguished and experienced a physicist as Röntgen, who, in section 10 of his first paper, writes: "I find, using a Weber's photometer, that the intensity of the fluorescent light varies nearly as the inverse squares of the distance between screen and discharge tube. This result is obtained from three very consistent sets of observations at distances of 100 and 200^{mm}. Hence air absorbs the X-rays much less than the cathode rays. This result is in complete agreement with the previously described result, that the fluorescence of the screen can be observed at 2 metres distance from the vacuum tube." Röntgen does not mention any diffusion observed by him in these experiments, and it is certain that he would have mentioned the existence of diffusion in experiments made to determine a law of radiation, and which diffusion necessarily would have invalidated the law of inverse squares.

The radiation from the Crookes tube, used in the experiments described in this paper, came from a calcined shell supported by the anode wire and placed opposite the cathode. The tube was not sensibly heated during the experiments and the actinic power of its radiation remained constant. It was proved by taking a pin-hole photograph of the naked tube, with an exposure of two hours, that by far the larger proportion of the X-rays emanated from a 4^{mm} square surface of the shell which was acted on by the cathode rays. The walls of the glass tube, as was proved by other independent photographic experiments, furnished a small percentage of X-rays but not enough to make their presence known in the pin-hole photograph, which had furnished quite a dense image of a portion of the shell. Furthermore the X-rays from the glass wall itself were cut off and prevented from reaching the photographic plate by a diaphragm of lead with a circular opening of one-half inch, and at one inch distant from the radiant source. It is also to be remarked that this second source of the X-rays was nearer to the photographic plate only by $\frac{7}{10}$ inch minus ·06 inch, the thickness of the tube, hence any effects due to them may be neglected, as indeed the results in the experiments on the inverse squares show.

The experiments described in this paper were made in the private laboratory of Professor Rood in Columbia University. Professor Rood not only gave me the use of his apparatus, which he had made the subject of a special investigation before investigating with it, but he also gave me the advantage of the experience obtained during his researches on the X-rays.

ART. LV.—*On the* PITHECANTHROPUS ERECTUS, *from the Tertiary of Java;* by O. C. MARSH.* (With Plate XIII.)

NEAR the beginning of last year, a discovery was announced that excited great interest throughout the scientific world, especially among those interested in the origin and antiquity of man. The announcement first made was that remains of a veritable missing link between man and the higher apes had been found in Java, in strata of Pleistocene age. The discovery was made by Dr. Eugène Dubois, a surgeon in the Dutch army, who had been stationed in Java for several years, and had devoted much time to the vertebrate fossils of that island.

The first definite information received in this country was in December, 1894, when Dubois's memoir on *Pithecanthropus* arrived.† One of the first copies reached the late Professor Dana just as he was printing the last pages of his great work on geology. He at once wrote to me in Washington, asking me to look up the memoir, and telegraph my opinion of the discovery, so that he could refer to it in his book. On inquiry, I ascertained that this memoir had not then been received at any of the scientific centers in Washington, and that the discovery itself was not known. On returning to New Haven, I found a copy of the memoir awaiting me (received December 29, 1894), and at Professor Dana's request, I wrote a review of it, which appeared, with illustrations, in this Journal for February, 1895.‡

The memoir of Dr. Dubois was an admirable one, and, although written in Java, with only limited facilities for consulting the literature on the subject and for comparing the remains described with living and extinct forms to which they were related, the author showed himself to be an anatomist of more than usual attainments, and fully qualified to record the important discovery he had made. In my review, therefore, of this important memoir, I endeavored to state fairly the essential facts of the discovery, as well as the main results reached by Dr. Dubois after a careful study of the remains.

* Abstract of communication made to the National Academy of Sciences at Washington, April 24, 1896.

† *Pithecanthropus erectus.* Eine menschenaehnliche Uebergangsform aus Java. Von Eug. Dubois, Militairarzt der niederlaendisch-indischen Armee. Mit zwei Tafeln und drei in den Text gedruckten Figuren. 4to, Batavia, 1894.

‡ The figures then given in Plate II are repeated in the plate accompanying the present article.

My own conclusions in regard to this discovery, briefly stated in my review, were as follows:—

"It is only justice to Dr. Dubois and his admirable memoir to say here, that he has proved to science the existence of a new prehistoric anthropoid form, not human indeed, but in size, brain power, and erect posture, much nearer man than any animal hitherto discovered, living or extinct. . . . . . Whatever light future researches may throw upon the affinities of this new form that left its remains in the volcanic deposits of Java during later Tertiary time, there can be no doubt that the discovery itself is an event equal in interest to that of the Neanderthal skull.

"The man of the Neander valley remained without honor, even in his own country, for more than a quarter of a century, and was still doubted and reviled when his kinsmen, the men of Spy, came to his defense, and a new chapter was added to the early history of the human race. The ape-man of Java comes to light at a more fortunate time, when zeal for exploration is so great that the discovery of additional remains may be expected at no distant day. That still other intermediate forms will eventually be brought to light no one familiar with the subject can doubt."

In most scientific quarters, however, both in this country and in Europe, Dr. Dubois's discovery was not received with great favor, and the facts and conclusions stated in his memoir were much criticised. Among a score or more of notices of this elaborate memoir which appeared subsequent to my review, I do not recall a single one that, in attempting to weigh the evidence presented, admitted the full importance of the discovery made by Dr. Dubois. The early conclusions seemed to be that the various remains discovered were human, and of no great age; that they did not belong to the same individual; that the skull apparently pertained to an idiot; and that both the skull and femur showed pathological features. In fact, the old story of the distrust aroused by the discovery of the Neanderthal skull, nearly forty years before, was repeated, although in a milder form. Dr. Dubois has stated in a late memoir that, with the exception of Professor Manouvrier of Paris and myself, no one else, until very recently, regarded the remains as evidence of a transitional form between man and the apes.

It was a fortunate thing for science that the Dutch government appreciated the importance of the discovery made in its Javanese province by Dr. Dubois, and last summer allowed him to return to Holland and bring with him the precious remains he had found, and so well described. Not only this, but he was also permitted to bring the extensive collections of other vertebrate fossils which he had secured from the same horizon and in the same locality where the *Pithecanthropus* was discovered. All these were shown at the International Congress of Zoologists, held at Leyden, in September last, and on the 21st of that month, Dr. Dubois read an elaborate paper on his original discovery and on his later explorations in the same region. This communication was in many respects the most important one of the session, and its presentation with the specimens themselves was a rare treat to the large audience present, especially to those fitted to appreciate the evidence laid before them.*

Professor Virchow of Berlin was president of the meeting on that day, and had brought many specimens to illustrate the remarks he was to make in the discussion. The famous Leyden museum was also drawn upon for an extensive series of specimens of man and the higher apes, so that, if possible, the true position of *Pithecanthropus* might then be determined once for all. Dr. Dubois, moreover, kindly invited Professor Virchow, Sir William Flower, and myself, to come an hour before the meeting, and personally examine the remains he was to discuss, and this invitation was most gladly accepted.

The first sight of the fossils was a surprise, as they were evidently much older than appeared from the descriptions. All were dark in color, thoroughly petrified, and the matrix was solid rock, difficult to remove. The skull-cap of *Pithecanthropus* was filled with the hard matrix, firmly cemented to it. The roughness of the superior surface, especially in the frontal region, was apparently due to corrosion after entombment, and not to disease, as had been suggested by some anatomists. The femur was free from matrix, but very heavy in consequence of the infiltration of mineral matter. The exostosis on its upper portion is a conspicuous feature, but of course is pathological. This feature is of little consequence, as very similar outgrowths occur on fossil bones of even Eocene age. The two teeth showed no characters that indicated their interment under circumstances different from that of the skull or femur. All the physical characters impressed me strongly with the idea that these various remains were of Pliocene age, and not Post-Tertiary, as had been supposed. The description of the locality and the account of the series of strata there exposed, as given by Dr. Dubois in his communication, confirmed this opinion, and a later examination of accompanying vertebrate fossils placed the Pliocene age of all beyond reasonable doubt.

* Compte-Rendu des Séances du Troisième Congrès International de Zoologie, Leyden, September, 1895, pp. 251–271, 1896. See also Transactions Royal Dublin Society, vol. vi, pp. 1–18, February, 1896; and Anatomischer Anzeiger, Bd. xii, pp. 1–22, 1896.

The facts relating to the discovery itself, and the position in which the remains were found, as stated by Dr. Dubois in his paper, together with some additional details given to me personally, convinced me that, in all probability, the various remains attributed to *Pithecanthropus* pertained to one individual. Under the circumstances, no paleontologist who has had experience in collecting vertebrate fossils would hesitate to place them together.

In figure 1, below, a geological section is given, showing the series of strata exposed in the bank of the river Bengawan, near Trinil, in central Java, where all the remains of *Pithecanthropus* were found. The exact positions of these various specimens when discovered are also indicated.

1.

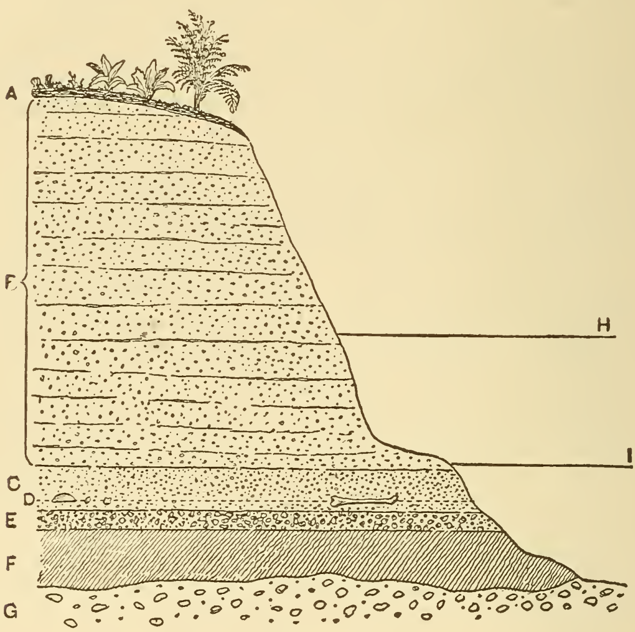


FIGURE 1.—Section of the bone strata at Trinil. (After Dubois.)
A, vegetable soil; B, sand-rock; C, bed of lapilli-rock; D, level in which the four remains were found; E, conglomerate; F, clay-rock; G, marine breccia; H, rainy season level of river; I, dry season level of river.

