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ERRATUM.

In the paper by M. Carey Lea on the *Color relations of atoms, ions and molecules* published in the May number of this Journal, by an unfortunate mistake on the part of the printer, the groups in the table on page 362 have been transposed so that groups three and four take the place of groups five and six and conversely. On page 361 the groups appear in their proper order.

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Art. I.—*On the Correlation of New York Moraines with Raised Beaches of Lake Erie*; by Frank Leverett.

About three years since the writer discussed the relation of certain moraines of northern Ohio to the raised beaches of the western portion of the Erie basin.* The fact that the several raised beaches terminate in a successive series from higher to lower in passing eastward from northern Ohio to southwestern New York, had previously been determined by Mr. G. K. Gilbert, and had suggested to him the hypothesis of ice occupancy eastward from the termini of the beaches. In that paper it was shown that a study of the moraines supports the hypothesis. The position of the moraines on the south border of the Lake Erie basin and their relation to beach lines which terminate in northern Ohio is such as to indicate that the eastern portion of the Lake Erie basin was still occupied by the ice sheet while the western portion was occupied by the lake which formed these beaches. At the time that paper was prepared the glacial features of western New York (where Mr. Gilbert had discovered that two lower beaches terminate) had not received attention, and it was not until the autumn of 1893 that opportunity was afforded to examine these features. The examination of these features was not premeditated, otherwise it would have been more thorough and would have been preceded by a fuller understanding of Mr. Gilbert's results. It was taken up in connection with a study of the moraines bordering the re-entrant angle in the glacial boundary in southwestern New York. When that study was entered upon it was planned to examine only the southern border of the

* This Journal, April, 1892, pp. 281–301.

glaciated district, but the morainic complications are such that it was found necessary to work northward nearly to the border of the old lake. After the completion of the main line of investigation a few days were spent in the study of the features in the vicinity of the termini of the beaches, but the approach of winter prevented its satisfactory completion. The phenomena prove to be complicated and in some ways obscure, but it is thought that fuller study of certain features may clear up the difficulties. It will be observed that an untouched field remains at the eastern terminus of the upper (Sheridan) beach, a field which is likely to yield definite results when given proper attention. This and other defects do not leave in doubt the main question of the correlation of the beaches with the moraines. That the beaches are absent because of the presence of the ice-sheet at that time, in the region to the east of their eastern termini, is made clear by the position of the moraines and their features near the termini of the beaches. Inasmuch as opportunity for completing the study is not at present open, it seems advisable to set forth the situation so far as now understood.

Mr. Gilbert spent considerable time, in 1886, in the study of the beaches here discussed. He has delayed publication in the hope of having opportunity to round out the subject. But as there is no immediate prospect for doing so, he has kindly furnished from his unpublished notes some of the data here presented. I wish also to acknowledge indebtedness to Mr. Gilbert for a careful revision of this paper, as well as for guidance in field observations.

A word seems necessary concerning the introduction of names for the beaches here discussed. They are the names chosen by Mr. Gilbert about the time he made the study referred to and are the names of towns situated on the beaches. It seems probable that the Sheridan beach constitutes the continuation of the Belmore, but until this matter is fully settled it is considered advisable to use a separate name. The Crittenden beach is perhaps the same beach which, on the Canadian shore, Dr. Spencer has called the Forest,* but as yet these observers have not made sufficiently close connection to render the correlation entirely certain. It seems best, therefore, for the present to employ both names.

The Sheridan Beach.—The upper of the two raised beaches which border the Lake Erie basin eastward from Cleveland has been traced by Mr. Gilbert to Sheridan, New York, a village about 30 miles southwest from Buffalo. (See Map, Fig. 1.) It is thought by him that the beach may extend to the vicinity of Hamburg, immediately south from Buffalo, but he expresses

* This Journal, vol. xli, 1891, pp. 203–204.

uncertainty concerning the portion east from Sheridan, owing to the fact that the ground has been but partially examined, and also because the beach phenomena are in places somewhat obscure. From Hamburg eastward the absence of this beach is a matter of concurrent observation by Mr. Gilbert and the writer.

FIG. 1.—MAP OF WESTERN NEW YORK, BY FRANK LEVERETT.

Explanation of Map.—The shaded portions represent moraines. Their mapping is incomplete east from the Genesee valley and interrogation points there mark the lines of continuation. The glacial boundary, indicated by a series of broken lines and dots, here reaches its most northern point between the Atlantic Ocean and the great plains west of the Missouri river. Striæ are represented by arrows. The raised beaches are indicated by continuous lines. A series of broken lines are introduced, in the district between Sheridan and Hamburg, where it is thought that the Sheridan beach may have a continuation. Drumlins are represented by elongated ovals, which indicate their trend. Eskers are represented by straight lines which also indicate their trend. These should be distinguished from striæ by the absence of an arrow head. They are numerous in the vicinity of the bend of Oak Orchard creek in southwestern Orleans county, as indicated in the text.

From Sheridan, New York, westward to Cleveland, Ohio, the Sheridan beach lies but a short distance south from the present shore of Lake Erie and may be seen at numerous points from the railway lines which follow the lake shore from Buffalo to Cleveland, as may also a lower beach (the Crittenden). Westward from Cleveland its identification is not made entirely certain. At the time of the preparation of the paper on the correlation of moraines with the beaches of the western part of the Lake Erie basin, it was the writer's opinion that the Leipsic and Belmore beaches, which had been traced eastward to the Cuyahoga valley, each connected with a correlative moraine in the vicinity of that valley. Nothing has been found to completely set aside this view, but upon further reflection an alternative view has presented itself, viz: that the upper, or Leipsic, beach may be the correlative of both the moraines and that the Belmore beach may find its eastward continuation in what is here called the Sheridan beach. I take occasion, therefore, at this point, to set forth the situation more fully than was done in the earlier paper. In my former paper the statement is made (p. 298) that I have learned through correspondence with Mr. Gilbert that neither the Leipsic nor Belmore beaches continue east from Cleveland. We have since that time conferred more fully on this matter and find that his data do not seriously conflict with this alternative view, as will appear in the table of altitudes of the Sheridan beach given below.

For a few miles east from the mouth of the Cuyahoga it is difficult to identify the upper beach, there being a bluff-like rocky escarpment along the south shore of Lake Erie thinly clad with drift and rising to a considerable height above that of the beaches. On this escarpment several shelves appear. These shelves are of varying width from a few feet up to 80 rods or more. They are probably due to a combination of agencies embracing differential degradation in preglacial time, moulding by the ice-sheet, and wave action. The extent and influence of wave action was not fully and satisfactorily worked out. It is certain, however, that but a small portion of the cutting can be due to wave action, some of the shelves being much too broad to be formed by this agency alone in the not lengthy interval necessary to the formation of the beach. A few miles east from Cleveland the slope of the escarpment becomes less abrupt, and drift deposits of considerable depth occur, upon which the waves have left distinct traces.

In the southwest part of Cleveland the Belmore beach stands about 170 feet above the lake. Passing east to the nearest point where the beaches are well developed, a short distance east from the city limits of Cleveland, we find that the uppermost beach (which is here called the Sheridan) stands only about 160 feet above the lake. Above this level the topography is morainic, and so far as the writer could detect it presents no indications of wave action. The ice-sheet seems, therefore, to have been present here while the lake, west from Cleveland, was standing at the level of the Leipsic beach (about 200 feet above Lake Erie). We refer to our earlier paper for descriptions of the two moraines whose western termini are found to be near Cleveland. The replacement of beach phenomena by morainic, in passing to the east of Cleveland, is a matter concerning which we express no doubt. The question is whether both the beaches are thus replaced, or only the upper one. Since continuous tracing is difficult, this may perhaps best be determined by a comparison of beaches in the two districts. In the district east from the city of Cleveland only two strong and well defined beaches appear above the present shore. One of these, the Crittenden, may be traced continuously through Cleveland and westward past the point where the beaches west of the Cuyahoga set in. There is no question as to its identification. We have, therefore, only to decide upon an equivalent for the Sheridan beach west from the Cuyahoga. By reference to the map of raised beaches west from Cleveland, prepared by Prof. A. A. Wright,* and the accompanying discussion by Dr. Newberry, it will be seen that there are but two important beaches above the Crittenden, one the "South Ridge," standing about 200 feet above the lake, the other the "Middle Ridge," standing about 155 feet above the lake throughout much of its course from the Vermilion to Rocky river (the range being from 148 to 162 feet), but standing a few feet higher for a few miles between Rocky river and the Cuyahoga. There is also a local and inferior line appearing at an altitude of 135 feet above Lake Erie for a few miles in the Cuyahoga embayment. The upper beach or "South Ridge" is entirely too high to be connected with the Sheridan beach. But were the altitude of the portion of the "Middle Ridge" between Rocky and Cuyahoga rivers as low as the portion west from Rocky river, the entire "Middle Ridge" system would be in excellent harmony with the Sheridan beach. The writer examined this portion of the beach in the spring of 1893, in company with Prof. H. P. Cushing, of Adelbert College. Our barometric determinations show the ridge to be slightly higher at the crossing of the C. C. C. & St. L. railway than farther west. This point by railway survey is only 170 feet above Lake Erie instead of 178 feet, as given on the map. We conclude that the map contains a slight inaccuracy and that this portion of the beach is, therefore, more nearly in harmony with the remainder of the "Middle Ridge" and also with the Sheridan beach than the altitudes there published would indicate. The variation from the normal height

* Geol. of Ohio, vol. ii, pp. 58, 59.

may not exceed 10 feet. The inner slope of the beach in this highest portion extends down to about as low a level as the portions to the east and west. This fact, together with the fact that neither the beach above this one nor the beach below it show unusual height in this portion of their course, leads to the conclusion that the unusual height is not due to crust warping. A possible cause is discussed below.

Another point in favor of the correlation of the Belmore beach or "Middle Ridge" with the Sheridan beach is its similarity in strength. Were the Sheridan beach much weaker than the Belmore there would be doubt as to its being the full correlative, even though it has the same altitude, but no essential difference in strength could be detected.

The beaches have not yet all been traced through into connection with those at the western end of the Lake Erie basin. Mr. Gilbert's studies at the western end of Lake Erie bring out a similar series there to that found by Prof. Wright west from Cleveland except that there is a still higher beach present west from Findlay, Ohio. There is but one beach between the Belmore or "Middle Ridge" and the present shore. This beach has an altitude in harmony with the Crittenden beach, and in all probability constitutes its continuation. Dr. J. W. Spencer considers the Ridgeway beach of Michigan a continuation of the Belmore beach or "Middle Ridge." If this identification and that of the writer are correct, the Sheridan beach, "Middle Ridge," "Belmore beach" and "Ridgeway beach" are but a single beach line. The several names should, perhaps, be retained until fuller identifications are made.

According to our earlier view the lowering of the lake in the western part of the Erie basin from 200 feet above the present lake level down to 150–170 feet occurred before the later of the two moraines which terminate near Cleveland was formed. According to the later view it took place at about the time the ice-sheet receded from that moraine. The absence of notable wave action above the level of the Sheridan beach eastward from Cleveland indicates that the higher lake level was not held for a long period after the ice-sheet had begun to recede. The fact that the portion of the beach east from Cleveland is about as strong as that west, indicates that the lake had not dropped to the lower level much before the ice-sheet withdrew.

A possible cause for the unusual height of the portion of the beach near Cleveland may be found in the attraction of the ice-sheet. Such a mass of ice would, no doubt, attract the water near its margin to an altitude slightly above the normal level of the lake. It remains to be determined whether the excess of altitude is too great to be due to such an attraction or whether other causes may be found.

None of the beaches west from the meridian of Cleveland show marked differential uplift, the height being only about 20 feet greater at Cleveland than in the extreme western end of the basin. The following table embraces the data at hand which have a bearing upon the crust warping in the eastern part of the basin along a line parallel with the south shore of the lake:

Table Showing Altitude of Raised Beaches East from Cleveland.

Station.	Distance, Miles.	Sheridan Beach.	Crittenden Beach.	Remarks.
Cleveland, Ohio	0	743 ft.	668–675 ft.	Ridge, Numerous surveys.
Euclid, Ohio	9	735	---	Terrace, Aneroid.
Wickliffe, Ohio	14	742	---	Ridge, Aneroid (Gilbert).
Wickliffe, Ohio	14	---	682	" Locke level (Gilbert).
Willoughby, Ohio	19	735–740	675–680	" Aneroid.
Mentor, Ohio	23	---	670	" Est. from railway.
Painesville, Ohio	29	---	670	" " "
Madison, Ohio	40	725–730	---	" " "
Madison, Ohio	40	723	673	" Geol. of Ohio.
Unionville, Ohio	42	725–730	---	" Est. from railway.
Geneva, Ohio	45	730	675	" " "
Kingsville, Ohio	60	775 (An.)	700	" " "
Cross Station, Pa.	78	765	---	" Railway survey.
Erie, Pa.	95	778	---	" City Engineer.
Northeast, Pa.	110	790	---	Several beaches bet. 710 and 790 ft. Locke level (Gilbert).
State line	115	785	---	Railway survey.
Ripley, N. Y.	118	790	---	Est. from railway.
Westfield, N. Y.	120	835	725–750	Aneroid.
Near Brocton, N. Y.	128	---	713?	Ridge, Aneroid (Gilbert). ?
Sheridan, N. Y.	146	834	752–773	City Engineer.
Brant, N. Y.	155	---	770	Ridge, Aneroid (Gilbert).
North Collins, N. Y.	160	---	792	Terrace, Aneroid (Gilbert).
Hamburg, N. Y.	175	---	790–815	Ridges, Aneroid.
Near Hamburg, N. Y.	175	865	---	Terrace, Aneroid (Gilbert).
Elma Center, N. Y.	190	---	820–828	Railway survey.
Alden, N. Y.	200	---	864–870	Est. from railway.
Crittenden, N. Y.	204	---	848–860	Ridges, Locke level (Gilbert).

It will be seen by the above table that the beaches have slightly lower altitude 40–45 miles east from Cleveland than in the vicinity of that city, though there is but little departure from horizontality throughout this distance. Further east there is marked eastward differential uplift. The data, it will be observed, are largely based upon careful levels, either by railway survey or city engineers. There can, therefore, be no mistake as to the uplift. The Locke level measurements are close approximations. The aneroid readings were carefully taken, but are liable to contain errors of considerable amount. The observations at Kingsville and Westfield need verification by careful leveling, as they seem to give the beach an altitude at these points inconsistent with the adjacent more refined determinations.

Probable Correlative Moraines of the Sheridan Beach.—There are two morainic lines in southwestern New York, the date of whose formation is thought to have been contemporaneous with that of the Sheridan beach. The outer of these two morainic belts is well defined as far southwest as the Cattaraugus valley near Gowanda, about 15 miles east from Sheridan. Westward from Gowanda, along a line leading past Perrysburg, Nashville and Forestville, there is a bowlder belt which is now thought to mark the line of continuation of the ice margin. This has been traced westward only to the valley of Walnut creek near Forestville. At the time this bowlder belt was examined the well defined morainic belt leading northeast from Gowanda had not been observed, and it was supposed to be only an unusually bowldery inner border of the Dayton moraine, a moraine which lies immediately south of it. But upon examining the district east from Gowanda the well defined moraine alluded to was discovered and found to be distinct from the Dayton moraine and to be very thickly set with bowlders. These features suggested the possibility that the bowlder belt west from Gowanda should be distinctly separated from the Dayton moraine. With this suggestion arose the query whether the belt may not be a correlative of the Sheridan beach. No opportunity came for revisiting the region and testing the value of these after thoughts by a careful study of the relations of the bowlder belts to the eastern terminus of the beach. It is certain that the bowlder belt does not continue with such strength beyond the valley of Canadaway creek unless it be inside (north of) the Sheridan beach, for the writer made a careful examination of the narrow district between the Dayton moraine and Sheridan beach for about 30 miles westward from the creek valley, and at frequent intervals to the western terminus of that moraine 100 miles further west, near Cleveland, Ohio. In the 8–10 miles between Walnut creek and Canadaway creek, where we now suspect a connection between the moraine and beach to occur, no observations were made.

The position of the moraine is indicated on the accompanying map. At its eastern end it connects with the northern part of the great interlobate belt which occupies the "Watershed of Western New York." The moraine, where well defined, has a breadth of 1–2 miles. The bowlder belt has about the same breadth. It is not a bulky moraine even where well defined, its usual relief being but 10–20 feet above the district southeast of it. A few knolls have a height of 30 feet, but the majority are 10–15 feet in height. They are, as a rule, closely aggregated and, together with the liberal supply of surface bowlders, they give a decidedly morainic cast to the belt and a contrast to the nearly plane tracts on either side. Along the bowlder belt a few knolls and ridges 10–20 feet or more in height were noted, but the greater part of the surface is plane.

On the inner (northwest) border of the moraine and bowlder belt the drift is exceedingly thin as far east as the meridian of Buffalo and Hamburg and north to the shore of the lake. Over extensive areas there is scarcely enough material to conceal the rock and form a soil, and the average thickness probably falls below 10 feet. Further east the drift is, on the whole, thicker, and a well defined moraine appears north from the one under discussion.

The moraine referred to is the inner one of the two correlated with the Sheridan beach. It may be traced from Hamburg eastward to the northern end of the great interlobate belt in Wyoming county, which it joins a few miles southeast of Alden, near the corners of Genesee, Wyoming and Erie counties. Its course may be seen on the accompanying map. The continuation of the ice margin beyond Hamburg was probably northwestward, there being a more liberal supply of bowlders in that direction than in adjoining districts to the north or south.

This moraine also is not a bulky one. Its breadth is seldom so much as two miles, and its relief but 20–30 feet. It carries fewer bowlders than the one outside of it, but its surface expression is decidedly morainic. Some of its knolls are exceedingly sharp and there are frequently basins among them. Near the western end, one or two miles east from Hamburg, a few basins occur on its inner border north from the Crittenden beach. Their depth is slight, but they no doubt have been filled greatly by the lake waves. The extreme western end of the moraine, for a mile or so east of the village of Hamburg, is a gently undulating till ridge standing but a few feet above the bordering districts.

There is need for further study to determine the exact relations between the Sheridan beach and this moraine. In the district immediately southwest from the terminus of the moraine, where we should expect the beach to appear, the conditions are not favorable for a beach ridge to be formed, there being a bluff-like escarpment of shale very thinly coated with drift. This escarpment rises in a series of steps or shelves to a height far above the level of the Sheridan beach. It is evident that these shelves are mainly due to other agencies than wave-action, and it becomes difficult under such conditions to decide how far wave action has extended. The presence of water-worn or wave-washed material, or even of gravelly ridges resembling beaches, may not be satisfactory evidence of the lakes occupancy, for the ice sheet has carried such material from low to high altitudes and occasionally, where water was abundant, has formed deposits which closely resemble beaches. Such deposits are, however, rare in this district. Mr. Gilbert has noted places south of Hamburg which seemed to show wave action at about the level of the Sheridan beach, but the action was so obscure that he entertains only a suspicion not a conviction. In case Mr. Gilbert's suspicions are confirmed, the connection with the western end of the moraine may be very close.

The Crittenden Beach.—The Crittenden beach was studied in detail by the writer only from Hamburg eastward. For this reason, and because its eastern terminus is a matter of especial interest, the discussion is confined mainly to that part of the beach. The course of the beach is quite definitely known from Cleveland eastward, being nearly parallel to, and but a short distance from the present shore of the lake. The portion eastward from Hamburg extends beyond the present shore, but the extreme eastern terminus is not more than 30 miles distant from the lake. Westward from Cleveland it is found within 30 miles from the lake throughout its course in Ohio.

This beach is not confined to a simple ridge but consists of a system of ridges closely associated. The vertical range, at some points between the highest and lowest members of the system, is about 30 feet, and a range of 20 feet is common. In his discussion of the portion at the western end of Lake Erie, Mr. Gilbert notes a range of 25–30 feet, the highest members, or upper limit of deposits being 90, and the lowest 60–65 feet above the present lake level.* In his discussion of the portion near Cleveland Dr. Newberry notes a similar range, the highest point being 118 feet and the lowest 95 feet above the lake.† In the eastern part there is a range of at least 25 feet and possibly more.

In the table of altitudes given above the upper limits of the beach are taken wherever practicable, but in some instances it is uncertain that the highest member was found. At Crittenden only the lower members are present, the higher having terminated near Alden, as shown below.

Between the upper limits of the Crittenden and lower limits of the Sheridan beach there is usually a space of about 50 feet where beach ridges are rare. The observations taken are not sufficiently full nor refined to make it clear whether or not a measurable amount of differential uplift took place between the formation of the Sheridan and Crittenden beaches. The amount since the date of the Crittenden is certainly closely similar in the two beaches.

* Geol. of Ohio, vol. i, 1873, p. 554.
† Geol. of Ohio, vol. ii, 1874, p. 59. Also map, p. 59.

Taking up now the detailed discussion of the eastern terminus of the Crittenden beach, we find the beach leading somewhat directly northeastward from Hamburg to Alden township, Erie county, where a branching occurs, the higher portion passing E.N.E. through the village of Alden and beyond to the western border of Genesee county, while the lower portion bears northeast to, and beyond, Crittenden.

Between Hamburg and Alden the beach traverses the villages of Abbotts Corners, Websters Corners, Springbrook, Elma Center and West Alden. In this portion of the beach distinct ridges are not usually developed, though at one point (south of West Alden) three ridges were found with a difference in altitude of fully 15 feet between the highest and lowest, and at Hamburg two distinct ridges appear whose difference in altitude, as determined by Aneroid, is about 25–30 feet and whose trend is quite dissimilar (see map). The beach usually consists of a single main ridge below which there is a sandy or gravelly slope on which subordinate lines appear which are less continuous than the main ridge and above which there are also subordinate lines. The main ridge is, therefore, in the midst of the system rather than at its upper limit. Whether or not this is true of the portion west from Hamburg the writer is not prepared to say. The main ridge is usually 20–30 rods in breadth and has a gravelly or sandy deposit 8–10 and occasionally 15 feet in depth. At the point where streams entered the old lake, notably at Cazenovia creek west of Springbrook, at Buffalo and Little Buffalo creeks west of Marilla, and at Cazenovia creek south of West Alden, there are delta accumulations of considerable extent. These deltas contain gravelly rather than sandy material.

The portion of the beach which passes eastward from West Alden has the form of a series of beachlets or short ridges so arranged that the eastern end of one lies south of, or outside, the western end of its neighbor, the whole series occupying a breadth of nearly one-half mile. These extend into the western end of Darien township, Genesee county, about three miles E.N.E. from Alden station, where they terminate very abruptly on a low plain bordering Ellicott creek. The altitude farther east is such that the lake could have covered it to a depth of but a few feet at most, and this may perhaps account for the limitations of the beach. There is, however, another feature which may have been influential. A till ridge of morainic type begins north of Alden between this outer portion of the Crittenden beach and the main beach line (which leads to Crittenden) and this till ridge leads eastward into Genesee county past the end of the beach. It is distant only about a mile from the beachlets and has sufficient height to have stood above lake level and protected the narrow bay back of it from the action of strong waves. The strength of the beachlets for the three or more miles in which they are developed in the lee of this till ridge is perhaps more remarkable than the absence of the beach in the eastern portion of the plain. We would remark, however, that in case this till ridge is a correlative of the beach (as it appears to be) we may suppose that prior to its formation the ice front at times stood sufficiently far to the east to leave the beachlets open to the sweep of waves from the broad lake which lay to the west.

Returning to the point of separation of the outer and inner portions of the Crittenden beach, near West Alden, and following the inner portion we find it passing northward to Alden Center, where it is crossed by Ellicott creek. From this point its course is northeastward to Crittenden. Throughout much of the distance it lies along the inner face of the till ridge just mentioned and falls short 10–20 feet of reaching the level of its crest. The breadth of this portion of the beach is about as great as the breadth of the main beach west from West Alden, showing a range from 20 rods up to 40 rods or more and the depth of gravel is usually 10–15 feet. The beach maintains this strength to a point about two miles east from Crittenden in a course parallel to, and immediately north from, the New York Central Railway. Here at a point almost due north from the eastern terminus of the beachlets composing the outer or upper portion this division of the beach also becomes ill defined.

Immediately east from the point where the Crittenden beach becomes obscure a complicated series of morainic ridges sets in which occupy the interval between the New York Central Railway and Tonewanda creek eastward to the bend of that stream near Batavia. These are discussed below as probable correlatives of the Crittenden beach.

Upon examining closely the district west from the ends of these morainic ridges we find occasional developments of low gravelly ridges, apparently the product of wave action. They seldom rise more than three feet above the bordering plain and are but a few rods in width. On the lakeward side of these ridges, however, there are, in places, quite extensive deposits of sand and gravel with plane surface which have the appearance of being the deposits of a lake bottom. These occasional developments of beach phenomena occur as far northeast as a point two miles north of the village of Indian Falls in the southern part of Alabama township, Genesee county (the northwest township of the county). The action of waves is there indicated on the brow of the Corniferous escarpment by a narrow bench cut in the drift and bordered on the east by a low ridge of gravel. Upon passing eastward along the brow of the escarpment a morainic belt is soon entered which leads thence northwestward past Lockport, and which marks apparently the terminal accumulation of the ice lobe when it had withdrawn nearly to the limits of the Lake Ontario basin. This morainic line also is discussed as a probable correlative of the Crittenden beach and is called the Lockport moraine.

Probable Correlative Moraines.—Having followed the Crittenden beach as far east as it is distinctly traceable and found its terminus to be closely associated with the western ends of a series of morainic ridges, we are prepared to consider these moraines briefly and to discuss the question whether they are the correlatives of this beach.

The morainic belt which sets in near Alden between the outer and inner portion of the beach, leads eastward to the north end of the interlobate moraine already referred to as occupying the "Water shed of Western New York" and which connects the moraines of the Finger Lake region with those of districts further west. It is so inferior to the great interlobate belt that it scarcely admits of tracing when combined with that belt. Later belts, also, become mingled with it in that district so that it forms a distinct belt only for a few miles. Its breadth is fully a mile except near its western terminus where it becomes more narrow. Its relief is 20–30 feet above bordering plains. The surface is gently undulating with knolls 10–15 feet high. The knolls show a tendency to arrangement in chains or to ridging in line with the belt. For two or three miles from the western end a well defined and narrow crest is developed, but further east the crest becomes obscure though the general relief of the belt remains about the same.

The western end of the till ridge presents features which are thought to indicate the combined influence of glacial and lacustrine agencies. The ridge is composed mainly of till except at its western end, but there for about a half-mile it becomes gravelly like the beach and it drops down to about the same altitude as the beach and if our aneroid readings are correct to a slightly lower altitude than the Alden beachlets. This gravelly portion differs from the beach in one important feature. It carries on its surface basins such as commonly occur on glacial deposits or on the overwash aprons outside of moraines. The basins are small, occupying usually but a few square rods, but they are several feet in depth. They occur both on the slopes and crest of the ridge. These features are thought to indicate that the ridge is a joint product of glacial and wave action. The gravel deposits may well be the result of wave action. The basins were perhaps produced by masses of ice which were dropped into the gravelly deposits or persisted during their deposition and which upon melting left the basins. No way has suggested itself in which the basins could have been produced by the lake waves alone. Were the materials sandy we might suppose wind to have been a leading agent in their production, but the fact that they are of a gravelly nature forbids this supposition.

A reconnaissance was made into the district west and north from the western terminus of this ridge with a view to determining the line of continuation of the ice margin beyond the beach. There is a broad tract of old lake bottom open to view between the Crittenden beach and the shore of Lake Erie, and the conditions seemed favorable for such a determination. There is abundant evidence of a southwesterly ice movement across the region, at least to the vicinity of Buffalo, for striæ in the north part of Buffalo have that bearing and so also have striæ and drumlins in the district between Buffalo and Lockport. But the ice margin seems not to have been held at any one line sufficiently long to build up a strong moraine. Nothing was found connecting closely with the Alden till ridge. A few miles to the north, along a line following the base of the Corniferous escarpment from Akron westward to Buffalo, there are a series of short ridges and low knolls of drift banked somewhat closely against the escarpment and filling recesses or embayments in it. Possibly the knolls and ridges represent the line of the ice margin at one stage of the retreat. It seems, however, quite as probable that they are attributable in some way to the resistance of the ledge to the ice movement, in which case they may be submarginal instead of terminal deposits.* Aside from these knolls and a few drumlins in southern Niagara county the surface is very flat over the entire district in Niagara and Erie counties southwest from the Lockport moraine. Bowlders are in places abundant, but so far as discovered they do not constitute a well defined belt. Had the ice sheet terminated in a deep body of water it would be less remarkable that no moraine could be traced, since icebergs might transport the material widely or cause the margin to have considerable oscillation. The margin might, because of

*Dr. J. W. Spencer has published the view that a well defined beach line called by him the Lundy leads southwestward from Akron near the line of the knolls and ridges just mentioned. (This Journal, vol. xlvii, 1894, pp. 207–212.) I did not observe such a beach line, perhaps because my studies were not sufficiently complete. As I have had no opportunity to visit the ground or to confer with Dr. Spencer since his paper appeared I do not feel warranted either in concurring with or dissenting from the interpretation he has made. I can only state that the gravelly ridges in the vicinity of Akron have not in any case so far as personally observed seemed to present decisive evidence of a lacustrine origin. On the contrary they seem in most instances to be decidedly glacial in type.

the breaking off of icebergs, have extended farther on the shore than in the midst of the lake. With a very deep lake it might perhaps be possible for the ice on the shore to stand at Alden while that in the lake held the position of the Lockport moraine. But in the case in hand the water was very shallow for several miles from the shore and nowhere south from the Niagara escarpment (the district under consideration) did it much exceed 250 feet. I, therefore, consider it improbable that the Lockport moraine is to be correlated with the Alden till ridge. It seems more probable that the ice sheet, at the time the Alden ridge was formed, covered the old lake bottom at least as far south as a line from Alden west to Buffalo.

The morainic ridges between the Alden ridge and the Lockport moraine which connect somewhat closely with the eastern end of the well defined portion of the Crittenden beach are very bulky, their altitude being seldom less than 50 feet and in some places 60–75 feet above the beach. They show a decided east to west trend, a feature which apparently indicates a thrust from the north. Their trend is widely divergent from that of the Lockport moraine though they become closely associated with that moraine at the eastern end. The appearance is that of a pivotal recession of the ice front, the pivot or stationary part being just west of Batavia where the moraines are coalesced. A reference to the accompanying map will make this apparent. It will be observed that this pivotal portion lies nearly north from the interlobate moraine which connects the loops bordering the "Finger Lakes" with those farther west. The ice appears to have lingered in the northern portion of the "Finger Lake" region until it had entirely withdrawn from the Lake Erie basin, the closing stage of this withdrawal being indicated by the ridges under discussion. When the ice had retreated to the Lockport moraine it still extended to the north part of the "Finger Lake" region but had no extension into the Lake Erie basin.

The drift ridges between the Lockport and Alden moraines contain much more assorted material for a mile or so at their western ends than farther east, a feature which is perhaps due to the rapid escape of water from the ice-sheet into the bordering lake. The western ends are also capped in places by sand. The date and method of deposition of this sand were not worked out. It may be either a postglacial wind drift from the plain on the west, or a deposit connected in some way with the melting of the ice and escape of its waters.

The Lockport moraine is the principal morainic line thought to be a correlative of the Crittenden beach. Its distribution from Batavia to Lockport has already been indicated and its further distribution and the relations to the Crittenden beach may be seen by reference to the accompanying map. The name Lockport seems a fitting one to apply to the moraine since it is well developed immediately northeast from the city. Being crossed there by the Niagara Falls Division of the New York Central railway, it may be seen to good advantage by travelers.

The phases of topography which this moraine presents are more varied than is common in the moraines of that region. For a few miles south from the present shore of Lake Ontario it was washed by the waves which formed the Iroquois beach, a raised beach of Lake Ontario standing some 400 feet lower than the Crittenden beach.* Only a few low swells remain, but the position of the ice margin is readily traced by bowlders which appear in great profusion. They occupy a belt at least two miles in width along which, on nearly every farm from the present shore of Lake Ontario to the Iroquois shore (a distance of eight or nine miles), they are heaped in great piles in the fields and built into wall fences. Though not rare on the bordering districts there is a very appreciable diminution in number so that the main line of deposition is easily traced.

South from the Iroquois shore line the moraine soon rises to the brow of the limestone escarpment on which Lockport stands, the rise being about 200 feet. It consists of a series of knolls and basins which are plastered against the abrupt face of the escarpment, giving an effect strikingly in contrast with the smooth face presented by the escarpment west from Lockport.

Between the brow of the Niagara escarpment and the Tonewanda swamp (in northwestern Genesee county) the moraine consists of ridges of till forming a somewhat complex system but one in which the individual ridges harmonize rudely in trend with the general trend of the belt (W.N.W.–E.S.E.). A few conical or slightly elliptical knolls are associated with these ridges. They are not closely aggregated but are separated usually by nearly plane tracts of considerable extent. The height of the knolls and ridges seldom reaches 40 feet and is more commonly but 20–25 feet; this low elevation, however, on the flat tract which they traverse makes them a conspicuous feature.

At the Tonewanda swamp the moraine is interrupted for about two miles by a very level tract. On the east border of this swamp it reappears in the form of a stout till ridge 30–50 feet high with well defined crest which traverses the central portion of Alabama township, Genesee county, and has con-

* See "History of the Niagara River," G. K. Gilbert, Sixth Annual Report of Commissioners for Niagara Reservation, 1889, pp. 67–70, and Plate II, opposite p. 68. Also J. W. Spencer, "Deformation of Iroquois Beach and birth of Lake Ontario." This Journal, vol. xl, 1890, pp. 443–451.

siderable prominence for at least four miles. It is here that it makes its closest approach to the northeastern terminus of the Crittenden beach, the interval being scarcely two miles. Its altitude along the highest portion of the crest is nearly 100 feet below the level of the Crittenden beach. In the eastern portion of Alabama township, near Smithville, the moraine rises to the escarpment of Corniferous limestone and attains an altitude 50 feet or more above the level of the Crittenden beach. On this escarpment its features are different from those displayed by the moraine where it lies at a lower level than the beach line. Instead of a stout ridge of till with gently undulating surface and well defined crest there is a series of low knolls sharp in contour enclosing basins and sloughs but presenting no main ridge. This phase of the moraine is continued for many miles to the eastward. The moraine was traced as far as the Genesee river which it crosses near Avon. The width of the belt is seldom less than a mile and often reaches two or three miles.

Features Inside (*northeast of*) *the Lockport Moraine.*—In the district northeast from the Lockport moraine the surface is sharply in contrast with that on the southwest. It embraces the great drumlin belt of western New York and an intricate series of drift knolls and ridges of various types. Only a small part of the surface is plane. In the district southwest from the Lockport moraine and west from the Crittenden beach there are only a few drumlins and a few inconspicuous drift knolls and ridges. The contrast in drift features is nearly as great between these districts as it is between the portion of southwestern New York which stood above lake level and that which stood below.