The above section, taken from Dr. Dubois's Dublin paper, makes clear many points as to the locality where the discoveries were made, which were left doubtful in the original memoir.

The three specimens originally described, the tooth, the skull, and the femur, were found at different times in the same horizon, all imbedded in the same volcanic tufa, as indicated in figure 1, D. The tooth was found first, in September, 1891, in the left bank of the river, about a meter below the water level during the dry season, and twelve or fifteen meters below the plain in which the river had cut its bed. A month later, the skull was discovered, only a meter distant from the place where the tooth lay. In August, 1892, the femur also was found, about fifteen meters distant from the locality where the other specimens were imbedded. Later, in October of the same year, a second molar was obtained at a distance of not more than three meters from where the skull-cap was found, and in the direction of the place where the femur was dug out.

The fossils thus secured were all carefully investigated by Dr. Dubois, who regards them as representing a distinct species and genus, and also a new family, which he has named the *Pithecanthropidæ*, and distinguished mainly by the following characters:

Brain cavity absolutely larger, and, in proportion to the size of the body, much more capacious than in the *Simiidæ*, yet less so than in the *Hominidæ*. Capacity of the skull about two-thirds the average of that of man. Inclination of the nuchal surface of the occiput considerably greater than in the *Simiidæ*. Dentition, although retrogressive, still of the simian type. Femur equal in its dimensions to that of man, and like that adapted for walking in an upright position.

Of this skull, the upper portion alone is preserved, the line of fracture extending from the glabella backward irregularly to the occiput, which it divides somewhat below the upper nuchal line. The cranium seen from above is an elongated oval in outline, dolichocephalic; and is distinguished from that of other anthropoid apes by its large size and its higher arching in the coronal region, as shown below in figure 3. The greatest length from the glabella to the posterior projection of the occiput is 185^{mm}. The greatest breadth is 130^{mm}, and the smallest, behind the orbit, is 90^{mm}. The cranium in its original condition must have been of somewhat larger dimensions. The upper surface of the skull is without ridges, and the sutures all appear to be obliterated.

This dolicocephalic skull, with an index of 70°, is readily distinguished from that of the Orang-utan, which is decidedly brachycephalic. The absence of the characteristic cranial crests will separate it from the skull of the adult Gorilla. In its smooth upper surface and general form, it shows a resemblance to the skull of the Chimpanzee, and still closer to that of the Gibbons (*Hylobates*).

A figure of the present specimen and the skull of a Gibbon for comparison are shown in figure 2, Plate XIII. These figures and those that follow are reproduced from illustrations in Dr. Dubois's memoirs.

In comparing the cranium of *Pithecanthropus* with skulls most nearly allied, both human and simian, the outlines given in figure 3, below, will prove especially instructive. The basis of this cut is the figure given by Dr. Dubois in his Leyden paper. This I have modified by omitting the outline of the microcephalic idiot, and substituting that of the well-known Neanderthal skull.*

3.

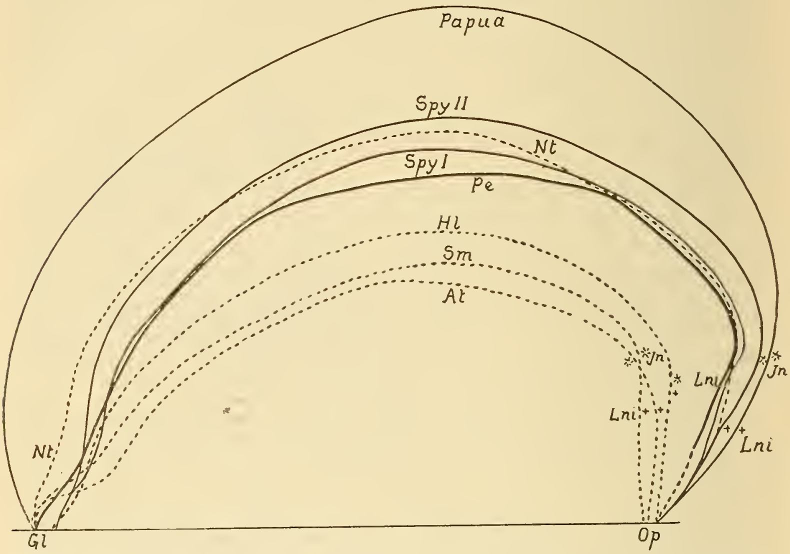


FIGURE 3.—Profile outline of the skull of *Pithecanthropus* (*Pe*), compared with those of a Papuan man, the man of Spy No. 1, Neanderthal man (*Nt*), man of Spy No. 2, and *Hylobates leuciscus* (*Hl*), *Semnopithecus maurus* (*Sm*), and *Anthropopithecus troglodytes* (*At*). (Modified from a figure by Dubois.)

Gl, glabella; *Op*, opisthion; *Jn*, linea nuchæ superior; *Lni*, linea nuchæ inferior.

Dr. Dubois's conception of the skull of *Pithecanthropus*, when entire, is indicated by his attempted restoration shown in figure 6, on page 481. Future discoveries must determine the accuracy of this restoration.

* In presenting the present paper before the National Academy of Sciences at Washington, I was fortunately able to exhibit a cast of the *Pithecanthropus* skull, recently sent to me by Dr. Dubois, and also to compare this with a cast of the Neanderthal skull. The latter was not available during the discussion at Leyden.

The tooth, the first specimen found, is represented in figure 4, below. It is the last upper molar of the right side, and is in good preservation. It indicates a fully adult, but not very old, animal. The crown is subtriangular in form, with the corners rounded, and the narrowest portion behind. The antero-posterior diameter of the crown is 11·3^{mm}, and the transverse diameter 15·3^{mm}. The grinding surface of the crown is concave, and less rugose than in existing anthropoid apes. The diverging roots are a simian feature.

4.

FIGURE 4.—Third right upper molar of *Pithecanthropus erectus*. Two-thirds natural size. (After Dubois.)
a, back view; *b*, top view.

6.

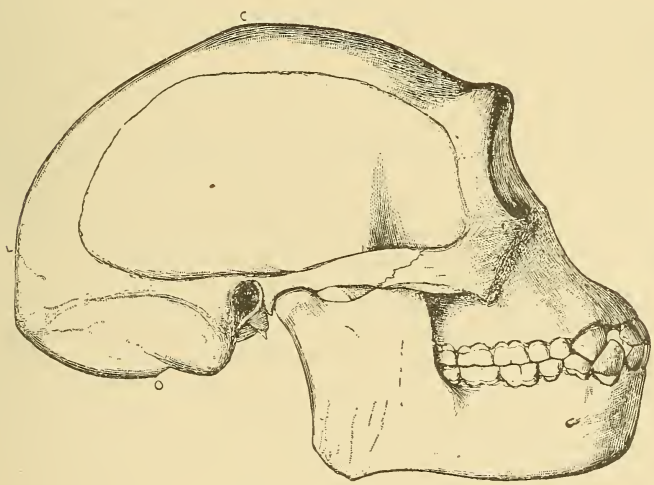


FIGURE 6.—Restoration of the skull of *Pithecanthropus erectus*. Two-fifths natural size. (Reduced from a figure by Dubois.)
C, sutura coronalis; L, sutura lamboidea; O, foramen occipitale.

The femur, which is from the left side, is in fair preservation, although it was somewhat injured in removing it from the surrounding rock. It belonged to a fully adult individual. In form and dimensions, it resembles so strongly a human femur that only a careful comparison would distinguish one from the other. The bone is very long, its greatest length being 455^{mm}. The shaft is slender and nearly straight. The general form and proportions of this femur are shown in figure 5, Plate XIII, with a human femur for comparison.

These various remains of *Pithecanthropus* were again described in detail and compared with allied forms by Dr. Dubois in his paper at Leyden, and in the discussion that followed, the whole subject was once more gone over by anthropologists, zoologists, and geologists, in a most thorough and judicial manner. To attempt to weigh impartially the evidence as to the nature of *Pithecanthropus*, presented by Dr. Dubois in his paper and by those who took part in the critical discussion that followed its reading, would lead far beyond the limits of the present communication. I can only say that this evidence was strongly in favor of the view that the skull of *Pithecanthropus* is not human, as the orbital and nuchal regions show, while at the same time it indicates an animal much above any anthropoid ape now known, living or extinct. Opinions differed as to whether the various remains pertained to the same individual, but no one doubted their importance.

The varied opinions expressed in regard to the anatomical characters of each of the specimens have already been published, and need not be repeated here. Dr. Dubois, in his papers above cited, has met all the principal objections made to his views since he announced his discovery. He has also given full references to the literature, which promises to be voluminous as the importance of the subject becomes better known. Among the authorities thus cited may be mentioned Cunningham, Keith, Lydekker, Turner; Manouvrier, Pettit, Topinard, Verneau; Haeckel, Krause, Martin, Ten Kate, and Virchow, who have all taken part in the discussion.

After a careful study of all the *Pithecanthropus* remains and of the evidence presented as to the original discovery, the position in which the remains were found, and the associated fossils, my own conclusions may be briefly stated, as follows:

(1) The remains of *Pithecanthropus* at present known are of Pliocene age, and the associated vertebrate fauna resembles that of the Siwalik Hills of India.

(2) The various specimens of *Pithecanthropus* apparently belonged to one individual.

(3) This individual was not human, but represented a form intermediate between man and the higher apes.

If it be true, as some have contended, that the different remains had no connection with each other, this simply proves that Dr. Dubois has made several important discoveries instead of one. All the remains are certainly anthropoid, and if any of them are human, the antiquity of man extends back into the Tertiary, and his affinities with the higher apes become much nearer than has hitherto been supposed. One thing is certain: the discovery of *Pithecanthropus* is an event of the first importance to the scientific world.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The molecular weight of sulphur.*—Previous investigations have shown that the sulphur molecule probably corresponds to the formula S_8, or to S_6, at a temperature slightly above its boiling point, and that as the temperature rises the molecular weight becomes smaller, until between 860 and 1700° it is constant and corresponds to a normal molecule, S_2. Previous work upon the molecular weight of sulphur in solution, as determined by the boiling-point and the freezing-point methods, has in most cases pointed to the formula S_8. ORNDORFF and TERRASSE have now described an elaborate series of experiments in which the boiling-point method has been used with various solvents, and they conclude from their results that at temperatures below its melting-point the molecule of sulphur is S_9, while with solvents whose boiling-points are above the melting-point of sulphur, the molecular formula is S_8. The interesting fact was observed that when dissolved in sulphur chloride (S_2Cl_2) the molecule of sulphur corresponds to the normal formula, S_2. The authors have also made the observation that in carbon disulphide, from which only orthorhombic sulphur crystallizes out, and in benzene and toluene, from which the monoclinic form alone separates, the same molecule, S_9 exists.—*Am. Chem. Jour.*, xviii, 173. H. L. W.

2. *The absorption of the Röntgen rays by chemical compounds.*—NOVÁK and ŠULC have examined nearly 300 substances in this respect. Their method of investigation consisted in attaching rings of glass to a sheet of paper and placing uniform layers of the finely pulverized materials in the different rings so that the thickness of the layer was $0{\cdot}4^{cm}$ in each case. The paper with the rings was then placed over a photographic plate which was enveloped in black paper, and exposed to the Röntgen rays for a period of 20 to 25 minutes. By comparing the photographic effect of the rays where the substances were interposed, the relative absorptions were determined. The authors found that a great number of organic compounds containing only carbon, hydrogen, oxygen and nitrogen, are equally penetrable, and hence they conclude that the absorption has no relation to molecular weight or the arrangement of the atoms. Organic halogen derivatives were found to possess much greater absorption, which increased with the number of halogen atoms present. This effect increased with the atomic weights of the halogens, two atoms of bromine having a greater effect than six chlorine atoms, while iodine derivatives were entirely impenetrable under the conditions used in the experiments. This indication of the influence of elements of varying atomic weight led the authors to examine a series of elementary substances, all of rather low atomic weights. The absorptive power was as follows:

$$\underset{32}{S}=\underset{31}{P\beta}>\underset{27}{Al}>\underset{24}{Mg}>\underset{11}{B}=\underset{12}{C\alpha}(=\text{Air}).$$

This series agrees in a striking manner with the order of the weights of the atoms, and the metallic or non-metallic character of the substance seems to be without influence. Salts of different metals with the same acid showed a variation, in like manner, with the atomic weights:

$$NH_4<\underset{7}{Li}<\underset{23}{Na}<\underset{39}{K}<\underset{85}{Rb}$$

also,

$$\underset{9}{Be}<\underset{24}{Mg}<\underset{40}{Ca}<\underset{87}{Sr}<\underset{137}{Ba}$$

The calcium salts are almost equal to the potassium salts, while the strontium and rubidium salts are also nearly alike, thus showing the influence of almost identical atomic weights.

Salts of different acids with the same metal also formed regular series:

Carbonate<Nitrate<Sulphate<Chloride<Bromide<Iodide.
Chlorate<Bromate<Iodate.
Phosphate<Arsenate, etc.

With compound radicals it seems as though the absorptive power depended upon the average atomic weights of the component atoms. For example, ammonium, NH_4, $\frac{14+4}{5}=3{\cdot}6$, gives less absorption than lithium. This view is in harmony with the easy penetrability of organic compounds composed of the elements C, H, O and N of low atomic weight.—*Zeitschr. Physikal. Chem.*, xix, 489. H. L. W.

3. *A Dictionary of Chemical Solubilities, Inorganic;* by A. M. Comey, 8vo, pp. 515 (Macmillan & Co., 1896, price $5).—More than thirty years have elapsed since the appearance of Storer's Dictionary of Solubilities, and Professor Comey has rendered a valuable service to chemists in writing a modern work upon this subject in such an excellent manner. The author has aimed to include all analyzed inorganic compounds, so that the book is a compendium which will serve a purpose in inorganic chemistry similar to that of Beilstein's "Handbuch" in the organic domain. The full references to the literature make the work especially valuable. The typographical work is admirable, but we think that a word of protest should be entered against the uncut "tops," especially for a dictionary. H. L. W.

4. *Les Fermentations*, par P. Schützenberger, 8vo, pp. 314, Paris 1896 (Félix Alcan).—In presenting this, the sixth edition of his work on fermentation, to the public, the eminent author has entirely re-written the book and has placed it in harmony with the present condition of the science. It is divided into two parts, the first treating of direct fermentation, produced by organisms, the second part being devoted to soluble ferments, or indirect

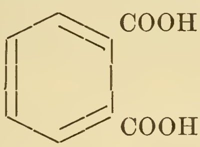
fermentation. The work gives a clear and accurate survey of this very interesting and important department of chemistry.

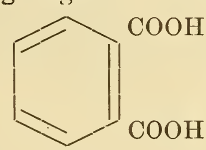
H. L. W.

5. *Répertoire des Réactives Spéciaux*, par F. JEAN et G. MERCIER, 12mo, pp. 121, Paris 1896.—This little book gives the formulæ for preparing special chemical reagents which usually bear the names of the originators. The main arrangement is alphabetical according to the names of the authors, while another alphabetical list is given of the substances to be detected. More than four hundred reagents are included, and the book will doubtless be a convenience to all practical analysts. The value of the work would have been considerably increased if references to the original articles had been given. H. L. W.

6. *The existence of two Orthophthalic Acids.*—Considering the great amount of work that has been done with orthophthalic acid by various chemists, the recent discovery by W. T. H. HOWE, that this compound exists in two isomeric modifications, seems remarkable. The two acids are identical in composition, molecular weight and molecular refraction, but they differ (1) in melting-points, (2) in electrical conductivity, (3) in solubility, (4) in the properties of their salts, and (5) in their reduction-products. The melting-points of the two acids, when finely pulverized, are 184°, and 203°. The lower melting acid is converted into the higher simply by boiling the aqueous solution for several hours. The reverse change takes place by boiling a solution in 30 per cent. sodium or potassium hydroxide for some time and precipitating the acid from the cold solution by means of hydrochloric acid.

The author is inclined to explain the isomerism by a change in the arrangement of the single and double bonds in Kekulé's benzene ring, as is shown in the following diagrams:





This establishment of a case of two isomeric ortho-derivatives of benzene has an important bearing upon the theory of the structure of the benzene nucleus, for the previous lack of well-established cases of such isomerism has been considered to be a strong argument against Kekulé's celebrated ring formula in its original form.—*Am. Chem. Jour.*, xviii, 390. H. L. W.

7. *On the nature of the X-rays.*—D. A. GOLDHAMMER states his reasons for believing that the X-rays are ordinary transverse waves of light of which the wave-length are much smaller than the hitherto observed ultra violet rays. Röntgen concluded that the effect observed by him was not due to ultra violet light from the following :

a. The X-rays suffer no observable refraction in passing from air into water, bisulphide of carbon, aluminum rock salt, glass, zinc, etc.

b. They are not regularly reflected by known bodies.

c. They are not polarized by ordinary means.

d. Their absorption depends only on the factor of thickness of absorbing layer.

According to the author, the absence of observed reflection could be due to a wave-length extremely small in comparison with the inequalities of even highly polished surfaces. The absence of polarization can also be explained by similar reasoning; *b* and *c* are thus explained. The behavior of the new rays toward metals and other substances is compared with the behavior of certain solutions like fuchsin, and aniline toward ordinary light. In the case of fuchsin solutions the absorbtion is proportional to the concentration. If we compare Röntgen's results on the effect of thickness of layers on the rays, with the absorption of fuchsin, one is led to believe that the thickness of bodies plays the role with X-rays of the concentration of fuchsin solutions for ordinary light. Prisms filled with fuchsin solutions give anomalous refraction and dispersion, is it not possible that the bodies investigated by Röntgen exhibit anomalous dispersion? By means of anomalous refraction and dispersion *a* and *d* can thus be explained. With rays of extremely short wave-length, the absorption fitness of bodies may be mainly determined by their thickness. It is possible that the X-rays are present in the arc spectrum of platinum or lead.—*Ann. der Physik und Chemie*, No. 4, 1896, pp. 635–638. J. T.

8. *Recent work with Röntgen Rays.*—*Nature*, April 30, 1896, has a résumé of this work. Dr. A. Winkelmann and Dr. R. Straubel (Jena) have investigated the refraction of the Röntgen rays and by using prisms of various metals obtained in each case a value of about 1:0·0038 referred to air. Professor Rhigi and Drs. A. Fontana and A. Umani (Rome) find that the radiation from a Crookes tube does not effect the radiometer in any way. Various observers have determined the relative opacity of different substances. Professor E. Doelter of Graz finds (1) that the opacity of minerals does not always increase with the density, although minerals having a specific gravity greater than 5 are relatively opaque; (2) that the complexity of the chemical constitution of a mineral effects its opacity, but no general law of relationship can be enunciated; (3) dimorphous minerals exhibit but slight differences in their behavior with regard to the rays in their different forms; (4) in most crystals, the amount of absorption does not depend sensibly on the direction of the incident rays; (5) all minerals naturally fall into about eight well-defined groups, corundum, talc, quartz, rock salt, Iceland spar, etc. The diamond is ten times as transparent as corundum and 200 times as transparent as tin foil. Dr. Filippo Campanile and Dr. Emilio Stromei (Naples) have succeeded in obtaining Röntgen rays from ordinary Geissler tubes. A variety of new forms of Crookes tubes have been invented. Professor Elihu Thomson has devised a double focus tube for use with a Thomson or Tesla coil. Both

terminals consist of aluminum mirrors. The rays impinge upon a V-shaped reflector of platinum which is placed in the middle of the tube. The effects obtained with this tube are very remarkable. I have been able to trace the outline of the heart and of the liver and to see all the ribs. The shadow of the hand can be seen through two oak doors at a distance of fifteen feet; and sensitive plates are fogged through brick walls a foot thick at a distance of fifteen feet. It has been found possible to construct tubes which are much better able to stand the strong excitation of a Tesla coil than hitherto. J. T.