In the district northeast from the Lockport moraine the altitude, with the exception of a narrow belt in the vicinity of the moraine, is below that of the eastern terminus of the Crittenden beach. The low altitude cannot be due to postglacial crust warping for what warping has occurred is that of *eastward* differential uplift instead of westward. This district must, therefore, have been occupied by the lake and subjected to wave action unless barred out by the ice sheet. Furthermore it is apparent that upon the withdrawal of the ice sheet this region would be invaded by the lake at least for a brief period, since it was then, as it is now, lower than any outlets to the west. This being the case the effects of wave action may be looked for at any level below that of the Crittenden beach, even if the lake was held at that level by an ice barrier. In case there was no ice barrier we should expect a similar amount of wave action throughout the entire border of the basin. But if the eastern or Ontario portion had been for a considerable portion of the time occupied by ice, while the lake was washing the borders of the western or Erie portion of the basin, we should expect beach lines and wave action generally at any horizon above the present level of Lake Erie to be less conspicuous in the former than in the latter district. The fact that the raised beaches of the Lake Erie basin occur at only a few levels apparently indicates that the lake dropped rapidly from the level of one beach to that of the next lower, for had the interval of lowering been prolonged beachlets of considerable strength would have been formed at various levels.*

In the district east from the Lockport moraine we should expect wave action to be pronounced in but a narrow zone, even if the ice-sheet had withdrawn before the Crittenden beach was formed. If it did not withdraw until after that beach was formed we should expect, at most, but an ill defined zone of wave action. Upon examining the district eastward from northwestern Genesee county (where the Lockport moraine and the Crittenden beach intersect) we found a narrow belt at about the level of the Crittenden beach where the drift

* In studying the effects of the waves the depth to which effective wave action extends becomes a question of considerable importance. The depth of lowest wave action is, of course, related to the magnitude of the waves and this to the size of the water body, being greater on the ocean than on our great lakes. The great lakes are, or were, each of the same general order of magnitude, and their wave work may properly be compared. Prof. Shaler and Mr. Gilbert have examined jointly a district at the eastern end of Lake Ontario with this subject in mind. Prof. Shaler has published the following statement of results:

"*Exposed off shore Deposits.*—It might be supposed that wherever in relatively recent times a beach now elevated has been formed the surface of the earth below its level would retain some indications that it had been beneath the water. It might reasonably be expected that a submergence which had endured long enough to permit the formation of characteristic beach accumulation would have sufficed for the formation of a tolerably enduring marine deposit lying off shore."

"At the outset of my studies of the elevated beaches of the Atlantic coast, the remains of which are of a rather fragmentary nature, I was led to doubt the verity of the indications by the absence of these marine deposits from the surface of the lower lying land. To test the matter I resorted to the country lying on the east and south of Lake Ontario, where the well preserved Iroquois beach indubitably proves long continued sojourn of the waters at a considerable height above their present level. I found that below the plain of the beach the general surface of the country showed no distinct indications that it had been submerged. In fact I was unable to find any criteria which would enable me to discriminate the areas below and above the ancient sea-margin. It must be believed that where the submergence has endured for a long time a certain amount of sediments would be laid down in the off shore district and that the period required for the formation of such a beach as that last mentioned should have brought about a considerable accumulation of clay. It seems, however, likely that in a few thousand years of exposure such clay deposits would, by the down bearing action of the rain waters, be carried down into the earth or washed away into the streams." (Bull. G. S. A., vol. vi, pp. 151–152.)

Mr. Gilbert's testimony is as follows: "It seems to us that after going 50 feet below the lowest member of the Iroquois series there was practically no modification of the drift forms; and while riding over the drift hills the only indication we could see of the lake occupancy was a loamy deposit from a few inches to a few feet in thickness which could often be distinguished between the soil proper and the unmodified drift. The evident inference was that the water had fallen from one level to the other in a very short time." (Personal correspondence.)

forms seem to have been somewhat modified by the action of waves or currents of water. This is considered a possible lake level or perhaps a lake outlet. There is a large amount of gravelly drift in this belt but so far as discovered it is not arranged in beach lines, the surface being either plane or having a gentle undulation as if the drift knolls had suffered reduction or modification by waves or currents. This gravelly drift occupies usually a breadth of two or three miles. In places it occupies the entire interval between the Lockport moraine and the drumlin belt which lies north of it. At the southern end of these drumlins for a few miles west from the Genesee river, knolls and ridges of morainic type occur, and these are frequently bordered by gravelly aprons or delta-like accumulations; near the western end of the drumlin belt, also in the vicinity of Careyville, Genesee county, there is a gravel plain dotted with basins. These features are thought to indicate that the ice-sheet for a time occupied the drumlin area and country to the north but did not extend so far south as to completely bar out the water from the Lake Erie basin. It may, at times, have covered the gravelly belt while at other times it may have afforded an eastward outlet along the south border of the ice-sheet.*

Still later the ice-sheet halted along a line just north of the drumlin belt, as is indicated by a small moraine which follows quite closely the line of the Erie canal from Rochester westward to Albion. (Its course has not been determined west from Albion.) South from this moraine there are, in the vicinity of the Genesee valley, quite heavy deposits of sand capping the drumlins and the plains among them. The sand extends north to the south border of this moraine but does not overspread it. This limitation of the sand is thought to be an indication that the ice-sheet was occupying the moraine at that time. The phenomena indicate that the ice-sheet held a narrow body of water in the Genesee valley and this may also have had an extension along the ice front some distance east and west, between this moraine and the elevated country to the south. It is not yet known whether it afforded, at that time, an outlet to the Mohawk valley.

The district between the Lockport moraine and the Iroquois beach presents other features which, when fully understood, promise to throw light upon the relation of the ice-sheet to the lake. We take time to mention the features of but one locality. North from the western end of the drumlin belt

* Prof. H. L. Fairchild has recently published the opinion (this Journal, vol. xlix, Feb., 1895, pp. 156–157), that there was a temporary outlet from the eastern end of the Lake Erie basin through Seneca Lake to the Susquehanna, near Elmira. Prof. Fairchild's studies, now in progress, promise to shed light upon this and other questions connected with the lake outlets and the descent of the lake from the Crittenden to the Iroquois beach.

there is, in southwestern Orleans county, a peculiar system of gravelly ridges and knolls. The ridges vary in type, some being low like bars or beaches of a lake and presenting much the appearance of lake strands. Others are 40–50 feet or more in height and resemble eskers. The smaller ridges have a tendency to east to west trend and are best developed along the watershed north of Oak Orchard creek. With a few exceptions the esker-like ridges have, like the drumlins, a N.E.–S.W. trend, probably conforming nearly to the line of ice-movement. Besides the ridges there are clusters of sharp gravelly knolls of kame-like type 30–40, and occasionally 60–75 feet, in height. They are usually strewn more thickly with bowlders than the bordering district, a feature which, taken in connection with their topography, strongly supports the view that they are morainic. The diversified features, combining those of lake ridges with ridges of glacial type, lead us to anticipate that they will throw much light upon the method of departure of the ice-sheet, but as yet their significance is not clear.

The Lake Outlets.—My former paper discusses the outlets at the time of the higher stages of the lake which occupied the Lake Erie basin. The evidence is clear that during the formation of the upper two beaches an outlet was found to the Wabash past Ft. Wayne, Indiana. At the time the third or Belmore beach was formed (and its probable continuation, the Sheridan beach) this outlet had been abandoned. It is thought that the ice-sheet had retreated so far from the Huron and Michigan basins as to open a lower outlet through these basins than that past Ft. Wayne. It seems improbable that an eastward outlet was then open, for the district south of Lake Ontario was apparently still occupied by the ice-sheet. It is evident that no outlet to the east could have existed until the ice-sheet had withdrawn from the Lockport moraine sufficiently for a passage eastward along its southern margin. If my interpretations are correct the Crittenden beach had been for a long time occupied by the lake before an eastward outlet was opened, a time sufficient, not only for the Lockport moraine, but for several other slightly older minor moraines to be formed. During that time the lake, in all probability, discharged westward through the Huron and Michigan basins past Chicago. When the gates to the eastward were opened by the withdrawal of the ice-sheet there was probably a brief period in which the lake discharged through the Seneca valley into the Susquehanna. But soon the lower outlet by the Mohawk was opened and the lake fell rapidly to that level, leaving but feeble traces of beach or wave action in its intermediate stages.

Denmark, Iowa, March, 1895.

Art. II.—*On some Compounds containing Lead and extra Iodine;* by H. L. Wells.

About two years ago the writer described* the double salts of lead tetrachloride, $(NH_4)_2 PbCl_6$, K_2PbCl_6, Rb_2PbCl_6 and Cs_2PbCl_6, and upon attempting to prepare the corresponding bromides and iodides, an entirely different kind of double salts was discovered.† These peculiar salts were $K_3Pb_2Br_8 . 4H_2O$ and $K_3Pb_2I_8 . 4H_2O$. They are remarkable in containing but a single atom of extra halogen in the formula as given above, and they apparently correspond to no previously known compound. I was unable to obtain, with the alkali metals, any bromides or iodides corresponding to the chlorides, but it is interesting to notice that Classen and Zahorski‡ have obtained such salts with quinoline, $(C_9H_7NH)_2PbBr_6$ and $(C_9H_7NH)_2PbI_6$§.

The isolation of lead tetrachloride by Friedrich‖ and the discovery of lead tetra-acetate, $Pb(CH_3CO_2)_4$, by Hutchinson and Pollard¶ were very interesting additions to our knowledge of the compounds of tetravalent lead. These articles appeared almost simultaneously with that of Classen and Zahorski which has been referred to above, and with my own work mentioned at the beginning of this article.

As a sequence to my former investigations, it has seemed to be desirable to reinvestigate two previously described compounds containing lead and extra iodine, because it seemed possible that a further study of them might throw some light upon the nature of the curious salt, $K_3Pb_2I_8 . 4H_2O$.

Johnson's Salt.—By mixing a hot, concentrated alcoholic solution of potassium triiodide with a saturated solution of lead acetate in boiling alcohol, filtering off the small precipitate thus produced and cooling, G. S. Johnson** obtained a crystalline substance to which he gave the formula, $Pb_8C_{36}H_{54}O_{28}K_6I_{17}$. Concerning this he remarks, "The formation of a *rational formula* has at present baffled all my endeavors."

Johnson also obtained the salt by recrystallization from alcohol and by evaporating the mother-liquor over sulphuric acid, but there is no evidence that he analyzed more than one sample of it. He does not give the quantities used in making his preparation.

* This Journal, xlvi, 180, 1893. † This Journal, xlvi, 190, 1893.

‡ Zeitschr. für anorg. Chem., 4, 107, 1893.

§ Classen and Zahorski gave a formula of different type, $5NH_4Cl . 2PbCl_4$, to the double ammonium chloride. It seems certain from analogy, from Friedrich's results and from my own work, that their product was contaminated with ammonium chloride.

‖ Berichte, 26, 1434, 1893.

¶ Chem. Soc. Jour., lxiii, 1136, 1893.

** Chem. Soc. Jour., xxxiii, 189, 1878.

I have made a large number of crops of the compound, all of which agreed with Johnson's description in forming rectangular crystals of a black color having a marked brassy luster upon four of the six faces, and occurring usually in intergrown groups of nearly square, flat plates. In preparing these products the conditions were varied considerably. As a starting-point 30 g. of potassium iodide and 50 g. of iodine were invariably used. These amounts give a slight excess of iodine over the proportion required for potassium triiodide. From 40 to 100 g. of crystallized lead acetate were used, and it was found that beyond these limits the preparation was unsuccessful.

The solvent varied from absolute alcohol, diluted only with the water of crystallization of the lead acetate, to alcohol diluted with one-half its volume of water. Several crops were prepared in the presence of glacial acetic acid, and a volume of this amounting to $\frac{1}{15}$ of the total liquid (20^{cc}) was used with success. The total volume of solvent varied from 200 to 500^{cc}, the larger amounts being used when it was not expected to obtain the product by simple cooling. It was customary to dissolve the potassium iodide and iodine in about one-half of the solvent to be used and the lead acetate in the remainder. The solutions were sometimes mixed boiling hot, while at other times a lower temperature was employed. A precipitate, evidently consisting chiefly of lead iodide, was always produced by mixing the two liquids, but its quantity was usually small. The effect of the presence of iodine in preventing the precipitation of lead iodide to a great extent is very remarkable. The solutions were filtered, sometimes while hot, sometimes after a longer or shorter period. The products obtained by cooling formed coherent crusts composed of very small, intergrown crystals, while by evaporation over sulphuric acid much larger isolated crystals, or groups of crystals were deposited. All the analyses given below were made upon crops obtained by evaporation, except in one instance. Two partial analyses of products made by cooling are not included in the list, because the results varied rather widely from each other and from the results obtained with the products of evaporations. The omitted results differed still more from Johnson's analysis than the others. Two or three successive crops were often obtained by evaporating a single solution, and the twelve products, analyses of which are given, represent six different original solutions. The products were well crystallized and most of them seemed entirely satisfactory in regard to purity. They were all examined microscopically, and as far as could be judged from the appearance of an opaque substance, no impurities were present. The samples for analysis were very carefully pressed upon filter-paper in order to remove the mother-liquor. The salt is practically stable in the air, so that decomposition was not to be feared during the drying operation.

Lead and potassium were determined by dissolving the substance in dilute nitric acid, evaporating with sulphuric acid, separating the lead sulphate by filtration, weighing it, and determining potassium in the filtrate by weighing it as sulphate. Iodine was determined by treating the substance with a solution of sodium arsenite, acidifying with nitric acid and digesting with an excess of silver nitrate, and finally weighing silver iodide. Carbon and hydrogen were determined by combustion with lead chromate, where the front part of the tube contained a layer of metallic silver which stopped the passage of any iodine.

The variations in the results of the analyses are considerable, and it is probable that the salt, being always deposited in a concentrated mother-liquor, was never quite pure, but there is no evidence that the variations in composition have been regularly influenced by the variations in the conditions of preparation. The analyses are given in the order in which they were made. The last three probably represent better material than the others.

	Lead.	Potassium.	Iodine.	Carbon.	Hydrogen.	Oxygen (difference.)
I	35·51	4·01	37·50	----	----	----
II	36·24	4·33	36·16	----	----	----
III	35·83	4·32	36·01	----	----	----
IV	35·29	4·07	37·78	----	----	----
V	36·21	4·59	----	----	----	----
VI	35·43	4·20	----	----	----	----
VII	35·65	4·40	36·49	----	----	----
VIII	35·35	4·15	----	----	----	----
IX	34·80	4·42	----	----	----	----
X	34·85	3·93	37·92	9·14	1·39	12·77
XI	34·72	3·97	39·26	9·17	1·41	11·47
XII	34·33	3·94	39·83	8·77	1·31	11·82
Calculated for $5Pb(CH_3CO_2)_2 . 3KI . 6I$,	35·87	4·07	39·62	8·31	1·04	11·09
Johnson found,	33·195	4·668	43·37	8·63	1·106	9·031

It must be admitted that the results do not agree very satisfactorily with the calculated quantities, and that the formula is somewhat uncertain. It seems probable, however, that the compound is a combination of lead acetate with potassium triiodide with the formula $5Pb(CH_3CO_2)_2 . 3KI_3$. It is not certain that the extra iodine is combined with the potassium rather than with the lead, but since KI_3 is a well-known compound, and since the acetic acid radical is present in the proper proportion to form lead acetate, this view seems to be the most plausible one.

Johnson's analysis differs chiefly from the new ones in its higher iodine and consequently lower oxygen as determined by difference. His oxygen is considerably too low for the amount required to give CH_3CO_2 with the carbon and hydrogen, and this was evidently the main cause of his inability to arrive at a rational formula. It seems probable that there was an error in his determination of iodine.

Gröger's salt.—A compound has been described by Max Gröger* as corresponding to the remarkable formula, $PbO . PbI_2 . I_3$. As he prepared it, it was an amorphous precipitate which had been washed with water, and exposed to the air for a long time in order to allow iodine with which it was mixed to evaporate, and, consequently, there seemed to be room for doubt as to its freedom from decomposition after it had undergone these operations, even if it could be supposed to have been a pure substance when it was precipitated.

I have undertaken a reinvestigation of this salt, and have succeeded in preparing it in a beautifully crystalline condition in which there was no doubt about its purity, and have found that Gröger really analyzed a pure compound, but that he overlooked some water that it contained. With the addition of one molecule of water his formula becomes correct, but this formula, $Pb_2I_5O . H_2O$, or as it may be written $Pb_2I_5(OH)_2$, is no less remarkable than the one which Gröger advanced.

This substance, in a crystallized condition, had been observed in this laboratory a short time before Gröger's work was known here. At my suggestion, Mr. J. H. Pratt had made some experiments with the dark colored precipitate produced by mixing strong aqueous solutions of lead acetate and potassium triiodide. Such precipitates were collected upon filters, treated while still moist with boiling alcohol and the resulting liquid, after filtration, was evaporated over sulphuric acid, with the result that small, brilliant, black crystals were sometimes obtained. Several partial analyses of this substance showed that it contained lead and iodine in the ratio 2 : 5, and were as follows:

	I.	II.	III.	Ratio of average.	Calculated for $Pb_2I_5O . H_2O$
Lead	37·84	----	37·32	2·00	38·23
Iodine	57·66	58·71	58·62	5·07	58·63

The yield of this product was very small, and it was difficult to obtain it in a pure condition since it was often mixed with the well-known compound PbIOH and with other substances which were not identified. The presence of water in the salt was established, but the circumstances were such that the investigation was interrupted at a point where the pure

* Monatshefte für Chemie, xiii, 510, 1892.

material at hand had been exhausted and no accurate determination of water had been made.

My thanks are due to Mr. Pratt for his valuable assistance in the investigation of the compound up to this point. When I subsequently obtained Gröger's salt in a crystallized condition it proved to have the same form and composition as the product mentioned above, so that a further study of the latter was deemed unnecessary.

In order to obtain Gröger's compound in a well crystallized condition, it is necessary to modify his method of preparation by using a small amount of acetic acid. It is also advantageous to use boiling water instead of cold water for the precipitation, and to use a somewhat larger volume of this than is recommended by him. I have obtained the best results by the following method: Dissolve 10 g. iodine in 100^{cc} absolute alcohol, then 50 g. crystallized lead acetate in 150^{cc} water, 3^{cc} glacial acetic acid and 300^{cc} absolute alcohol. Mix the two solutions, let stand 14 to 16 hours at the temperature of the room, filter to remove the small precipitate, then dilute with 1500^{cc} of boiling water. Let the whole stand until cold, when the compound sought will have crystallized out mixed with iodine. Pour off the liquid and wash the crystals with cold alcohol in small quantities until the iodine is removed. Dry the product upon filter-paper, and then in the air at ordinary temperature.

The product consists of very brilliant black crystals, usually $0·5^{mm}$ or less in diameter. They form octahedrons, apparently of the tetragonal system, with faces that are much curved and otherwise distorted. The powder of the crystals is similar in color to Gröger's precipitate, and it agrees with it in being practically stable in the air and scarcely acted upon by cold water or alcohol.

Two separate crops of apparently perfect purity were analyzed. Lead and iodine were determined by the methods described above under Johnson's compound. Water was collected and weighed in a calcium chloride tube, the substance being ignited in a tube behind a layer of granulated sodium carbonate which held back the iodine completely. Free iodine was determined volumetrically by the use of sodium thiosulphate solution. The results were as follows:

	Found. I.	Found. II.		Calculated for $Pb_2I_5(OH)_2$.
Lead	38·54	38·22		38·23
Iodine	58·41	58·62		58·63
Water	1·83	1·82		1·66
Oxygen (diff.)	1·42	1·34		1·48
	100·00	100·00		100·00
"Free" iodine	34·78	----	I_3	35·18
Loss by heating	36·43	36·43	I_3+H_2O	36·84

I have also prepared the compound, exactly according to Gröger's directions, as a reddish-brown precipitate, and after the product was apparently free from intermixed iodine and air-dry, it was dried for three days, spread out in a very thin layer under a bell-jar well charged with solid potassium hydroxide. This product gave the following results on analysis:

	Found.	Calculated for $Pb_2I_5(OH)_2$.
Water	1·80	1·66

This result indicates that Gröger overlooked water in his compound, and that his precipitate is identical with the crystallized product.

I have observed the formation of this salt under various conditions when alcoholic solutions containing lead acetate and iodine, and in some cases potassium iodide also, were diluted, but the purest crops have been obtained only when the ingredients were used nearly in the proportion which Gröger recommends, and also when the alcoholic mixture has been allowed to stand for the proper period. The compound cannot be recrystallized from water, alcohol or mixtures of the two liquids, and it seems probable, as Gröger suggests, that it is formed by the decomposition of some other compound by water. This view does not conflict with the fact that it was prepared, as described above, by the evaporation of certain alcoholic solutions, because these always contained water which increased in proportion to the alcohol as the evaporation went on. The presence of an acetate seems to be indispensable to its production, for I have made a number of experiments using lead nitrate instead of the acetate with no indication of its formation. It seems probable that a soluble compound closely related to Johnson's salt is formed at first and that this yields Gröger's compound by the action of water.

I have made unsuccessful attempts to prepare a bromide corresponding to Gröger's salt, and my attempts to replace a part of the iodine in it by bromine have also failed.

Conclusion.—The two compounds which have been re-investigated, $5Pb(CH_3CO_2)_2 . 3KI . 6I$ and $PbI_2 . PbO . 3I . H_2O$ show no evident relation to each other nor to the compound $2PbI_2 . 3KI . I . 4H_2O$, which I have previously described, except that all of them are of complicated composition and they all contain extra iodine without showing evidence of the existence of lead tetraiodide. Classen and Zahorski's quinoline salt, previously referred to, seems to furnish the only evidence of the existence of this higher iodide in combination.

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

Art. III.—*The Estimation of the Halogens in Mixed Silver Salts;* by F. A. Gooch and Charlotte Fairbanks.

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

Known methods for the estimation of chlorine, bromine, and iodine in mixed silver salts depend either upon the reduction of the salts to metallic silver or their conversion to a single definite silver salt. The old but by no means ideal methods for the determination of chlorine and bromine in mixed silver chloride and bromide by reduction of the salts to silver in hydrogen at high temperatures or conversion to silver chloride in an atmosphere of chlorine are typical. Perhaps the best of all are the electrolytic method of Kinnicutt* for the reduction of the fused chloride and bromide, the battery process of Whitfield† which involves the electrolysis of the solution of the silver salts in potassium cyanide and the method of Maxwell–Lyte‡ according to which the silver in the cyanide solution of the silver salts is thrown down by potassium iodide and sulphuric acid. Even in these processes there are points against which objection may be raised with reason. Thus, in the processes of Whitfield and Maxwell–Lyte it is next to impossible to secure complete and speedy solution of the dried silver salts in potassium cyanide without recourse to intermediate washing and treatment with nitric acid; and in Kinnicutt's method, which has been applied only to the analysis of the mixed chloride and bromide, difficulty is found in the speedy removal of all sulphuric acid from the spongy mass of silver formed in the reduction.

We have tried many experiments with a view to simplifying the analysis of the mixed silver salts. Ignition with mercuric cyanide according to Schmidt's method for sulphides;§ treatment with cuprous chloride dissolved either in ammonia or in hydrochloric acid; the action of ferrous oxalate dissolved in potassium oxalate, Eder's reagent;‖ treatment with chromous chloride or chromous acetate; contact with powdered magnesium under dilute acid; and many other plans of action with powerful reducers have failed to yield analytical results comparable with those of the known methods. Hydrogen sulphide, dry or moist, and ammonium sulphide attack the halogen salts of silver with varying intensity, the chloride very

* Am. Chem. Jour., iv, 22.
† Am. Chem. Jour., viii, 421.
‡ Chem. News, xlix, 3.
§ Ber. d. chem. Gesell., xxvii, 225.
‖ Ber. d. chem. Gesell., xiii, 500.

easily, the bromide with less ease, and the iodide most difficultly —as might be predicted from a knowledge of the thermal values involved in the reactions. A current of hydrogen sulphide charged with ammonium sulphide effects the complete conversion of silver chloride to silver sulphide at a temperature below 200°C; but we have never succeeded in securing absolutely complete conversion of the bromide to the sulphide by similar treatment even at much higher temperatures, and the iodide resists conversion more obstinately than the bromide. Nor have we been able to find conditions under which the chloride may be converted while the bromide and iodide remain unattacked. In a study of the conditions best adapted to the reduction of silver salts electrolytically we have obtained results which point to advantageous modifications of the methods heretofore known. We find that the treatment of the fused salts may be simplified, made more accurate, and extended to mixtures containing silver iodide.

In Kinnicutt's process the difficulties lie, first, in the impossibility of destroying the paper, upon which the silver salts have been collected and washed, without affecting the conduction of the salts; secondly, in the obstinacy with which the spongy silver holds the sulphuric acid during washing; and thirdly, in the tendency of the chlorine liberated when a chloride is present to attack the electrodes.

Upon the first point nothing need be said; the difficulty is obvious and well known. As to the second source of error, our experience shows that rapid washing is not sufficient to remove the sulphuric acid included in the reduced silver, even when excessive amounts of wash-water are used; but that a considerable time is indispensable for the escape of the acid from the silver to the wash-water by diffusion. In several cases we have found errors, ranging from a single milligram to six or seven, due to inclusion of the acid in residues which had been washed freely but rapidly, and which, even after ignition, yielded slowly hot water extracts which gave the test for a sulphate by barium chloride.

The results of some experiments made to test the effect of the halogens set free in electrolysis are shown in the accompanying table:

Electrolyte, 15 cm³ of H_2SO_4, (15 per cent) with the substance named.	Strength of current in amperes.	Time in hours.	Change in weight of the containing crucible grm.	Change in weight of wire electrode grm.	Connection of crucible.
1·7 grm. KI	0·46–0·25	24	0·0000	0·0000	Cathode
1 " KBr	0·50–0·18	35	0·0000	0·0000	Cathode
1 " KCl	0·48–0·18	26	0·0008—	0·0001—	Cathode
0·5 " HCl	----	--	0·0009*—	0·0000	Cathode
0·5 " HCl	0·3	48	0·0004—	0·0004+	Anode

So it appears that, while neither bromine nor iodine attacked the platinum perceptibly under the conditions of the experiments, though set free in abundance, an appreciable amount of the metal did dissolve under the action of chlorine. Moreover the solubility seems to depend chiefly upon the area of surface exposed and not upon the electric polarity. The metal dissolved was reprecipitated by the action of the current only in the experiment in which, by reversing the direction of the current and thus making the area of the anode large while that of the cathode was diminished, a corresponding increase of current density upon the cathode was brought about. It is obvious that under ordinary conditions of electrolytic reduction the solvent effect of the chlorine upon the platinum will naturally produce an apparent deficiency in the weight of silver reduced.

These sources of error in the electrolytic reduction of the fused silver salts we have endeavored to overcome. The danger of change in the constitution of the salts during preparation for weighing we avoid by collecting them upon asbestos in a perforated crucible instead of upon paper; but in order to secure perfect electrical conductivity throughout the mass of silver salts subsequently collected, dried, and weighed, we place a disc of perforated platinum foil upon the prepared felt of asbestos. In this way perfect electrical contact is obtained, though the rapidity of filtration is somewhat impaired. The disc also serves the useful purpose of preventing the disturbance of the felt by the gas evolved from the walls of the crucible in the electrolytic process.† When the silver salts have been collected, washed, dried and weighed, their fusion is effected by placing the capped crucible upon an anvil and directing the flame of a small blowpipe with care upon the

* Platinum tested for and found in solution.

† This device has been suggested by Puckner (Jour. Am. Chem. Soc. 1893, 710) for holding down the asbestos in an ordinary filtration, and is no doubt of value when suitable asbestos is not at hand. A fairly good asbestos properly prepared, and deposited upon a perforated surface in which the holes are sufficiently numerous—best, as numerous as can be—does not, however, tend to rise during a filtration so long as the suction pump is in action.—F. A. G.

mass from above. The anvil keeps the crucible cool and tends to prevent the soaking of the asbestos with the fused silver salts, which would be disadvantageous in the washing process which follows the reduction. A rubber band cut from rubber tubing of suitable diameter is adjusted so as to cover the junction between the cap and crucible and make a water-tight electrolytic cell. When the electrolytic reduction is finished the band and cap are removed, the crucible is put upon the pump, the liquid is drawn through and the precipitate washed in the usual manner.

It is obvious that the difficulty of washing out the sulphuric acid from the reduced silver may be avoided if it is possible to substitute for the sulphuric acid an electrolyte which, even if it were not easily removed by washing should be volatile at gentle heat without affecting the silver; and the danger arising from free chlorine may be obviated by taking care to have the chlorine absorbed by the electrolyte as soon as it is liberated. We find that twenty-five per cent alcohol containing a tenth of its weight of oxalic acid meets all the conditions for the electrolytic reductions of the mixed chloride and bromide of silver. Such a solution while possessing sufficient conductivity absorbs the free chlorine to such an extent that, as we have found experimentally no perceptible solvent action takes place upon the platinum and nothing remains in the silver reduced under such a solution which is not volatile at gentle heat without affecting the weight of the silver.

In the test-experiments recorded in the accompanying table known amounts of silver chloride and bromide were precipitated, collected, washed, dried at 150°C., and weighed in the filtering crucible provided as usual with a layer of asbestos which was in this case covered with the perforated platinum disc. The cap was put in place, the crucible set upon an anvil, and the salts fused with a blowpipe flame in the manner described. The rubber band was adjusted, the crucible nearly filled with the ten per cent solution of oxalic acid in twenty-five per cent alcohol, and the current passed in the usual manner, the crucible serving as the negative electrode. When the reduction was judged to be complete the band and cap were removed, the crucible set upon the pump, and filtration of the liquid and washing of the residue carried out as usual. Finally the crucible, cap, and residue were ignited at a very low red heat and weighed. The entire treatment was repeated until the constant weight of the residue showed that the reduction was complete.

AgCl taken. grm.	AgBr taken. grm.	Ag calculated. grm.	Ag found. grm.	Error. grm.
1·0608	----	0·7985	0·7990	0·0005+
1·4380	----	1·0823	1·0823	0·0000
0·9998	----	0·7525	0·7522	0·0003−
----	0·9959	0·5721	0·5723	0·0002+
----	0·9979	0·5731	0·5732	0·0001+
1·0044	0·4988	1·0426	1·0422	0·0004−
0·4933	0·4966	0·6559	0·6568	0·0009+

The manipulation of the method is very easy, and the results show that it is capable of yielding accurate results. The current ranged from 0·5 to 0·25 amperes, and for convenience the process was continued over night though the reduction of amounts such as we treated is usually complete in six or seven hours.

Unfortunately this process which works so well with the mixture of chloride and bromide is not applicable to the reduction of silver iodide or to mixtures containing it. Experiment proved that the iodine set free in the electrolysis works over and over again upon the spongy silver constantly regenerating silver iodide to a greater or less degree. As the result of many attempts to destroy the liberated iodine without introducing anything objectionable into the solution we finally settled upon a mixture made by neutralizing two parts by volume of ordinary (40 per cent) acetic acid with ammonia, adding one part of ammonia, one part of alcohol, and one part of aldelyde (75 per cent). Such a solution we found to work very well on the whole, but as the reduction progresses it frequently happens that a deposit of white ammonium iodate forms upon the anode, which introduces too great resistance to the current. This deposit of iodate is, however, easily removed from the electrode by dipping it into hot water. Whenever the solution is so exhausted that free iodine begins to appear the liquid should be carefully decanted and replaced by fresh; and before the operation is ended the decanted solutions and the washings of the electrode should be filtered through the crucible, and the residue submitted again to the action of the current, to make it certain that loosened particles of silver or silver salt possibly poured off or removed on the electrode shall not be lost finally. The necessity of keeping the process under occasional supervision renders it undesirable to continue the action over night. In some cases of prolonged action without attention we have noticed the formation of gummy carbonaceous matter which could not be subsequently removed without the application of a degree of heat which might endanger the platinum in contact with the reduced silver.

Many of the experiments recorded in the following table were completed within seven hours with a current not exceeding 0·5 amperes :

AgCl taken. grm.	AgBr taken. grm.	AgI taken. grm.	Ag calculated. grm.	Ag found. grm.	Error. grm.
0·4779	----	----	0·3596	0·3591	0·0005 —
0·6096	----	----	0·4588	0·4591	0·0003 +
0·6774	----	----	0·5098	0·5099	0·0001 +
----	0·9969	----	0·5727	0·5726	0·0001 —
----	1·3703	----	0·7872	0·7875	0·0003 +
----	----	1·0613	0·4878	0·4877	0·0001 —
----	----	1·0621	0·4882	0·4875	0·0007 —
----	----	1·0140	0·4661	0·4662	0·0001 +
----	----	1·2012	0·5521	0·5530	0·0009 +
----	----	1·5031	0·6910	0·6914	0·0004 +
0·5035	0·4984	----	0·6653	0·6653	0·0000
1·0020	0·9998	----	1·3285	1·3283	0·0002 —
0·4939	----	0·6561	0·6734	0·6733	0·0001 —
----	0·5000	0·5304	0·5310	0·5316	0·0006 +

These results show that the process affords an accurate reduction of the chloride, bromide, and iodide of silver and mixtures of these salts. When the problem concerns the reduction of the chloride and bromide only, we give the preference to the reduction in alcoholic oxalic acid as being the simpler process. The latter process we have also applied successfully on a larger scale to the recovery of the silver in chloride residues.

Art. IV.—*On the Pitch Lake of Trinidad;* by S. F. Peckham.

At the risk of saying a superfluous word, I am led after a recent visit to Trinidad, to add my testimony to that of the numerous observers, who for more than a hundred years have written concerning this remarkable phenomenon.

The earliest account of a visit to Trinidad, accessible to English readers, was published in the Transactions of the Royal Society of London in 1789, by Alexander Anderson.* He describes point La Brea as a promontory fifty feet high jutting into the Gulf of Paria. Ascending to the Lake he describes it as three miles in circumference divided into "areola" resembling those upon a turtle's back, the surface of each being "horizontal and smooth." He was there in the rainy season, and concluded that evaporation on the clear afternoons removed the torrents of water that fell in other parts of the day, as there was no other outlet. He further states that the soil around La Brea consists of cinders and burnt earth, being evidently the product of subterranean fires, as there were hot springs in the neighboring woods.

The next visitor is Dr. Nicholas Nugent, who published an account of a visit made in October, 1807.† He landed on the south side of La Brea point which he describes as consisting of a bluff of porcelain jasper, "generally of a red color." Ascending to the Lake he perceived a strong sulphurous and pitchy smell, like that of burning coal, and soon after had a view of the Lake, which at first sight, appeared to be an expanse of still water, frequently interrupted by clumps of trees and shrubs, but on a nearer approach it was found to be a plain of mineral pitch with frequent crevices filled with water. "The surface of the lake was not polished or smooth so as to be slippery; the consistence was such as to bear any weight, and it was not adhesive; though it partially received the impression of the foot, it bore us without any tremulous motion whatever, and several head of cattle were browsing on it in perfect security. The interstices or chasms are very numerous, and being filled with water, present the only obstacle to walking over the surface. The arrangement of the chasms is very singular, the sides are invariably shelving from the surface, so as to nearly meet at the bottom, but there they bulge out towards each other with a considerable degree of convexity. These crevices are known occasionally to close up entirely, and we saw many marks or seams from this cause. The lake contains

* Philosophical Transactions, lxxix, 65, 1789.

† Transactions of the Geological Society of London, i, 63, 1811.

many islets covered with long grass and shrubs. It is not easy to state precisely the extent of this great collection of pitch; the line between it and the neighboring soil is not always well defined. The main body may perhaps be estimated at three miles in circumference; the depth cannot be ascertained, and no subjacent rock or soil can be discovered. The negro houses in the vicinage, built by driving posts into the earth, frequently are twisted or sunk on one side. In many places it seems to have actually overflowed like lava, and presents the wrinkled appearance which a sluggish substance would exhibit in motion. In some parts it is black, with a splintery or conchoidal fracture; in other parts so much softer, as to allow one to cut out a piece in any form with a spade or hatchet, and in the interior it is vesicular or oily; this is the character of by far the greater portion of the whole mass: in one place it bubbles up in a perfectly fluid state, so that you may take it up in a cup."

"In the southeastern part of the island there is a similar collection of this bitumen, though of less extent, and many small detached spots of it are to be met with in the woods; it is even said that an evident line of communication may thus be traced between the two great receptacles."

Dr. Nugent devotes considerable space to a discussion of the geology and origin of the bitumen. As his opinions are based on theories no longer accepted by geologists I will only remark *en passant*, that he associates the mud volcanoes of Cedros Point with the agencies that have been active in bringing the bitumen to the surface.