9. *Diminution of the intensity of Sound with the distance.*—Various attempts have been made to determine the diminution of the intensity of sound with the distance especially by Vierordt and by Wien. The former experimented with the sound produced by weights falling on plates from different heights. He reached the result, that the sound diminished according to a linear relation with the distance. Wien measured the diminution of the sound intensity by means of determination of the amplitude—and stated the law that the intensity of sound diminishes with the square of the distance—the law is modified by frictional resistances. KARL L. SCHAEFER takes up the question anew, by the following method. A watch is placed at a certain distance from one ear and a telephone excited by a suitable interrupter is placed at a certain distance so as to just overcome the slightest ticking of the watch. Then the observation is repeated with a different position of the telephone and from a combination of the observations, it was seen that Vierordt's results were unreliable. The sound intensity in the neighborhood of the telephone diminishes more slowly than the square of the distance. With increasing distance the diminution increases, until the quadratic diminution is approximately reached and afterwards even exceeded.—*Ann. der Physik und Chemie*, No. 4, 1896, pp. 785–792. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *Fifteenth Annual Report of the United States Geological Survey.*—This report has just been delivered by the Public Printer. It is a handsome volume of 755 pages and 48 plates, and contains, besides the administrative reports of the Director himself and of chiefs in charge of work, the following special papers: "Preliminary Report on the Geology of the Common Roads of the United States," by Prof. N. S. Shaler; "The Potomac Formation," by Prof. L. F. Ward; "Sketch of the Geology of the San Francisco Peninsula," by Andrew C. Lawson; "Preliminary Report on the Marquette Iron-bearing District of Michigan," by Prof. C. R. Van Hise, W. S. Bayley, and H. L. Smyth; and "The Origin and Relation of Central Maryland Granites," by C. R. Keyes, with an "Introduction on the General Relations of the Granitic Rocks in the Middle Atlantic Piedmont Plateau," by the late Prof. G. H. Williams.

From these titles it is evident that the paper of most popular interest is the first one, on roads, by the versatile Harvard professor. He treats of the history of American roads, the methods of using stone in road-building, the relative value of road stones, their distribution, sources of supply, etc.; and thus makes a timely contribution to a subject which is receiving special attention in all parts of the country.

This is the last report made by Major J. W. Powell as Director of the Survey, who until recently has had charge of the work, under different organizations, for twenty-five years.

2. *Topographical maps of the U. S. Geological Survey;* CHAS. D. WALCOTT, director.—The following sheets of the topographical maps of the edition of 1895, are published and ready for distribution:

The San Francisco sheet, Cal.; Bryon, S. Dak.; Alpine, Tex.; Chispa, Tex.-Mex.; Dayton, Wyo.; Aberdeen, S. Dak.; Laramie, Albany Co., Wyo.; Bodreau, La.; Marfa, Tex.; Hickory, N. C.; Ocala, Fla.; Fort Ann, Vt.; Panasoffkee, Fla.; Aspen, Col.; White Hall, N. Y.-Vt.; Wartburg, Tenn.; Ned Lake, Mich.; Perch Lake, Mich.; Amsterdam, N. Y.; Sierra Blanca, Tex.; Williston, Fla.; Nomini, Md.-Va.; Sherwood, Tex.; Duluth, Minn.; Tsala Apopka, Fla.; Oriskany, N. Y.; Oneida, N. Y.; Chittenango, N. Y.; Kingfisher, Oklahoma; Willsboro, N. Y.-Vt.; Crawford Notch, N. H.; Tazewell, Va.-W. Va.; Citra, Fla.; Cripple Creek (Special), Col.; Crandall Creek, Wyo.; Ishawooa, Wyo. H. S. W.

3. *A summary Description of the Geology of Pennsylvania.*—This compact summary of the long series of reports of the second Pennsylvania survey is now complete.* The first volume of 719 pages by the state geologist, contains the descriptions of the Laurentian, Huronian, Cambrian and Lower Silurian formations, and the author states in his preface that he has written the report "in Saxon English, for the use of the people of Pennsylvania," in which he has "endeavored to avoid dogmatic statements not made by a consensus of the geological opinion of to-day," and he further describes the book as "almost wholly a practical description of facts discovered and verified by the observation of the members of the corps of the geological survey in their several districts." At the end of the several chapters appear full-page plates of half-sized reproductions of the fossils of the formations considered in the chapter, being reproductions of the figures which originally appeared in report P. 4, Dictionary of the Fossils of Pennsylvania. In volume ii, the upper Silurian and Devonian formations are treated in like manner; and both these volumes were published in 1892, and contain continuously paged 1628 pages.

* "A Summary Description of the Geology of Pennsylvania," in three volumes, with a new geological map of the state, a map and list of bituminous mines, and many page-plate illustrations. J. P. Lesley, state geologist, pp. 1–2638, plates 1–611.

Volume iii, part I, was begun by the state geologist, whose health broke down after completing the earlier chapters; the remainder of the work was prepared by Messrs. E. V. d'Invilliers and A. D. W. Smith. This part includes the discussion of the Carboniferous in general. In the second part of vol. iii, the bituminous coal fields are described by M. d'Invilliers, and the New Red of Bucks and Montgomery counties is described by Benjamin Smith Lyman. For the purposes for which these volumes were designed they seem to be admirably adapted, and for scientific students of geology they constitute a very convenient summary of the immense amount of detail of Paleozoic geology developed by the corps of the Second Pennsylvania Geological Survey. Mr. Ingham, the secretary of the Board of Commissioners, has added under separate covers a general index with an appendix containing a list of, and brief guide to, the publications of the survey. H. S. W.

4. *The Geology of the Road-Building Stones of Massachusetts, with some Consideration of Similar Material from other parts of the United States;* by N. S. Shaler; (extract from 16th Ann. Report U. S. Geol. Survey 1894–95, Part II, pp. 277–341.)—Following the more general treatment of the geology of common roads of the United States, which appeared in the 15th Annual Report, Professor Shaler has here given, in his customary clear, terse and vivid manner, a practical account of the nature, mode of occurrence and values for road-making of the rocks found on the surface of Massachusetts. In the section upon tests the author emphasizes the considerable importance of the cementing quality of the fine material produced by the wear of the stone; remarking that the experiments "indicate that it may be desirable in certain cases, when a stone otherwise suitable for macadam purposes does not afford from its powder a good cement, to cover the road with dust made by grinding some other variety of stone which will form a firmer bond." He speaks of the saving of expense in the use of properly selected glacially-distributed bowlders over quarry stone, and estimates that an average of 35 cents per ton may be thus saved in the construction of roads in the State of Massachusetts, amounting in the aggregate to seven million dollars in twenty years. In the Connecticut valley region the finest of all road-metal is found in the "trap" rock of the dikes. The materials available for road-making are discussed primarily under three divisions: i.e., drift-materials, bedded rock and dike and vein stones, and under each of these heads the distribution within the state is noted.

A table of statistics closes the report, concerning the resistance to wear of road-building stones based upon tests made by Mr. L. W. Page, Geologist of the Massachusetts Highway Commission. H. S. W.

5. *The University Geological Survey of Kansas, conducted under authority of the Board of Regents of the University of Kansas;* by Erasmus Haworth and assistants. Vol. 1, pp.

1–320, plates i–xxxi, figures 1–11. 1896.—The plan of committing the execution of the geological survey of states to the geological department of its chief university is excellent in many ways. Not only does it enable those who are likely to be the best fitted for, and most interested in investigating the geology of the state to do the work, but it must result in raising the tone and value of the geological department of the university which carries on the investigation. In organizing the geological survey, Kansas, by act of the legislature in 1889, provided that a geological survey should be one of the functions of the university. In 1893 active work was begun, and in 1895 the board of regents declared the state geological survey organized with the following officers, viz: F. H. Snow, chancellor of the university, *ex-officio* director; in charge of the several departments, Prof. S. W. Williston of paleontology, Prof. Erasmus Haworth of physical geology and mineralogy, and Prof. E. S. Bailey of the department of chemistry. Beginning with the summer of 1893, the professors, assisted by advanced students, made a preliminary survey of the state, and the present report is the result of their labors. The Carboniferous formations of the state have been mapped, classified and named, and the characteristic fossils of each of the formations recorded.

The nomenclature and classification adopted has already been reported in these pages (vol. 1, pp. 452–466).

The authors have followed the principle adopted by the U. S. geological survey in giving local names to each of the distinguishable formations, a principle which has the advantage of expressing the facts which the geologist observes and therefore knows, without committing him to a correlation which only the paleontologist can determine after a comparative study of the fossil faunas or floras. The evil of this system is more apt to arise from the limited knowledge of the observer than from any fault in the system itself. New names should be given only where the stratigraphic and structural continuity with formations in contiguous areas already surveyed is not recognizable. For the object to be attained is not to give names to the formations which shall be familiar to the local geologist, but to properly distribute the formations in the standard geological scale. H. S. W.

6. *Geological Survey of Canada.*—The following reports and maps have been recently published, viz:

Summary Report of the Geological Survey Department for the year 1895, by the Director, G. M. Dawson, pp. 154, 1896.

Report on the Surface Geology of eastern New Brunswick, northwestern Nova Scotia and a portion of Prince Edward Island, with maps Nos. 558, 559, 561, 562, 563, by R. Chalmers, pp. 149, 1896.

Report on the Area of the Kamloops map-sheet, British Columbia, with maps, Nos. 556 and 557, by George M. Dawson, pp. 427, 1896.

Laurentian area to the north and west of St. Jerome, Province of Quebec, by F. D. Adams, pp. 20, 1896.

List of Publications of the Geological Survey of Canada, Ottawa, pp. 52, 1895.

Contribution to Canadian Paleontology. Vol. II. Part 1.

Canadian Fossil Insects, Myriapods and Arachnids, by Samuel H. Scudder.

1. The Tertiary Hemiptera of British Columbia.
2. The Coleoptera hitherto found fossil in Canada.
3. Notes on Myriapods and Arachnids found in Sigillarian stumps in the Nova Scotia Coal Field, pp. 66 and plate V. 1895.

7. *Das Tierreich, eine Zusammenstellung und Kennzeichnung der rezenten Tierformen. Herausgegeben von der Deutschen Zoologischen Gesellschaft. Generalredakteur*, FRANZ E. SCHULZE. *Probe-Lieferung—Heliozoa* bearbeitet von FRITZ SCHANDIN. pp. 24 (R. Friedländer & Sohn, Berlin), 1896.—The Deutsche Zoologische Gesselschaft announce their purpose to prepare a comprehensive representation of the whole animal kingdom, naming and giving the characters of every known species now living, or which has in recent times become extinct. About fifty specialists have been selected to prepare the "lieferungs" on the special groups. It is expected that 25 years will be required to finish the work. The publishers (Friedländers of Berlin) have sent out a sample number on the Heliozoa, which is before us. In these 24 pages 59 species are cited, full references to original descriptions and bibliography for species, genera and orders are given, generic descriptions, and brief indications of the distinctive specific characters, and habitat and geographical distribution are given in each case. The systematic part and the publishers' part are also all that could be desired. The first lieferung is announced for the beginning of the year 1897. H. S. W.

8. *The Comparative Morphology of the Galeodidæ*, by H. M. BERNARD. Trans. Linn. Soc., London, 2d ser., vol. vi, part 4, pp. 305–417, plates 27–34, 1896. Few comparative anatomists or morphologists are so suggestive in their teleological discussions as the author of the present paper on *Galeodes*. His first important work on the *Apodidæ*, published in 1892, in which the Crustacea are deduced from a bent carnivorous annelid, has only lately received the recognition it deserves, and, remarkably enough, several inferences made upon theoretical grounds have been fully verified by recent discoveries relating to the ventral anatomy of Trilobites. The adverse criticism which this book first received was entirely uncalled for, and is an instance where dogmatism and autocracy are allowed to take the place of judiciousness. Hostility was incited mainly by its attitude on the "Limulus-an-Arachnid" question, although the work itself was not in the slightest degree polemical.

The *Galeodidæ* are undoubted Arachnids possessing marked primitive characters. They show the original metamerism of the body more strongly than any other Arachnid. The only fused segments are the three anterior cephalothoracic somites. The others are free, including also the ten segments of the abdomen. Therefore, these animals offer inviting opportunities for comparative morphological studies.

Most important and interesting are the discussions on the phylogeny of the Arachnida and their lack of affinity with the Merostomata. An ancestral Arachnid is reconstructed having eighteen segments, divided into two regions. The anterior portion consists of six segments, which with their appendages are specialized for locomotion and prehension. The posterior region of twelve segments is a vegetative sac. It is shown that the first fusion of segments involved the three anterior ones. In the Arachnids, the first segment was distorted and prolonged dorsally for the purpose of developing the first pair of appendages as powerful prehensile organs; while in the Merostomata, the primitive differentiation occurred through a backward ventral distortion and bending of the first segment.

Considering the mouth as primarily anterior, its ventral position in the Crustacea is the result of modification. *Galeodes* with its anterior mouth is in this respect the most primitive Arachnid, and to develop this type from *Limulus*, the latter "would have to recover its long-lost Annelidan segments almost in their primitive condition, and then, after tilting the first back on to the dorsal surface, further develop this primitive Arachnidan specialization till it reached the Scorpion stage. So that an animal having carried one specialization to an extreme would have to undo it all, in order to try a specialization the exact opposite of its own. I think it fairly safe to say that this is impossible."

A similar reversion and secondary progression would be required to develop the Arachnid sternites out of a Limuloid, or to produce the Arachnid abdomen from the specialized region in *Eurypterus* or *Limulus*. Furthur conclusions of a like nature are drawn from the construction of the beak out of a labrum and labium; from the ocular tubercle, which is unknown in other Arthropods; from the vestigial abdominal limbs, the nervous system, the œsophagus, etc. "They separate the Arachnids completely from all other Arthropods, and furthest of all from *Limulus*, whose essential morphology, or, in other words, whose early differentiation of the primitive ancestral metamerism was the very reverse of that in the Arachnids. As Anthropods, no relation whatever exists between them; as segmented animals however, they are both derivatives from the Chætopod Annelids, but along different and opposite lines of specialization." C. E. B.

9. *The Characeæ of America;* by Dr. T. F. Allen.—The third fascicle of Part II of Dr. Allen's monograph has just appeared and contains descriptions of ten species of Nitella with nine plates. The new species are *N. Leibergii* from Oregon, and *N. transilis*, founded on *N. tenuissima* var. *longifolia* of Allen's Char. Exsic. Amer. There is also a full description and figure of the little known *N. Asagræana* Schaffner from Mexico, and critical notes on several varieties of *N. mucronata*, *N. capitellata*, *N. gracilis* and *N. tenuissima*. W. G. F.

10. *Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz. Hysteriaceæ, Discomycetes* (Pezizaceæ); by Dr. H. Rehm.—This large volume of more than 1,200 pages, with many figures illustrating the structure of the different genera, is one of the best of the excellent monographs which, taken collectively,

form the second edition of what is generally known as *Rabenhorst's Kryptogamen-Flora.* On the death of Dr. G. Winter, by whom was written the volume including Uredineæ, Ustilagineæ, Basidiomycetes and Pyrenomycetes, the work on the orders of fungi was continued by Dr. Rehm, whose account of the Discomycetes is now completed in 20 parts, of which the first appeared in 1887. The full Index, prepared by Dr. Pazschke, forms an additional part. The number of species described is 6023, the last of the series being the American *Dermatea acericola*, which has lately been found in Saxony and Switzerland. The work of Dr. Rehm shows a vast amount of labor and erudition, involving the examination of authentic specimens of Discomycetes from all parts of the world. The different volumes of the *Kryptogamen-Flora*, although all valuable, vary very much in the method of presentation of the subject. In some, especially that on higher cryptogams, there is such an excess of details that the reader is embarrassed rather than helped thereby. Dr. Rehm has arranged his material admirably. The descriptions are clear, neither too condensed nor too diffuse, and the copious notes are especially valuable to American mycologists since they contain references to American species related to those of Europe. The limits of genera are drawn less easily in Discomycetes than in some other orders of fungi, and the difficulty was all the greater in the present case, because a considerable number of species formerly generally placed in lichens, but in reality having no gonidia, have been regarded by Dr. Rehm as fungi and incorporated with other Discomycetes. W. G. F.

11. *Phycotheca Boreali-Americana*; by F. S. Collins, Isaac Holden and W. A. Setchell.—The fourth fascicle of this valuable series has recently been issued and maintains the excellent character of the earlier numbers. The striking feature of the present fascicle is the considerable number of species of Batrachospermum represented by very well-prepared specimens. Among the interesting Nostochineæ distributed are *Rivularia Bornetiana* and *Arthrospira Gomontiana* recently described by Setchell. W. G. F.

III. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—The following is a list of the papers presented for reading at the meeting of the National Academy held in Washington, April 20–25.

E. W. Hilgard: The geological efficacy of alkali carbonate solutions.

M. Carey Lea: On the color relations of atoms, ions, and molecules.

E. D. Cope: On the characters of the Otocœlidæ.

A. M. Mayer: Exhibition of a linkage whose motion shows the laws of refraction of light. Location in Paris of the dwelling of Malus, in which he made the discovery of the polarization of light by reflection. (1) On experiments showing that the X-Rays cannot be polarized by passing through herapathite; (2) the density of herapathite; (3) formulæ of transmission of the X-Rays through glass, tourmaline, and herapathite.

W. A. Rogers and Frederick Brown: On the X-Rays from a statical current produced by a rapidly revolving leather belt.
G. W. Hill: Biographical memoir of James Edward Oliver.
C. H. Davis: Biographical memoir of Charles Henry Davis.
C. A. White: Biographical memoir of George Engelmann.
T. C. Mendenhall: Legislation relating to standards.
E. W. Morley and W. A. Rogers: On the determination of the coefficient of expansion of Jessop's steel, between the limits of 0° and 64° C., by the interferential method. On the separate measurement, by the interferential method, of the heating effect of pure radiations and of an envelope of heated air.
C. S. Peirce: On the logic of quantity.
J. W. Powell: Judgment in sensation and perception.
A. W. Peckham: The variability in fermenting power of the colon bacillus under different conditions.
O. N. Rood: Experiments on the reflections of the Röntgen rays.
H. A. Rowland: Notes on Röntgen rays.
Ira Remsen: Some studies in chemical equilibrium. The decomposition of diazo-compounds by alcohol. On double halides containing organic bases.
T. J. J. See: Results of researches of forty binary stars.
A. E. Verrill: On a remarkable new family of deep-sea Cephalopoda and its bearing on molluscan morphology. The question of the molluscan Archetype, or Archi-mollusk. On some points in the morphology and phylogeny of the Gastropoda.
A. A. Michelson and S. W. Stratton: Source of X-Rays.
A. W. Wright: The relative permeability of magnesium and aluminum to the Röntgen rays.
C. Barus: The state of carbon dioxide at the critical temperature. The motion of a submerged thread of mercury. On a method of obtaining variable capillary apertures of specified diameter.
C. S. Hastings: On a new type of telescope free from secondary color.
W. K. Brooks: The Olindiadæ and other Medusæ.
W. K. Brooks and George Lefevre: Budding in Perophora.
W. K. Brooks and Gilman Drew: Anatomy of Yoldia.
O. C. Marsh: On the *Pithecanthropus erectus* from the Tertiary of Java.