The next notice that appeared, was written in September, 1832 by Capt. J. E. Alexander, 42^d Royal Highlanders.* He says, "at the small hamlet of La Braye, a considerable extent of coast is covered with the pitch, which runs a long way out to sea, and forms a bank under the water. The Pitch Lake is situated on the side of a hill, a gradual ascent leads to it, which is covered with pitch in a hardened state, and trees and vegetation flourish upon it. The pitch at the sides of the lake is perfectly hard and cold, but as one walks off towards the middle with shoes off, in order to wade through the water, the heat gradually increases, the pitch becomes softer and softer, until at last it is seen boiling up in a liquid state, and the soles of the foot become offensively warm. During the rainy season, it is possible to walk over the whole lake, nearly, but in the hot season a greater part is not to be approached. The Lake is about a mile and one-half in circumference; and not the least extraordinary circumstance is, that it should contain eight or ten small islands, on which trees are growing close to the

*Journal of the Franklin Institute, 1833, xv, 337. New Edinburgh Philos. Magazine.

boiling pitch. In standing for some time on the lake near the center, the surface gradually sinks until it forms a great bowl, as it were; and when the shoulders are level with the general surface of the lake, it is high time to get out. The flow of pitch from the lake has been immense, the whole country round, except near the Bay of Guapo, being covered with it; and it seems singular that no eruption has taken place within the memory of man, although the principle of motion still exists in the center of the lake."

Speaking of Point Cedros, he says, "what renders this point so interesting to the stranger is an assemblage of mud volcanoes, of which the largest may be about one hundred and fifty feet in diameter. At times the old craters cease to act, but when that is the case new ones invariably appear in the vicinity. The mud is fathomless, yet does not overflow, but remains within the circumference of the crater. From what I recollect of the Crimea, I should say that there is a remarkable similarity between it and Trinidad;—geologically speaking, in both there are mud volcanoes, in both there are bituminous lakes, and both have been frequently visited with earthquakes."

The next observer was Mr. N. S. Manross, who visited the lake in 1855, and has been widely quoted. He says, "the village of La Brea stands on a projecting tongue of land which owes its preservation from the inroads of the sea to the fact that it consists entirely of hardened pitch, which withstands the waves far better than the loose materials of the accompanying formations. The shore for miles, both north and south, consists mainly of the same material, and juts boldly out into the sea wherever it is thus pitch-bound. A road leads up from the landing to some sugar estates beyond the lake. It ascends a gentle slope of hardened pitch, which, where left to itself is covered with a dense growth of reeds and bushes. The road itself is a fine illustration of the adaptation of pitch to the purpose of paving. Where too much mixed with earth it has become pulverized to a depth of a few inches, but in many places it is still so pure and solid that the wheels of heavily loaded sugar wagons and the hoofs of horses make but a slight, and even that, a transient impression. In no part of the ascent to the shore of the lake does the stream of pitch appear to be covered by more than one or two feet of soil, while in most places it is entirely bare. In places where the surface is not protected by vegetation it becomes so far softened by the sun as to be still making progress downward.

"On nearing the lake the ascent becomes steeper. Here the pitch is bare, or but slightly covered with grass. Its appearance is not that of a sudden simultaneous overflow in a single smooth stream, but that of a great number of streams each but a few yards or rods in breadth. Their surfaces are drawn out into all manner of contortions, and where the edges meet, small ridges have been thrown up and the pitch broken into fragments not unlike the scoriæ of lava currents. These fragments of pitch were on fire in several places, having been kindled by a fire that ran through the 'bush' a few weeks before."

"On ascending the last slope of this pitchy glacier a singular scene meets the eye. A black and circular plain of pitch one-half mile in diameter lies flush with the edge of the stream. It is surrounded by a dense wall of forest in which various species of tall palm are most conspicuous. The lake itself is entirely bare of vegetation, except about twenty small clumps of trees which are arranged in a sort of broken circle about one-half way from the center to the circumference."

"The entire surface of this circular plain is seen to be interspersed by a network of water channels. Its appearance is exactly that of marbled paper. The pitch is divided into flat or slightly convex areas, mostly polygonal but sometimes circular. They vary from one to eight rods in diameter. The intervening spaces are full of water. These channels (or spaces) have heretofore been described as crevices or cracks in the pitch. This description however is incorrect, for the material, though apparently almost as hard as stone, is yet far too plastic to admit of anything like a fissure remaining open in it. The channels are produced and maintained by the following singular process. Each of the many areas into which the Lake is divided possesses an independent revolving motion in this wise: at the center of the area the pitch is constantly rising up, not breaking out in streams, but rising *en masse.* It is thus constantly displacing that which previously occupied the center, and forcing it towards the circumference. The surface becomes covered with concentric wrinkles and the interior structure somewhat laminated. When the edge of such an expanding area meets that of the adjoining one the pitch rolls under, to be thrown up again at the center at some future period. The material is nearly soft enough to meet and form a close joint at the top but descends with a rounded edge and at a considerable angle. The conclusion then to which a close observation leads us in regard to the present condition of this singular lake is, not that it has suddenly cooled down from a boiling state, as heretofore described, but that, as the material is, it is still boiling although with an infinitely slow motion. As the descent of the glacier may be considered the slowest instance of flowing in nature, so the revolutions of the scarcely less solid bitumen of this lake may be set down as the slowest example of ebullition."

"Towards the center of the lake several detached areas are met with, the surfaces of which yield under the foot. On standing ten or fifteen minutes one may find himself ankle deep. A person standing long enough would undoubtedly sink and perhaps disappear in it; but in no place was it possible to form those bowl-like depressions around the observer as described by former travelers."

"The water which filled the crevices of the pitch is clear and very pure. It is the favorite resort of all the washerwomen for miles around. As the water is flowing now, the pitch has formerly flowed from the lake in all directions. The entire surface covered by it is estimated at 3000 acres. The pores of the pitch are full of water which oozes out on the slightest pressure, and by moistening the skin prevents adhesion. Streams of gas issue, sometimes rising through the water, but more frequently from small openings in the pitch above water level."

"In one of the star-shaped pools of water, a column of pitch had been forced up from the bottom, expanding into a sort of center-table about four feet in diameter. Pieces torn from the edge of this table sank readily, showing that it had been raised by pressure and not by buoyancy."

"About a mile and one-half south of the lake I observed numerous beds of indurated clay filled with the remains of leaves and vegetation. A little further on appears a bed of brown coal and lignite, about twelve feet thick. It has such a dip and direction that, if continuous, it would pass under the lake at a great depth. About a mile to the northwest of the lake another bed of brown coal crops out upon the shore. It is about twenty feet thick. From the occurrence of such considerable accumulations of vegetable matter, so situated as apparently to pass under the lake, it seems reasonable to regard them as the source of the pitchy matter. Indeed, many pieces of wood may be observed in the beds of brown coal, which differ in no respect in their appearance from many of the pieces thrown up in the lake itself."

Mr. Manross* is completely at sea in his points of the compass.

The observations upon which the descriptions of this lake, from which I have made careful abstracts, were based, were made from forty to one hundred and six years ago. I have been able to verify them in almost every particular, and these descriptions clearly portray the appearance and condition of the lake at the time I visited it in March, 1895. In addition to these descriptions, other observations quite different in character and purpose have been made concerning the island

* This Journal II, xx, 153, 1855.

of Trinidad, and incidentally of the Pitch Lake, during the last thirty-five years. In 1860 Messrs. Wall and Sawkins published quite an extended report upon the geology of Trinidad, including observations upon the occurrence of bitumen throughout the island.*

Dr. Nugent remarked in the article above quoted, "and it must be remembered that geological enquiries are not conducted here with that facility with which they are in some other parts of the world; the soil is almost universally covered with the thickest and most luxuriant vegetation, and the stranger is soon exhausted and overcome by the scorching rays of the vertical sun." † These observations exactly express the conditions under which these gentlemen performed their undertaking. It is therefore not surprising that errors should have been found in their conclusions and corrected by later observers.

Mr. J. R. Lechmere Guppy, in 1892, thus stated the conclusions that he had reached in reference to Trinidad Geology.‡

"It appears from the evidence derived from the nature of the Naparima rocks, their fossil contents, and the movements which have effected them and the other formations of Trinidad, that during the Cretaceous and Eocene periods, there was a sea having a considerable but variable depth of water, say up to one thousand fathoms and more. It is probable that this sea extended on the North to the base of the northern range of hills, a distance of some twenty or twenty-five miles from the northern limit of the Naparima deposits. During the Cretaceo-Eocene period the northern mountains probably formed an unbroken chain with the littoral cordillera of Venezuela. This chain may be c alled the 'Parian Range.' According to abundantly clear evidence given by me in 1877,§ the great chasms between Trinidad and Venezuela called the Bocas del Drago were produced by subsidence. Previous to this the 'Parian Range' probably formed the southern boun-

* Report on the Geology of Trinidad, by order of the Lords Commissioners of Her Majesty's Treasury, London, 1860.

† Loc. cit., p. 70.

‡ Quar. Journal Geological Soc., 1892, xlviii, 519–536. Ditto, xxii, 571; ditto, xxiv, 11; ditto xxvi, 413; ditto, xlviii, 221.

The "Naparima rocks" consist of an anticlical that abutting in a bluff near San Fernando, on the Gulf of Paria, extends across the island almost to the East coast. They also appear on the mainland of Venezuela near tho Bay of Cumana. The lowest strata are Cretaceous and are called together with the Eocene above them the "Older Parian." The "Newer Parian" above is Miocene and contains lignites and bitumen. Here orbitoides and nummulites are found in a mass of rock projecting into the Gulf of Paria, supposed to be Miocene. In the Western Hemisphere orbitoides are supposed to characterize the Eocene. In the Eastern Hemisphere nummulites are characteristic of the same formation. The deposit that here contains them both lies between other Miocene deposits.

§ Proceed. Scien. Assoc., Trinidad, Dec., 1877, p. 103.

dary of the Carribean continent and was a barrier through which no large river found its way. The 'Parian Range' may be regarded as one of those 'stable areas' which has never been submerged since Paleozoic times."

"To the westward the Cretaceo-Eocene sea probably extended as far as the present low-lying alluvial plains of Venezuela. In this direction it was no doubt bounded by the high lands now forming the Pico de Cumanacoa and the Cerro del Bergantin, ranges at present twice as high as any in Trinidad. Its southern extension went presumably near to the granitic and gneissic ranges and plateaux of Guiana."

"After the close of the Miocene period there was probably in the region south of the 'Parian Range' a slow and gradual upheaval which brought the oceanic deposits above the level of the sea, during which process they suffered great denudation. The Gulf of Paria was then land, and Trinidad was then united to the mainland. At that time the river Guarapiche probably flowed across Trinidad from Venezuela, while the Orinoco continued to pour its waters into the ocean at some distance southward. The disruption of the 'Parian Range' and the formation of the Bocas and the Gulf of Paria followed. There are paleontological reasons for believing that this submergence did not take place until a late geological epoch."

From this conclusion it is manifest that the Miocene period was one of frequent alternation of elevation and submergence, during which there were long periods when the different members of the formation were covered with tropical swamps having luxuriant vegetation, that are now represented by the great swamp at the east end of the island. The buried vegetation of these swamps has been converted into coal through Pliocene and recent times which has been distilled at low temperatures, probably initiated by fermentation within the mass of the coal itself, assisted by the water of thermal springs.

Messrs. Wall and Sawkins discuss at length the phenomena peculiar to the lake and disagree with previous observers to such an extent that, after a careful examination of their paper I am forced to the conclusion that their study of the subject was extremely superficial. In illustration: they say of the "areas," "the surface is frequently marked with ridges, especially near the edges; these are due to the constant expansion and contraction which is supposed to occur." A most singular explanation, resting on *supposed* phenomena that were neither observed nor proved theoretically. Although they quote Bischoff,* it is only to prove a possible origin for the asphaltum

* Bischoff, Chem. and Phys. Geol. (Cav. Soc. Ed.), i, 288, 290, 291.

by direct conversion from woody fiber, leaving entirely out of consideration the conclusions of this eminent author in reference to the production of hydrogen sulphide, to which further reference will be made. It is, however, just to these authors to remark that the general knowledge of the world concerning bitumens and their origin has been vastly increased during the thirty-five years that have elapsed since they issued their report.

Charles Kingsley and some others have written descriptions of the lake since 1860, but no new facts are stated by them.*

During 1892 the Hon. W. P. Pierce, then United States Consul at Port of Spain, at the request of the department, made a very full and able report upon the asphalt of Trinidad.† The fullness with which all sources of information are made to lend their quota towards a general conclusion in regard to all possible aspects of this question, is of itself the best guarantee, to any unprejudiced reader, of the eminent fairness of this report. Its appearance was almost immediately followed by another report made by Mr. Clifford Richardson, at that time Inspector of Asphalt and Cement for the District of Columbia.‡

This report of Mr. Richardson, while seemingly emanating from a wholly disinterested source, presents statements and conclusions in many respects quite different from those reached by Consul Pierce and previous observers. It was for the purpose of satisfying myself as to the facts, and also of studying the occurrence of bitumen in Trinidad in the light of such observations as I had made in California and elsewhere, that I lately made a trip to Trinidad and the Pitch Lake.

On approaching Point La Brea from the northwest, the reef of asphaltum that forms a barrier around the point and against the sea, is plainly visible. Upon the point itself and jutting into the sea are what appear like low ledges of rock, which a nearer inspection proved to be masses of asphalt taken from village lots, that had been p led for shipment, but had been so long left in the tropical sun that they had melted and flowed into a solid homogeneous mass, that looked at a short distance off like ledges of slate. The piles, which were originally about twenty-five feet in height, were not more than three feet thick. Near these masses were other piles of the same material, from which lighters were being loaded, and which had not remained in the sun long enough to melt. Many hundreds of tons were included in these masses, the original pieces of which had so far coalesced that the asphalt had to be again broken with a pick before removal.

* A Christmas in the West Indies, London, 1879.

† Consular Reports, No. 145, Oct, 1892.

‡ Reports of the operation of the Engineer Department of the District of Columbia, for the fiscal year ending June 30th, 1892, Washington, 1893.

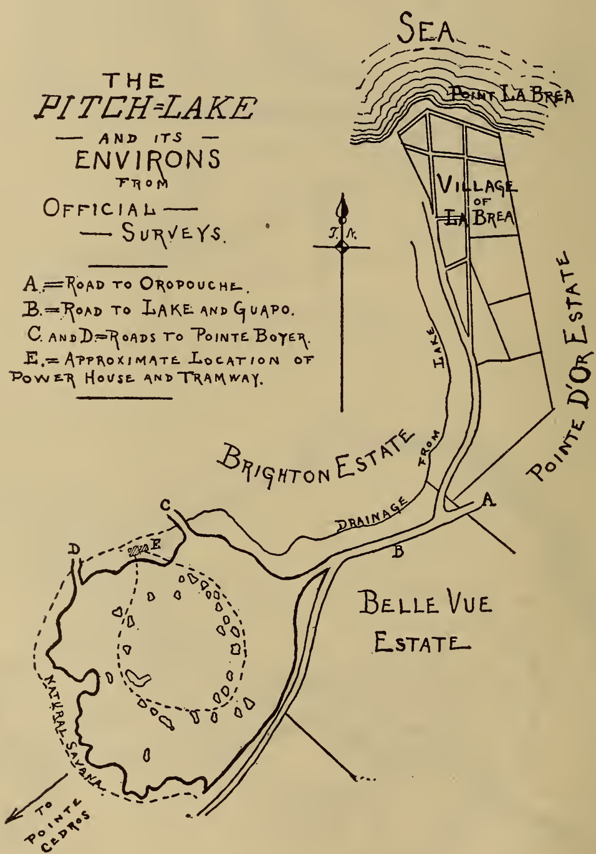
1.

2.

PLAN OF PITCH LAKE AND VICINITY.

Passing on shore and beyond these piles, the plant of the pitch lake concessionaires was encountered, in which the operation of boiling a mixture of so-called land asphalt, the ordinary lake asphalt and the soft pitch from the center of the lake was going forward. The operation is conducted in kettles, resembling open sugar kettles, and is a very crude and simple operation. Passing eastward, I next encountered a wide area

3.



covered with asphalt, that had melted in the sun to a level surface perhaps two feet in depth. I was told that this asphalt was dug from a village lot, the ownership of which was in dispute; that originally the piles were at least twenty feet in height, but while the owners disputed the piles melted in the sun.

Farther on I struck the road to the lake, which appeared to me exactly as Mr. Manross had described it forty years ago. The houses in the village were in the same condition described by Dr. Nugent in 1807. The slope leading up to the lake was in exactly the condition in which all previous observers had described it, as resembling a lava flow—a black glacier. The several points at which asphalt had been and was being excavated, showed in the most admirable manner that the movement of the asphalt down the slope and towards the sea is still in progress. Every excavation was in a short time partially refilled by a movement of the asphalt up from the bottom and in from the sides, the cavity in time becoming filled full to the level of the surrounding area. One illustration of this fact was the spot from which the noted cargo of the Teneriffe was taken, every trace of former excavation having completely disappeared.*

The Trinidad Bituminous Asphalt Company were excavating a lot near the road, and had also recently uncovered a lot that had become almost completely refilled in a few months, after the removal of several thousand tons of asphalt. Farther up the slope the Trinidad Asphalt Company were taking out asphalt from lots on the Belle Vue estate. These lots, like most of the others, were covered with a dense tropical jungle, consisting of palms, sedges, canna and other plants, from three to ten feet in height. It did not need the testimony of Mr. Manross to show, that in all probability, fire had more than once consumed this mass of vegetation, producing a terrific heat, that had melted and converted into so-called "iron-pitch" much of the surface of the pitch. The "iron pitch" is present in greater or less quantity, both within and without the boundaries of the lake, wherever fire has consumed the vegetation, and consists simply of melted pitch which has been heated so hot as to deprive it of its water and more volatile constituents, causing it to flow in streams, often to considerable distances. Below these melted masses the pitch lies in its normal and unaltered condition.

It must, however, be constantly borne in mind, while reading the statements of different observers made on different occasions, that the lake and its principal overflow have presented different phenomena at different periods. While it was evident at the time I visited the overflow that fire had swept over its surface, it was equally evident that it had for a long time been free from any such visitation. I have seen similar flood-plains of asphalt in California that had been on fire for

* I was told by those who witnessed the digging of this cargo, that apparently no care was exercised in its selection. One gentleman declared that it was the dirtiest cargo of pitch ever sent from the island.

months, and others that had been burned some time previous to my visit to them. I can imagine that after such a fire the resemblance of the overflow of the lake to a "black glacier" would be much more pronounced than when covered with a rank growth of vegetation, as it now is. It is not, however, the surface that flows, covered as it is, by masses of coke, iron-pitch, vegetation and rubbish. The houses in La Brea now all rest on blocks. In this position they are much more stable than on posts, although anything resting upon the overflow is unstable. It is the cheese-pitch, full of water and containing more or less gas, buried beneath these surface accidents, that has flowed and still flows.

Although a large amount of clay and vegetable débris fills the interstitial spaces of the rough surface of the asphalt, the vegetation is not confined to such surfaces, but seems to flourish equally well upon the bare pitch, the roots penetrating the pitch without the slightest difficulty, except where it had been converted by melting into iron-pitch. There is also considerable coke where the fires have been hottest. All of these impurities are carefully excluded from the pitch that is mined, both for boiling and for shipment in the crude state, by all of the men employed by the different companies in extracting it. This selection is not difficult, as the appearance of the iron-pitch is very different, and the amount very small, as compared with the pure or cheese-pitch.

Near the crest of the ascent to the lake the road divides, one branch passing to the left and south ascends over the rim of the basin of the lake, and skirting the lake for about a quarter of its circumference passes over the hill to the southwest, as described by Mr. Manross. The right hand branch follows the flow of the pitch and enters upon the lake simply by a change of grade from a sharp ascent to a very slight inclination upwards towards the center of the lake. I was particularly impressed with this fact, and took pains to verify my first impression upon a second visit, as it proved conclusively that, notwithstanding the vast quantities of pitch that had been removed from the lake, there is still a movement out of the lake, glacier-like, down the slope to the sea.

My first impression as I looked over the expanse of the lake was a surprise. I had expected a scene of desolation. Nothing could be further from the reality. In the center were the islets so often described. Within and around them a dark area resembled the muddy bottom of a pond from which the water had been drawn off, with here and there patches and intervening streams of water remaining. From the border of this dark center, the vegetation arose higher and higher around almost the entire circumference of the lake, until it reached a border of palm trees from thirty to fifty feet high. As I looked over the lake I beheld on a vast scale the appearance of asphalt beds that I had many times seen in California.

An examination of the borders of the lake showed that it occupied a bowl-like depression in a truncated cone that rested against the side of a hill that rises above the lake to the southwest. Along the line of ascent that I had followed, the slope towards the northeast to the sea is very gradual. In other directions the ascent is abrupt, sometimes steep, especially toward the south. These slopes are covered with tropical jungles consisting of palms of various species, sedges, canna and wild vines. The border of this depression presents upon the inside for the most part an escarpment of sand and clay, that has evidently been built up and afterwards broken down in many places by water. Wherever excavations have been made in the cone or the escarpment they show that the cone consists of both asphalt and earth. At a point on the south side, near where the road leaves the lake, the appearance of the surface indicates that the drainage of water from the lake was frequently in that direction to a considerable amount, notwithstanding numerous artificial drains lead out of the circumference of the lake and the wide natural outlet down the slope to the sea. To the northwest towards the sea, a heavy stream of asphalt has overflowed to the sea, forming a barrier reef for a considerable distance. Asphalt has also overflowed to the south, and the general appearance of the escarpment seemed to indicate that at some remote period the basin now occupied by the lake had been filled some three feet higher than the present level of the lake. I looked in vain for any evidence that the mass within the lake had been recently depleted; but I am aware that observations at considerable intervals of time would be necessary to establish that fact, by referring the mean level of the lake to some fixed point by means of a very careful trigonometrical survey.

A very careful study of the present appearance of the lake and its boundaries led me to believe that the suggestion of Mr. Richardson, that the lake occupies the crater of an old mud volcano, is correct, and that it has been built up of very unstable material, through contact of water issuing in large quantity from subterranean springs which has come in contact with strata identical with or resembling those described by Mr. Guppy.* Into this ascending current, resembling

* Guppy says, (Quar. Jour. Geol. Soc., xlviii, 527, note) "When a piece of the foraminiferal rock is placed in water, it absorbs it rapidly and falls asunder, and the water which enters into union with it is given up only to evaporation. . . . From these properties it follows that the natural soil roads passing over these rocks become in the wet season the worst quagmires it is possible to imagine." Of another bed, "In the presence of water this rock is the most incoherent of any I have ever met with. . . . It falls into powder at the mere contact of water."

a quicksand, was projected bitumen, at intervals in very large amounts, so that irruptions of mud have coincided with and alternated with irruptions of bitumen, the whole building up the cone and at times overflowing it, while the basin has gradually filled with bitumen to the exclusion of mud.

It is, however, equally evident that for an indefinite period there has been an outflow of bitumen from the crater towards the sea, at La Brea, not over its rim, but through a crevice in its side; in fact through its broken down side; and that, notwithstanding the vast quantities of asphalt now being taken from the lake by the concessionaires, the movement is still out of the lake.

Capt. Alexander, in 1832, spoke of the flow out of the lake as "immense." Manross, in 1855, says, "this stream of pitch has been dug through in several places, averaging from 15 to 18 feet in depth." A well dug at one point on the slope of the overflow, was abandoned still in asphalt, at the depth of forty feet. Several village lots have been excavated to a depth of twenty feet, still in asphalt. The invariable reply of the negroes to the question, "Have you ever dug through the asphalt?" was, "No, sir." The conclusion that I reached on the ground is, that the asphalt flowing down the slope to the sea fills a ravine excavated by water, and that it is slowly moving out of the lake with the pressure of the asphalt in the lake behind it. This conclusion is in harmony with the testimony of all of the observers above quoted for the last hundred years.

Concerning the condition of, and appearance of, the pitch within the lake, I think it is quite certain from all the observations above quoted that the pitch has gradually become harder and more stable during the last 106 years. I do not think that later observers have any right to question the veracity of those who have preceded them. Dr. Nugent says that in 1807, the center was so soft that it could be dipped up with a cup. Alexander describes it in 1832 as so unstable that the weight of a man produced a bowl-like depression to the depth of one's shoulders and that the heat gradually increases as one walks off towards the middle with his shoes off. Manross 23 years later, says, "It may be that the material has become much harder since the first accounts of it were written; but it is difficult to understand how the weight of a man can have displaced a mass of pitch equal to a 'great bowl' as deep as the shoulders." Kingsley 24 years later, is practically of the same opinion. At the time of my visit, a man was loading a cart near the center of the lake, and while they did not remain in one place long enough to secure a large load, there was no apparent danger of their being engulfed.

Yet it must not be assumed that the cosmical agencies that produced this deposit of bitumen have ceased to be active, or are even simply quiescent. Abundant evidence is to be found in the neighborhood and even within the lake itself, that such forces are still active. A few miles to the southwest of the lake, at Guapo, large springs of maltha or "liquid asphaltum" are now flowing, and within the boundaries of the lake near the power station of the tramway, and within only a few rods of the edge of the cone, I observed what the workmen called (and very properly) a "blowhole." This was a circular hole, about six inches in diameter, from which bitumen, more nearly fluid than any I saw elsewhere upon the island, had been ejected to the amount of perhaps a barrel. It was so soft as to flow readily, of a brilliant black color, and appeared to contain little, if any, mineral matter. I was told by a workman that such holes occurred quite frequently and so far apart as apparently to have no connection with each other.

Asphalt beds occur in California that are the product of the hardening of maltha, or mineral tar, which escapes over a considerable area. Sometimes it flows continuously from a central orifice, but oftener the flow through the hot summer seems to be arrested by the lower, winter temperature, when the orifice through which the flow took place becomes plugged. The succeeding season the maltha issues along a line of less resistance and flows through the summer, when it in turn becomes plugged. These plugged orifices are often several rods apart for successive seasons, and present the appearance of a cicatrix. I have no doubt that more extended observations than I was able to give would reveal a similar condition of outflow at and in the vicinity of the lake.

I carefully studied these phenomena as likely to offer some suggestion concerning the origin of the deposit. As a description of the observed facts, I can add nothing to that of Mr. Manross. I do not understand why Messrs. Wall and Sawkins observed nothing of the sort described by him, or thought it not "very obvious to what force or what influence this is attributable." These "areola" are very irregular in shape. I think their form may be, to some extent, determined by the weight of water pressing against their sides. The surface of each one is slightly rounded from the center to the edge of the water; they then round off at a very sharp angle, finally descending almost perpendicularly. These areas consist of pitch inflated with gas to such an extent, that when broken into, the structure exactly resembles an over fermented cheese —hence the term "cheese-pitch." The cavities are from one to three or more inches in dimensions. The gas that they contain is constantly rising to the surface, where it bubbles out and bursts, thus forcing the center up and causing a slow but irresistible movement from the center towards the circumference, where the pitch continually rolls under, exactly as Manross has described it. His suggestions concerning the ebullition of the mass within the lake were confirmed to the very letter.

This action is explainable in this wise: Mr. Richardson's analysis of asphalt water shows it to be very rich in sulphates. As has been elsewhere shown, sulphates, especially those of the alkalies, when in solution are decomposed, when the water containing them flows through strata impregnated with organic matter, into hydrogen sulphide and a carbonate of the oxide present. When hydrogen sulphide infiltrates strata containing carbonate of lime, gypsum is formed and sulphur deposited, or converted into free sulphuric acid.*

The Miocene bituminous strata of Southern California are full of sulphur springs and numberless deposits of sulphur. One such deposit in the southern part of Kern County is supposed to contain several thousand tons of sulphur.

The reaction between sulphates present in the lake water and the bitumen or other organic material of the formation, furnishes a ready explanation of the presence of hydrogen sulphide; but I must confess that the odor of that gas was much less apparent about the lake than I had been led to expect. Analysis will alone show what the gases are that inflate the asphalt, but of their presence in enormous volume, there can be no question. At a rough estimate, I should say that from one-third to one-half the volume of the mass as it exists in the center of the lake, is gas. I also hazard the opinion that this gas makes the *mass* specifically lighter than water, else the tables described by Manross and Kingsley would not rise and spread on the surface of the water and further the masses of asphalt would coalesce, and the water would float upon the asphalt. Moreover it is without any doubt, that through this motion or ebullition which is produced, not by escape of vapor generated by heat, but by gases forced upward by their own specific gravity through a yielding mass, that the asphalt and mineral matter which forms the floors and sides of the crater, are mixed together until the asphalt is saturated; i. e. it reaches such a condition of plasticity and viscosity, that it will no longer absorb any more mineral matter in presence of water. I cannot account for the almost uniform character of the mixture of water, bitumen and mineral matter, on any other hypothesis.†

* Proc. Am. Philos. Soc., x, 445. Bischoff, Chem. and Phys. Geol., (Cav. Soc. Ed.) II. 28; Ibid., i, 15, 340. T. S. Hunt. Chem. and Geol. Essays, pp. 23, 87, 99, 111.

† Mr. Richardson asserts that 90 per cent of the 80 per cent of insoluble mineral matter in the pitch is silica. As a possible explanation of the presence of

Asphalt is very inert to changes of temperature. It is a very poor conductor of heat, and even under a tropical sun, the daily surface changes of temperature and consequent expansions and contractions are wholly inadequate to produce conditions affecting such enormous masses of material as the crater contains.

The frequent use of the term "volcanic" in connection with the supposed origin of this mass of bitumen is in my judgment misleading. With the term volcanic is usually associated streams of melted lava, scoria and pumice. The masses of porcellanite and jasper mentioned by all observers as found in the neighborhood of the lake, do not require for their origin any "subterranean fires." It only requires that hot water, holding silica in solution under high pressure, shall percolate a bed of clay. The distillation of beds of lignite, requires nothing more. In one case the product is red or yellow jasper, in the other a deposit of bitumen. The less the pressure, the more dense will be the bitumen. Water will inevitably bring the bitumen to the surface, unless it is held down by impervious strata. If the water accompanied by bitumen, encountered in its upward passage such strata, as have been described by Mr. Guppy, a mud volcano yielding bitumen would be the inevitable result. It appears to me that all of these conditions are present in and about the pitch lake. They are exactly the conditions that have produced enormous tar springs and asphalt beds in California, excepting that there the strata necessary to produce mud volcanoes are wanting, but the porcellanites, the hot springs, the sulphur springs, and the bitumen, are all there, and in some localities on a scale that vies with Trinidad.

I looked in vain for specimens of wood in process of transformation into asphalt. I enquired of many intelligent men, and others connected with mining the pitch, if they had ever seen such specimens; they invariably answered "no." Two or three remarked that the wood never decayed in the pitch, that it came out as it went in. One man replied that, "if it went in rotten it came out rotten." I saw in several excavations along the tramway masses of vegetable matter that appeared to have been converted into humus, and was told by the workmen that in time these masses would become incorporated with the pitch. Such masses account for the organic matter in solution in the lake water, and also for the amorphous organic matter not bitumen, observed by Mr. Richardson.

so much silica, I would suggest that the hot water that distilled the bitumen, might have held silica in *solution*, which has been precipitated within the pitch as it has cooled. The fact, if it be a fact, that so much silica exists in the pitch as hydrate, may account for the large amount of water held in the pitch.

The concessionaires of the lake, have recently put in operation a tramway and pier by which the pitch can be very rapidly and easily removed from the lake to vessels lying at the pier. The tramway forms a loop, which in a general way may be said to pass just outside the circle of islets. (See map.) In building the tramway much of the vegetation on these islets has been destroyed. The laying of the tramway presented some peculiar engineering difficulties, that have been successfully overcome. The islands float on the pitch, and I believe that they represent portions of the edge of the crater broken off during violent irruptions and placed in, and maintained in their relative positions through their relations to the various centers of ebullition into which the surface of the lake is divided. These islets, which largely consist of vegetable matter, float, while logs of wood and palm-tree ties sink in the pitch; it therefore occurred to Mr. Freeman, the engineer in charge of the work, to support his tramway on palm leaves, of which many specimens are twenty-five feet in length. This expedient has proved a complete success, not only upon the summits of the "aroela" but in crossing the crevices that separate them. The tramway furnishes a succession of admirable points from which to view the lake, as no difficulty is experienced in walking upon the ties around the entire loop. The cars are run in groups of four, which when loaded have a gross weight of about six thousand pounds. I carefully watched the passage of successive groups of these cars and could not observe any change of level in the road bed, as they passed along; yet I am quite certain if a group had been allowed to stand for several hours, that both tramway and cars would have sunk in the pitch.

The pitch is excavated along this tramway upon the summits of the "areola." Wherever the surface of the pitch is broken, the vesicles are uniformly smaller as the pitch is taken from points removed from the center of the lake. As the water dries out, the vesicles collapse and the color changes from brown to bluish black. If left long enough in the sun, any of the pitch, no matter from what spot it may be taken, will first melt upon the surface and finally flow into a more or less compact mass. The pitch being dug by the Trinidad Asphalt Company, both within and without the lake, was brown when freshly dug, changing to black on exposure. The same might be said of that dug farther down the slope from village lots by the Trinidad Bituminous Asphalt Company. It was quite evident that as the pitch was taken from points farther and farther from the center of the lake it had been subjected to more and more pressure, the gas being forced out as a consequence, the vesicles made smaller and the specific gravity thereby increased.

There are enormous masses of pitch within the lake that could not in my opinion be distinguished by the eye, from the pitch taken from village lots by either of the companies before mentioned. I am therefore quite at a loss to determine why Mr. Richardson alleges such a specific distinction between what he is pleased to term "lake" and "land" asphalt. It appears to me to be a distinction without a difference.

For further facts concerning the commercial and economic relations of Trinidad Asphalt, the reader is referred to the report of Consul Pierce, which I believe to be one of the most complete and impartial of all the valuable consular reports issued by the State Department.

It was my intention to include in this paper some statistics regarding the enormous amount of asphaltum of different varieties shipped from La Brea since January 1st, 1890.

When a friend applied to the custom house in Port of Spain for an official statement, he reported that such information had been refused, on the ground that such a statement would make public private interests, inasmuch as the Trinidad Asphalt Company had shipped several cargoes of "land pitch" to the United States since that date.

By referring to the maps the reader can clearly distinguish the relative positions of the lake and the adjacent portions of the island.

University of Michigan, Ann Arbor, Michigan, April 15th, 1895.

ART. V.—*The Determination of Selenious Acid by Potassium Permanganate;* by F. A. GOOCH and C. F. CLEMONS.

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

THE fact that sulphurous and tellurous acids may be oxidized quantitatively by a sufficient excess of potassium permanganate suggests naturally the application of the same general method to the determination of selenious acid. It is the object of this paper to record the results of experiments in this direction.

Brauner* found that in the action of the permanganate upon tellurous acid, whether in a solution acidified with sulphuric acid or made alkaline by caustic soda, the reduction of the permanganate does not proceed to the lowest degree of oxidation, the tellurous acid being unable to reduce the higher hydroxides of manganese which separate. In employing the reaction quantitatively it is necessary, therefore, to add the permanganate in distinct excess and then to destroy the surplus by means

* Jour. Chem. Soc., 1891, p. 238.

of standard oxalic acid added to the solution acidified with sulphuric acid, subsequently determining the excess of oxalic acid in the warmed solution by addition of more permanganate. The difference between the amount of permanganate actually used and that required to oxidize the known amount of oxalic acid introduced should naturally be the measure of the tellurous acid acted upon. Brauner found, however, an error in the process, by no means inconsiderable, due to the decomposition of the permanganate outside the main reaction. In a subsequent paper from this laboratory* it was shown that if the precaution is taken to restrict the amount of sulphuric acid present in the solution when the permanganate acts the secondary decomposition involving loss of unutilized oxygen is kept within narrow bounds. In our work upon the oxidation of selenious acid we have followed the suggestions gained in the treatment of tellurous acid by Brauner's method.