2. *New England Meteorological Society.*—A circular from the Secretary, Wm. M. Davis, bears the information that at the last, thirty-sixth, regular meeting held in Boston on the 25th of April, the Society dissolved by vote of its members. The undistributed copies of the Society's investigations were presented to the Astronomical Observatory of Harvard College, subject to the disposal of the Director of the Observatory, who will hereafter receive all publications addressed to the Society.

Obituary.

Dr. Carl Nicolaus Adalbert Krueger, Director of the Observatory at Kiel and editor of the latest forty volumes of the *Astronomische Nachrichten*, died at Kiel, April 21st, in the 64th year of his age.

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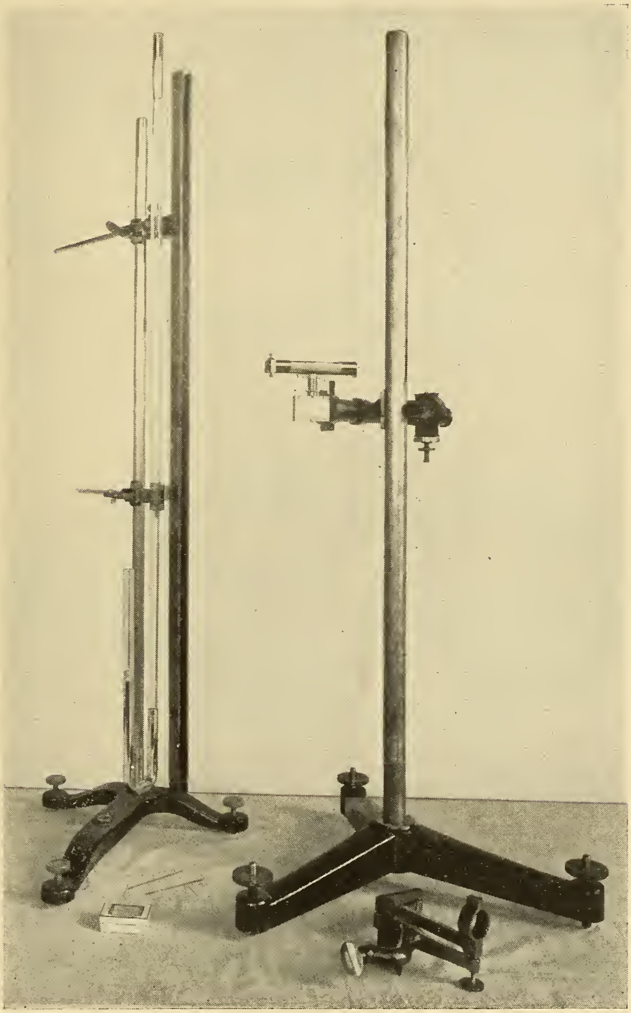

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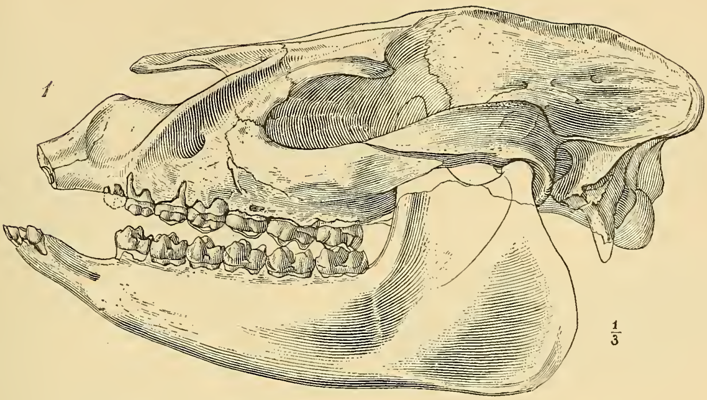

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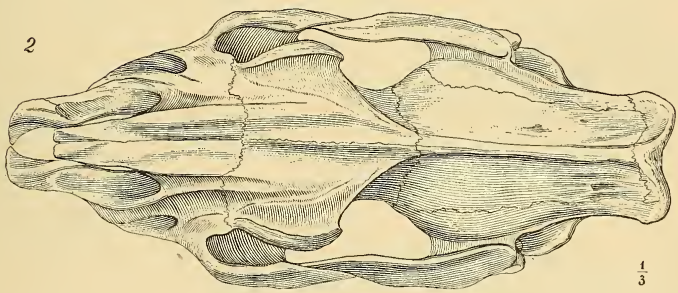

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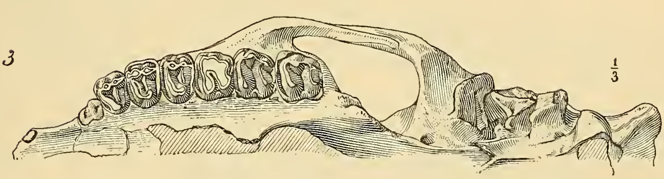

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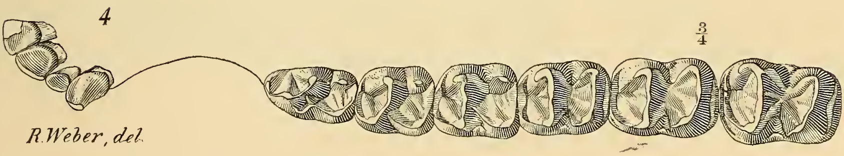

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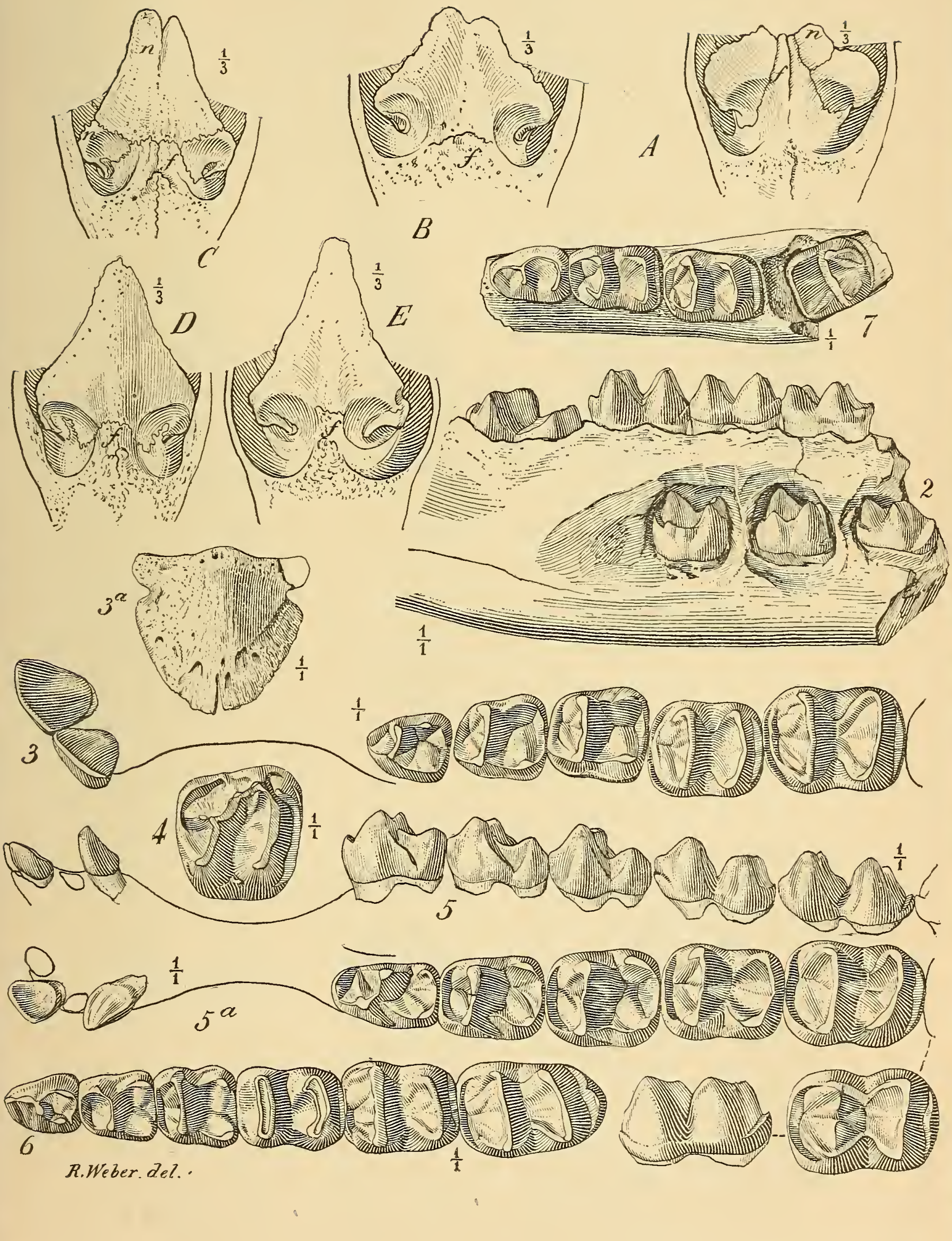
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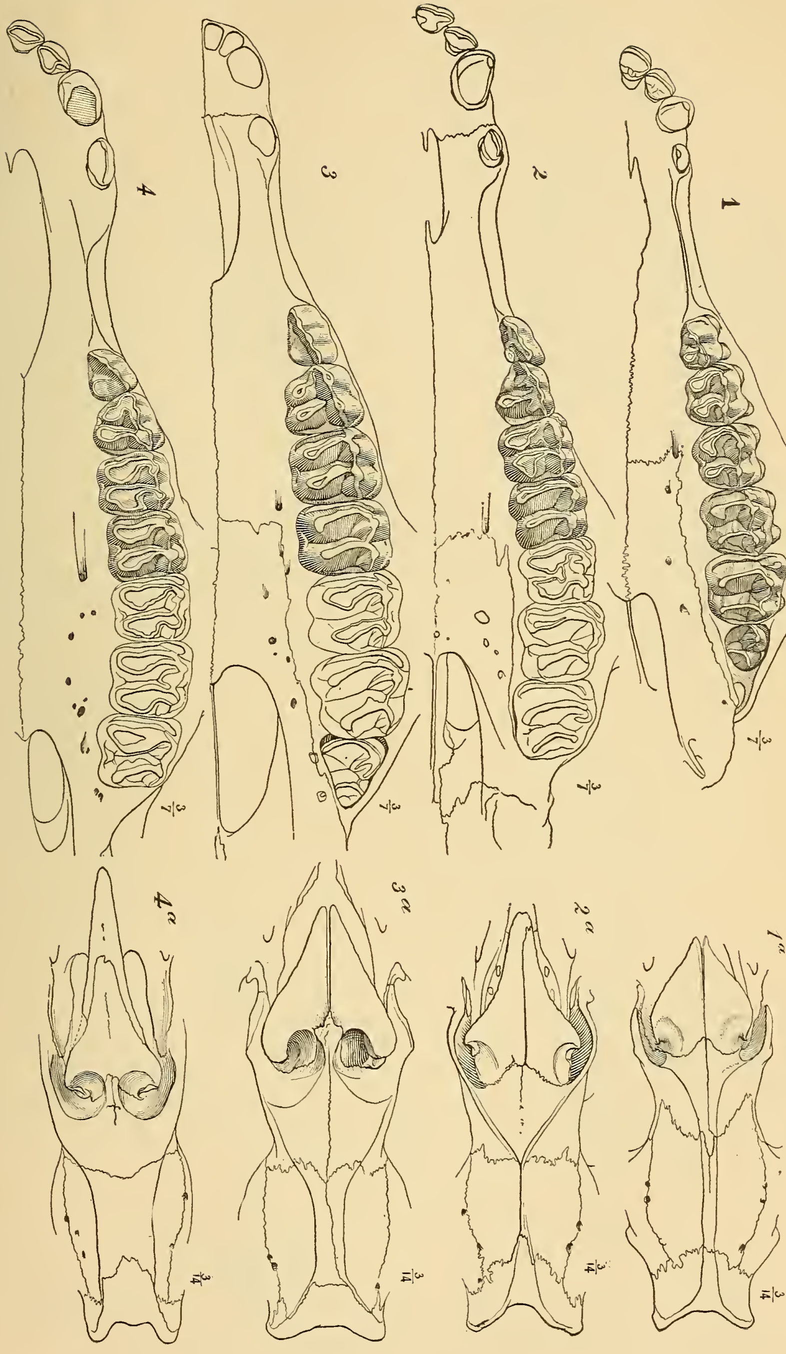
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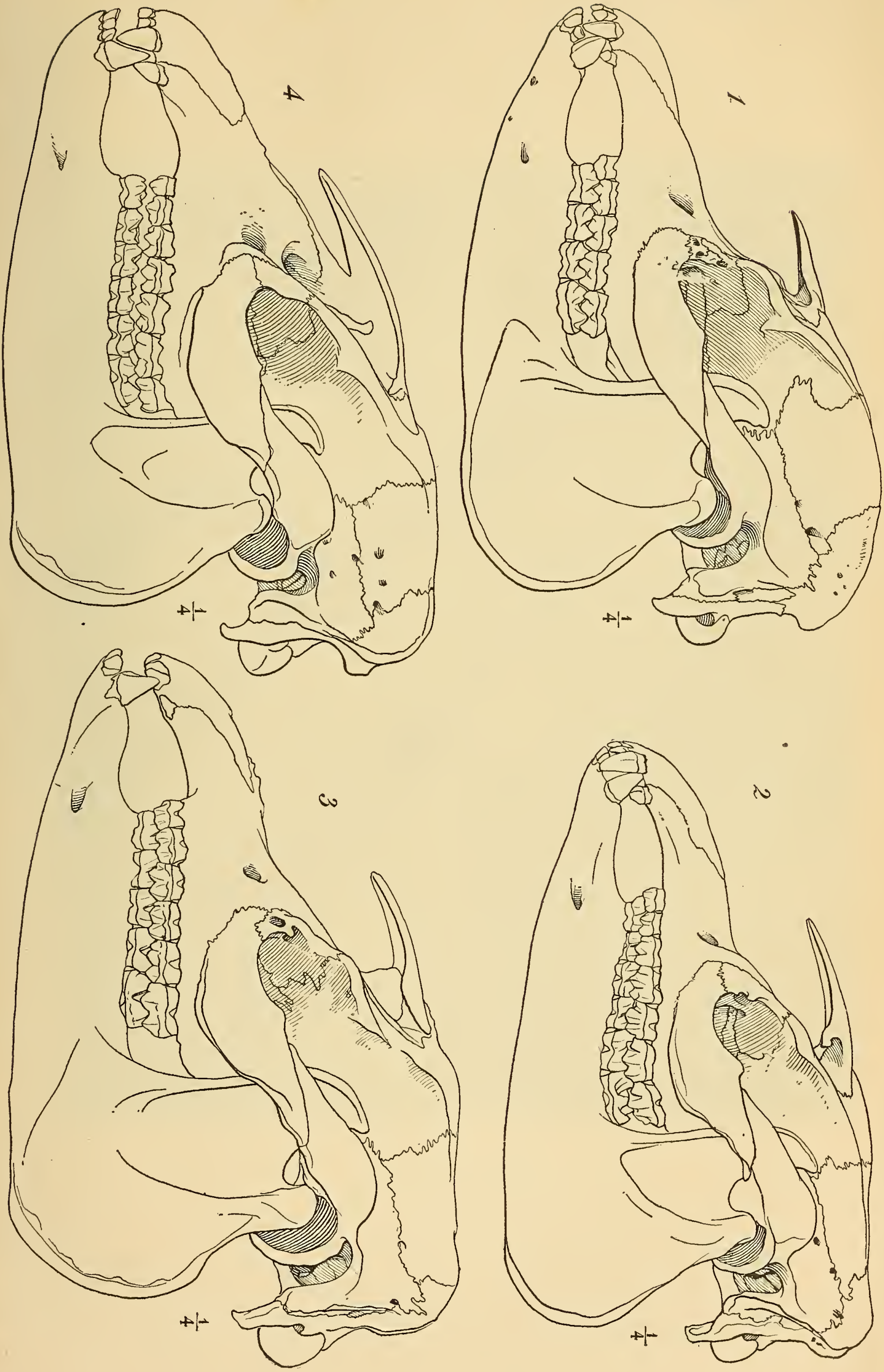
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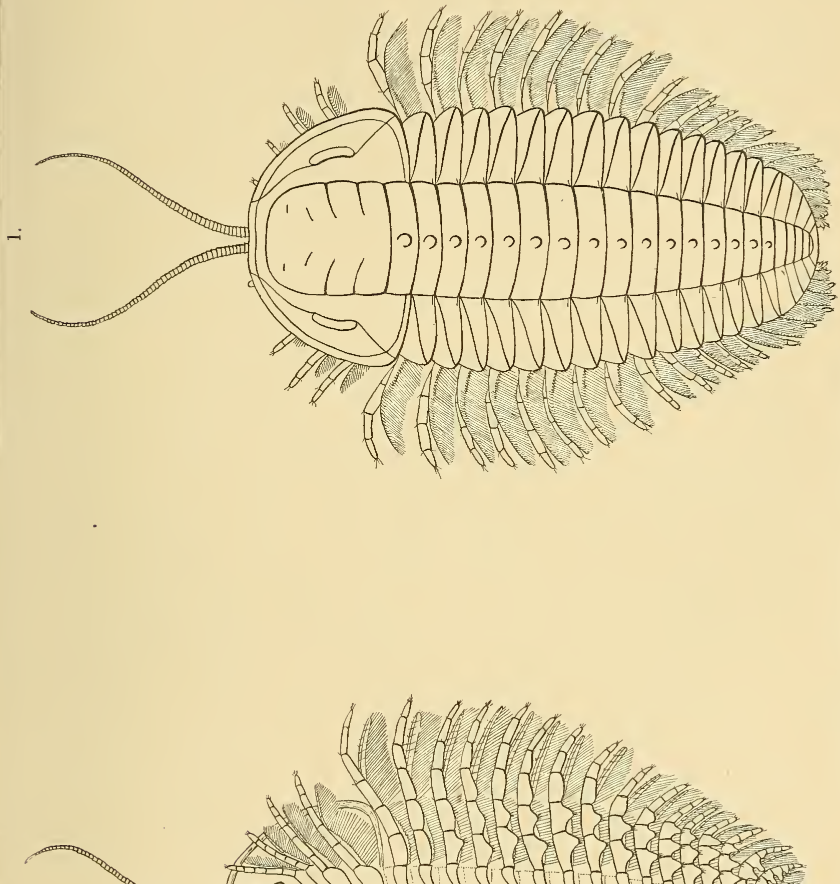

TRIARTHRUS BECKI Green. × $2\frac{1}{2}$. (Beecher.)