The selenium dioxide which we employed was prepared from so-called pure selenium by dissolving the element in strong nitric acid, removing the nitric acid by evaporation, treating the aqueous solution with barium hydroxide to throw out any selenic acid formed in the oxidation, evaporating the solution to dryness, and subliming and re-subliming the residue in a current of dry air until the product was white. The oxide thus prepared was weighed out for individual experiments or was dissolved in a standard solution from which definite portions were drawn for use.

In the first series of experiments, the results of which are recorded in Table I, the selenium dioxide was dissolved in 100 cm^3 of water, 10 cm^3 of sulphuric acid of half-strength were added, an approximately decinormal standardized solution of potassium permanganate was added until the characteristic color predominated over that of the brown hydroxide deposited during the oxidation, oxalic acid in solution of known strength was introduced until the excess of permanganate had been destroyed and the insoluble hydroxide dissolved, and, finally, after heating the solution to about 80° C., more of the permanganate was added to the color reaction. The final volume varied from 250 cm^3 to 350 cm^3, so that the sulphuric acid (absolute) present varied from about five per cent at the start to from one and a half to two per cent at the end.

When the permanganate is first introduced into the acidified solution the color vanishes, leaving a clear colorless liquid, but as more is added the solution becomes yellow and deepens gradually in color to a reddish brown, until turbidity due to the deposition of a brown hydroxide of manganese ensues, and finally the characteristic color of the permanganate is plainly

* Gooch and Danner, this Journal, xliv, 301.

distinguishable. The exact point at which precipitation of the manganic hydroxide begins depends upon the dilution, acidity, and temperature of the solution. In experiments (1) and (2), the permanganate was added to the cold solution at the first, but the liquid was heated after the addition of oxalic acid and before the final titration with the permanganate. The remaining determinations of the series were made in solutions kept hot throughout.

TABLE I.

[Se=79·1, O=16.]

	SeO_2 taken. grm.	Oxygen equivalent of permanganate used. grm.	Oxygen equivalent of oxalic acid used. grm.	SeO_2 found. grm.	Error. grm.
(1)	0·1000	0·03026	0·01571	0·1010	0·0010+
(2)	0·1002	0·03038	0·01578	0·1014	0·0012+
(3)	0·0997	0·02634	0 01182	0·1008	0·0011+
(4)	0·0999	0·02568	0·01122	0·1004	0·0005+
(5)	0·1000	0·02536	0·01077	0·1012	0·0012+
(6)	0·1000	0·03226	0·01765	0·1015	0·0015+
(7)	0·1001	0·04455	0·02992	1·1016	0·0015+
(8)	0·2001	0·05448	0·02543	0·2018	0·0017+
(9)	0·1997	0·05219	0·02318	0·2014	0·0017+
(10)	0·1997	0·05215	0·02318	0·2011	0·0014+
(11)	0·5178	0·13215	0·05721	0·5203	0·0025+
(12)	0·5197	0·14105	0·06541	0·5252	0·0055+

An examination of these results develops the fact that the action proceeds regularly in the main under the conditions of experimentation, but that there is an apparent waste of permanganate in the process. It was observed that the addition of a little permanganate beyond the exact amount necessary to produce the end-reaction occasioned the precipitation of manganese hydroxide, evidently, according to Guyard's reaction, by interaction between the permanganate and the manganous sulphate present. Plainly the amount of sulphuric acid present, which we kept purposely low to obviate the spontaneous decomposition of the permanganate, was not sufficient to prevent the ultimate formation of the hydroxide at the temperature of action. The natural inference is that the difficulty in the determinations may have been due rather to an interference with the color reaction at the end of the oxidation process, due to the incipient tendency of the permanganate to act upon the manganous salt, than to direct loss of oxygen from the permanganate. If this is true, the obvious and simple remedy should be found in effecting the oxidation of the oxalic acid at the end of the process at a temperature so low that the inclination of the permanganate and manganous sulphate to interact shall be diminished. Table II contains the record of experiments in which this precaution was taken. The entire process of oxidation, which was otherwise similar to that of the previous experiments, was brought about between the temperature of 75° C. at the beginning and 50° C., or even a little less, at the end. The end-reaction was in every case sharp and the final color was permanent for several minutes at the least.

TABLE II.

	SeO_2 taken. grm.	Oxygen equivalent to permanganate used. grm.	Oxygen equivalent to oxalic acid used. grm.	SeO_2 found. grm.	Error. grm.
(13)	0·1000	0·03506	0·02065	0·1001	0·0001 +
(14)	0·1000	0·03519	0·02073	0·1004	0·0004 +
(15)	0·1000	0·03706	0·02255	0·1007	0·0007 +
(16)	0·1000	0·03853	0·02422	0·0994	0·0006 —
(17)	0·1000	0·03512	0·02065	0·1005	0·0005 +
(18)	0·2000	0·06124	0·03256	0·1994	0·0006 —
(19)	0·2011	0·06069	0·03177	0·2008	0·0003 —
(20)	0·2004	0·06072	0·03177	0·2010	0·0006 +
(21)	0·2020	0·06083	0·03185	0·2012	0·0008 —
(22)	0·2038	0·06106	0·03185	0·2028	0·0010 —

These results are evidently an improvement upon those of the first series of experiments, and are fairly satisfactory so far as concerns the estimation of the amounts of selenium dioxide discussed. The determination of large amounts of selenious acid by this method is somewhat less advantageous than it would be if the reduction of the permanganate proceeded farther in the first action. One hundred cubic centimeters of a standard solution is as much as can be conveniently handled in a single process of titration, and that volume of decinormal permanganate (which is about as strong as the standard solution should be when accurate work is expected) is capable of oxidizing about $0·25^{grm}$ of selenium dioxide.

The process which we recommend consists, in brief, in the addition of standard potassium permanganate to the solution of selenious acid containing not more than five per cent of its volume of strong sulphuric acid, the introduction of standard oxalic acid until the liquid clears, and the titration of the excess of oxalic acid by permanganate, at a temperature not much exceeding 50° or 60° C. The permanganate and the oxalic acid should be standardized under similar conditions of acidity and temperature, and for a standard of final reference we prefer pure crystallized ammonium oxalate.

We have made experiments in which the initial oxidation of the selenious acid was made in alkaline solution, but inasmuch as the amount of permanganate required for the oxidation is about three times as great as that needed in the acid solution the treatment in alkaline solution is practically inferior.

ART. VI.—*On some Reptilian Remains from the Triassic of Northern California;* by JOHN C. MERRIAM.

ALTHOUGH the Mesozoic of California is remarkably developed, both as regards thickness of section and richness of invertebrate faunas, it has so far appeared singularly barren of those characteristic and often abundant reptilian forms occurring in most Mesozoic rocks. Probably the only reptilian remains of this age found in California up to this time were collected in the summer of 1893 by Prof. Jas. Perrin Smith of Stanford University, in the Triassic of Shasta Co. Through the kindness of Prof. Smith it has recently been the writer's privilege to examine these specimens and prepare the following note.

The saurian remains, representing two individuals differing greatly in size, were found in the black Triassic limestone of Shasta Co., associated with a rich invertebrate fauna made up of such forms as *Arcestes*, *Trachyceras*, *Atractites*, *Aulacoceras* and *Tropites subbullatus*, all characteristically Triassic. The more exact stratigraphic relations of the horizon as determined by Prof. Smith place it in the upper portion of the Triassic.

Both skeletons are very fragmentary and were so closely united with the matrix that in the case of the vertebræ successful preparation was almost impossible. The remains of the larger individual, consisting of eight consecutive vertebræ, a few fragments of ribs, and both coracoids, were imbedded in a loose slab about two feet square, and from the position of the parts present it might be inferred that they were in their natural relative positions. If this is the case the vertebræ would belong to the anterior part of the dorsal or posterior part of the cervical region. The rib fragments next the vertebræ and evidently belonging to them seem to be from the thorax. The *vertebræ*, Fig. 1, which resemble very much those of *Ichthyosaurus*, were very deeply bi-concave, possessed separated neurapophyses resting on a distinct facet on either side of the deep neural groove, and supported rather heavy single headed ribs. The centra are much shortened anteroposteriorly, measuring 34–38^{mm} long by 60^{mm} high and 70^{mm} broad. Those at the anterior end of the series are somewhat shorter than the others. The neurapophyses, as shown in the figure, were much thickened transversely by a broad rib running from the upper to near the lower end of the process. Zygapophyses were preserved on only one spinal process and seemed in this case to be small and weak. The *ribs* differ

*Journal of Geology, Vol. ii, No. 6, p. 607.

decidedly from those of *Ichthyosaurus*, articulating with one head only on the ample facets of the diapophyses and failing to show the external groove characteristic of many species of this genus.

1.

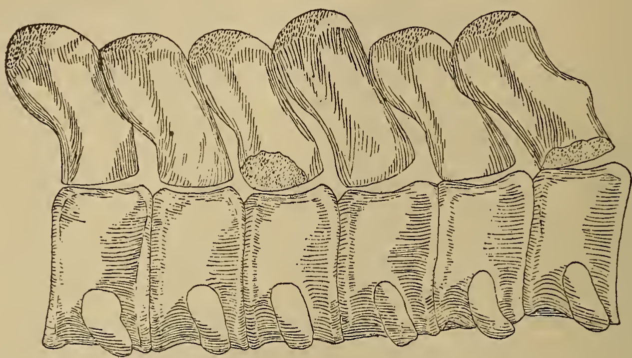


FIG. 1.—Anterior dorsal (?) vertebræ of *Shastasaurus pacificus* gen. et sp. nov. One-third natural size.

The strong and robust *coracoids*, one of which, Fig. 2, is perfectly preserved, were proximally much thickened and deeply notched on the anterior side. That they met on the median line, is shown by the sudden straightening of the distal margin shown in the figure. Judging from the small size of the surface of articulation with the scapula this element was small. The articular surface for the humerus being exceptionally large, this bone, as well as the whole fore-limb, probably partook of

2.

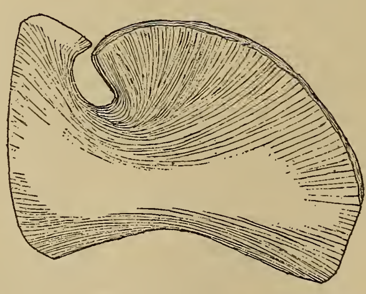


FIG. 2.—Right coracoid of *Shastasaurus pacificus* from below. One-third natural size.

the robust character common in the anterior limbs of Enaliosaurs. The coracoids differ markedly from those *Nothosaurus*, but approach the form of this element in some ichthyosaurian species.

Owing to paucity of material it is hardly possible to determine with certainty the exact affinities of the species described above, so much, however, is certain, viz: that its systematic position falls within the limits of the old order, *Enaliosauria*, which has perhaps not altogether outlived its usefulness. The majority of the characters, such as extreme shortness of centra, high degree of biconcavity of vertebræ, small zygapophyses, character of articulation of neurapophyses, and form of coracoid indicate ichthyosaurian affinities. Some of these characters, however, are also found occasionally in the *Sauropterygia*, while heavy, ungrooved, single headed ribs are characteristic of this order and do not occur in the *Ichthyosauria*. As no genus heretofore described contains this assemblage of characters the new generic and specific name *Shastasaurus pacificus* is proposed for this form.

The second and smaller individual is represented by about twenty-five vertebræ, mostly anterior caudals. As the whole series measures only 200^{mm} long the animal was many times smaller than *S. pacificus*. In the characters of the vertebræ alone there is nothing which would separate this species from *Ichthyosaurus*, but an ungrooved, single headed rib belonging to the anterior or middle dorsal region indicates shastasaurian affinities. This specimen probably represents a form different from that described above, but the material at hand is insufficient for specific characterization.

University of California, Berkeley, May, 1895.

Art. VII.—*A further Contribution to our knowledge of the Laurentian;* by Frank D. Adams. With Plates I and II.

The chief of the great protaxes of the North American Continent, having an area of about two million square miles, lies as is well known for the most part in the Dominion of Canada, and in it Logan distinguished two great systems or series of rocks—the Huronian and the Laurentian—the former being a distinctly clastic series, while the latter showed no undoubted clastic structure but consisted chiefly of gneisses of various kinds. He also found associated with these Laurentian gneisses in certain parts of the protaxis an abundance of quartzite and crystalline limestone, as well as much anorthosite and eventually divided the Laurentian into two parts, viz: the Upper Laurentian—consisting of the anorthosites (supposed to be stratified rocks), with some of the gneiss and crystalline limestone, and the Lower Laurentian consisting of the Grenville series, distinguished by the presence of numerous bands of crystalline limestone, quartzite, etc., resting upon the Fundamental Gneiss.

These two divisions, the Upper and Lower, were supposed to be unconformable.

In a paper which appeared two years ago in the Neues Jahrbuch für Mineralogie,* under the title "Ueber das Norian oder Ober-Laurentian von Canada," it was shown from a study of all the areas of the so-called Upper Laurentian, that the rocks which had been assigned to it do not constitute an independent series, but that the anorthosites occur as a series of great intrusions, while the associated gneisses and crystalline limestones are merely portions of the Grenville Series or Fundamental Gneiss as the case may be.

In a paper which was recently presented to the Geological Society of America, moreover, Ells states it as his belief from a reëxamination of Logan's typical area that the crystalline limestones of the Grenville Series are not concentrated at some four widely separated horizons as Logan supposed, but come in gradually, as interstratified bands, attaining their principal development at the summit of the series.

It appears, therefore, that what has been called the Laurentian in Canada consists of an underlying series of gneisses and granites called the Fundamental Gneiss, much of which may be and probably is of igneous origin, and an overlying series of gneisses often differing from these in petrographical character, associated with crystalline limestones and quartzites, and known as the Grenville Series.

* Beilage Band, viii, 1893.

The areas occupied by the Grenville Series although of very considerable extent, being known to aggregate many thousand square miles, are probably small as compared with those underlain by the Fundamental Gneiss. The relative distribution of the two series has not been ascertained except in a general way in the more easily accessible parts of the great Archean protaxis. The Grenville Series is known to occupy a large part of its southern margin between the city of Quebec and the Georgian Bay, while the discovery of crystalline limestone in the gneiss elsewhere at widely separated points, as for instance on the Hamilton river in Labrador, in the southern part of Baffin Land, on the Melville Peninsula and at the head of Chesterfield Inlet, makes it probable that other considerable areas will with the progress of geological exploration be found in the far north. Over the greater part of the protaxis, however, the more monotonous development of the Fundamental Gneiss seems to prevail.

In the present paper it is desired to present in a very condensed form the chief results, more especially those bearing on the question of the origin of the series, of a somewhat extended study of the stratigraphical relations and petrography of a typical area of the Grenville Series containing subordinate masses of the Fundamental Gneiss and a number of anorthosite intrusions, which area lies immediately to the east of that examined by Logan and Ells and is continuous with it. The work was carried out for the Geological Survey of Canada and a detailed report on the area will appear shortly in the publications of the Survey. I am indebted to Dr. Geo. M. Dawson, the Director of the Survey, for permission to reproduce the accompanying photograph. (Plate II.)

Stratigraphy.—The area in question is represented in the accompanying map (Plate I). Its general geographical position is indicated by the River St. Lawrence with the city of Montreal at the southeast corner. Lying at the edge of the Archean protaxis, the northwest portion of the map is occupied exclusively by the crystalline rocks in question, whose eroded surface is to the southeast covered up by the flat-lying Cambrian (Potsdam) sandstone. The area underlain by the crystalline rocks is 3,500 square miles, of which about 1,000 square miles is anorthosite, of which there is one large development known as the Morin anorthosite and ten smaller masses. This Morin anorthosite area is rudely circular in form, but sends off a large arm to the southeast which passes under the Potsdam sandstone. It encloses detached masses of the gneiss often of considerable extent. There are also two intrusions of acid rocks, one of syenite in the southwest covering an area of thirty-six square miles and a much larger one of granite in the northeast, a portion of which only is embraced within the limits of the map. The rest of the crystalline area is occupied by the Grenville Series with the exception of a subordinate area about Trembling Mountain and possibly another to the west of St. Jerome, which are to be referred to the Fundamental Gneiss. The crystalline limestones of the Grenville Series are represented on the map. The distribution of these in the extreme southwest corner has been taken from Logan's map, as this portion of the area has not been personally examined in detail. It will be observed that these limestones are cut off by the anorthosite intrusions. The various gneisses, quartzites and pyroxenic rocks making up the rest of the Laurentian have in the map been classed together, as it would be impossible to represent them separately on so small a scale. In one portion of the area, however, the township of Brandon, they have been separated and will be so represented on a map accompanying the report above mentioned.

Desiring to maintain as objective an attitude as possible, the Grenville Series will not in the present paper be referred to as stratified or bedded; it may be safely stated however that the rocks composing it frequently alternate in well-defined bands, the whole series also exhibiting a well-defined foliation usually parallel to the banding. The series thus often has a decidedly stratified appearance similar to that presented by bedded sedimentary rocks.

The direction of the strike where actually observed is, on the accompanying map, indicated by the short black dashes; these are connected up by interrupted lines which serve to bring out the structure more distinctly.

It will be seen that the whole area was, at a time long antedating the Potsdam, but subsequent to the intrusion of the anorthosite and granite, subjected to great pressure which induced a foliation not only in the banded gneisses but in portions of these intrusions also, as is especially well seen in the eastern portion of the Morin anorthosite. It will also be noted that probably owing to a flattening of the eastern portion of this anorthosite mass in a north and south direction by this pressure, a certain movement of both gneiss and anorthosite along the line of contact has taken place, especially to the northeast of Lac Ouareau, where the gneiss is seen to undergo an abrupt change in strike amounting to nearly ninety degrees along its contact with the anorthosite, while there is everywhere a tendency for the strike to follow the outline of the large intrusions, the small intrusions being squeezed flat and foliated with the surrounding rocks.

We have here then a marked example of the structural effects of pressure acting on a large Archean area.

The attitude of the various members of the complex to one another in the eastern portion of the area is seen in the section A–B, which covers a distance of twenty-seven miles across the strike. The scale of the section is a true one, the angles of dip not being exaggerated, but it is double that of the map, thus enabling the structure to be more distinctly seen. The gneisses which on the west dip at angles of 40°, toward the east become nearly flat, often quite so, and these nearly flat gneisses extend to the north and east far beyond the limits of the map, underlying an area of several thousand square miles and often presenting low quaquaversal dips suggesting most forcibly a thin crust buoyed up by some semi-fluid or plastic material below. This is probably a great batholitic granite mass of which the Brandon granite is a portion laid there by erosion.

Throughout this area of flat-lying rocks, the gneisses with their interstratified limestones and quartzites are as highly crystalline as in the most highly contorted districts and have evidently undergone an extensive stretching or rolling out, resulting in the tearing apart of the less plastic bands with the flowing of the material of the more plastic bands into the spaces between the separated fragments. This is also very noticeable about the eastern border of the Morin anorthosite where the movement along the contact above referred to has taken place. The appearance presented by the horizontally banded rocks of this area when seen in section is shown in the accompanying plate (II), reproduced from a photograph of a cliff which bounds the valley of the Black River at a point about two miles northwest of St. Jean de Matha, and about three miles southwest of the township of Brandon, the rocks here consisting of bands of garnetiferous quartzite and garnetiferous quartzose gneiss, with some bands of very rusty weathering gneiss to be more particularly described further on.

Owing to the fact that investigations in recent years have shown, that while foliation is almost invariably the result of pressure even banding may in some cases be induced in massive rocks by this agency, the banded character of these rocks can no longer be considered as such indubitable evidence of original stratification as it has been hitherto regarded by some writers. It is conceivable that a complicated series of igneous rocks intruded through one another in the form of a net work of dikes and larger eruptive masses, or a series of eruptive masses in which irregularities in composition have been produced by the processes at work during the cooling of molten magmas, which processes have recently attracted so much attention, if subjected to enormous movements, rolled out very thin as it were, might develop an apparently bedded structure.

In view, however, of the continuously banded character of these rocks over very wide areas and the well-defined character of the individual bands this is an extreme supposition and one which as will be shown is rendered yet more untenable by the chemical composition and structure of the rocks themselves. The fact, moreover, that in the movements induced by pressure and resulting in the foliation of the complex, the more basic and less plastic bands are continually observed to be torn apart and resolved into a series of disconnected fragments, shows that if the banding was produced by pressure in the first case, subsequent pressure acting in the same direction tended to destroy it.

Petrography.—Our knowledge of the petrography of this area is based on careful studies in the field, as well as upon a careful microscopical study of one hundred and sixty typical specimens representing so far as possible all varieties of the rocks occurring in the district.

It is found that the rocks fall into four classes:

1. Anorthosites and granites, of igneous origin.

2. Augen gneisses, leaf gneisses, granulites and foliated northosites, genetically connected with the last group and largely if not exclusively of igneous origin also. The structure characteristic of this class is the cataclastic or granulated structure, formed by the mechanical breaking down of the web of the rock under movements induced by great pressure, which movements produce in the rock a foliation more or less distinct according to their intensity. By leaf gneisses are understood very finely foliated gneisses very rich in orthoclase and containing numerous thin leaves of quartz—they are usually almost free from iron-magnesia constituents.

3. A series of crystalline limestones and quartzites, together with certain gneisses usually found associated with them, and which are probably wholly or in part of sedimentary origin. In these rocks the granulated structure is very subordinate or entirely absent. They are characterised by a very extensive recrystallization with the development of new minerals, they also differ from the rocks of classes 1 and 2 in chemical composition.

4. Pyroxene gneisses, pyroxene granulites, and allied rocks whose origin is as yet doubtful.

It appears, therefore, that the great pressure which has squeezed and foliated these rocks has acted in two ways, it has granulated one class and recrystallized another.

The granulated rocks of class 2 are prevailing poor in iron-magnesia constituents, being composed either of plagioclase on the one hand or of quartz and orthoclase on the other, that is to say being either granulated anorthosites, or granulated granites poor in mica or hornblende. These sometimes occur as independent masses but elsewhere are found forming the peripheral parts of great intrusions of anorthosite or granite where the pressure is most intense. In these latter cases there can be no doubt concerning their origin, as all possible gradations are seen from the massive to the perfectly foliated rock. The progress and extent of this granulation is excellently brought out in thin sections of these rocks by polarized light. An extended description of the action of this pressure and the effects produced by it is, however, beyond the scope of the present paper. In the massive uncrushed anorthosite, the twinning of the plagioclase is well seen and there are no pressure effects. The structure is that of an ordinary plutonic rock. In the anorthosite near the edge of the mass, however, the web of the rock is seen to be breaking down. The broken crystal fragments have moved over one another, little areas and strings of plagioclase grains derived from the breaking down of the larger individuals are seen between and about the latter. The structure is distinctly cataclastic.

In the distinctly foliated anorthosite from the periphery of the area, the rock is seen to be in an advanced stage of granulation, uncrushed remnants of plagioclase more or less numerous however still remaining. These possess irregular jagged edges and show well-marked strain shadows. Little fragments of plagioclase can be seen in the very act of being separated from the parent mass. Lines of broken material often run through the length of large remnants, in this way dividing them longitudinally into two parts, one of which then moves over the other. Two remnants or cores are thus produced and a much greater surface is presented to the action of the granulating forces which continue to act until all the remnants have been destroyed and a uniform mass of white granulated plagioclase results, resembling an appearance of saccharoidal marble. The whole rock thus moves under the pressure like so much dough, its continuity being nevertheless perfectly maintained. This foliated anorthosite has in fact been selected on account of its toughness for the construction of the pavements of several of the streets in the city of Montreal near the wharves, which from the continued passage of heavy freight are subjected to especially intense wear.

This structure is, I believe, the most widespread and important one exhibited by the Archæan rocks. It gives rise to Professor Heim's "Umformung ohne Bruch," millions of little breaks taking the place of a few large ones, and it is by this process that granites, and many gneisses and other crystalline rocks when deeply buried, under great pressure and probably very hot, move and accommodate themselves to strains. This it will be observed is quite distinct and different from the shearing accompanied by the development of new minerals, which takes place under other conditions and probably nearer the surface.

The *third class* of rocks referred to as forming part of the Laurentian consists of crystalline limestones, quartzites and a set of peculiar gneisses, all intimately associated and usually interbanded. The limestones are thoroughly crystalline, more or less pure granular marbles, which although presenting many features of a special interest need not here be further referred to. They are in all respects similar to those described by various writers in other Laurentian districts.* The quartzites which have been examined are entirely crystalline, nothing has been detected in them which distinctly proves them to be of clastic origin. Professor Rosenbusch, however, believes that the specimens from one locality present structures which indicate that the rock was originally a sandstone.

The gneisses which are as a general rule intimately associated with the limestones and quartzites are quite different from those of the second class just described. They are almost always highly garnetiferous and frequently consist essentially of garnet and sillimanite. Quartz and orthoclase are present in subordinate amount. Some of them contain pyroxene, scapolite and other minerals. A very rusty weathering gneiss, containing in some cases nearly five per cent of pyrite, is associated in a particularly intimate manner with the limestones, often in very thin bands showing wonderful contortions precisely like those described by Dr. Kemp in the Adirondack region,† and by other writers elsewhere in the Laurentian of Canada.

These gneisses show no granulated structure, the minerals constituting them have crystallized under the influence of the pressure which has granulated the gneisses of class 2 and are not in any marked manner deformed by it. Furthermore these rocks are generally well banded ; this structure being frequently much more pronounced than the foliation, and graphite, which does not occur in the igneous granulated gneises of class 2, is very frequently present and is often abundant. As localities where these rocks are well seen, the northern part of the township of Rawdon, the township of Cathcart and the district about St. Jean de Matha may be instanced.

When any granite or granitic rock is for long periods exposed to a process of gradual decay there results finally a mass of kaolin, often mixed with more or less chloritic material,

* Logan, Geology of Canada, p. 24, etc.; Hunt, Laurentian Limestones of North America, Rep. Geol. Survey of Canada, 1863–66; Kemp, Bull. Geol. Soc. of America, 1895.

† Loc. cit.

holding the quartz of the original rocks as grains scattered thickly through it. When sorted by the action of moving water it gives rise to beds of sand and clay. The chemical processes at work during this process of decay consist in the more or less complete removal of the alkalies of the feldspar, and of the decomposition of the iron magnesia constituents with the loss of a large proportion of the lime as compared with the magnesia. On comparing the analyses of a series of granites with those of a series of slates, as for instance those given in Roth's "Gesteins Analyzen," the latter are seen to be on an average considerably higher in alumina and much lower in alkalies, while at the same time they are lower in silica, which has been separated both as sand and in combination with the alkalies which have gone into solution, and in most cases contain more magnesia than lime instead of more lime than magnesia, as is usual in granites.

The average percentage of alkalies in the thirty-seven analyses of granites from various parts of the world given by Roth in his work above mentioned is 7·35 per cent, while twenty-three primitive clay slates (Urthonschiefer) contain on an average only 4·70 per cent and twenty-five slates of Silurian age 4·82 per cent of alkalies. The slates thus contain on an average about two-thirds of the amount of alkali present in the average granite. A typical slate is thus distinctly different in chemical composition from an ordinary granite, although sediments having an intermediate composition are frequently produced by the disintegration of granite without complete decay giving rise to rocks such as arkose, grauwacke, feldspathic sandstones and so on.

It seemed probable therefore that some evidence as to the origin of these apparently sedimentary gneisses might be obtained from a study of their chemical composition. Four typical representatives of these gneisses were accordingly selected and analyzed, as well as one of the gneisses of class 2 known to be of igneous origin. These analyses are given in the accompanying tables, together with analyses of three slates and of a granite, for purposes of comparison. Analyses Nos. II, V, VII and VIII were made for me by Mr. Walter C. Adams of this University and analysis No. I was made by Mr. Nevil N. Evans, Lecturer in Chemistry in McGill University. To both gentlemen I desire to acknowledge my great indebtedness.

I. Gneiss from St. Jean de Matha Province of Quebec. A fine grained garnetiferous sillimanite Gneiss containing also much quartz and orthoclase. Graphite and pyrite are also present, the latter causing gneiss to weather to a very rusty color. It occurs in thick bands interstratified with white garnetiferous quartzite, the whole lying nearly flat and forming a southerly continuation of the series of horizontally banded gneisses shown in the accompanying photograph.

II. Gneiss from the west shore of Trembling Lake, Province of Quebec. A fine grained dark gray gneiss composed of quartz and orthoclase with much biotite and containing numerous little white streaks which were evidently at one time continuous little bands. These are composed of sillimanite. Garnets appear here and there in the darker portion of the rock. It occurs near a band of crystalline limestone which occupies the bed of Trembling Lake.

III. An ordinary roofing slate from Wales. Analyzed by T. Sterry Hunt. (Phil. Mag., 1854, 237.)

IV. A similar roofing slate of Cambrian age, from the large quarries in the township of Melbourne, in the southern portion of the Province of Quebec. Analyzed by T. Sterry Hunt. (Geology of Canada, 1863, p. 600.)

V. Gneiss from Darwin's Falls near the village of Rawdon, Range V of the township of Rawdon, Province of Quebec. It is a highly quartzose garnetiferous gneiss and occurs in well defined bands interstratified with white quartzite, which is also often highly garnetiferous, the bands being from a few inches to several feet in thickness.

VI. Red slate from near Tinzen in the district north of the Engadine, Switzerland. Highly siliceous, containing 9·12 per cent of silica as quartz. (Vom Rath, Z. d. G. G., 1857, 242.)

VII. Gneiss, Lot 20, Range VII of the township of Rawdon. Gneiss composed essentially of malacolite, scapolite and orthoclase and holding a considerable amount of graphite and of pyrite. Weathers very rusty. Occurs in well defined bands interstratified with a grayish weathering garnetiferous gneiss.

The four gneisses I, II, V and VII, show no cataclastic structure, but when examined with a microscope seem to have undergone complete recrystallization under the pressure to which they have been subjected, no signs of crushing being now visible in the thin sections.

The analyses show that the first three of these gneisses have the composition of slates. Nos. I and II have the composition of ordinary roofing slate, as will be seen by comparing these analyses with analyses III and IV and are quite different in composition from any igneous rock. The high content in alumina, the low percentage of alkalies and the great preponderance of magnesia over lime, above mentioned as characteristic of slates will be noted.

No. V is a gneiss which is so highly quartzose that it might almost be termed an impure quartzite and also has a composition differing from that of any igneous rock, but one which is identical with many highly siliceous slates. No. VI is such a slate from the Engadine district in Switzerland and is as will be seen almost identical in composition with No. V. Siliceous bands from the Canadian slate quarries also have a similar composition. The alumina here is low on account of the preponderance of quartz which also lowers the contents of alkalies. The magnesia preponderates over the lime as before. No. VI lost 1·92 per cent on ignition before analysis and these figures do not therefore appear in the analysis as given above.

	I. Gneiss. St. Jean de M.	II. Gneiss. Trembling Lake.	III. Slate. Wales.	IV. Slate. Melbourne.	V. Gneiss. Rawdon.	VI. Slate. Tinzen.	VII. Gneiss. Rawdon.
SiO_2	61·96	57·66	60·50	64·20	74·70	79·97	54·89
TiO_2	1·66						1·66
Al_2O_3	19.73	22·83	19·70	16·80	8·88	8·62	13·67
Fe_2O_3					9·64	6·63	1·35
FeO	4·60	7·74	7·83	4·23			
FeS_2	4·33						4·43
MnO	trace.	trace.	trace.		·50		·62
CaO	·35	1·16	1·12	·73	1·07	·76	5·63
MgO	1·81	3·56	2·20	3·94	1·87	1·52	4·70
Na_2O	·79	·60	2·20	3·07	·42	·64	1·95
K_2O	2·50	5·72	3·18	3·26	·95	2·30	8·34
Ign.	1·82*	1·50	3·30	3·42	1·05		(2·76†)
	99·55	100·77	100·03	99·65	99·08	100·44	100·00
Total alkalies	3·29	6·32	5·38	6·33	1·37	2·94	10·29

	VIII. Gneiss. Trembling Mt.,	IX. Granite. Carlingford.
SiO_2	69·24	70·48
Al_2O_3	14·85	14·24
Fe_2O_3	2·62	3·72
MnO	·45	
CaO	2·10	1·48
MgO	·97	·40
Na_2O	4·30	3·66
K_2O	4·33	4·26
Ign.	·70	1·59
	99·56	99·83
Total alkalies	8·63	7·92

The fourth of these gneisses, No. VII, differs entirely from the others. The low content of alumina, combined with low silica, the high alkalies and the preponderance of lime over magnesia mark it off as quite distinct from the slates and gneisses just considered. If it be an altered sediment it is one which has suffered very little leaching during deposition and must have been of the nature of a tufaceous deposit, or one formed from the rapid disintegration of an igneous rock having the composition of a basic trachyte or syenite. It is there-

* Water. † Water and graphite (by difference).

fore a rock, which so far as its composition is concerned, might be either an altered sediment or an altered igneous rock, and it is impossible therefore to draw from its chemical composition any definite conclusions as to its origin.

Many other gneisses including some in the Grenville Series, especially those of class II, have undoubtedly the composition of igneous rocks. As an example of these, Logan's typical Fundamental gneiss from Trembling Mountain was selected. An analysis of it is given under No. VIII. It forms almost the entire mass of Trembling Mountain, a long ridge rising on the east side of Trembling Lake to a height of 2500 feet and forming the highest point in the Laurentians in this part of Canada. It is a rather fine-grained gneiss, uniform in character and is under the microscope plainly seen to be a crushed or granulated hornblende granite. The analysis shows it to possess a chemical composition quite different from that of the other gneisses and slates just described. The silica is high but the alumina comparatively low. The alkalies are also high, the percentage being that which is commonly found in granite, while the lime preponderates largely over the magnesia. The analyses of the granite from the Carlingford District in Ireland by Haughton (IX) will serve to emphasize this identity.

In the cases of those gneisses then, Nos. I, II, V and VII, whose stratigraphical relations and microscopical character suggest a sedimentary origin, the first three have the composition of slates, that is to say of clay; in the case of No. V of clay mixed with sand, while in the case of No. VII no definite conclusion can be drawn.

No. VIII on the other hand, which from its stratigraphical relations and microscopical character can be recognized as a crushed granite, has an entirely different chemical composition and one which is identical with a normal granite.

With regard to the rocks of class III therefore we find that: (1) The presence of numerous and heavy beds of limestone and quartzite. (2) Their prevailing banded character, accompanied by a very extensive recrystallization. (3) The frequent occurrence of graphite in all rocks of the class, and (4) The fact that the gneisses of this class have in many cases at least the composition not of igneous rocks but of sands and muds—combined to make it extremely probable that we have, in the case of many of these rocks at least, extremely altered forms of very ancient sediments.

The *Fourth Class*, composed of pyroxene gneisses and pyroxene granulites, comprises a set of rocks which are very abundant in this particular area and occur associated with both of the other classes of gneissic rocks. Lehmann* from his

* Enstehung der altkrystallinischen Schiefergesteine, pp. 230–236.

studies of the Saxon Granulit-Gebirge was led to believe that certain of the Saxon rocks which closely resemble some members of this class, represent altered sediments, on account of their resemblance to certain contact products. Further study, however, is needed before any very definite conclusions can be arrived at concerning these members of the Laurentian in Canada.

It may be said, therefore, without going beyond that which the facts warrant, that there are in the district under consideration at least two distinct sets of foliated rocks. One of these comprising limestone, quartzites and certain garnetiferous or sillimanite gneisses, represent in all probability highly altered and extremely ancient sediments. The other set intimately associated with these are of igneous origin, and comprise numerous and very extensive intrusions both acid and basic in character which were probably injected at widely separated times. Those masses which were first intruded and have been subjected to all the subsequent squeezing and metamorphism are now represented by well defined and apparently interstratified augen-gneisses and granulites, others intruded at later periods though showing the effects of pressure retain more or less of their massive character, while still others, which as has been shown, have been injected since all movements ceased, are recognized by all as undoubted igneous intrusions. Furthermore the limestones, quartzites and sedimentary gneisses above mentioned are in this area distributed through the Grenville Series, being met with in various parts of the district, occurring at what appear to be various horizons and are separated by gneisses of igneous origin or by great bodies of pyroxenic or other gneisses whose origin is yet doubtful, the whole being so intimately associated that it has been found impossible in most cases to separate them in mapping.

The Grenville Series therefore comprises certain primeval sediments which have been deeply buried, invaded by great masses of igneous rocks and recrystallized. They may perhaps in some cases have been mingled with these igneous masses by actual fusion. The whole complex has also been subjected to great dynamic movements. In this way has resulted a series of rocks whose original character cannot in all cases be deciphered, but which can be recognized as being of composite origin, the sedimentary portion representing extremely old if not the oldest sediments with which we are acquainted.

McGill University, Montreal.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Correction to the paper on Argon, Prout's Hypothesis and the Periodic Law;* by Edwin A. Hill. (Communicated.)—The author of the above paper, published in the May number, desires to call attention to an unintentional omission for which he is responsible. On page 408, reference is made to "Lord Rayleigh's paper" and on p. 416 it is stated that "Lord Rayleigh has shown that at 13° C. water absorbs 4 per cent of its volume of argon, etc." In both cases no reference is made to the name of Professor Ramsay, who shared with Lord Rayleigh the joint authorship of the important papers referred to as well as the experimental work upon which they are based. This omission was unintentional and was indeed noticed before the paper was actually printed although too late to correct the proof. The scientific world appreciates so well the very important work of Professor Ramsay as co-laborer with Lord Rayleigh in this memorable research that this correction may seem to some unnecessary, but the author feels that it is due to himself that he should not fail to make it.

Two other corrections should also be made in the same article: In the note to page 414, 2d paragraph, for "*silent discharge*" read "*electric spark*" and on page 408, line 15, for "*force of gravitation*" read "*forces of attraction.*"

2. *Porosity of solid bodies for the Light Ether.*—Zehnder describes an interference apparatus by means of which he has endeavored to detect movements of the ether in connection with movements of surrounding bodies. The work was undertaken to test the following hypotheses of Fizeau, that either the ether adheres to the molecules of bodies and shares their movements; or that it is free and is not influenced by such movements; or that only a portion of the ether is free and that another portion is bound to the molecules of bodies and moves with them. Zehnder's apparatus consisted of an air-tight receptacle connected with long tubes through which light can be sent and suitably refracted and reflected in order to produce interference bands. By means of a moving piston the air in the tube can be set in motion and a change in the interference bands can be noted. Afterward the entire apparatus is exhausted of air and again the piston is moved in order to set the ether in movement. No change however could be observed in the latter case, and Zehnder remarks upon the limits of porosity of iron for the light ether. Michelson's experiments on the relative motion of the ether and the earth's atmosphere are commented upon and are repeated with similar negative results. The author concludes that the relative motion between the earth and the enveloping ether, at the observing station in Freiberg, did not attain the value of the

800th part of the velocity of the earth in its path.—*Ann. der Physik und Chemie*, 1895, No. 5, pp. 65–81. J. T.

3. *Wave length of the Ultra Violet lines of Aluminium.*—C. RUNGE has made a determination of the strong line of aluminium in the ultra violet by means of a Rowland concave grating of a meter radius. The whole apparatus was placed in an air-tight apparatus from which the air could be exhausted, and for the observed lines the following values were obtained:

At 760^{mm} and 20° C.	1854·09	1862·20	1935·29	1989·90
In vacuum	1854·77	1862·81	1935·90	1990·57
According to Cornu	1852·2	1860·2	1933·5	1988·1

The author calls attention to the discrepancy between his results and those of Cornu.—*Ann. der Physik und Chemie*, 1895, No. 5, pp. 44–48. J. T.

4. *Electrical Resonance.*—V. BJERKNES has collected in a long and exhaustive paper the results of his experimental and mathematical study of the subject; and he shows that for quantitative measurements of electric waves great regard must be paid to the following five conditions: (1) The time of vibration of the oscillator. (2) The time of vibration of the resonator. (3) The logarithmic decrement of the oscillator. (4) The logarithmic decrement of the resonator. (5) The constant which measures the intensity of the vibrations. He shows that resonance phenomena are in general only suitable for quantitative measures when the mean value of the logarithmic decrement of the two conductors is smaller than 1. He indicates that quantitative measures with a spark micrometer are subject to error and that the electrometer method used by him is more suitable for the determination of the above five conditions. The student of Hertz effects will find this paper the best analysis of the conditions to be observed in performing experiments with Hertz apparatus which has appeared.—*Ann. der Physik und Chemie*, No. 5, 1895, pp. 121–169. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Geological Survey of Michigan*; LUCIUS L. HUBBARD, State Geologist. Vol. V, Part I. Upper Peninsula; Iron and Copper Regions. Part II. Lower Peninsula; Deep Borings. Lansing, Mich., 1895. The first part is a Geological Report on the Upper Peninsula of Michigan, exhibiting the progress of work from 1881 to 1884; Iron and Copper regions by C. ROMINGER, pp. 1–179, with a map and 2 geol. cross sections. Part II. The geology of Lower Michigan with reference to deep borings, edited from notes of C. E. Wright, late State Geologist, by ALFRED C. LANE, Assistant State Geologist, with an introduction on the origin of Salt, Gypsum and Petroleum by LUCIUS L. HUBBARD, pp. i–xxiv, 1–100 and plates i–lxxiii.—These reports refer to investigations which were made between the years 1881–1888 and in part have been referred to in Dr. Wadsworth's

annual reports to the Board published in 1892. The second report contains a careful compilation of the notes made by the late Mr. C. E. Wright, when state geologist, of the borings in various parts of the state; and the thickness and basin-like structure of the whole paleozoic series of southern Michigan, from the Trenton upward, is graphically shown in the sections. The following section and thicknesses are based chiefly upon borings at Jackson and Monroe. The names are those given to the formations by the authors.

Quaternary	3–600 ft.	
Woodville sdst.	304. +	=Carboniferous.
Jackson coal group	47. ±	
Parma? sdst.	0–200.	
Grand Rapids group	305 ±	
Marshall sdst.	50 ±	
Coldwater shales	667–1000 +	= Cuyahoga and Berea shales.
Black bituminous shale	62.	
Richmondville or Berea sdst.	65	
Huron (15 ft.) or St. Clair black shales	145–300.	=Devonian.
Traverse group	100–600.	
Dundee limestone	40–160.	
Munroe beds	650–2000	=Silurian.
Niagara	350	
Medina	100.	
Hudson River	420.	= Lower Silurian.
Utica	80.	
Trenton	?	

These measurements show a considerably greater thickness than has been given in previous estimates by either Winchell or Rominger, especially in the Coal Measures and the Upper Silurian strata. H. S. W.

2. *The Geological and Natural History Survey of Minnesota.* N. H. Winchell, State Geologist.—The following three reports of this survey have recently been received, viz: *The Geology of Minnesota, vol. iii, part I of final report. Paleontology, by Leo Lesquereaux, Anthony Woodward, Benjamin W. Thomas, Charles Schuchert, Edward O. Ulrich, Newton H. Winchell, pp. i–lxxv, 1–474, 41 plates and 34 figures, Minneapolis, 1895.*

22d Annual Report for the year 1893, pp. 1–210, Minneapolis, 1895. 23d Annual Report for the year 1894, pp. 1–255, Minneapolis, 1895.

Part I of the Paleontology was communicated to the Secretary of State in 1891, and the several chapters of which it is composed have already appeared as separate brochures, and may have been examined already by many of our readers. The publication of these separate memoirs in this permanent form constitutes a valuable contribution to the detailed paleontology of the upper Mississippi valley area.

In the chapter on the Cretaceous Flora by Leo Lesquereaux, the author remarks upon the impossibility of explaining the sudden appearance in the Dakota fauna of the rich dicotyledonous flora by any gradual modification of the floras known from earlier epochs. "No species of the dicotyledonous series has as yet shown any such intermediate characters indicating by its inferiority a degree of transition: nor has there been found in the series of lower divisions of plants occurring below any whose characters would indicate a tendency to a transition to a higher order." The flora collected in this limited area from only three localities contains 28 species, only two of which are gymnosperms. And the dicotyledonous species are referable to 18 genera, and to the three great subdivisions of the dicotyledons; the *Apetaleæ*, the *Gamopetaleæ* and the *Dialapetaleæ*.

Cretaceous foraminifera are described by Messrs. Woodward and Thomas, the sponges, graptolites and corals of the Lower Silurian by Messrs. N. H. Winchell and Schuchert, and the larger part of the volume is devoted to "Descriptions of the Lower Silurian Bryozoa" by E. O. Ulrich, and the "Lower Silurian Brachiopoda" by Messrs. N. H. Winchell and Chas. Schuchert. The annual reports contain, among other papers, a critical examination of Dr. Williams' discussion of the greenstone schists of the Menominee and Marquette region of Michigan (Bull. U. S. G. S. No. 62), by N. H. Winchell, who defends his previously expressed opinion "that the great bulk of the 'greenstones' as an Archean terrane, ought to be classed as *pyro-clastic*, i. e., that they originated from eruptive agencies, as tuffs and all kinds of volcanic debris, sometimes very coarse and even distributed and somewhat stratified by the waters of the ocean into which the materials fell." A preliminary report on the Rainy Lake gold region is given by H. V. Winchell and U. S. Grant. Warren Upham gives in the latter report the evidence derived from the beaches of the various glacial lakes in the St. Lawrence basin; following a paper, in the previous report, in which occurs a detailed account of the glacial drift and morains of northeastern Minnesota.

H. S. W.

3. *Doctorate Theses in Geology.*—Two theses by Americans studying geology in European universities have been received, viz:

Die Klippen region von Iberg (*Sihthal*), von Dr. Edmund C. Quereau aus Aurora, Ill., 4 geol. charts, 4 profile plates and 13 zinkographs, pp. i–xi and 1–158, Bern, 1893.—This paper constitutes the 33d number of the Beiträge zur Geol. Karte der Schweiz.

Beiträge zur Kenntniss der Gattung Oxyrhina mit besonderer Berücksichtigung von Oxyrhina Mantelli Agassiz, (Palaeontographica, Bd. xli, pp. 149–191, Taf. xvi–xvii, Stuttgart, 1894) von Chas. R. Eastman, Assistant an dem Museum Comparative Zoology, Cambridge, Mass.

4. *The Laccolitic Mountain Groups of Colorado, Utah and Arizona;* by G. Whitman Cross. 14th Ann. Rep. U. S. Geol. Surv. Washington, 1895, p. 157–241.—This work represents a general summation of the author's studies extending over a period of years upon the Anthracite and Crested Beetle districts of Colorado, where the opportunities for the study of laccolites on an extended scale are especially fine. In doing so he has been led to a general study of the literature upon this subject and has collated all the facts bearing upon the occurence of these intruded masses of igneous rocks in the plateau region of Western America so far as known.

The paper opens with a review of Gilbert's work in the Henry Mts. and with a definite restatement and affirmation of the principles laid down by that investigator. Following this the work of the earlier geological explorers in this region, especially Holmes and Peale, is reviewed, and it is shown that many of the detached mountain groups visited by them are to be referred to this mode of origin. The author then presents in detail the result of his own studies in the field mentioned above, and concludes with a general statement of principles.

Especially valuable are the results showing the asymmetric form of laccolites when intruded into strata already flexed and under compressive stresses or tensional strains or containing resistant masses of former intrusion. It is of interest also to note the extremely uniform type of rock in these occurrences over such a vast range of country. Mr. Cross shows also that a certain type of rock structure is a nearly constant resultant of the processes involved. It is impossible to say more of this work here than that it is a very valuable contribution to general dynamical geology and the writer feels from his own experience that it will be of distinct service in solving many problems in connection with the occurrence of igneous rock-masses. The paper is illustrated with many diagrams, sketches, photo-engravings and contains a geological map. L. V. P.

5. *A Petrographical sketch of Aegina and Methana;* by H. S. Washington. Journal of Geology (Chicago), vol. ii, No. 8, vol. iii, Nos. 1 and 2, 1895.—This paper contains a careful and detailed study of the igneous rocks occurring in a limited area in Greece. It is accompanied by a geological map and possesses many facts of interest to petrologists. It is especially valuable in being accompanied by a large number of excellent analyses which enable the author to discuss the region from a broad standpoint of general petrology. It thus possesses distinct features of general interest beyond those of petrographic detail. L. V. P.

6. *Geologische und geographische Experimente* ausgeführt mit Unterstützung der K. Akademie der Wissenschaften von Ed. Reyer. III, Heft, Rupturen. IV, Methoden und Apparate. 32 pp. with 12 plates. Leipzig, 1894 (Wm. Engelmann).—The author continues in this small volume his earlier investigations and gives interesting results and conclusions drawn from them

in regard to ruptures of various kinds, volcanic cracks, faulting and so on. The methods and apparatus are briefly but clearly described, the text being illustrated by numerous figures.

7. *On a new locality for Xenotime, Monazite, etc., on Manhattan Island;* by WILLIAM NIVEN. (Communicated.)—The xenotime crystal measured by Mr. H. S. Washington and announced by Mr. W. E. Hidden in this Journal for November, 1888 (vol. xxxvi) was found by the writer in a vacant lot at 175th street near 10th avenue, New York City, amongst loose blocks of mica schist and gneiss which had been dumped there some years before: the exact locality, therefore, remained in doubt. Recently, however, while prospecting in the extensive excavations for the new speedway on the Harlem River I found a number of crystals of this interesting mineral in place, also monazite, titanite, epidote, beryl, menaccanite and others.

Prof. A. C. Gill of Cornell University has determined the xenotime by measurement of the angles, finding that they agree to within 1′ with those given by Mr. Washington in Mr. Hidden's article, one crystal showing a very narrow pyramid of the second order $P\infty(101)$ in addition to the forms $P(111)$, $\infty P(110)$ and $3P3(311)$ which were identified by Mr. Washington. This face $P\infty(101)$ is new to New York xenotime, although observed elsewhere. The most interesting crystal showed an abnormal development along the vertical axis producing a prismatic form like that common in zircon, while in close proximity to it was a crystal of the ordinary habit. The monazites were usually found in close association with the xenotimes. All were well defined crystals, and one was exactly of the habit shown in figure 2, page 750, Dana's System of Mineralogy, sixth edition, as occurring at Watertown, Conn.

The titanites have a remarkable resemblance to those from Tyrol and were usually about 12^{mm} in size, one crystal measured fully 40^{mm} and some fragments were transparent. A surface of the schist over 20^{cm} by 28^{cm} in size showed more than 40 yellowish green crystals.

The xenotimes and monazites were mostly embedded in oligoclase near a coarse granite vein at 185th street and Harlem River and were associated with menaccanite, while the titanite and epidote occur in a chloritic mica schist at 167th street and Harlem River. My thanks are due to Prof. A. C. Gill for identifying and measuring the crystals.

8. *Brief notices of some recently described minerals.*—LAWSONITE, named after Prof. A. C. Lawson, is a new rock-forming mineral described by F. Leslie Ransome, from the crystalline schist of the Tiburon Peninsula, Marin County, California; also occurring in larger crystals embedded in a micaceous mineral determined as margarite in veins in the schist. It forms crystals of prismatic habit belonging to the orthorhombic system: prismatic angle 67° 16′; cleavage perfect parallel to *b* and less so parallel to *c*; crystals colorless to pale blue; hardness about 8; specific gravity 3·084. An analysis gave:

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	H_2O
38·10	28·88	0·85	18·26	0·23	0·65	11·42 = 98·39

This yields the formula $H_4Ca\ Al_2Si_2O_{10}$; a possible relation to carpholite is suggested.—*Bull. Dept. Geol., Univ. California*, vol. i, No. 10.

ELPIDITE.—A silicate of zirconium and sodium from Igaliko, Greenland, described by G. Lindström. It occurs in fine fibrous forms with silky luster; the color varies from white to yellowish white and light brick-colored; hardness about that of quartz; specific gravity 2·524 to 2·594. Analysis gave:

SiO_2	ZrO_2	Na_2O	K_2O	FeO	CaO	$H^2O(100°)$	H_2O(ign.)	Cl
59·44	20·48	10·41	0·13	0·14	0·17	3·89	5·72	0·15 CuO, TiO_2 *tr*=100·53

The calculated formula is $Na_2O.ZrO_2.6SiO_2.3H_2O$.—*Geol. För Förh.*, xvi, 330, 1894.

LOSSENITE.—A new arsenate from Laurium, Greece. Described by L. Milch. It occurs in small red-brown crystals referred to the orthorhombic system and resembling scorodite in form. Analysis by Auerbach gave (after deducing gangue)

As_2O_5	SO_3	Fe_2O_3	PbO	H_2O (comb.)	H_2O
34·33	3·84	35·45	10·91	3·84	12·12 = 100·49

For this the complex formula $2PbSO_4 . 6(FeOH)_3\ As_2O_8 . 27H_2O$ is calculated.—*Zeitschr. Kryst*; xxiv, 100, 1894.

DIETZEITE.—A name proposed by Osann for the iodate and chromate of calcium occurring, as described by Dietze, with the calcium iodate, lautarite, at the Pampa del Toro, Chili (Zeitschr. Kryst., xix, 447, 1891 and Dana, Syst. Min., 1892, p. 1040). Osann describes monoclinic crystals.

URBANITE.—A name proposed by Sjögren for a so-called iron-schefferite analyzed by Mauzelius, from Långban, Sweden. Igelström later calls it *lindesite* and claims priority on insufficient grounds.—*Geol. För. Förh.*, xiv, 251, 1892; *Zeitschr. Kryst.*, xxiii, 590, 1894.

MINERVITE.—A phosphate of aluminum occurring in seams in a calcium phosphate, a formation in the "Grotte de Minerve" on the shores of the river Cesse, Dept. Aude, France. The formula $P_2O_5 . Al_2O_3 . 7H_2O$ is deduced for it described by A. Gautier.—*Bull. Soc. Min.*, xvii, 132, 1894.

WEBNERITE.—An argentiferous variety of zinckenite described by Stelzner from Oruro, Bolivia. It has been found in massive form only. An analysis by P. J. Mann gave:

S	Sb	Pb	Ag	Cu	Fe
23·10	40·86	24·30	10·25	0·65	0 53=99·69

This leads to the formula $PbS . Sb_2S_3$ in which silver replaces lead, the ratio for Pb : Ag being about 5 : 2.—*Zeitschr. Kryst.*, xxiv, 125, 1894.

9. *Note on a Garnet from California;* by F. W. CLARKE. (Communicated.)—In March, 1895, I received from W. J. Knowlton of Boston, for examination, a waterworn pebble found at

Eltoro, 40 miles south of Los Angeles, California. The specimen weighed 525 grams, was very compact, quite highly polished, and pale apple-green in color. In fact, it was supposed to be jade; and, so far as appearance was concerned, it fully justified the supposition. Believing it to be either nephrite or jadeite, I had an analysis of it made by Mr. George Steiger, in the U. S. Geological Survey laboratory, which showed it to be really grossularite garnet. The data are as follows:

SiO_2	37·54
TiO_2	trace
Al_2O_3	22·84
Fe_2O_3	·79
FeO	·26
CaO	36·66
MgO	·44
Alkalies	·13
P_2O_5	trace
Ignition	1·74
	100·40

Specific gravity, 3·485. The loss on ignition includes a trace of carbonic acid. On treating 0·2 gram of the powdered mineral with hydrochloric acid, evaporating to dryness, and then redissolving, about 16 per cent of alumina and 20 per cent of lime went into solution. In this respect the specimen is therefore somewhat unusual. But as a garnet simulating jade it is certainly interesting.

10. *Physikalische Krystallographie und Einleitung in die krystallographische Kenntniss der wichtigeren Substanzen* von Paul Groth. Dritte vollständig neu bearbeitete Auflage. III Abtheilung, pp. i–xvi, 529–783, Leipzig, 1895 (Wm. Engelmann).—This third part completes the revised edition of Professor Groth's Physical Crystallography, already noticed on p. 74 of the last volume. It is devoted to a discussion of the methods of calculation applied to crystals, and to the apparatus and methods of investigation in the departments of Crystallography and Physical Mineralogy. To those who are acquainted with the earlier editions of the author's work, it is unnecessary to say that these topics are treated with all desirable completeness and clearness and that the most recent and important improvements in instruments are fully described.

III. Botany.

1. *Die natürlichen Pflanzenfamilien.*—Recent numbers of this serial work bear the single name of Professor Engler, of Berlin. After the loss of Eichler, its founder, and of Prantl, a co-editor, the entire conduct of editing was entrusted to Professor Engler. He has not introduced any new elements into the work, and the collaborators pursue their specialties on the same lines as at first. The present installments contain *Hippocastanaceæ*, by F. Pax; *Sapindaceæ*, by L. Radlkofer; *Sabiaceæ*, by O. Warburg; *Tamaicaceæ*, by F. Niedenzu; *Cistaceæ*, by K. Reiche; *Bixaceæ*, *Winteranaceæ*, (*Canellaceæ*,) by O. Warburg; *Koeberliniaceæ*, by A. Engler; *Violaceæ*, by K. Reiche and P. Taubert. From this can be seen the wide range of contributions, and some idea can be gained from this of the immense difficulty of editorial supervision, in keeping everything within due limits of space and in proper proportion. Aside from the annoyance of having the installments appear in different parts of the field, a fact inseparable from the mode of preparation, the work has progressed to the satisfaction of subscribers. The promises of the publishers have been more than kept, especially as regards excellence and copiousness of the engravings and the high order of typographical execution. The English translation will be received with a hearty welcome. G. L. G.

2. *Familiar Flowers of Field and Garden*, by F. Schuyler Mathews. New York, 1895. (D. Appleton & Co.)—The increasing number of popular works on various subjects in Natural History may be taken as an expression of an increasing interest in some phases of Zoology and Botany. Even the wretched text and misleading illustrations of a botanical work published during the past year, as a premium for a syndicate of newspapers, may be perhaps interpreted as an indication of a desire on the part of the public to gain information in regard to plants. Happily some of the recent popular works on Botany are of an entirely different character, being generally trustworthy and in good taste, although they may be rather unsatisfying on account of the limited scope. Among such useful works may be mentioned Mrs. Dana's work, in which color is made to serve as an aid to the beginner in studying plants, and also the book which we have placed at the head of this notice. Mr. Mathews is an artist and has studied the plants around him chiefly from the point of view of an intelligent lover of form and color. His sketches, about two hundred, are spirited and faithful. The descriptions are sufficiently detailed to be helpful to one who is just entering on the study of flowers, and no serious mistakes are observable in any part of the book. The little treatise is attractively printed and is bound in flexible covers, of a size fitting it for the pocket. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *The Cambridge Natural History, vol. iii. Molluscs*, by A. H. Cooke, *pp. 1–460; figures 1–311; Brachiopoda, Part I, Recent Brachiopoda*, by A. E. Shipley, *pp. 461–488; Part II, Paleontology of the Brachiopoda*, by F. R. Reed, *pp. 489–512; figs. 312–334.*—This is a fresh, modern, popular treatment of the interesting Natural History facts about Molluscs, well illustrated by figures, mostly original, taken from specimens in the Cambridge University Museum of Zoology. The subjects more fully illustrated are those of variation, abnormal forms and organs of sense and the dentition of Gastropods: there is also an interesting series of illustrations of characteristic species of the several land regions of distribution. The chief elaboration is regarding Gastropoda and Pelecypoda, the other groups of Mollusca and the Brachiopoda are little more than repetitions of such treatment as was given in the old Woodward's "Manual," and later in Paul Fischer's Conchyliologie. The character of the book is well indicated by the motto, quoted from "Middlemarch," placed on the inside of the title page. "Why, you might take to some light study: conchology, now; I always think that must be a light study." H. S. W.

2. *American Association for the Advancement of Science.*—The preliminary announcement of the forty-fourth meeting of the American Association was issued May 20th. The meeting, as before stated (xlix, 327), is to be held at Springfield, Mass., from August 28 to Sept. 7. Full information is given in the circular in regard to all the special arrangements for railroad rates, local accommodation, excursions, etc.; the general program is also given for the sessions of the several sections under their respective vice-presidents with the subjects of the addresses by the latter. A list is added of the affiliated societies which will hold summer meetings in Springfield, as the Geological Society, Aug. 27 and 28, the Chemical Society on the same dates, etc. The retiring president is Dr. Daniel G. Brinton of Media, Pa., and the president-elect Professor E. W. Morley of Cleveland. The address to be delivered Thursday evening, August 28, by Dr. Brinton will be upon "The Aims of Anthropology." The citizens of Springfield are making every effort to arrange for the entertainment of their visitors. Information on any points connected with the meeting may be obtained from Prof. F. W. Putnam, permanent secretary, Salem, Mass.; or in reference to local arrangements, from the local secretary, W. A. Webster, Springfield, Mass.

OBITUARY.

Joseph Granville Norwood, M.D.,L.L.D., died in Columbia, Mo., May 6, 1895. He was born in Woodford County, Ky., Dec. 20, 1807. He began life as a printer in Lexington, Ky., then for a time he was connected with a commission house in Louisville, Ky. He next entered Transylvania College and applied himself to medicine and began to practice in Madison, Ind., in 1835. In 1836 he graduated in medicine. In 1840 he was Professor of Surgery in Madison Medical Institute. In 1843 he was appointed Professor in the Medical Department of St. Louis University, which position he held until 1847. From 1847 to 1851 he was Assistant Geologist with D. D. Owen on the Geological Survey of Wisconsin, Iowa and Minnesota; his work being chiefly near Lake Superior. From 1851 to 1858 Dr. Norwood was State Geologist of Illinois, and from 1858 to 1860 Assistant Geologist of Missouri. From 1860 to 1880 he was Professor in the University of Missouri. He held the chairs of Geology and Chemistry, also of Natural Science including Physics, Anatomy and Physiology, and for several years was Dean of the Medical College of the University. On account of ill health his active work with the University ceased in 1880. Since then his name has remained on the Catalogue as Emeritus Professor of Physics. Part of the time between 1861 and 1865 the regular University exercises were suspended and the University building was occupied by U. S. troops, but Dr. Norwood came to the building regularly and remained all day faithfully watching over the University property.

For over 12 months previous to his death he suffered at times very much. But to the last his mind was clear and bright. He was devoted to his family, faithful to his friends, fearless in his views and yet was never known to speak unjustly of any one. His mind was strong, he possessed a gentle grace and a dignity that made all who knew him love and respect him. His scholarship was broad, he was accomplished in Natural Science and a thorough instructor and universally loved by his pupils.

In 1847 Dr. Norwood described and figured the *Macropetalicthys rapheidolabis* obtained by him from the Devonian of Indiana,—the first fossil fish described from the United States. In 1847 Dr. Norwood with D. D. Owen published a pamphlet on the geology of Central Kentucky with figures of thirteen carboniferous fossils. In 1852 the Geol. Rep. of Wisconsin, Iowa, and Minnesota was published, a large quarto and included Dr. N.'s report of over 200 pages. In 1854 a Monograph of *Productus, Chonetes* and other fossils by Norwood and Pratten was published by the Academy of Sciences of Philadelphia. It included descriptions and figures of over thirty species of fossils. Before the close of Norwood's term as State Geologist of Illinois he had material on hand and about ready to print of 1000 or 1200 pages and the committee appointed by the legislature recommended its publication and also further appropriations. The committee reported Feb. 10, 1857. The committee further report a very large collection made by Norwood.

G. C. B.

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THE

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[THIRD SERIES.]

ART. VIII.—*The Earth a Magnetic Shell;* by FRANK H. BIGELOW.

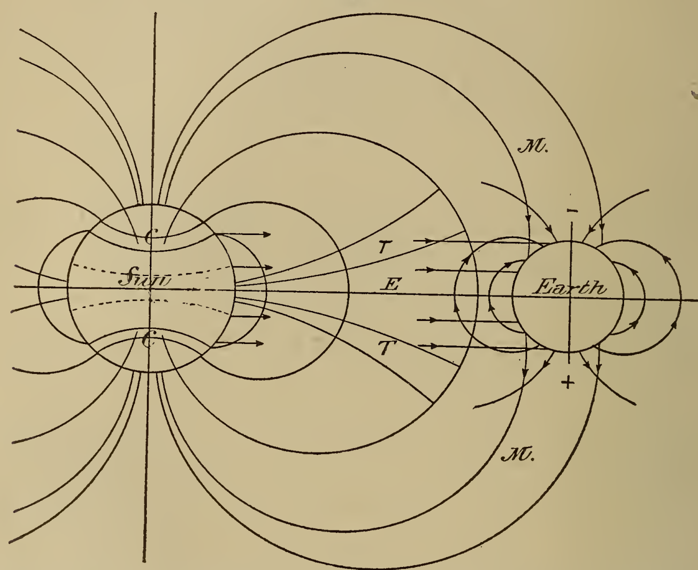
[Communicated by permission of the Chief of the Weather Bureau.]

THE working hypothesis, upon which my research into the modes of the transference of energy from the sun to the earth has been conducted, includes the electro-magnetic radiation along the ecliptic, and the magnetic radiation at right angles to the ecliptic, near the earth. There are evidently three principal branches to the problem, (1) the vectors of the electro-magnetic field at the earth, (2) the vectors of the magnetic field at the earth, (3) the transformation of these ether vibrations in the atmosphere into heat, electricity and mechanical forces. In previous papers, the vectors of the electro-magnetic field have been given, some important relations in the transformation of the magnetic field into heat have been shown and the nature of a number of subordinate problems developed.

In this paper it is proposed to give the vectors of the polar magnetic field at the earth, together with certain deductions suggested by the same. It is most important to exhibit in detail the stream lines of this cosmical magnetic field emitted by the sun, at the earth, because the theory of a magnetic radiation from the sun is so novel to science, that its existence may have seemed purely hypothetical to many who have not attempted to study the same in its individual effects. If the several sets of phenomena attributed to it, namely the aurora, magnetic disturbances, earth currents, and meteorological periodic variations, actually have their seat in this cause, then it is clear that a definite system of forces, well adapted to produce such effects, must be found in the observations. The labor of computing the observations has heretofore delayed the production of such facts as will establish the existence of the polar field, to whose agency these important scientific conclusions have been attributed.

The following schematic figure may assist to a clear conception of the general relations that apparently exist in the space surrounding the sun, at least to the distance of the earth. The

Fig. 1.



Schematic Figure of the Electro-magnetic and Magnetic Fields between the Sun and the Earth.

electro-magnetic field E radiates from the sun in all directions in straight lines, some of those near the ecliptic falling upon the earth; the magnetic field M fills all spaces with curved lines, the tube emanating from the polar regions of the sun, at $4\frac{1}{2}°$ from its magnetic pole, falling upon the polar regions of the earth. The magnetic field at the earth has therefore three components, the so-called permanent magnetism, the field E and the field M. In Bulletin No. 2, U. S. Weather Bureau, 1892, "Notes on a New Method for the Discussion of Magnetic Observations," my process for the separation of these three components was fully described and illustrated, the same having been used in all branches of the problem. It has also been shown that the visible coronal lines are other magnetic lines of the field M, having their bases in two belts C C about 10°

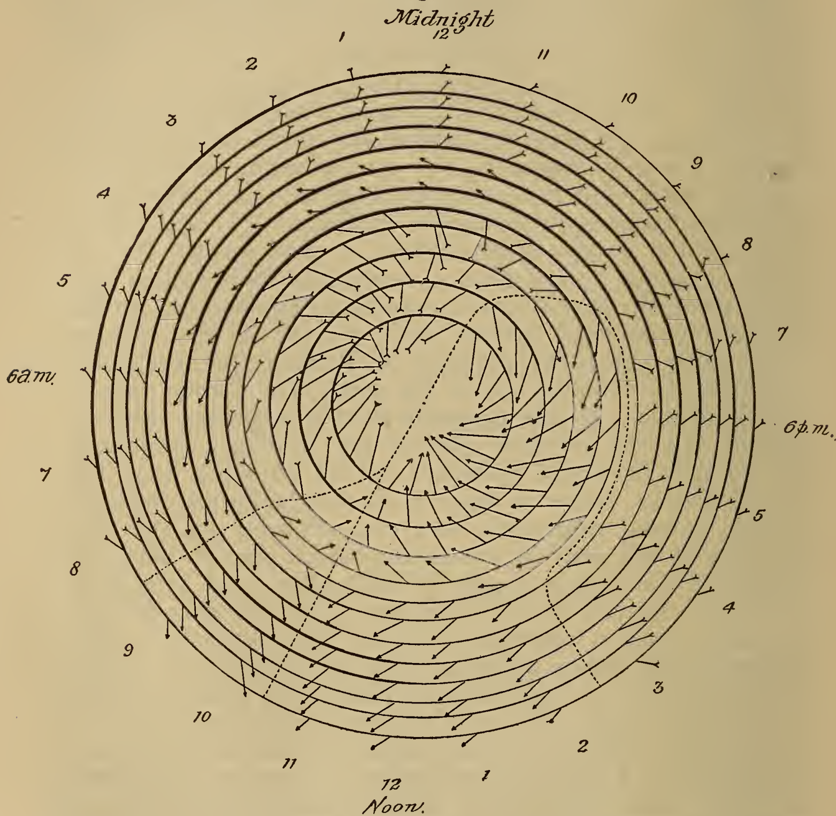
wide, and at the mean distance 34° from the magnetic poles; that the southern pole precedes the northern by about 102°; that the synodic rotation period of the sun is 26·68 days, corresponding to the equator, and not to some mean value derived from the angular velocity of the sun spots in latitudes 12° to 15°.

There is one more suggestion, not heretofore advanced, to be derived from this magnetic system of the sun, namely, regarding the trumpet-shaped extensions of the outer corona, discovered by Professor Holden, in some photographs of January, 1889. If we adopt J. J. Thomson's language regarding the formation of a magnetic field by the motion of positive and negative Faraday tubes along the corresponding equipotential surfaces (see Recent Researches in Electricity and Magnetism, pp. 28-33), we have two possible conditions: (1) If the tubes move on the equipotential surfaces in circles about the axis of the magnetic sphere, then a mechanical force will be generated along the curved lines produced by a meridianal section of the equipotential system as T T; (2) if the Faraday tubes move along the sections T T then the mechanical force will be circuital about the axis. The former type is more probable. If this magnetic field is radiating, then the electric and the pressure systems are necessary attendants, and we shall have such extensive curved radiating lines T T as will dispose matter in space in the tubular forms displayed in the coronal extensions, and also probably in the two branches of the disks of the zodiacal light. At the earth the vectors of the electro-magnetic field have been briefly described* as derived from 30 stations. The following diagram was made from a photograph of my 30-inch globe model, looking directly down upon the north magnetic pole. About half the stations are omitted in the drawing to avoid confusion of the vector lines. The polar zone and mid-latitude zone are seen with their characteristic systems. The trace of tangency of the sheet at 8.30 a.m., through the pole, and back along the circle of division to 2.30 p.m., and the trace of zero deflection in declination at 10.30 a.m., are shown by dotted lines. From these vectors, and their variations, are derived the motions of the needle in the diurnal and annual periods, these impressed forces causing the observed deflections of the normal terrestrial magnetic field. These vectors were eliminated from the tabulations of observed magnetic forces in absolute measure by discussing the hourly variations on the monthly means. Besides such impressed forces, it is evident by an inspection of the record, that there is also the system of deflecting forces to

* Astron. and Astrophysics, Oct., 1893.

be obtained by treating the variations of the daily means on the monthly mean. It is the principal object of this paper to show the result of the detailed computation carried out for 26 stations, whose cause has been attributed to the polar magnetic field from the sun.

Fig. 2.



Deflecting forces of the Equatorial Electro-magnetic Field, North Magnetic Hemisphere.