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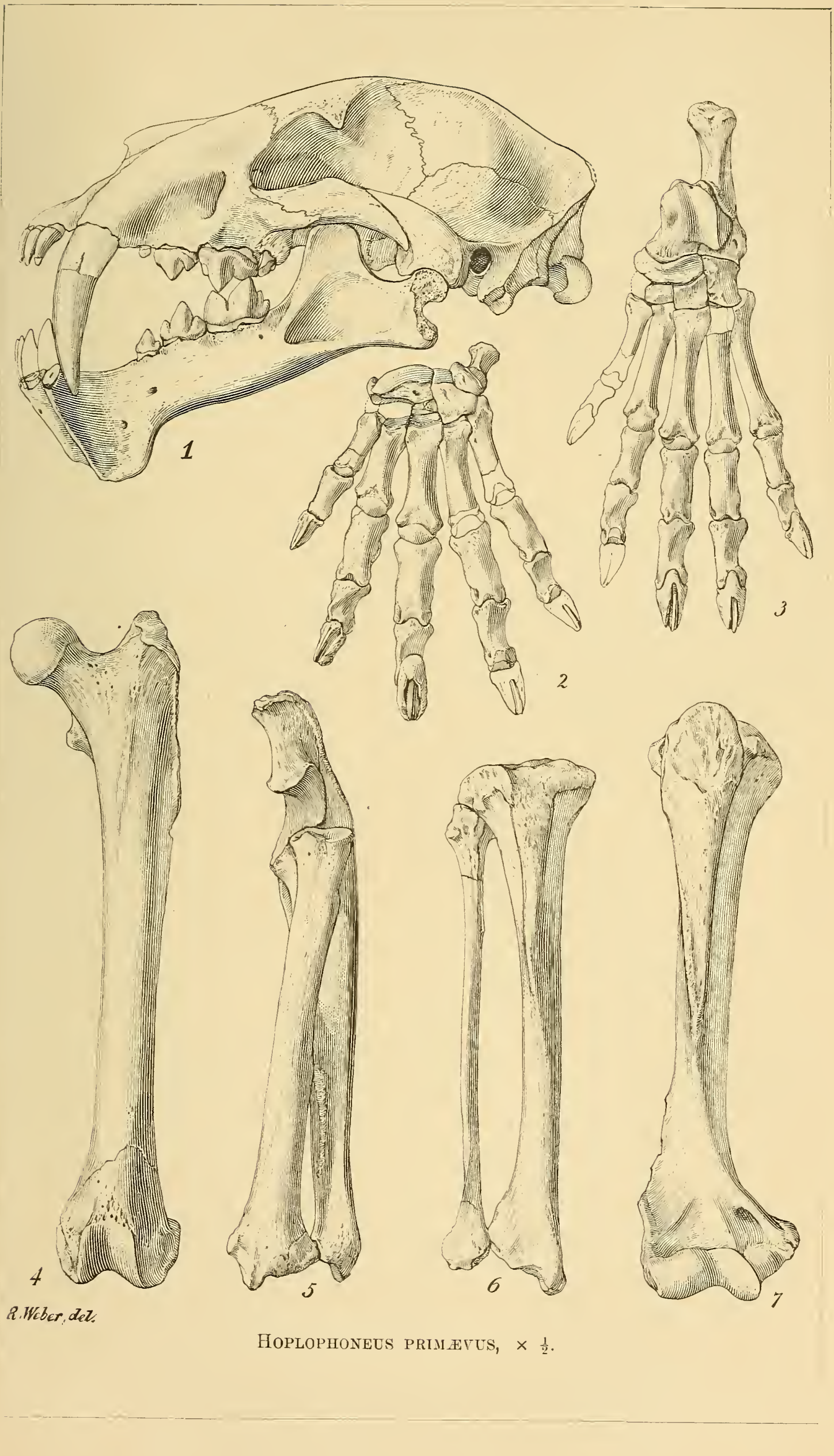
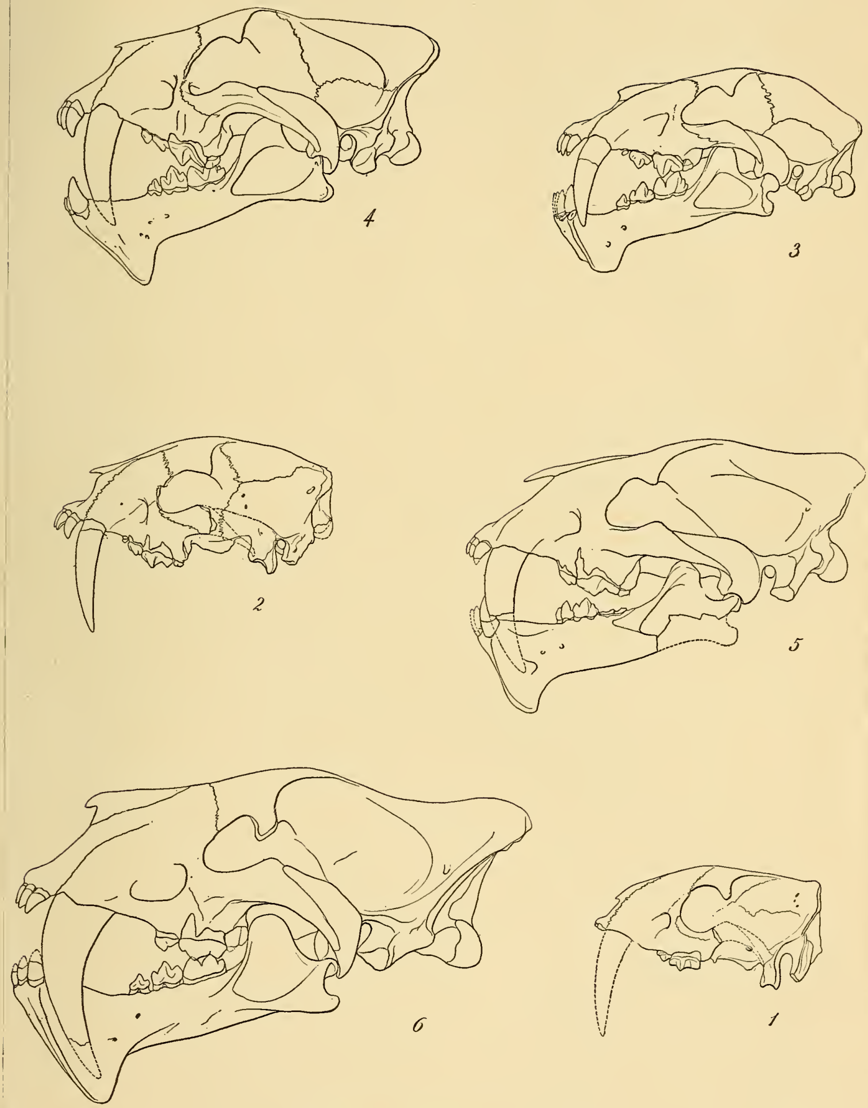
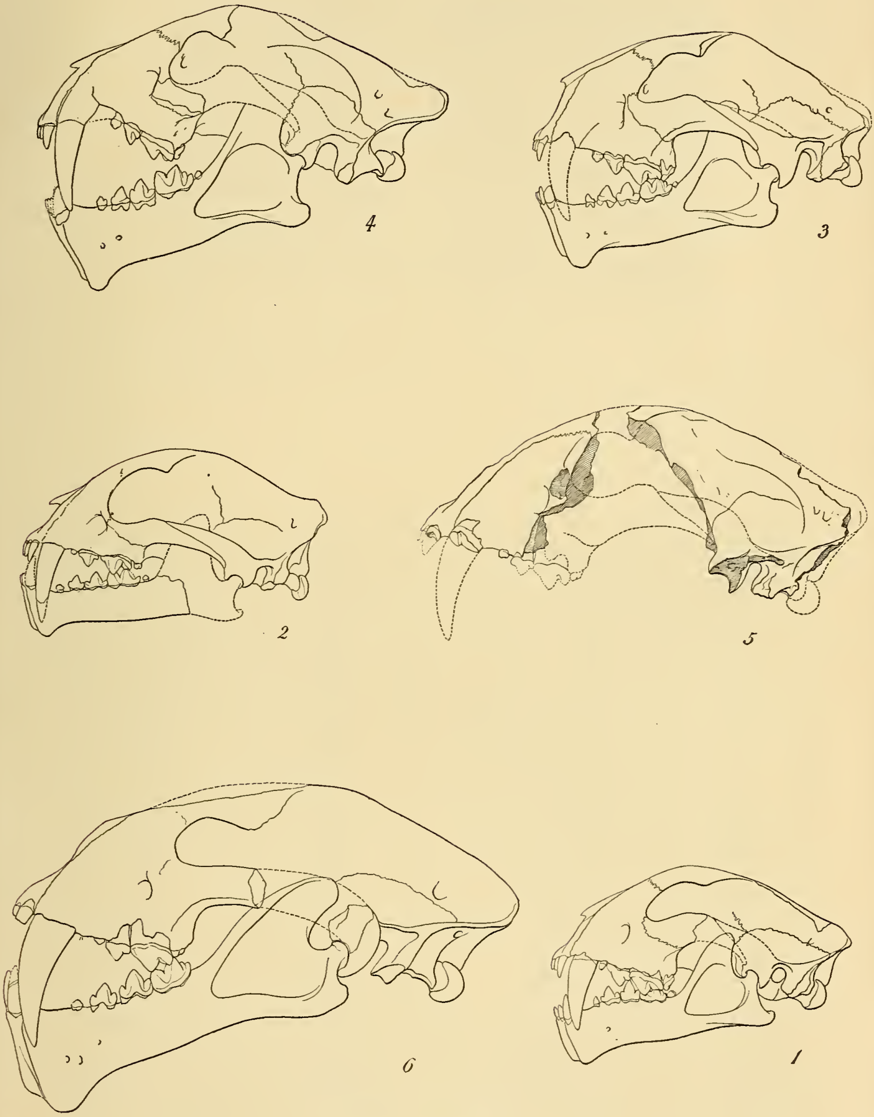
Chas. D. Walcott.



HOPLOPHONEUS PRIMÆVUS, × ½.



HOPLOPHONEUS SERIES, × $\frac{1}{4}$.



Dinictis series, $\times \frac{1}{4}$.

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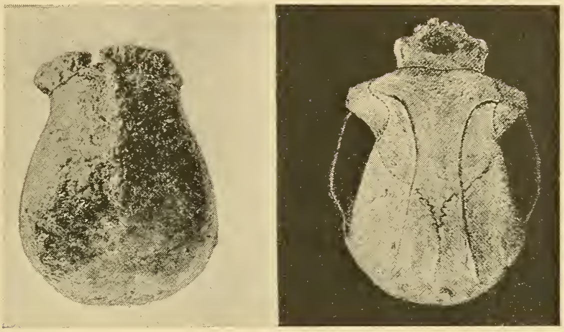

FIGURE 2.—P. Cranium of *Pithecanthropus erectus*, $\frac{1}{6}$.
Hs. Skull of *Hylobates syndactylus*, $\frac{1}{3}$. (After Dubois.)

5.

P H

a *b* *a* *b*

FIGURE 5.—P. Left femur of *Pithecanthropus erectus*, $\frac{1}{6}$.
H. Left femur of man, $\frac{1}{6}$. (After Dubois.)
a, front view; *b*, exterior view.

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