The elimination of the polar field from the permanent and the electro-magnetic fields consists in taking the variations of the daily means of the 24 hourly observations on the mean for the months. This gives the three rectangular coördinates Δ H, Δ D, Δ V, of the impressed vector that disturbs the mean from day to day. These values, as they appear in the volumes, are transformed into C. G. S. units of the fifth decimal place dx, dy, dz; finally the equivalent polar coördinates are computed, so that we have *s. σ. α. β.* the total vector in magnitude, its horizontal component, the angle with the horizon, and the angle with the magnetic meridian, respectively. Only such stations could be used as have published reports of hourly observations for about a year, in all three of the magnetic elements. This involves about 225,000 individual observations and reductions for each element, together with more than 9000 transformations from rectangular to polar coördinates.

The results for each station were divided into two groups according to the azimuth β, all between 90° and 270° in one group, and all between 270° and 90° in the other group. Thus all the vectors pointing south magnetically, and all those pointing north, are given by themselves. The means are taken by 26·68 day periods, in some cases by months before the year 1875, and finally the mean of these periodic means, the result being contained in the following table.

Summary of South and North Vectors.

		Long.	Lat.	Mag. Lat.	Year.	South. β	α	s	σ	North. β	α	s	σ
		h m	°	° ′									
1	Kingua Fjord.	4 29 W.	+66·6	77 52	1882–3	161	+ 5	45	27	337	− 6	37	23
2	Fort Rae.	7 43 W.	+62·6	76 2	1882–3	190	+ 8	46	30	5	− 8	39	22
3	Point Barrow.	10 26 W.	+71·3	73 8	1882–3	180	− 6	59	29	4	+ 5	55	29
4	Cap Thordsen.	−1 3 E.	+78·5	71 4	1882–3	186	−14	62	28	6	+ 8	50	23
5	Jan Mayen.	0 33 W.	+71·0	68 49	1882–3	180	+10	54	29	4	− 9	44	22
6	Bossekop.	−1 36 E.	+70·0	64 25	1882–3	188	+14	43	29	18	− 6	33	19
7	Toronto.	5 17 W.	+43·6	62 14	1847	176	−28	32	18	356	+27	25	11
8	Sodankyla.	−1 46 E.	+67·4	61 24	1882–3	184	+ 5	16	15	14	− 2	14	12
9	Washington.	5 8 W.	+38·9	55 34	1890	179	+19	18	7	357	0	20	8
10	Pawlowsk.	−2 2 E.	+59·7	55 3	1882–3	196	+10	12	10	15	− 9	10	8
11	Greenwich.	0 0	+51·5	50 24	1887	175	− 6	13	9	359	+ 1	13	9
12	Parc St. Maur.	−0 9 E.	+48·8	47 17	1884	177	+ 2	12	9	357	− 4	11	8
13	Vienna.	−1 5 E.	+48·2	44 47	1882–3	178	+ 5	19	15	1	− 1	20	16
14	Pola.	−0 55 E.	+44·9	41 43	1892	183	+14	23	16	1	− 6	17	11
15	Los Angeles.	+7 53 W.	+34·0	40 20	1883	181	+10	22	12	0	− 8	23	10
16	Tiflis.	−2 59 E.	+41·7	36 7	1882–3	182	+ 6	15	12	13	− 7	13	11
17	Zi-ka-wei.	−8 6 E.	+31·2	27 37	1882	187	− 4	42	32	351	+ 5	33	23
18	Bombay	−4 51 E.	+18·9	9 53	1863	182	+ 4	36	20	3	− 5	33	16
19	Madras.	−5 21 E.	+13·1	3 50	1855	185	+ 2	13	11	349	− 1	12	10
20	Singapore.	−6 55 E.	+ 1·3	− 6 25	1845	182	− 2	14	11	359	− 8	12	10
21	St. Helena.	0 23 W.	−15·9	−11 12	1843	178	−10	17	9	349	− 2	17	8
22	Batavia.	−7 7 E.	− 6·2	−15 8	1890	182	+13	16	8	1	−12	16	9
23	Süd Georgien.	2 24 W.	−54·9	−29 48	1882–3	187	+26	52	20	8	−17	47	15
24	Cape Horn.	4 41 W.	−55·6	−33 29	1882–3	176	− 2	15	13	6	+ 4	13	10
25	Cape Good Hope.	−1 16 E.	−33·9	−33 54	1842	185	+16	19	11	353	− 3	16	11
26	Hobarton.	−9 50 E.	−42·9	−54 50	1842	176	+22	26	15	0	−27	22	13

The table gives the stations, their geographical position, the equivalent magnetic latitude, the year of the observations computed, and the group of south and north vectors. It is seen that the impressed vectors lie practically in the planes of the magnetic meridians in all latitudes, and hence approach the earth nearly perpendicular to the ecliptic. In the south group the value of α is generally positive and in the north group generally negative: that is the vectors pointing south generally enter the earth, and those pointing north generally emerge from the earth. The earth is near the magnetic equator of the sun, and the mechanical pressure is sometimes greater on the northern and sometimes on the southern side of the ecliptic at the earth. The variation in pressure is shown by a certain line of force entering the earth at a definite angle in a given latitude, depending upon the slope of the horizontal plane at the station to the axis of the external field, and the material of the earth as compared with the ether.

Unfortunately the accuracy of this kind of work depends upon the vertical force magnetometers, and these are much less reliable than those for the horizontal elements. Also the use of soft iron deflecting bars in so many of the polar expeditions of 1882–83 renders the observations less trustworthy. It would be easy enough to point out the probable source of the discrepancy of certain stations in the instruments used, but it may be omitted in this abstract. The angle α for a given day is due to many combined forces working together, and shows very considerable unsteadiness in each group from day to day, the value of α here given being the algebraic mean. Now it should be remembered that whether the angle α is plus or minus the values of s and σ will be the same at a station, because an external line of force will approach the surface at a given angle whether above or below, on account of magnetic refraction in the case of the earth, as will be seen from sections that follow in this paper. Hence we may obtain from the mean angle, the general fact of entry and emergence at the surface, and from s and σ, the value of the angle itself, $\cos \alpha = \frac{\sigma}{s}$. These computed values are then to be graphically adjusted, so as approximately to eliminate local irregularities and obtain a mean system. The values of α. σ. s. are plotted as ordinates on an abscissa equivalent to 180°, at the point corresponding to the magnetic latitude of each station, and a curve passed through these ordinate points, so as to give equal weights to the stations. The following table gives the computed values of the angle α and the adjusted values of the vectors for the south and the north groups.

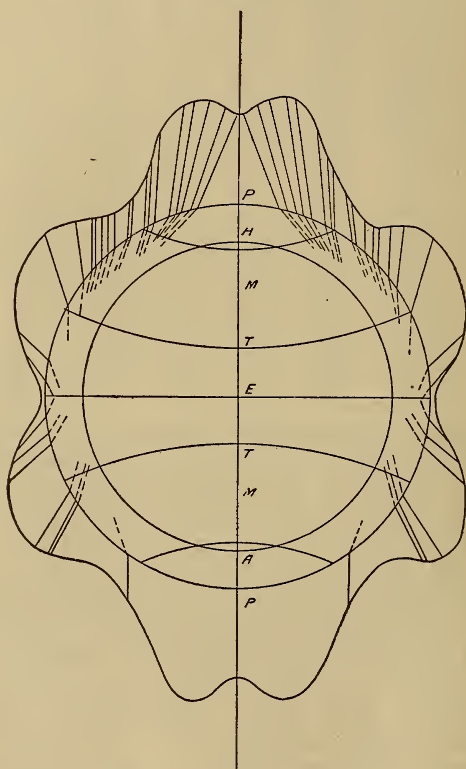
ADOPTED VECTOR VALUES.

Station.	Computed a. S.	Computed a. N.	Mean a.	Adjusted Vectors. South s	South σ	South a	North s	North σ	North a
	°	°							
1	53·1	51·6	52·4	45	28	54	38	23	54
2	49·3	55·7	52·5	53	29	55	43	24	55
3	62·0	58·2	60·1	60	30	58	52	24	58
4	63·2	62·6	62·9	59	30	59	52	23	59
5	57·5	60·0	58·8	55	27	60	49	22	60
6	47·6	54·8	51·2	42	23	58	33	17	58
7	55·8	63·9	59·9	34	18	55	26	13	55
8	20·3	31·0	25·7	31	15	54	24	11	54
9	67·1	66·4	66·7	20	12	48	14	8	48
10	33·6	36·9	35·3	18	10	47	13	8	47
11	46·4	46·2	46·3	14	9	43	10	7	43
12	41·7	43·3	42·5	13	10	41	10	8	41
13	37·9	36·9	37·4	14	11	40	11	9	40
14	45·6	49·7	47·8	16	12	38	12	9	38
15	57·0	64·2	60·6	17	12	37	13	10	37
16	36·9	32·2	34·6	23	19	37	17	16	37
17	40·4	45·8	43·1	38	27	43	32	23	43
18	56·3	61·0	58·7	31	20	53	25	15	53
19	32·2	33·6	32·9	19	14	36	15	11	36
20	38·2	33·6	35·9	15	11	39	11	8	39
21	58·2	61·9	60·1	16	10	57	12	7	57
22	60·0	55·8	57·9	22	12	58	15	8	58
23	67·4	71·4	69·4	36	19	47	31	16	47
24	30·0	39·7	34·8	25	13	44	19	10	44
25	54·6	46·6	50·6	20	12	43	15	9	43
26	54·8	53·8	54·3	26	14	52	22	12	52

The only stations which differ between the computed and adjusted values for the angle a to any important extent, are Sodankyla, Washington, Los Angeles and Süd Georgien. Sodankyla and Süd Georgien used soft iron bars in measuring the vertical force and therefore have less weight. Sodankyla shows a vertical force nearly eight times too large, and yet the reduced values being published in C. G. S. units, there appears to be no room for doubting the method of interpreting the observations. Los Angeles had trouble with the vertical force balance throughout the series at that station, only a couple of years being retained in their report. Washington has used an unsymmetrically shaped magnet, which was suspected of lack of sensitiveness. The four stations give values too large to agree with the rest of the series. These remarks apply only to the vertical force, as the horizontal elements are correct. In order to show the meaning of the vectors, they have been plotted on the accompanying diagram.

The system is a magnetic meridian of the earth with the adjusted vectors at the surface. The notable features are the increased vector lengths in the polar regions and in latitudes 10° to 35°, with diminished vectors at the poles in the middle latitude zones and at the equator. The angles show that an *exflected* system exists around the magnetic poles, and an *inflected* system in the tropical belts. The problem before us is to obtain the value of the permeability or magnetic conductivity of the earth, and the paths of the lines of force through the earth, that will conform to the observed external vectors. It will be remembered that this diagram represents the results of observations, without any admixture of theory or assumption of any kind.

Fig. 3



Vectors of the Polar Magnetic Field derived from Observation.
$\mu = 2 \cdot 0$ H=0.00035.

If a paramagnetic body or a diamagnetic body be plunged in a magnetic field of force, with the axis of magnetization, either permanent or induced, parallel to the direction of the field of force, then the following formulæ are applicable.

Compare Maxwell's Electricity and Magnetism, vol. ii, 434, 436; Sir W. Thomson's Electrostatics and Magnetism, p. 486; Sir W. Thomson's Mathematical and Physical Papers, vol. i, p. 35; Watson and Burberry's Electricity and Magnetism, vol. ii, pp. 18–43; Paul Drude's Physik des Aethers, pp. 36–51.

	Inflected.	*Exflected.*
External Potential,	$V\varepsilon = +R^3\frac{\mu-1}{\mu+2}H\frac{x}{r^3} - Hx$	$V\varepsilon = -R^3\frac{\mu-1}{\mu+2}H\frac{x}{r^3} - Hx$
External Force,	$X\varepsilon = -H\frac{\mu-1}{\mu+2}\frac{R^3}{r^3}\left(1-\frac{3x^2}{r^2}\right)+H$	$X\varepsilon = +H\frac{\mu-1}{\mu+2}\frac{R^3}{r^3}\left(1-\frac{3x^2}{r^2}\right)+H$
	$Y\varepsilon = -H\frac{\mu-1}{\mu+2}\frac{R^3}{r^3}\left(1-\frac{3xy}{r^2}\right)$	$Y\varepsilon = +H\frac{\mu-1}{\mu+2}\frac{R^3}{r^3}\left(1-\frac{3xy}{r^2}\right)$
	$Z\varepsilon = -H\frac{\mu-1}{\mu+2}\frac{R^3}{r^3}\left(1-\frac{3xz}{r^2}\right)$	$Z\varepsilon = +H\frac{\mu-1}{\mu+2}\frac{R^3}{r^3}\left(1-\frac{3xz}{r^2}\right)$
Magnetization,	$I = \frac{3}{4\pi}\frac{\mu-1}{\mu+2}\frac{H}{R}x$	

R = radius of sphere; r = radius vector to point $x.\ y.\ z.$; μ = magnetization constant; H = magnetic force of field.

From these can be found expressions for the potential and force at the surface or inside the sphere.

For $x = r\cos\theta$, $y = r\sin\theta$

The normal and tangential components are,

$$F_n = X\cos\theta + Y\sin\theta = X\frac{x}{r} + Y\frac{y}{r}$$

$$F_t = -X\sin\theta + Y\cos\theta = -X\frac{y}{r} + Y\frac{x}{r}.$$

From the values of $X\varepsilon$, $Y\varepsilon$ given above,

$$\frac{\mu-1}{\mu+2} = \pm\frac{F_n\sin\theta + F_t\cos\theta}{(F_n+F_t)\sin\theta - (F_n+2F_t)\cos\theta} \quad \text{Inflected System. Exflected System.}$$

$$H = \frac{(F_n+2F_t)\cos\theta - (F_n+F_t)\sin\theta}{1-3\sin\theta\cos\theta}. \quad \text{Both systems.}$$

provided the paths inside the surface are known.

Stream Lines.

Differential Equation, $\frac{dV}{dp}dx - \frac{dV}{dx}dp = 0,$

where p is perpendicular to the axis of symmetry x.

$$N = \int\left(p\frac{dV}{dp}dx - p\frac{dV}{dx}dp\right) = \text{Const.}$$

$$N = \pm\frac{\tilde{\omega}p^2}{r^3} + \tfrac{1}{2}Hp^2 = \pm\frac{\tilde{\omega}p^2}{(x^2+p^2)^{\frac{3}{2}}} + \tfrac{1}{2}H\,p^2 \quad \text{Inflected. Exflected.}$$

$$x^2 = \left[\pm\frac{2R^3\frac{\mu-1}{\mu+2}\cdot y^2}{\frac{2N}{H} - y^2}\right]^{\frac{2}{3}} - y^2 \quad \text{Inflected. Exflected.}$$

From an inspection of the diagram of the observed vectors it is clear that we have to deal with each system, Inflected and Exflected, in turn, but the following fact confronts us at the outset. If μ be computed for the polar stations from the formula $\frac{\mu-1}{\mu+2}$, the value of $\mu=0{\cdot}70$. Now this would imply a physical condition of the material of the earth which is highly improbable, if μ is taken as the magnetization constant of the substance of the interior of the earth. For in all known substances except bismuth, μ is greater than 1, and this differs very slightly from 1. Hence we must interpret the polar vectors as stream lines flowing around an obstacle in the interior of the earth. In other words, the outer stratum of the earth is permeable to the external magnetic forces, while the nucleus is not, that is to say, *the earth is a magnetic shell.*

The diameter of the central nucleus can be approximately determined as follows: If μ is to be taken greater than 1, its value from the tropical stations is 2. The value of μ for nearly all dielectrics is 2, and is adopted for this computation. To obtain H, I have taken the sum of the vectors from the pole of the equator, as given by the boundary drawn through the ends of the vectors, and distributed it uniformly, as if undisturbed by the earth. The result is 0·00035 C.G.S. Substituting these values in the formula for exflected forces

$$x^2 = \left(\frac{0{\cdot}50\, y^2}{y^2 - \frac{2\text{N}}{35}}\right)^{\frac{2}{3}} - y^2.$$

N will have values from 0 to 8·8 and the radius of the internal nucleus is 0·794 R.

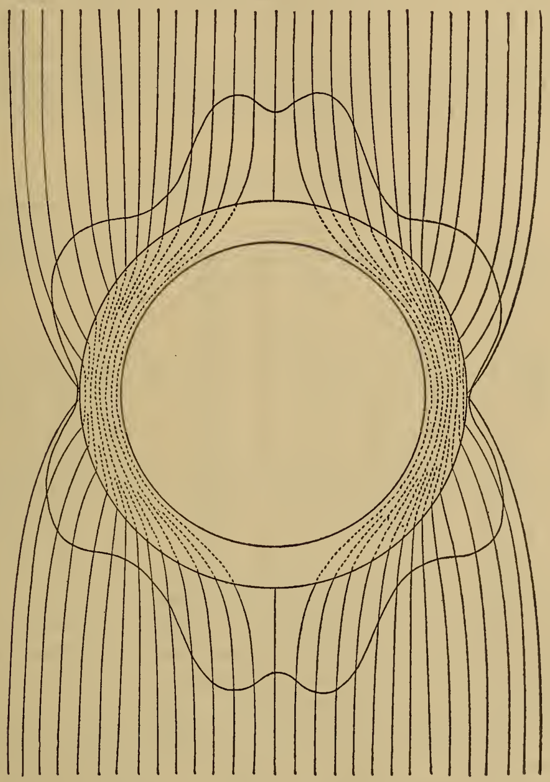
For the tropical vectors μ is 2, and the formula is

$$x^2 = \left(\frac{0{\cdot}50\, y^2}{\frac{2\text{N}}{35} - y^2}\right)^{\frac{2}{3}} - y^2.$$

N ranges to 26·3 in this case, and the value of the nucleus is 0·794 R. The true value of the radius of the nucleus of the earth is about 3170 miles, of the shell 790 miles.

The difficulty with the problem is this: the formulæ are deduced on the supposition that the lines of force inside the surface of the sphere pass parallel to the axis of x. In the case of a shell we do not know exactly the internal paths, and hence are at the disadvantage of having either very complex formulæ for practical solutions, or else of resorting to less rigorous methods. It will be proper, whenever the magnetic observations are sufficiently numerous and accurate to justify the labor involved, to compute μ definitely. This implies that from station to station the internal axis changes its position in the sphere, in the passage around the shell, and while we can never be absolutely exact in locating it, the attempt will be worth making.

Fig. 4.



Stream Lines through a Magnetic Shell.

If the internal paths were definitely known, the value of μ would be most simply found by the continuity of the tangential components of the external and internal force, and the discontinuity of the normal components in the ratio μ.

$$H_{1\cdot t} = H_{2\cdot t} \qquad H_{1\cdot n} = \mu . H_{2\cdot n}$$

I have taken the value $\mu=2$ and plotted the internal lines by magnetic refraction at the surface.

$$1 : \mu_2 = \tan \varphi_1 : \tan \varphi_2,$$

where φ_1, φ_2 are the external and internal angles of the line of force with the radius of the sphere at the station.

The spherical harmonic potential system of a shell is given by Maxwell, Vol. II, p. 56, but in that case the shell is hollow; in our case it is filled with an impenetrable obstacle.

From the formulæ for the exflected and the inflected systems and the constants above determined, the internal and the external systems of lines were computed. On comparison of the observed and computed systems the agreement is very close.

The following table gives the coördinate values of y for given x. N. and is the basis of the stream-lines shown in the diagram. The radius of equivalent flow is 1·25 times the radius of the earth, about 4950 miles.

COMPUTED ORDINATES y.

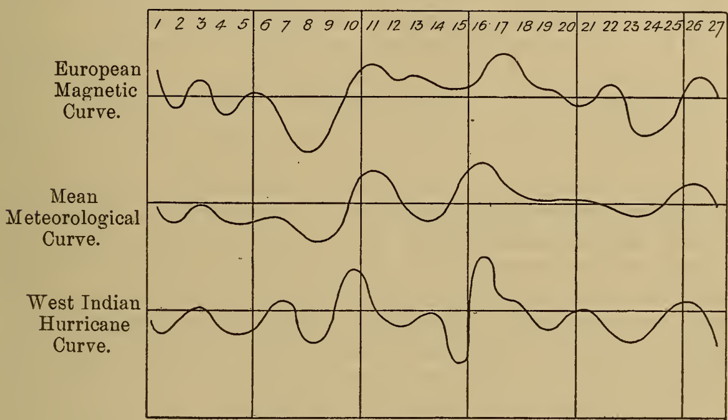
	Exflected.							Inflected.				
N=	0·0	0·5	1	2	4	6	8	10	15	20	24	27
x= 0	·80	·81	·82	·83	·87	·92	·95					·80
·1	·79	·80	·81	·82	·86	·92	·95					·88
·2	·77	·78	·80	·81	·85	·91	·94				·82	·95
·3	·74	·75	·77	·80	·83	·90	·93			·78	·89	1·00
·4	·68	·70	·72	·77	·81	·88	·92			·83	·94	1·05
·5	·61	·64	·67	·71	·78	·85	·90		·64	·87	·99	1·09
·6	·52	·57	·60	·65	·72	·81	·87	·50	·70	·90	1·02	1·13
·7	·38	·44	·50	·57	·68	·77	·84	·55	·75	·93	1·04	1·15
·8	0	·34	·41	·50	·63	·73	·82	·60	·78	·95	1·06	1·17
·9	0	·28	·35	·46	·60	·71	·80	·62	·81	·97	1·08	1·19
1·0	0	·24	·31	·42	·58	·69	·78	·64	·83	·98	1·09	1·20
1·1	0	·21	·30	·40	·56	·67	·77	·66	·85	·99	1·10	1·21
1·2	0	·20	·29	·39	·54	·64	·74	·67	·86	1·00	1·10	1·22
1·5	0	·19	·27	·38	·50	·61	·71	·69	·89	1·03	1·11	1·23
2·0	0	·18	·25	·34	·49	·60	·69	·71	·91	1·04	1·12	1·24

It is evident that the system of forces described in the preceding paragraphs is adapted to explain several important correlated phenomena, whose causes and relations have been the subject of the extensive research and discussion. As shown by Loomis (Enclyl. Britann., *Aurora*), and others, the sunspot frequencies, the magnetic field, and the auroras, vary simultaneously in long periods, but especially in the 11-year period. My computations on the magnetic elements and the meteorological terms* indicate a synchronism of the same character, even to minor details. The following group of curves exhibits a similar sympathetic action in the 26·68 day period of the sun's equatorial rotation. Referring to the Amer. Meteorological Journal, Sept., 1893, it is found that a series of variations was obtained by grouping very diverse observations in this period, which were roughly similar to each other and to the European magnetic impulse. The lack of complete harmony is due to the fact that convectional movements, inversions, and all other disturbing terms were not considered,

* This Journal, Dec., 1894.

hence the purely magnetic periodic impressed forces are not entirely eliminated. The first curve is the European magnetic curve, 1878–1889, reproduced; the second is the numerical mean of the curves 3 to 15 inclusive as they stand; the third is the relative number of West Indian hurricanes for 20 years. (Astron. and Astrophysics, June, 1894). The short period synchronism is evident, and in view of the action of the earth's shell on the magnetic field, very interesting. It is thus concluded that the sun emits a polar radiation, as well as an electro-magnetic, which at the distance of the earth *continuously* acts upon the terrestrial magnetic and meteorological systems.

Fig. 5.



Magnetic and Meteorological Curves.

The external polar field is concentrated in two belts, Fig. 3 (1) the auroral belt, A, (2) the tropical belt T; with a strongly depressed zone at the poles, P, another in the mid-latitudes M, and a third at the equator E. Unfortunately our permanent magnetic observatories are placed in the two depressions M and E, the American and European being all outside the aurora belt A, the Asian being all, except Zi-ka-wei, near the magnetic equator. The work in the southern hemisphere is nearly suspended. The auroral belt was surveyed satisfactorily for only one year, 1882–83, and the tropical belts T T have been quite overlooked in planting fixed observatories. It is hoped that these defects may soon be remedied.

The auroral belt receives its concentration from the fact that the shell turns aside the magnetic rays from the pole to a broad belt in the latitudes indicated. This belt is a rude oval embracing the magnetic and the geographic poles. (See Petermann's Mittheilungen, vol. 20, 1874, ix.) The maximum of frequency is about 20° from the poles, in the schematic diagram, corresponding to the maximum trace in the ovals. The auroras fall off towards the pole and towards the equator. The long and the short periods of auroral visibility are clearly due to the change of intensity of the external field; an increase of magnetic force meaning a corresponding spreading of the field towards the equator; the astronomical changes of position of the poles, in summer and winter, to the equatorial field affecting the conditions of visibility; the atmospheric constituents also modifying them. Like phosphorescence and fluorescence we may regard the auroral light as the product of the transformation of vibrating energy into the required period, by means of the atomic and molecular elements of the air, as a system of step-up transformers.

It is well known to meteorologists that the locality of generation of distinct cyclonic circulations is to be found in two belts, (1) sub-polar and (2) tropical.* One may readily perceive that the main track of the movement of the Lows is just along the edge of the auroral belt A, in an oval following it closely (Dunwoody's International Chart, 53). Furthermore the High Pressure Belt of Lower Latitudes is underneath the second belt of concentration T, and receives nearly half of the energy of the external field. From this belt a series of storms is known to proceed northward, omitting the eastward drift due to the general circulation. Thus the Colorado, Texas, Gulf of Mexico storms and the West Indian hurricanes are examples of this type of storm generation. The eastward march of these storm centers seems to be in part regulated by the mid-latitude low magnetic belt, where the exflected and inflected fields touch each other. This is the significance of the third curve in the group given above, and points distinctly to the source of energy mentioned in my earlier paper.

The problems of the seat of the so-called permanent magnetism of the earth, the secular variation of the same, the magnetic storms or perturbations, the earth's electric currents, and the sources of free atmospheric electricity, have an almost obvious explanation in general terms. If the nucleus of the earth cannot sustain magnetism, as it seems necessary to infer, then the reason for the earlier attempts to account for the surface distribution by a system of small equivalent magnets in the interior is obvious. Hence Gauss's solution of the potential is the only available method for interpolating at any given epoch. The secular variation of the *quasi*-permanent magnetism of a shell rotating in two variable external fields is the real problem to be considered. In my paper† some considera-

* See this Journal, December, 1894, for the United States.
† Amer. Meteorol. Journ., April, 1892.

tions on Wildes' Magnetarium were given, expressing a hope that the principles of a sphere rotating in external fields might be the ones to employ for this phenomenon. It would seem that this paper tends to confirm the suggestion in an important degree.

From the analysis of the two external fields, it is seen that the shell of the earth in the mid-latitude zone (Europe) is traversed by two systems of lines of force, at right angles to each other: in the polar and tropical zones only in one direction, that is along the meridians. It is quite clear from the observations on earth currents, that these are the prevailing directions, in the respective zones, their origin existing in the variable or spasmodic action of the solar field, disturbing the potential of the earth's shell, the currents being the transference of energy in readjusting the equilibrium. The atmospheric electric potential has also been shown to be periodic with the external field, though the data are very meagre, and the dissipation of the magnetic radiations very probably has a term in static electricity.

If the polar regions of the earth receive energy, in the form of magnetic radiation and this energy varies in intensity in short and long periods, then it is not far to seek in the sun as a variable star of very long period, in which the output goes through considerable changes from epoch to epoch, the cause of the glacial sheets that have alternately covered and retreated from the polar caps. As compared with the several astronomical theories of the cause of such great differences in heat, it seems more natural to extend our observed variations to cover the case of glacial periods.

I have now stated my argument for believing in the existence of the magnetic radiant energy from the sun, in addition to the electro-magnetic radiation, which has been so much studied during the past twenty years. The subject is new to science, because in general polar magnetic lines of force have not been regarded as radiant, only static. It is necessary to have a clear conception of the thing measured by the magnetic instruments, namely the ponderomotive or mechanical force due to the stresses in the medium. Using Heaviside's formula,* we have,

$$F\varepsilon = E\rho + [4\pi VDG] + 4\pi VDg_o - \tfrac{1}{2}E^2 \triangle c.$$
$$Fm = [H\sigma] + VJB + Vj_oB - \tfrac{1}{2}H^2 \triangle \mu.$$

The first term is the static electrification and [magnetification = wanting]: the second is the pressure due to the wave propagation [magneto-electric = wanting] and the electro-magnetic: the third due to the motions of and through the medium: the

* Electrical Papers, vol. ii, p. 562; Electro-magnetic Theory, vol. i, p. 107.

fourth due to the change of the medium, as the immersion of the earth in the ether. The currents J, G, contain the conduction, displacement and convection currents: j_o and g_o are due to the motion of the impressed and intrinsic forces: E, H, the forces, D, B, the displacement and induction, ρ, σ, the divergence, c, μ, the permittivity and inductivity. Some attempt has been made in this paper to give the value of μ for the earth. Several of the terms can be computed, since E. H. are approximately known for the electro-magnetic field, and the astronomical motions. We still need c.

About the mode of magnetic radiation no serious hypothesis has been advanced, that is, how energy is propagated through the ether along these widespreading curved lines, whether by a rotary polarized wave or not. Yet the physical aspect of the case demonstrates that energy is continuously arriving at the earth from the sun. Now the question arises, is the term 4πVDG really wanting in nature, since this is the one corresponding to the electro-magnetic radiation VJB? Is it possible that this is the mode of propagation of the auroral energy, and if so what is the mechanical form?

We must distinguish between the mechanical pressure of radiant energy, and the amount of energy received at a surface per second. In the case of light, the pressure is due to the wave of H=0·02 C.G.S. $E=6\times10_8$ from which the maximum translational force is 5 dynes per cu. cm. The action of this field on the unit magnet pole is 0·00070 C.G.S. in the polar regions, and 0·00030 C.G.S. in the mid-latitude zone. The action on the same hemisphere from the polar magnetic field is 0·00035 on the average, so that we have the same order of magnitude in both radiations to derive from the ether energy. The whole problem is obscure at present and can be developed properly only after the acquisition of further knowledge of the subject. If the portion of F due to radiation is

$$F=V\dot{D}B+VD\dot{B}=\frac{d}{dt}\,DB=V\frac{1}{v^2}\frac{dW}{dt}.$$

$$W=\tfrac{1}{4}Uu \qquad \frac{dU}{dt}=\frac{4U}{t} \qquad U=\tfrac{1}{2}ED=\tfrac{1}{2}cE^2$$

$$p=\tfrac{1}{3}U \qquad\qquad\qquad T=\tfrac{1}{2}ED=\tfrac{1}{2}\mu H^2$$

where W=flux, U=density of radiant energy, p=pressure; then p and W are related to temperature through the fourth power. $U=t^4$.

This to some extent outlines the path by which the external impressed energy is transformed into heat in the earth's atmosphere; and thence it passes into various meteorological circulations in the effort to restore equilibrium. Theoretical meteorology has heretofore considered only the effect of the electro-magnetic radiation. It seems clear that the general theory of cyclones must be somewhat recast, especially because the existing treatment has introduced so many limiting conditions as to deprive the result of the possibility of any strict comparison with the phenomena of nature. The three most pressing problems in our study are now :

(1.) The transformation of radiant energy into heat.
(2.) The distribution of magnetic activity in the nucleus of the sun.
(3.) The true stream line circulation in the anticyclones and the cyclones.

In all of them some progress has already been made. On comparing the values of s, σ, for the field south and north respectively, it is seen that the vectors pointing from north of the ecliptic towards the south, always exceed those oppositely directed, by several units in the 5th decimal place. It indicates some persistent physical difference, and it may be that the north pole of the sun is stronger and positive as compared with the southern. For this and the phenomenon that has been called "inversion of temperatures," no satisfactory explanations have been discovered.

Since these vectors represent cosmical forces of the same mechanical type as gravitation, connecting the sun with the planets, it would seem that they should be taken into account in general theoretical astronomy, or the celestial mechanics of the solar system.

We have been accustomed to think of gravitation as the only mechanical force between the sun and the planets, and theoretical astronomy has been constructed upon this basis. Yet there are several outstanding secular motions that apparently fail to comform to the simple Newtonian Law of the inverse square of the distance. Thus Newcomb gives in "Astronomical Constants," 1895, (1) the motion of the perihelion of Mercury, (2) the motion of the node of Venus, (3) the motion of the perihelion of Mars, (4) the eccentricity of Mercury, as the most important divergences of theory and observation. To account for these motions the following hypotheses of the action of unknown masses of matter are discussed :

1. The non-sphericity of the Sun.
2. An intra-Mercurial ring or group of planetoids.
3. An extended mass of diffused matter like that which reflects the zodiacal light.
4. A ring of planetoids between the orbits of Mercury and Venus.

Each of these hypotheses is regarded as improbable and unproven. Also Hall proposes that the exponent of the distance in the law of gravitation is not precisely 2, but about 2,000,000, 1574, as the compensation for at least two or three discrepancies.

To these secular motions may be added the short period variations of the terrestrial latitudes, as given by Chandler in the periods of 365 days, 428 days, and 12 years. All attempts to assign to these a suitable physical cause, whether meteorological or geophysical, have failed to meet with acceptable results.

Now the outcome of my research into the magnetic variations is to show that two systems of mechanical forces exist in the ether at the surface of the earth, besides gravitation, and that these must be added to account for all the known forces at work. The medium that sustains the gravity stress also contains stresses due to the two types of radiant energy as impressed by the solar action upon the ether. The discovery of the exact form of the gravitation stress and the radiant magnetic stress is yet to be made, on the supposition that the Hertzian electromagnetic stress is now understood. The order of the mechanical forces at the surface of the earth is as follows:

The earth's gravity, $g = 980 \cdot 60$ cm. = 386 inches per sec.

The sun's acceleration, $f = 0 \cdot 5929$ cm. = 0·2334 inch per sec.

The electro-magnetic field near the poles $\Delta \mathrm{H}p = 0 \cdot 00070$ cm. = 0·00028 in.

The electro-magnetic field in middle latitudes $\Delta \mathrm{H}m = 0 \cdot 00030$ cm. = 0·00012 in.

The polar magnetic field = 0·00035 cm. = 0·00014 in.

Ratios, $f = \frac{g}{1654}$. $\Delta \mathrm{H}p = \frac{f}{847}$. $\Delta \mathrm{H}m = \frac{f}{1976}$. $\Delta \mathrm{H} = \frac{f}{1694}$.

To explain the periods, we have,

365 *days*, the couples of the electro-magnetic field move up and down the earth with the sun's annual declination ;

428 *days*, the elasticity of the shell of the earth under gravitation is believed to give this inertia period ;

12 *years*, the variation of the polar magnetic field in the sun spot cycle is proven.

See this Journal, Dec. 1894, p. 448, and a large literature on sun spots, auroras, magnetic forces. This field varies at least 75%, and is attached to the midlatitude regions of the earth, appropriately to displace the axis of rotation. Chandler's dates of maximum are so closely associated with the dates of the maximum of sun spots for the last half century as to claim careful consideration.

If these mechanical forces are to be superposed upon gravitation, then the effect upon the motions of the earth and also of the other planets, should be expected, and the suggestion herewith made is that the outstanding motions may be due not to unknown masses of matter, nor to the modified law of gravitation, but to certain stresses imposed upon the ether by the radiant energy of the Sun.

The definite problem thus set before magneticians, namely, to determine fully the magnetic action of the sun on the earth, by means of the vector forces at the surface of the earth, should bring about two reforms in the observatory methods now in use. 1. The distribution of permanent observatories should be made in conformity to the field to be observed. 2. The type of instruments and the methods of reduction should be made uniform. It is very exasperating to employ the present heterogeneous material; and often the cause of misinterpretation is to be attributed to this divergence among the reported observations. The singleness of the main problem and the necessity of intelligent coöperation, together with the great importance of the cosmical physics involved, ought to raise magnetism of the sun and the earth into the front rank in science. The normal systems of the magnetic and electromagnetic fields evidently become the means of checking the performance of the instruments of any observatory, which will add much to the precision with which the instruments are handled. Also the elimination of the normal system from the observed values of the magnetic force, give certain residuals which are to be interpreted as forces indicating physical actions within the sun, or else in the atmosphere and the shell of the earth. In this way many sensitive variations of the traces of the photographic magnetograms will in due time find their true and useful interpretation for practical purposes. This system of measures, delicate to a remarkable degree, will therefore become available for forecasting weather and allied phenomena.

ART. IX.—*Note on the occurrence of Leadhillite Pseudomorphs at Granby, Mo.*;* by WARREN M. FOOTE.

AMONG some leadhillite specimens found a year ago in the Beer Cellar mine at Granby, Mo., were several examples of a mineral replacing calcite. These were preserved by the super-

* Mention is made of pseudomorphism in Messrs. Pirsson and Wells' description of the Granby Leadhillite, this Journal, Sept. 1894.

intendent, Mr. John Kingston, of whom they were obtained by Dr. A. E. Foote of Philadelphia. In examining them together with crystallized leadhillite, the writer observed one isolated scalenohedron possessing the high specific gravity, the perfect cleavage and pale green color of leadhillite, which subsequent qualitative tests proved it to be. This led to an examination of all the material then available and a further search on the old mine dump, which yielded several other specimens.

After Calcite.—The scalenohedrons were found in a chert-calamine rock and were generally pure cerussite. In a number of instances, however, leadhillite completely replaces the calcite either in hollow forms with the six-sided crystals (twins exhibiting hexagonal symmetry) in the interior, or by the solid massive mineral. In some cases minute crystals of calamine and cerussite are intimately associated on the inner surface of the pseudomorphs, apparently being a secondary crystallization. In the absence of crystal planes, the perfect cleavage distinguishes the leadhillite from the cerussite, which has a conchoidal fracture.

The chemical tests consisted simply in dissolving the powdered mineral in boiling dilute nitric acid. Cerussite dissolves with effervescence, leaving no residue, while the sulphato-carbonate (leadhillite) similarly dissolves but leaves a white precipitate of lead sulphate, which settles as the effervescence of carbon dioxide ceases. This precipitate gave reactions for sulphur on charcoal.

After Galena.—Pure white leadhillite replaces cubes of galena occurring in the same matrix with the calcite pseudomorphs, and showing in the same manner the fine crystallization of the leadhillite.

In the majority of crystals observed, however, a gray amorphous mineral in crusts and hollowed forms replaces the cube. Again there are many imprints of the galena, empty or partially filled with leadhillite or cerussite. The gray crusts when compact exhibit a slightly fibrous structure with inner surface botryoidal; hardness 2 to 2·5. They gave the same reaction as the crystallized mineral except that the residue left was gray. After effervescence ceased, this was boiled strongly and the residue became white and supernatant liquid clear.

This incomplete analysis would indicate that the gray color is due to the presence of unaltered lead sulphide, which dissolves after the solution of the sulphato-carbonate is completed. Several crystals showed patches of bright cleavable galena through the altered mass.

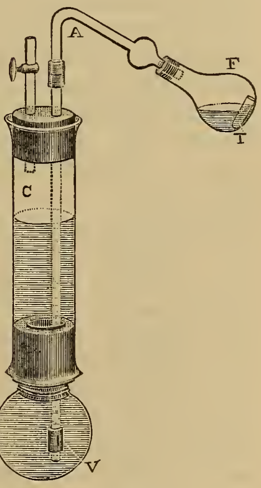
These facts have been thought worthy of note inasmuch as no definite report of such pseudomorphs has yet been made.

ART. X.—*The Precipitation and Gravimetric Determination of Carbon Dioxide;* by F. A. GOOCH and I. K. PHELPS.

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

THE method upon which reliance is most confidently placed for the determination of carbon dioxide in solid carbonates, involving as it does the liberation of that gas by the action of a strong acid and its absorbtion in weighed potash-bulbs, demands as conditions of the attainment of good results the careful observance of precautions and the expenditure of much time and attention. In the method described below we have sought to secure equal accuracy with greater economy of time and care. Our plan is to effect the rapid absorbtion of the carbon dioxide, evolved by the action of acids upon carbonates, in barium hydroxide contained in a specially devised apparatus, to filter and wash the precipitated barium carbonate under a protecting layer of xylene, to dissolve in hydrochloric acid the washed carbonate upon the filter or adhering to the receiver, to convert the barium chloride thus obtained into the form of the sulphate, and from the weight of the last to calculate the carbon dioxide originally liberated by acid from the carbonate.

1.



The apparatus which we use, and which is shown in the figure, consists of a flask for the evolution of the carbon dioxide, properly connected with a receiver in which the gas is retained until absorbtion is perfect. It is a form of a similar device employed by one of us* for the absorbtion of ammonia in hydrochloric acid and the complete retention of the ammonium salt thus formed, but so modified as to avoid the danger of diffusion of carbon dioxide through the rubber balloon—a source of error which we have found by experiment to be considerable when large amounts of the gas are handled.

The evolution flask (F) has a capacity of about 50 cm^3, and is fitted with a rubber stopper through which passes a tube (A) wide enough (about $0{\cdot}7^{cm}$ in interior diameter) to prevent the formation of bubbles, and expanded just above the stop-

* Amer. Chem. Jour., i, 450.

per to a small bulb. The absorbtion cylinder consists of a wide glass tube, (C) fitted at either end with a rubber stopper. The stopper at the lower end of the cylinder, placed vertically, carries a short tube, about $1·5^{cm}$ in diameter, to which is secured a smaller rubber balloon. The cylinder and balloon together hold about 100 cm^3. The upper stopper is perforated with two holes, through one of which passes the tube of a glass stop-cock, while through the other hole passes a long tube reaching to the interior of the balloon and provided with a valve (V)—preferably a modified Bunsen valve, of the pattern recently devised by Kreider and described on p. 132 of this number.

In using this apparatus a saturated solution of barium hydroxide (which is made hot, filtered into a siphon-bottle, and preserved from atmospheric action by a floating layer of kerosene) is introduced by pressure upon the air in the siphon-bottle or by suction applied to the stop-cock of the cylinder. Such a solution contains about five per cent. of its weight of the hydroxide, and we find it best to use in every case an amount at least a fourth in excess of the quantity theoretically required to absorb the carbon dioxide, and to fill the cylinder and balloon nearly full of liquid. The carbonate is weighed, introduced into the flask, and washed down with fifteen or twenty cubic centimeters of boiled water, which is protected in the wash-bottle from carbon dioxide in the breath by a balloon attached to the inlet tube. A small tube holding enough hydrochloric acid to effect the decomposition of the carbonate to be analyzed, is placed in upright position in the evolution flask. The stopper is inserted in the flask and connections are made as shown in the figure, the little tube containing the acid is overturned by inclining the flask, the acid mixes with the water and effervescence begins. Heat is applied and the liquid in the flask is boiled until that in the cylinder is heated by the steam nearly to the boiling point, in order that the precipitated barium carbonate may become as granular as possible. The carbon dioxide evolved and the air in the flask are transferred in the process to the absorbtion cylinder, the valve serving to prevent the back-flow of the liquid while the balloon expands to give room to the air and condensed steam. When the boiling is done the flask and tube are disconnected at the rubber joint, the cylinder is shaken to insure the absorbtion of the carbon dioxide, and the liquid carrying the greater part of the precipitate is transferred through the stop-cock to a filter carefully fitted to its funnel, moistened with water and containing about 5 cm^3 of xylene, (which we found to be preferable to benzene, kerosene, or amyl alcohol, the function of which is to rise to the surface when the aqueous solution is added so as to protect the barium hydroxide from the action of the carbon dioxide of the air. By manipulating the balloon and the stop-cock (to which a little funnel may be attached by a piece of rubber tubing for convenience in introducing wash-water) the cylinder may be emptied and washed out with hot boiled water, though, of course, a very considerable portion of the precipitate remains adhering to the walls of the absorbtion apparatus.

We prefer to prepare the filter for use with the suction pump, but in the early stages of filtration and washing very little suction should be applied. When the barium hydroxide has been nearly washed out of the precipitate, the xylene is dissolved in a little hot alcohol, the suction is applied and the washing is completed with hot water. The emulsion of xylene and water found in the filtrate is readily cleared up by alcohol. Finally, the barium carbonate in the absorbtion apparatus and upon the filter is dissolved in hydrochloric acid and precipitated in hot solution by sulphuric acid, the resulting barium sulphate is filtered, washed and ignited upon asbestos in a perforated crucible, and from its weight the carbon dioxide which originally precipitated the barium, now in the form of the sulphate, is calculated. The results of a series of determinations made in this manner are recorded in the following table:

[Ba = 137·43, S = 32·06, O = 16, C = 12.]

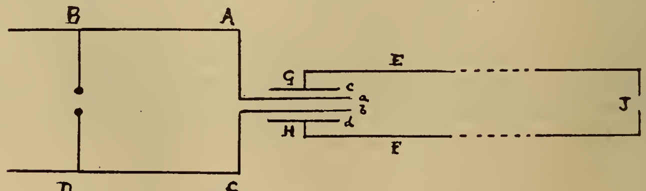
$CaCO_3$ taken. grm.	$BaSO_4$ found. grm.	CO_2 actually present. grm.	CO_2 calculated. grm.	Error in CO_2 grm.
0·0500	0·1180	0·0220	0·0222	0·0002 +
0·0500	0·1183	0·0220	0·0223	0·0003 +
0·1000	0·2329	0·0440	0·0439	0·0001 —
1·1000	0·2347	0·0440	0·0442	0·0002 +
0·2000	0·4660	0·0880	0·0878	0·0002 —
0·2000	0·4653	0·0880	0·0876	0·0004 —
0·5000	1·1650	0·2200	0·2196	0·0004 —
0·5000	1·1657	0·2200	0·2197	0·0003 —
1·0000	2·3323	0·4400	0·4396	0·0004 —
1·0000	2·3309	0·4400	0·4394	0·0006 —

Various modifications of method and manipulation were put to the test of experiment, but the process which we have described has proved on the whole the most satisfactory. It is fairly rapid and accurate.

ART. XI.—*On the Velocity of Electric Waves;* by JOHN TROWBRIDGE and WILLIAM DUANE. With Plate III.

IN the April number of this Journal (vol. xlix, 297), we published a preliminary paper on the determination of the velocity of electric waves. The wave length was determined by means of a bolometer and the period of vibration by photographing the spark in the secondary circuit. Since the waves in the secondary were not well formed when the spark gap was inserted, it seemed desirable to find an arrangement that would produce simultaneously a good wave and a spark that could be photographed. A number of condensers with plates of different sizes and shapes, and different substances for the dielectric were tried, and the apparatus to be described was finally adopted. The difficulties to be overcome were these. Too strong a reaction between the primary and secondary condensers could not be employed, because the increase in the damping of the primary due to the large amount of energy drawn off by the secondary, made good resonance impossible. The amount of energy in the primary at full charge must be much greater than that in the secondary. On the other hand, the capacity of the primary condenser must not be too great, for the self-induction of the primary circuit would have to be proportionately small, and this, too, means an increase in the damping. The secondary condenser, too, must have a capacity less than a certain magnitude in order that the node may fall on the circuit and not in the condenser plate. These points seem to indicate that small condensers are preferable to large ones, but a decrease in the size of the plates means a decrease in the light of the secondary sparks, and the sparks at the best can barely be photographed. Practically, therefore, our choice was much limited, and the particular arrangement to give the best results had to be selected by experiment, after a long series of trials. The arrangement and dimensions of the apparatus finally adopted were as follows:

1.



Two metallic plates *a* and *b* (fig. 1), 30×30^{cm}, placed in vertical planes, formed the primary condenser. The dielectric between them consisted of the best French plate glass obtainable ($k=8+$ probably), and was 2^{cm} thick. Outside the plates a and b, and separated from them by a hard rubber dielectric ($k=2+$ about) $1{\cdot}8^{cm}$ thick were the secondary plates 26×26^{cm}. The primary and secondary circuits were joined to the condenser plates as indicated in the figure. The primary circuit lay in the horizontal plane passing through the centers of condenser plates, and consisted of copper wires $\cdot 34^{cm}$ in diameter. In order to control the period of oscillation of the primary circuit, the portion BD, containing a spark gap with spherical terminals, was made to slide along parallel to itself. The distance between the straight portions AB and CD was 40^{cm}, and the lengths of AB and CD finally chosen for best resonance were 85^{cm}. Most of the secondary circuit lay in a horizontal plane 15^{cm} above that of the primary. The lengths GE and HF, however, were bent down and fastened to the middle points G and H of the secondary plates. The circuit consisted of copper wire (diameter $\cdot 215^{cm}$), and its total length from G through I to H was 5860^{cm}. At I was a spark gap with pointed terminals. With this apparatus we succeeded in producing a very regular wave formation, as indicated by the bolometer. So many curves have been plotted and published, to illustrate the characteristics of electrical waves, that it does not seem worth while to add to the number here. It will be sufficient to state that the ratio of the maximum and minimum deflections in the bolometer was about 15 : 1, and that there was a node at I, and another about 40^{cm} to the right of E. and F.

As stated in our first paper, the images of the secondary spark were thrown on a sensitive plate by means of a rotating mirror. Plate III gives an enlargement (about 10 times) of one of the sparks taken in our final measurement. The dots represent discharges from the negative terminals only, the positive discharges not being brilliant enough to affect the plate. The distance between successive dots was the distance on the plate through which the image of the spark gap moved during the time of a complete oscillation. Hence by determining the speed of the mirror and measuring the distances from the mirror to the plate the time of oscillation could be calculated. To measure the sparks we used a sharp pointer moved at the end of a micrometer screw, under a magnifying glass of low power. The instrument was originally intended for microscopic measurements, and was very accurately constructed. The rotating mirror was driven by an electric motor by means of a current from a storage battery of extremely constant voltage. To give great steadiness a heavy fly-wheel was attached to the axis of the mirror. The speed of the mirror was determined to within about one part in five hundred by means of an electric chronograph. This apparatus, requiring great technical skill, was made for us by the mechanician of the laboratory. The mirror consisted of a thick piece of glass with a concave surface accurately ground for this research by the well known optician Alvin Clark. For the extremely sensitive dry plates which we used, we are indebted to Mr. Gustav Cramer of St. Louis, Mo.

Upon photographing the secondary spark some curious phenomena were observed. In the first place the dots usually appeared in pairs. There would be two black dots followed by a space, then two or three dots either appeared faintly or were absent altogether; after which the two black dots would reappear followed again by a faint space, and so on for six or seven repetitions. All this, of course, occurred in a single spark. The explanation that first presents itself is that the two black dots are the results of the first two oscillations in the primary circuit, which, owing to the damping, are much more powerful than the others. If this were the true reason, the first of the pair of dots always ought to be blacker than the second, and every third dot ought to be the first of a pair. This is not the case, however. On the other hand, the phenomena cannot be explained as the result of a complex vibration, for the bolometer readings, taken only a few minutes before the photograph plates were exposed and with exactly the same arrangement of apparatus, indicated extremely regular waves. A clue to the mystery was furnished by several sparks, in which the dots made by one spark terminal had the characteristics just described, whereas those made by the other were quite regular. Following out this hint, we found that the particular substance used for the secondary spark terminals had a large effect upon the characteristics of the photographs. We tried spark terminals made of a number of different metals —tin, aluminum, magnesium, fuse-metal, etc., and finally adopted cadmium as productive of the best sparks. In the case of cadmium the characteristics described are much less marked, and we have succeeded even in producing a few sparks in which no difference in blackness could be detected between one dot and the next. The photographs from cadmium terminals, too, are far more distinct, and far more easily measured, than those from terminals of any other metal that we tried.

An interesting question arose here, as to whether the distance between two successive dots would depend upon the period of oscillation of the primary circuit, if the secondary were unaltered? To test this point, the circuits were brought into resonance, and a photograph taken. The self-induction of the primary circuit was increased by about 20 per cent. of its value, and a second photograph taken. In the first case the distances between successive dots were all within 2 or 3 per cent. of the average obtained, by measuring over several dots and dividing by the number of intervening spaces, whereas in the second case the measurements of some of the single spaces were from 8 to 12 per cent. greater, the average from long measurements being the same as before. This indicates that the vibrations of the secondary circuit are not perfectly regular, and at a distance apart fixed by the character of the wire, but are to be looked upon as a series of pulses traveling along the circuit and keeping at a distance from each other, which is determined by the exciter. Owing to the fact that the damping of the primary is much greater than that of the secondary, the seventh and eighth pulses started are too weak to obliterate the first and second, which have traveled the length of the circuit and back. We should expect from this that the bolometer throws, which measure the average length of the wave, would not indicate a shifting of the node, when the circuits are thrown slightly out of resonance, but that the minimum throws would be greater than when the circuits are exactly in resonance. This, as is well-known, is what happens.

The improved sparks, which the new arrangement of apparatus, and the use of cadmium as material for the spark terminals have enabled us to produce, have brought to light another interesting fact, namely, that even when the best resonance is obtained, and the most regular wave formation is excited, the distances between the first three or four dots are slightly greater than the distances between three or four dots taken farther down the spark. The explanation we offer for this is the following, and it applies as a criticism to all cases in which waves are excited in a circuit by a neighboring circuit possessing a much larger damping factor. The fact that the secondary waves last longer than the primary oscillation means that the last times the waves travel over the circuit, they do so under different end conditions from the first few times. The capacity of the secondary plates is slightly less after the primary spark has stopped than it was before, and therefore the length of the wires equivalent to the secondary plates is slightly less, and it takes a shorter time for the waves to travel along the circuit and back. Hence the observed decrease in the distance between the spark points and a certain mixing up of the dots, which occurs after the sixth or seventh oscillation. (See figure.) The sixth dot in the figure, apparently following its predecessor after about half an interval, is not a usual characteristic. In the vast majority of sparks the first few dots are far more powerful than those that follow them, and only occasionally do sparks occur that indicate more than five or six good complete oscillations. Hence these first few oscillations have the preponderating influence in fixing the length of the waves as indicated by the bolometer. In examining the sparks, therefore, we measured from the first oscillation as far down the spark as we could without passing over a space where dots were obliterated, and hence in every case we knew the number of dots between the points from which measurements were taken, and did not have to assume that good oscillations had occurred without affecting the plate.

The following table, containing the results of our measurements with the improved apparatus, explains itself. The distance from the mirror to the photographic plate was 302^{cm} in each case.

No. of revolutions of mirror per sec.	Distance between successive points on plate in cm.	Time of oscillation sec.	Length of wave cm.	Velocity of waves cm.
70·8	·05028	$1·869 \times 10^{-7}$	5670	$3·030 \times 10^{10}$
73·7	·05247	$1·877 \times 10^{-7}$	5670	$3·021 \times 10^{10}$
75·2	·05536	$1·940 \times 10^{-7}$	5670	$2·923 \times 10^{10}$
69·5	·05002	$1·897 \times 10^{-7}$	5690	$3·000 \times 10^{10}$
68·9	·04900	$1·876 \times 10^{-7}$	5690	$3·034 \times 10^{10}$
69·0	·04974	$1·899 \times 10^{-7}$	5690	$2·996 \times 10^{10}$
71·2	·05075	$1·879 \times 10^{-7}$	5660	$3·013 \times 10^{10}$
			Average value of velocity,	$3·0024 \times 10^{10}$

With the exception of three preliminary trials, which gave values differing from the mean by 10 or 12 per cent, these are the only complete determinations we have made.

In some cases the waves in the circuit were just as good with the spark gap as without. In others there was a decided wave formation when sparks occurred, but the node was not quite so well marked. For this reason, and since it did not appear to make any difference in their length, the waves usually were measured without the spark gap. As the sparks were quite regular, the difference in the bolometer readings must have been due to Faraday tubes, that were reflected from the spark gap, without forming a spark and reversing themselves.

As an example of the data taken to ascertain the position of the node we give the following table. The top line contains the distances of the bolometer terminals from arbitrary fixed points on the circuit.

Distances from fixed points,	20^{cm}	40^{cm}	60^{cm}
Bolometer deflections,	4·3	4·0	4·3
	4·5	4·1	4·4
	4·5	4	4·2
Average deflections,	4·43	4·03	4·3

From these deflections the position of the node was easily estimated. It appears from the best results that we have obtained, that the velocity of short electric waves traveling along two parallel wires differs from the velocity of light by less than 2 per cent of its value. It has been shown theoretically, that the velocity of such waves traveling along a single wire should be the velocity of light approximately. Our results, therefore, in a certain sense, confirm the theory, to an accuracy within their probable error.

Theoretically too, the velocity should be approximately equal to the ratio between the two systems of electrical units. The average of the best measurements of this ratio is 3·001, which is nearer the average velocity obtained by us than the velocity of light.

Jefferson Physical Laboratory.

Art. XII.—*On the Distribution and the Secular Variation of Terrestrial Magnetism,** *No. I;* by L. A. Bauer, Ph.D.

For the empirical results already obtained in my investigation on this subject, I refer the reader to an abstract published in this Journal.† The general conclusion was *that the two phenomena, the distribution and the secular variation, appear to be closely related; they obey similar laws and seem to be connected in some way with the rotation of the earth.*

In the following, I intend to establish this important result more conclusively, adopting a method somewhat different from the one previously employed. I shall for the present confine myself solely to observations of declination and inclination, since reliable intensity data cover but a comparatively small interval of time. A collection of observations of intensity is, however, being made and will be discussed at some future date.

Unfortunately the points on the earth's surface where we possess long series of magnetic observations are not uniformly distributed. The consequence is that it is very difficult at times to interpret the phenomena observed at any special locality or to discern the law governing the onward progression of a particular phase of the secular variation. To help me out of this difficulty, I adopted the idea of choosing hypothet-

* Under this title, I intend to publish a series of articles embodying and growing out of two papers presented to the Philosophical Society of Washington, May 25, 1895: "On the Secular Variation of Terrestrial Magnetism" and "A Preliminary Analysis of the Problem of Terrestrial Magnetism and its Variations." Both papers are abstracted in "Science," vol. I, No. 25.

† June, 1895, p. 471. For a fuller account see "The Physical Review" for May–June and July–August, 1895.

ical points distant 20° in longitude and situated on the parallels of latitude 60° N., 40° N., 20° N., equator, 20° S., 40° S. and 60° S. The data (declination and inclination) were scaled from isogonic and isoclinic charts. In this way was added to the list of secular variation stations already discussed, $7 \times 18 = 126$, symmetrically distributed.

In the case of the declination, material has been gathered covering a period of $3\frac{1}{2}$ centuries. Twenty-six charts from 1540 to 1890 were scaled, giving about 3000 declinations. In some cases the original charts as found in the European libraries were utilized. The curves expressing graphically the secular variation in declination for the 126 hypothetical points have all been laid down on a map in their true geographical positions. The outcome is a most interesting one and has fully repaid the requisite labor. Owing to lack of time, its publication and discussion must at present be deferred.

Inclination data are not so numerous. Little use, if any, can be made of Hansteen's isoclinic charts for the years 1600 and 1700. The earliest fairly reliable chart that can be utilized is the one by Hansteen for 1780. Besides this, the following were scaled: Erman and Petersen's (1829), Sabine's (1840–45), Evans's and Creak's (1860, 1870, 1874 and 1880) and Neumayer's (1885).

I then drew up tables of declination and inclination for the seven dates, 1780, 1830, 1842, 1858, 1872 and 1885. With these data I can construct the secular variation curves for the time interval 1780 to 1885 at 126 points uniformly distributed over the earth on the principle already laid down.* I am plotting them on a large map on Mercator's projection and on twice the scale formerly employed, i. e., I draw the curves described by a freely suspended magnetic needle whose total length is 80^{cm} instead of 40^{cm}. On this same map, I intend to give the curves derived from actually observed data. The pursuit of a secular wave around the earth, or the discernment of laws, will thus be materially facilitated. This work is fairly under way. I would like to suggest that those who are engaged in similar investigations adopt the same scale if possible.

To be sure the material obtained from isogonic and isoclinic charts cannot be relied upon as though it had been actually observed. Still it should be remembered that these charts were *based* on observations. While no doubt the constructor of the chart had to proceed arbitrarily at times on account of defective or deficient data, nevertheless, the data obtained from them possess a value of no mean degree, provided they are

* In "Beitraege zur Kenntniss des Wesens der Saecular-Variation des Erdmagnetismus," Mayer and Müller, Berlin, 1895. See article referred to in "Physical Review."

used critically. The following novel results will afford striking evidence of this.

I shall not give here the original data, as it is my intention some day to publish the total material together. The results can be understood without the original figures.

Table I is intended to exhibit mainly the "distribution" phenomena, Table II those of the "secular variation."

Table I.—*Distribution.*

Declination.

Date	Mean for Latitude. +60°	+40°	+20°	0°	−20°	−40°	−60°	Mean	Range for Latitude. +60°	+40°	+20°	0°	−20°	−40°	−60°	Mean
1780	+2°·2	+1°·1	+0°·5	+0°·5	+1°·1	+2°·3	+2°·8	+1°·5	70°·8	35°·7	28°·3	29°·2	33°·9	46°·7	66°·8	44°·5
1830	+2·0	+0·7	+0·3	+0·5	+1·3	+2·7	+1·4	+1·3	72·3	42·9	33·0	31·6	37·3	48·7	71·3	48·2
1842	+3·0	+1·0	+0·2	+0·2	+1·4	+3·0	+2·1	+1·6	96·0	41·0	30·2	31·7	37·3	44·3	73·5	49·1
1858	+3·7	+1·0	+0·3	+0·7	+1·6	+3·2	+2·4	+1·8	91·3	43·4	30·5	31·7	39·3	49·4	74·8	51·5
1872	+3·1	+0·7	+0·2	+0·8	+2·0	+3·3	+3·2	+1·9	86·2	44·0	30·3	28·8	38·8	50·2	74·3	50·4
1880	+2·0	+0·8	+0·4	+0·9	+1·8	+3·4	+3·5	+1·8	84·2	43·9	29·7	29·6	39·9	50 9	75·6	50·5
1885	+2·5	+0·7	+0·4	+1·0	+1·8	+3·5	+4·1	+2·0	86·8	43·0	29·1	29·7	39·1	51·1	78·3	51·0
Mean	+2·6	+0·9	+0·3	+0·7	+1·6	+3·2	+2·8	+1·7	82·5	42·0	30·2	30·3	37·9	48 8	73·5	49·3

Inclination.

Date	Mean for Latitude. +60°	+40°	+20°	0°	−20°	−40°	−60°	Mean	Range for Latitude. +60°	+40°	+20°	0°	−20°	−40°	−60°	Mean
1780	+74°·9	+58°·8	+33°·2	−1°·9	−34°·0	−59°·1	[−70°·8]*	+0°·2	13°·2	21°·4	39°·5	47°·8	38°·8	26°·3	[22°·0]*	29°·9
1830	+75·4	+60·1	+34·6	−1·8	−35·9	−57·7	−70·8	+0·6	14·3	21·5	37·4	55·2	47·1	30·1	23·6	32·7
1842	+75·3	+59·0	+34·2	−2·2	−36·0	−57·2	−70·9	+0·3	15·3	22·5	33·8	53 0	45·5	33·0	28·0	33·0
1858	+75·3	+60·2	+35·2	−2·1	−36·1	−57·2	−70·5	+0·7	15·6	23·0	35·5	50·5	49·5	34·5	27·0	33·7
1872	+75·4	+59·6	+35·0	−2·1	−36·3	−57·2	−70·6	+0·5	15·0	20·2	33·6	48·4	46·8	34·0	27·2	32·2
1880	+75·3	+59·9	+34·5	−3·1	−36·8	−57·6	−70·6	+0·2	15·4	20·2	32·8	50·2	46·3	36·3	28·0	32·7
1885	+74·9	+59·7	+34·3	−3·2	−36·8	−57·2	−70·2	+0·4	14·7	19·6	31·7	49·6	47·0	36·2	29·0	32·5
Mean	+75·2	+59·6	+34·4	−2·3	−36·0	−57·6	−70·6	+0·4	14·8	21·2	34·9	50·7	45·9	32·9	26·4	32·4

Meaning of Signs.—Plus: North Latitude, West Declination or Dip of north end of needle *below* the horizon.

Minus: South Latitude, East Declination or Dip of north end of needle *above* the horizon.

* Supplied temporarily from value for 1830.

TABLE II.—*Secular Variation.*

LARGEST SECULAR CHANGE BETWEEN 1780 AND 1885.

Long. E. of G.	*In Declination.* Latitude. +60°	+40°	+20°	0°	−20°	−40°	−60°	Mean	*In Inclination.* Latitude. +60°	+40°	+20°	0°	−20°	−40°	−60°	Mean*
0°	6·0°	5·2°	6·6°	5·7°	11·2°	15·4°	14·5°	9·2°	3·5°	8·0°	18·0°	23·7°	17·2°	7·1°	—°	14·8°
20	6·5	7·3	7·0	6·9	3·7	9·1	13·2	7·7	2·8	6·3	16·3	22·1	19·0	8·2	—	14·4
40	7·2	8·0	7·7	6·9	4·9	2·0	9·4	6·6	1·2	4·1	6·2	14 0	11·3	4·0	—	7·9
60	9·5	8·0	5·0	4·2	2·7	2·5	8·2	5·7	1·8	4·1	5·3	5·0	4·3	3·5	—	4·4
80	9·3	7·6	3·7	0·5	2·7	3·5	9·0	5·2	3·2	4·3	8·2	2·9	3·0	1·8	—	4·0
100	5·5	5·7	2·6	2·0	1·7	2·5	15·5	5·1	3·7	3·8	6·5	1·5	5·1	2·7	—	3·9
120	2·3	3·1	0·9	1·9	4·1	5·6	18·9	5·3	2·3	2·4	8·2	4·3	5·5	3·0	—	4·7
140	6·5	7·1	3·9	1·5	4·5	4·9	7·7	5·2	1·7	2·7	7·1	5·5	3·6	2·1	—	4·2
160	7·5	4·1	3·8	2·9	1·9	1·4	7·0	4·1	2·1	4·5	5·8	3·3	2·1	2·7	—	3·7
180	4·5	1·3	1·8	1·8	1·5	0·7	5·9	2·5	1·9	4·8	7·3	5·1	4·7	3·7	—	5·1
200	3·9	1·7	2·3	1·9	1·1	2·7	6·2	2·8	1·2	5·2	10·1	8·1	4·5	3·4	—	6·3
220	3·3	1·7	3·0	4·0	3·2	5·6	9·9	4·4	5·7	4·3	9·8	8 9	2·2	3·1	—	5·7
240	7·7	4·3	3·8	4·1	8·0	11·4	16·1	7·9	1·2	2·6	6·9	6·8	3·0	6·2	—	5·1
260	18·6	5·7	2·4	3·2	7·0	11·2	11·0	8·4	2·6	2·5	3·4	5·2	5·8	9·6	—	5·3
280	17·8	3·6	2·7	2·3	4·6	5·9	3·0	5·7	3·3	3·8	2·7	5·6	5·5	11·5	11·3	5·8
300	18·2	10·2	4·9	4·5	4·9	6·4	6.6	8·0	1·0	3·5	2·6	5·7	7·8	15·1	12·5	6·9
320	13·5	12·1	9·0	10·2	13·9	13·6	10·0	11·8	2·6	1·9	3·0	4·3	9·3	11·7	—	6·0
340	7·2	6·3	6·9	12·2	16·3	17·1	13·3	11·3	3·3	6·0	10·8	12·1	6·9	3·7	—	7·9
Mean	8·6	5·7	4·3	4·3	5·4	6·7	10·3	6·5	2·5	4·2	7·7	8·0	6·7	5·7	—	6·4
Range	16·3	10·8	8·1	11·7	15·2	16·4	15·9	13·5	4·7	6·1	15·4	22·2	16·9	13·9	—	14·9

Explanation of Table I.—The first column gives the dates to which the various quantities apply. The next seven columns give the mean declinations along the parallels of latitude designated at the top, as derived from 18 equidistant scalings (at every 20° longitude). It will be noticed that the quantities, though small, are invariably positive, i. e. there is a preponderance of *westerly* declination along every parallel. This has been found to be true also for other dates than given. It can be accepted then as a fact and must have a meaning.

The ninth column contains the mean declinations of the seven parallels. In looking over the figures it will be noticed that they are nearly constant. Whether the slight variation is real and not due to imperfection in the data cannot as yet be ascertained.

The following seven columns give the range or total change in declination encountered in going along a parallel of latitude. For example in 1780, in latitude 60° N. the maximum westerly declination (40·0) occurred in longitude 300° E. of Gr. and the maximum easterly (30·8) in 220° E., hence, a range of 70°·8

* This column gives the mean values for the five parallels +40° to −40°.

was obtained. A column of mean results is then given which perhaps exhibit some periodical inequality.

The inclination has been similarly treated in the subsequent columns.

There was a suspicion that perhaps columns headed "Mean" exhibited the sun-spot period ($11\frac{1}{9}$ year). Upon plotting the quantities, however, nothing decisive could be discerned.

From the bottom row of mean results the following laws are derived:

I. *The mean declination along a parallel of latitude is always westerly, the minimum occurring near the equator; the quantities, in general, increase upon leaving the equator.*

II. *The mean inclination along a parallel of latitude follows quite closely the law:*

$$\tan I = 2 \tan \varphi,$$

I *being the inclination and* φ *the geographical latitude.*

III. *The minimum range in declination along a parallel of latitude occurs near the equator, generally increasing upon leaving the equator.*

IV. *The maximum range in inclination along a parallel of latitude occurs near the equator, generally diminishing upon leaving the equator.*

The asymmetry of the mean quantities with respect to the geographical equator is, doubtless, to be referred to the eccentricity of the magnetic axis of the earth. How closely II follows the law given can be seen from the following figures:

Latitude.	I obs'd.	I comp'd.	O.–C.
°	°	°	°
60 N.	+75·2	+73·9	+1·3
40	+59·6	+59·2	+0·4
20	+34·4	+36·1	−1·7
0	− 2·3	0·0	−2·3
20	−36·0	−36·1	+0·1
40	−57·6	−59·2	+1·6
60 S.	−70·6	−73·9	+3·3

The theoretical significance of this empirical law will be pointed out in the next number.

Explanation of Table II.—Here we have given the largest secular change in declination and inclination during the epoch 1780 to 1885 for the 126 hypothetical stations. To illustrate: In latitude 60° N. and longitude 0°, the largest declination we have recorded occurred in 1842, the amount being 26·0 W.; the lowest recorded one we find in 1885, viz: 20·0 W., and hence, largest recorded change is 6°·0. Similarly, we find for the same point the largest change in inclination to be 3°·5. It must not be understood that these are the *maximum* declination and inclination changes during the interval 1780–1885. To have obtained these quantities it would have been necessary to establish interpolation formulæ or resort to graphical methods. To get results expeditiously I simply took the maximum and minimum quantities as they stood in my original tables; as only the mean results exhibited at the bottom were employed, this rapid method was sufficiently accurate.

It will be seen that the second last column is left blank except for the points 280° and 300° E. The reason of this is, that I could not scale safely the inclinations for this latitude on Hansteen's isoclinic chart of 1780. In consequence, the largest change in inclination during the interval 1780 to 1885 could not be determined for this latitude. It might have been obtained for the epoch 1830–1885, but these quantities would not have been strictly comparable with the others.

The 9th column headed "Mean" gives the mean largest change in declination from 1780–1885 at every meridian 20° apart, as determined from the seven symmetrically situated parallels. The last column gives the same quantities for the inclination. Here, however, in order not to disturb the symmetry only the five parallels +40°, +20°, 0, −20° and −40° could be utilized. Approximately then, we may regard the quantities given in these two columns as applying to points along the equator 20° distant in longitude.

The first horizontal row of figures gives as indicated the mean of the 18 quantities in each column. The figure 6·4 as given in the final column is the mean of the preceding five quantities of the row or of the 18 in the column above. The bottom row gives the difference or range between the largest and the smallest value in each column.

From this table a number of conclusions can be drawn. I shall mention, for the present, only two, preferring to draw attention to the others in their proper places.

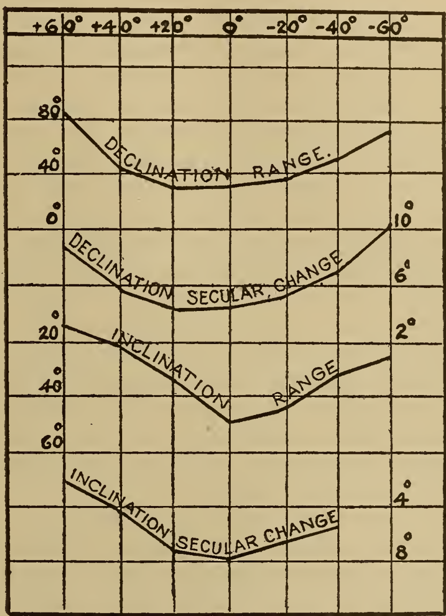
V. *The minimum average secular change in declination along a parallel of latitude from 1780 to 1885 occurred near the equator, the values generally increasing upon leaving the equator.*

VI. *The maximum average secular change in inclination along a parallel of latitude from 1780 to 1885 occurred near the equator, the values generally diminishing upon leaving the equator.*

These two laws* are precisely analogous to Nos. III and IV.

* It will be noticed that the bottom row of figures giving the "range" exhibit practically the same results.

To show that the empirical laws are identical, I have plotted the mean quantities for the interval 1780 to 1885, as taken from Tables I and II on the accompanying diagram. The inclination curves have been inverted. The distribution curves and the



secular variation curves are found to run parallel courses. We are thus forced once more to our former conclusion, viz: *that the distribution and the secular variation are intimately connected; they obey similar laws and will hence in all probability have to be referred primarily to the same cause.*

Washington City, June 2.

Art. XIII.—*Complementary Rocks and Radial Dikes;* by L. V. Pirsson.

The progress of petrological research within the past two decades has shown that areas of intrusion of massive igneous rocks are very frequently accompanied by smaller, less prominent intrusions, usually in the form of dikes and sheets, of rocks which in part are more acid and in part more basic than the main bodies with which they are geologically connected.

The study of the various types of rocks occurring at eruptive centers has shown that they are caused by the differentiation of igneous magmas, and that this differentiation in the main is due to the local concentration of lime, iron, and magnesia, by processes not yet fully understood. By this means arise bodies of magma, some relatively richer in silica, alumina and alkalies, others richer in lime, iron and magnesia than the original fluid from which they were formed. That such differentiation does take place seems now well established—in late years a large amount of indirect proof of it has been given and quite recently cases have been presented which furnish actual demonstrations of the fact.*

These smaller rock bodies then, if differentiation is admitted, are the resultants of a longer and more complete phase of the process than that represented by the main masses which they accompany, and it follows that they are younger in point of age.

The recognition of the genetic connection between these smaller rock bodies and the masses they are found with we owe chiefly to Rosenbusch, who perceived the association between the dikes of minette and vogesite and the granitic areas they accompany in eastern Germany. Rosenbusch, however, extended this idea of relationship still further and insisted that these smaller rock masses had their appearance strictly conditioned, that they typically appeared only in the form of dikes and accordingly as the main bodies or stocks which they accompanied were composed of rocks of different types, so also the dikes varied in type and the correspondence was absolute. That is that each kind of stock rock had its own particular satellites in the form of special dike rocks. This is, of course, well known to all petrographers.

Iddings,† however, has shown that these smaller, more highly differentiated bodies of magma, at eruptive centers, may appear

* Harker, Quar. Jour. Geol. Soc., vol. l, p. 311, 1894. Weed and Pirsson, Bull. Geol. Soc. Amer., vol. vi, pp. 389–422, 1895.

† Origin Igneous Rocks, Bull. Phil. Soc. Washington, vol. xii, p. 167, 1892.

in extrusive forms as well as intrusive ones, but that the mineral composition in each case depends largely on the physical conditions under which the magma cooled and crystallized. And *a priori* it does not seem reasonable to expect that such bodies of magma should appear only in the form of dikes but in intrusive sheets, laccolites, and smaller masses as well, while the smaller more highly differentiated magma of one locality may be the common type or main one at some other center.

Brögger in his interesting article on the basic rocks of Gran* has shown moreover that the types which these accompanying rocks assume are not necessarily conditioned by the type of the main bodies and that in the district studied by him camptonites and bostonites occur as the differentiation-products of a gabbro magma, and are not therefore attached unconditionally to nephelite syenite, as Rosenbusch had previously assumed.

Bearing the above facts in mind, it is nevertheless certainly true that the appearance of these companion rocks at centers of igneous intrusion is, as stated at the commencement of this article, a very frequent, though not a necessary one. And in those localities where the deep-seated rocks have been laid bare by erosive dissection, they will most commonly appear as dikes and intrusive sheets. It seems to us that to lose sight of, or to deny this, is to neglect one of the most useful and important features of general petrology.

For these accompanying rocks Brögger† has proposed the very apt term of "complementary rocks," meaning thereby that the basic forms (the high iron, lime, magnesia, low silica type) if combined in correct proportion with the acid ones (the high silica, alumina and alkalies) would give the composition of the main type of magma which they accompany and from which they have arisen by differentiation. Thus they complement each other.

To the basic forms of complementary rocks,—the types rich in ferro-magnesian minerals, occurring in this manner,—the general term of "lamprophyre" has long been employed. It is true that some object to the use of the term in this sense and the objections have been well stated by Zirkel in the recent edition of his Lehrbuch der Petrographie.‡ The term is, however, in such common use by the majority of petrographers that it would be probably impossible now to displace it. It makes less difference what the term is than that we have it and use it with a common meaning. The objections to it are based almost wholly on etymological grounds and we might as well object to the use of "porphyry" in a general sense because the majority of the rocks to which it is now applied are not red.

* Quar. Jour. Geol. Soc., vol. l, p. 15, 1894.
† Loc. cit.
‡ Zweite Auflage, vol. ii, p. 341, 1894.

What we do need, however, in petrographic nomenclature at the present time, is a general term for the acid forms of the complementary rocks. By some the term "aplitic form" has been used but has never become general. The author would suggest in this connection that for these acid types the general term of *oxyphyre* be employed.

These two terms lamprophyre and oxyphyre should then be regarded as correlative of each other, and taken together for any one district where such relations exist, they will form its complementary rocks. And it is to be understood that these terms are not to be used in a specific but in a general sense—subjectively, not objectively. It may well happen that a type of rock which in one district is a lamprophyre or an oxyphyre may in another locality be the main predominant type. And of course in many places no such complementary relations may exist.

Radial Dikes.—It is a fact well known to most petrologists that eruptive centers are frequently surrounded by mazes of dikes. Not only are the central stocks or massives cut by these dikes but they ramify outward among the tuffs, breccias and lava flows, if extrusive action has taken place, or if erosive agencies have carried these away, they are found in an outer zone among the sedimentaries, often extending for great distances. In such cases it is often to be noticed that the dikes have a pronounced radial disposition with respect to the central stocks with which they are connected. Instances of this will probably suggest themselves at once to most geologists and a very marked one is afforded in the Crazy Mts. in Montana, the radial disposition of whose dikes was first observed by Iddings as stated by Wolff*. The Livingston sheet of the Geological Atlas of the U. S. Geological Survey presents in a most graphic way this relation of the dikes in the southern portion of the Crazy Mts. Another very remarkable case of these radial dikes is afforded by the Highwood Mts. in Montana, an account of which has been recently given by W. H. Weed and the author.†

The origin of these dikes is by most geologists referred to the shattering of the strata by the force of the volcanic outbreaks which gave rise to the center of eruption and the subsequent filling of the cracks by intruded magmas. The idea might be illustrated by the disposition of the hole and cracks formed in a pane of glass when a missile has been violently hurled through it.

While by no means denying that dikes at volcanic centers may be and are formed in this manner, it seems evident to the writer that they cannot all have originated in this way, and this

* Bull. Geol. Soc. America, vol. iii, p. 451, 1892.
† Ibid., vol. vi, pp. 389–422, 1895.

is especially true in many cases of these systems of radiating ones.

If they were formed, so to speak, initially we should expect to find them filled with the same magma as that which forms the central stocks. In that case they would form apophyses from it. A study of them in several regions has shown, however, that they are of later origin than the filling of the central stock, that they represent indeed the very latest phase of eruptive activity in the district and that the rocks composing them are much more highly differentiated than those of the central masses.

The proof of their later origin is not that they represent more highly differentiated material (though this would be indicative of it) but in the fact that they frequently possess extremely dense or even glassy saalbands although they are found in the immediate neighborhood of the central stock, cut through apophyses of it or are even found in the stock itself.

It is in such systems of dikes that the most typical examples of complementary rocks, lamprophyres and oxyphyres are to be found.

When a large mass of molten magma is intruded into a region of sedimentary beds, a vast amount of heat is spread outward among the strata in a zone surrounding it. Besides effecting contact metamorphism this heat must cause a considerable expansion in the surrounding material, and expansion which it may readily be conceived will seek re-adjustment in various ways.

As the mass as a whole gradually cools, it must also contract and this contraction will not cause a reversal of the adjustment process but will seek relief in cracking. Cracks will thus occur not only in the cooling mass of igneous rock but in the heated zone of sedimentaries as well, and if these are homogeneous we should expect the cracks to assume a more or less radial position.

For the same reason one would expect these systems of cracks to be most typical where intrusions have taken place into areas of approximately homogeneous and undisturbed strata and to be obscure or even entirely wanting when the area has been greatly disturbed, faulted, etc., before intrusion and when it consists of dissimilar unhomogeneous rock masses. Such facts as have come under our observation tend to comfirm this view.

If this hypothesis be admitted it is easy to see how more or less radial systems of dikes may arise which are much later than the central stocks they surround.

It is generally considered at the present time by most petrologists that the process of differentiation in molten magmas takes place by the diffusion of the oxides of lime, iron and magnesia towards the outer cooling margins of the enclosed mass. Thus border zones of more basic material are formed and accordingly as one portion or the other is erupted at varying stages of the process, rocks of different types will be made. This assumption has been reached by indirect proof, but recently a positive demonstration of it has been shown to occur at Square Butte in the Highwood Mts. of Montana.* At this locality the mountain has an inner, acid, feldspathic core surrounded by a broad marginal zone of basic rock rich in ferromagnesian silicates, and a variety of facts and considerations prove that it was not formed by two separate intrusions but by the process of differentiation in an originally homogeneous molten magma.

While examples are known which seem to be the reverse of the process by which the outer margins of the differentiating mass become more basic, it may yet well be called the normal one. What laws condition it are not yet well known.

If we now imagine an intrusion of igneous magma to take place into the superficial crust of the earth from depths below, it can be seen that while the magma is cooling and crystallizing and the heated rocks still further cooling and cracking from contraction, that during this period processes of differentiation can go on in the still liquid material below. If further ejections of this differentiated material take place into the cracks produced by contraction, dikes, sheets and laccolites of complementary rocks will be formed.

If the differentiation has followed the normal course, it would then be reasonable to expect that the acid forms (the oxyphyres) would be most commonly found cutting the central stock or in its immediate neighborhood, while the basic forms (the lamprophyres) would chiefly occur in the outer zone of sedimentaries as dikes and intrusive sheets. Every geologist will recall how common it is to find granite areas cut by dikes of aplite, how much rarer these forms are at a distance from them, while with basic dikes the reverse holds true.

Moreover, another factor may contribute to this result. While the liquid mass below is cooling it is also becoming more viscous and this viscidity would naturally be more pronounced in the case of the acid feldspathic portion than with the more easily fusible basic one. Hence we should expect to find the oxyphyres in greatest amount where the rocks are the most intensely heated, that is at the center, and that the lamprophyres, being more liquid at a lower temperature, would be also more likely to be erupted and would therefore occur in greater

* Weed and Pirsson, op. cit.

mass volume than the oxyphyres. This relation of volumes would also be naturally dependant very greatly on the original composition of the magma; the theory is suggested for one of medium kind.

All sorts and modifications of this process may of course be expected to occur, but the above expression of it may be assumed as the theoretically normal type, whose perfection or completeness will depend on local conditions, some of which have been indicated above. The writer has offered this hypothesis as to the formation of complementary rocks and radial dikes because it explains best their occurrence at those centers which have come under his observation, but he believes it to be of general application.

Mineralogical and Petrographical Laboratory, Sheffield Scientific School, New Haven, May, 1895.

ART. XIV.—*Mineralogical Notes;* by WM. H. HOBBS. With Analyses by Herman Schlundt and Louis Kahlenberg.

1. *Cerussite with superficial film of galena from near Missoula, Mont.*

In February, 1894, I received from F. G. Bond, prospector at Missoula, Montana, a small specimen described as crystalline lead formed on the outside of a crystal. In the accompanying letter the following statements are made concerning it:

"The sample was found in a very soft talco-slate with narrow bands of dark limestone running parallel with the slate. The slate is cut by a dike of bird's eye porphyry that I traced over twenty miles. It is near this dike that our Iron Mountain mine is located."

The specimen sent is the only one that Mr. Bond had saved. The crystals referred to have a rather long prismatic habit with a length of 2–4^{mm}, and they show reëntrant angles in the prism zone, thus indicating that they are twinned individuals. They only rarely have terminal planes developed. They are white and somewhat translucent, but are partially covered by a glistening film of a metallic luster and very great tenuity. This thin superficial coating conforms perfectly to the form of the original crystal. A preliminary chemical examination showed that the material of the crystals is nearly pure lead carbonate. On charcoal in the oxidizing flame of the blowpipe the mineral boils and turns red but cools to yellow. In the reducing flame it yields a button of metallic lead. The crystals are completely soluble with effervescence in dilute nitric acid. Further examination failed to reveal any base besides lead. A complete chemical analysis of the mineral has been made on the small amount of material that could be spared for the purpose, by Mr. Herman Schlundt in the Chemical Laboratory of the University of Wisconsin. The results obtained in the analysis are given below in column I. Under II are given the calculated per cents of PbO and CO_2 in cerussite, and under III a recalculation of the analysis after deducting the silica, iron, and alumina which are derived from the gaugue at the point of attachment of the crystals, and which could not be mechanically separated without too much loss of the valuable material.

	I.	II.	III.
PbO	80·83	83·52	83·90
CO_2	15·51	16·48	16·10
Fe_2O_3 (and Al_2O_3)	·55	----	----
SiO_2	2·15	----	----
S	trace.	----	----
Total	99·04	100·00	100·00

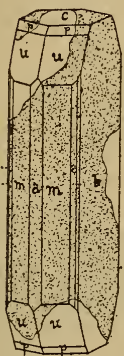
The substance was specially examined for other bases with negative results. The quantity of sulphur present was too small to be estimated in the quantity of substance available. The trace of sulphur and the excess of lead in the analysis over that in combination with CO_2 make it probable that the superficial coating on the crystals is galena.

Thanks to their metallic coating the crystals reflect well wherever it is present, though in other places they afford hardly a shimmer of light. By using a number of crystals complete measurement has been possible. The more important angles were measured a considerable number of times on different crystals. The observed forms are the following: *m*, ∞P (110); *a*, $\infty \bar{P} \bar{\infty}$ (100); *r*, $\infty \grave{P} 3$ (130); *b*, $\infty \breve{P} \breve{\infty}$ (010); *c*, oP (001); 𝔲, $\frac{3}{2}P$ (332); *p*, P (111); and 𝔟, $\infty \breve{P} \frac{8}{3}$ (380); the last mentioned form being, I believe, new to the species. These forms were determined by the following measurements:

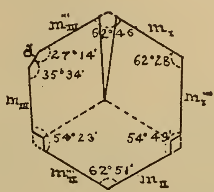
		Measured.	Calculated.
$m \wedge m$	$110 \wedge 1\bar{1}0$	62° 47′	62° 46′
$m \wedge r$	$110 \wedge 130$	29 10	29 58
$r \wedge b$	$130 \wedge 010$	28 43	28 39
$m \wedge b$	$110 \wedge 010$	58 32	58 37
$m \wedge a$	$110 \wedge 100$	31 19	31 23
$m \wedge$ 𝔲	$110 \wedge 332$	25 51	25 39
$m \wedge p$	$110 \wedge 111$	34 33	35 46
$m \wedge c$	$110 \wedge 001$	89 57	90 0
$m \wedge$ 𝔟	$1\bar{1}0 \wedge \bar{3}80$	31 19	31 35
$m \wedge \underline{m}$	$110 \wedge 110$	54 35	54 28
$m \wedge \underline{m}$	(over gap)	62 48	62 47
$m \wedge \underline{a}$	$110 \wedge 100$	27 15	27 14

With the exception of the face *p*, which is small, the reflections are good. Figure 1 illustrates the habit of an individual on which all the forms observed are represented. However, most of the crystals are stellate twins composed of three or more individuals. Figure 2 shows a cross section of such a twin composed of three individuals cut parallel to the basal pinacoid.

1.



2.



As the galena layer is nowhere found on the gangue material but occurs only on the surface of the cerussite crystals, it is clear that its formation is due to alteration of the cerussite by removal of carbon dioxide and addition of sulphur, probably through the action of sulphuretted hydrogen. It is therefore an *Umhüllungspseudomorphose* after cerussite. The pseudomorphs of calcite after cerussite from Grube Kautenbach bei Bernkastel show in cross sections a paper-thin layer of galena, which according to Blum* was formed on the surface of cerussite crystals. Calcite has been deposited over this and, after the removal of the cerussite, under it also. The Bernkastel pseudomorphs would thus seem to have been, in their first stage of alteration from cerussite, identical with those which are here described from near Missoula.

2. *Barite and Manganite from the Lucy Mine, Negaunee, Mich.*

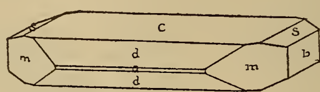
In the spring of 1894, Mr. J. R. Thompson of Ishpeming, presented to the Museum of the University of Wisconsin some large specimens of barite and manganite. They were taken from the Lucy mine, formerly the McComber mine, at Negaunee, Michigan. This mine is located in the S. W. cor. of Sec.

*Blum, Pseudomorphosen, iii, p. 212. Cf. also Roth, Allgemeine u. Chemische Geologie, i, p. 188.

6, T. 47 N., R. 26 W., and is on the same vein as that portion of the Jackson mine in which manganiferous iron ore has been found. Well-crystallized manganite has been found in the Jackson mine and has been described by Professor E. S. Dana.*

Barite.—The barite from the Lucy mine is fairly well crystallized but the tabular crystals are arranged radially to the *b* axis. They average from one to two centimeters in length in the direction of the macrodiagonal, the habit being lath-shaped in this direction with the base the tabular plane. The forms observed are *c*, oP (001); *m*, ∞P (110); *a*, $\infty\bar{P}\bar{\infty}$ (100); *d*,

3.



$\frac{1}{2}\bar{P}\bar{\infty}$ (102); *b*, ∞P∞ (010); and *S*, $\frac{1}{4}$P∞ (014)? Particularly in the zone of *c* and *a* precise measurements are of little value owing to the radial intergrowths of individuals, and hence the determination of *d* is only approximate. In the zone of *c* and *b* the following measurements were made:

		Measured.	Calculated.
$c \wedge b$ -----	$001 \wedge 010$	90° 6′	90° 0′
$c \wedge S$ -----	$001 \wedge 014$	17 12	18 12

The prism is easily determined to be the fundamental one *m* by being found parallel to the second cleavage.

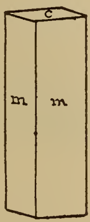
The crystals appear pink but the color is only superficial and is probably due to manganese, as the barite is associated with an ore of manganese. Figure 3 shows the usual development of the crystals.

Manganite.—The manganite from the Lucy mine is in quite simple crystals, those which are most intimately associated with the barite crystals being bounded simply by the fundamental prism and the base. The prism angle was measured by reflection and found to be 80° 4′, the calculated value being 80° 20′. These crystals are of columnar habit, 5–8^{mm} long, and usually of later formation than the barite. Other specimens of the substance less intimately associated with barite show crystals of a slightly different habit, the obtuse prism angle being truncated by the macropinacoid which has a large development. Rounding of the edge $a \wedge m$ and of the basal plane indicate the occurrence of indeterminate macroprism and brachydome. Figures 4 and 5 represent the type of manganite crystals from this locality.

* System of Mineralogy, 6th Ed., pp. 248 and 249.

An analysis of this mineral has been made by Mr. Herman Schlundt, Assistant in Chemistry at the University of Wisconsin, with the results given below in column I. In column II is given the theoretical composition of manganite and in column III the recalculated analysis with barium, calcium and magnesium, and hygroscopic water deducted.

4.



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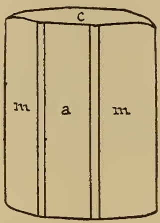


	I.	II.	III.
Mn	60·29	62·42	62·36
H_2O (Hygroscopic)	·06	----	----
H_2O (Combined)	10·04	10·24	10·39
$BaCO_3$ and $CaCO_3$	·58	----	----
$MgCO_3$	2·98	----	----
O (Calculated)	26·35	27·34	27·25
Total	100·30	100·00	100·00

A specimen of manganese ore from the Bonnie mine, Michigan, recently donated to the University of Wisconsin by John E. Burton, Esq., of Milwaukee, is quite pure manganite. A portion of the specimen exhibits rounded orthorhombic crystals not unlike the Lucy mine crystals, but these are less perfect and altogether unsuited to measurement.

3. *Chloritoid from blocks on the South Shore of Michigamme Lake, Michigamme, Mich.*

This mineral is included in specimens of a phyllitic schist which were collected by Dr. Van Hise from blocks on the south shore of Michigamme lake, Michigamme, Michigan. The blocks are very abundant and are often as large as a good sized room. Professor Van Hise feels sure that the rock will be found *in situ* in the near vicinity of the blocks, probably in the bed of the Michigamme river.

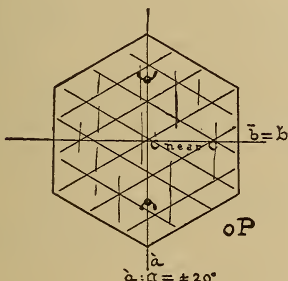
Thin sections of the rock show it to be largely made up of a colorless mica in fine scales, through the mass of which are distributed large flakes of biotite. The latter are not arranged with reference to any particular direction, but sometimes assume radial groups. They are many times the size of the muscovite scales and are probably like the chloritoid metamorphic in their origin. A few acicular crystals of black tourmaline from a third of a centimeter to a centimeter in length occur in the mass of the rock and also as inclusions in the large chloritoid crystals. Irregularly outlined masses of magnetite are likewise to be found both in the chloritoids and in the matrix of the rock, but those which are included in the chloritoids are surrounded by a zone of quartz, which was probably formed at the same time as the chloritoid as one of the products of the recrystallization of that portion of the rock now occupied by the large crystals of chloritoid and its inclusions. Besides the large porphyritic chloritoids, which are at times six centimeters or more across, a few small blades are disseminated like the biotite through the rock mass.

The porphyritic crystals of chloritoid are tabular parallel to the base, of hexagonal outline, and are on an average about one-third as thick as they are long or broad. Their hardness is between five and six of Mohs's scale. That they are generally twinned is seen in the examination of the hand specimen by the variation in the position of the plane of basal cleavage in different parts of the same crystal. In at least one specimen the twinning line is straight and runs parallel to one of the lateral faces ($\infty P \breve{\infty}$). Before the mineral had been examined in section and the nature of its enclosures had been determined, a specimen was submitted to Mr. Louis Kahlenberg of the Chemical Laboratory of the University of Wisconsin for chemical analysis. His results, which are given below, are therefore much affected by the included quartz and magnetite, which might have been excluded by treatment with the magnet and dissolving the residue as far as possible in sulphuric acid. The results are, however, sufficient to determine the mineral as chloritoid and are nearly identical with an analysis by Jackson of masonite from Natic, R. I., which like this was probably impure from admixed quartz and magnetite.

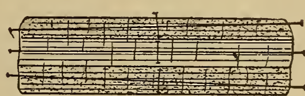
SiO_2	35·52
Al_2O_3	29·53
Fe_2O_3	5·85
FeO	22·38
MgO	0·76
CaO	1·38
H_2O	5·94
P_2O_5	trace.
Total	101·36

To determine the optical properties of the mineral a large twinned crystal was sawed so as to make three thin sections; the first parallel to the basal cleavage of a considerable part of the crystal (oP), the second normal to this section and parallel to the noticeable straight twinning line and its parallel edge $(\infty P \breve{\infty})$, and the third normal to the first two sections $(\infty P \bar{\infty})$. From an examination of these sections it was determined that the mineral is either monoclinic or triclinic with a close approach to monosymmetric character. The basal cleavage is very perfect and a second distinct cleavage runs parallel to either a steep pyramid or a prism, for the two directions are inclined about 120° to one another and about 90° to the base. A third irregular cleavage follows the clinopinacoid. The index of refraction is high and the double refraction very low. The

6.



7.



$\infty P \bar{\infty}$

plane of the optic axes bisects (nearly) the obtuse angle of the cleavage and the positive bisectrix (probably obtuse) is nearly normal to the base. The absorption is:

$\mathfrak{a}$ olive green to greenish gray.
$\mathfrak{b}$ deep robin's egg blue.
$\mathfrak{c}$ light yellow green.
with $\mathfrak{b} > \mathfrak{a} > \mathfrak{c}$

The crystal is polysynthetically twinned so that the "orthopinacoidal" section afforded lamellæ corresponding to three positions—one of which has parallel extinction, and the other two have extinction angles of 14–24° on opposite sides of the basal cleavage lines (see Fig. 5.) This corresponds to the Tschermak law where the individuals are inclined 120° to one another. These three sorts of lamellæ are also observed on the "clinopinacoidal" section.

4. *Apatite and Hessonite in a Pegmatite from Canaan, Ct.*

South of the Canaan Valley post office and east of the small stream known as the Whiting river in the township of Canaan, Ct., the gneiss of the district is cut by veins of pegmatite in which occur several crystallized minerals. As the locality has not been described the minerals of these veins may deserve a passing mention. The most abundant of these are a white feldspar which sometimes appears in crystals having dimensions of as much as eight inches, and a green or colorless muscovite in elongated hexagonal crystals measuring several inches on an edge. These muscovite plates frequently enclose quartz in bi-pyramidal crystals in form and size much resembling the well known quartzes from Edwards, N. Y. Biotite is less abundant than the muscovite and occurs in small black plates. Crystals and aggregates of black tourmaline as large as one's fist are not rare. A cinnamon-colored garnet is found sometimes in distinct crystals as much as a half-inch in diameter, sometimes intergrown with the feldspar so as to produce a structure resembling graphic granite. One crystal of green apatite was found which was over two and a half inches in length and an inch in diameter. It was broken in removing from the rock, but the fragments show the crystal to be bounded in the prism zone by both the first and second order prisms in about equal development. A more careful examination of the locality would perhaps reveal other minerals.

Art. XV.—*Calaverite from Cripple Creek, Colorado;* by W. F. Hillebrand.

The occurrence of tellurium in the ores of the mining district of Cripple Creek, Colorado, has been known from an early day in the as yet brief industrial history of that region. That it was, in part at least, associated with gold was likewise known from the observance of a crystallized gold-tellurium mineral. Although the ores of the district are chiefly gold carriers, they contain also a little silver, and since recognized silver minerals had not been observed, or at most only in minute amount, it seemed probable that the silver was associated with the gold in the tellurium compound. Indeed, Mr. R. Pearce, of Denver, came to the conclusion, from his examination* of certain ore concentrates, that this mineral was sylvanite. It is, however, of very sparing occurrence, so that it was

* Proc. Colo. Sci. Soc., Jan. 8, and April 5, 1894.

only by dint of much effort that material in sufficient purity for decisive tests was obtained by Prof. R. A. F. Penrose, Jr., who transferred it to me for chemical examination. The material was derived from three different mines in order to ascertain whether it was of constant or varying composition, or, in fact, whether there might not be more than one specific telluride. That the composition does vary within narrow limits the analyses show, but there is no reason apparent for assuming more than one species.

The material from the Prince Albert mine, the first received, was with little trouble brought into an almost ideal condition of purity. It was in part apparently fairly well crystallized, but the measurements made by Prof. S. L. Penfield, of New Haven, are unfortunately not decisive as to the system of crystallization, as shown by his notes at the close of this paper. The specific gravity of this material was 8·91 at 24° C., which becomes 9·00 when corrected for a small admixture of silico-ferruginous gangue of assumed specific gravity 2·70 (probably low). The other samples were imperfectly crystallized and held too much foreign matter of uncertain composition to make specific gravity determinations of any value.

ANALYSES OF CALAVERITE.

	I. Prince Albert Mine.	II. Raven Mine.	III. C. O. D. Mine.
Tellurium (Te)	57·27	47·69	53·89
Gold (Au)	38·95	33·93	39·31
Silver (Ag)	3·21	1·47	·85
Insoluble	·33	5·80	·91
Ferric oxide (Fe_2O_3)	·12*		
Iron (Fe)		5·41	1·67
Sulphur (S)		6·17†	1·58 (2·96 FeS_2)
Manganese (Mn)			·23‡
Calcium (Ca)			·51
Magnesium (Mg)			·10
Oxygen, Fluorine and Soluble Silica by difference			·95§
	99·88	100·47	100·00

Selenium has been reported to occur in traces in the district,‖

* This was included with the insoluble matter in arriving at the corrected density.

† Calculated from the Fe to make FeS_2.

‡ As MnO_2?

§ A part of the calcium found in solution was derived from fluorite, which likewise constituted some of the insoluble matter in this instance.

‖ F. C. Knight, Proc. Colo. Sci. Soc., Oct. 1, 1894.

but it could not be detected in the amount of mineral taken for the above analyses.

Excluding everything but gold, silver, and tellurium and recalculating to 100, the following comparison is obtained :

	I.	ratio.	II.	ratio.	III.	ratio.
Te	57·60	2·01	57·40	2·05	57·30	2·09
Au	39·17	1·00	40·83	1·00	41·80	1·00
Ag	3·23		1·77		·90	
	100·00		100·00		100·00	

The ratio here obtaining is that for sylvanite and calaverite, but the very low percentage of silver shows that the mineral is calaverite. Indeed the first analysis agrees almost exactly with Genth's analyses of the species. Interesting is the slight variation in the ratio between gold and silver, and the very low percentage of silver in the mineral from the C. O. D. and Raven mines. Calaverite, the lowest silver carrier of the gold-silver tellurides, has not heretofore been known to carry less than three per cent of silver.

The pyrognostic characteristics of the mineral from the Prince Albert mine were essentially those ascribed to calaverite. In the closed tube it fuses, giving a white coating near the assay, and a globular gray coating just above, which latter by strong heat can be in part driven higher up, leaving the glass covered with the same white fused coating as lower down. This latter is yellow while hot. On charcoal the mineral fuses with a green flame, giving a white coating and similar fumes, and leaving a yellow bead. The color is pale bronze-yellow, in powder greenish gray. The hardness is not less than and perhaps a little over 3. Specific gravity, as given above, 9·00.

The identity of the telluride occurring at Cripple Creek, which in oxidizing gives free gold and oxidized tellurium compounds* seems thus satisfactorily established, but unless there is another richer in silver the mode of occurrence of the silver in some of the ores is still in large part unaccounted for. It may be derived from a very rich argentiferous tetrahedrite of which Prof. Penrose submitted a small specimen for identification. This carries over eleven per cent of silver, but is said to be excessively scarce and therefore hardly to be considered in this connection, unless indeed this should have been the original source of most of the silver and later have suffered

* From tests made by myself on a number of specimens collected by Prof. Penrose the combination seems to be chiefly if not altogether with iron, but whether as tellurite or tellurate could not be ascertained.

oxidation to a great extent whereby the silver has become more evenly distributed throughout the ore.

Professor Penfield has kindly contributed the following notes on the crystallography of the mineral:

"The crystals of calaverite which were examined were developed with prismatic habit, but the prismatic zone was striated to such an extent that it was impossible to identify a single face in the zone, and on the reflecting goniometer almost an unbroken band of signals was obtained in a revolution of 360°. Owing to oscillatory combinations the crystals were also much distorted, so that they did not present regular cross sections.

The prisms were attached so that doubly terminated ones were not observed, while the faces at the free end were small and developed with so little symmetry that after a study of a number of crystals it was found impossible to determine with certainty the system of crystallization.

The crystals do not exhibit the perfect cleavage ascribed to sylvanite and krennerite, but are similar to the former in some of their angles. When placed in position to show their relation to sylvanite they have their prismatic development parallel to the *b* axis. One crystal, which owing to its development was more carefully measured than any of the others, was apparently a twin about 101, and showed at the end the forms 111 and 110. The measurements compared with the corresponding ones of sylvanite are as follows:

		Sylvanite.
111 $\wedge$ (111) over twinning plane	93° 35′	94° 30′
110 $\wedge$ (110) " " "	35 2	34 43
110 $\wedge$ 111	36 35	37 3
110 $\wedge$ 111 in twin crystal	36 33	37 3

Other forms which were measured could not be referred to the sylvanite axes, and it seems probable from their development and lack of symmetry that the crystals are triclinic; but no satisfaction was obtained after a long and careful study of the limited supply of material on hand.

In conclusion, therefore, it may be stated that the crystals are probably triclinic, but near sylvanite in angles and axial ratio."

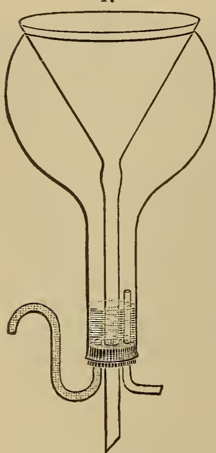
Laboratory of the U. S. Geological Survey, Washington, D. C., May, 1895.

Art. XVI.—*Notes on Convenient Forms of Laboratory Apparatus;* by D. Albert Kreider.

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

Hot Filter.—A convenient and satisfactory hot filter, so indispensable in many laboratory processes, may be easily improvised whenever steam is available, in the form which appears in fig. 1. It is always ready; hot at a moment's notice, and without a flame to endanger the filtration of combustible substances. The encasement for the funnel is made by removing the bottom of an ordinary flask of suitable size in the well known way of starting the crack with a scratch of a file and then directing it by applying a piece of iron heated to redness. Flasks unfit for other purposes may be utilized in this way and they are more serviceable than large glass funnels, because of the tendency of the latter to crack if cold when the steam is turned on. The neck of the flask is closed by a stopper containing perforations for the funnel, steam and waste tubes; the latter of which, in the absence of a drain pipe, may lead to any convenient receptacle. By prolonging the conducting tube of the steam somewhat above the level at which the condensed water is drawn off, higher temperature will be attainable and spattering avoided. Escape of steam with the water is prevented by the turn in the waste pipe. When steam taps are not accessible, steam may be applied from a wash-bottle.

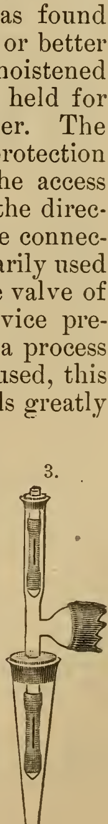
1.



2.

Valve.—In forcing a liquid or gas indifferent to rubber from one vessel to another, the ordinary Bunsen valve is apt to collapse in such a way as to permit a back flow. I have found that a stout glass tube of desirable size, sealed at one end and drawn out with an opening in the restriction, as indicated in figure 2, and a piece of rubber tubing containing a smooth slit placed over it, makes a valve in which collapse is impossible, and the power of which increases with the pressure to be overcome. That a valve similar in appearance to the one here described has been used, is not unknown to me: but the similarity is confined to the appearance, as will be evident from the following description: The restriction should not be greater than is necessary to leave a small space between the tube and the rubber when the latter is loosely drawn over it: but in order to work easily, should be long enough to permit a slit of about a centimeter's length to close tightly, which will require it to be about twice the length of the slit. A slit one centimeter long will be found to open under very slight pressure, and to accomplish its purpose it is only required to close sufficiently for the external pressure to force the rubber against the opening in the tube. This opening should be carefully rounded and a little higher rather than any lower than the surrounding glass, and is better made before sealing the end, in order to keep the tube perfectly straight. The rubber should fit tightly about the larger parts of the glass tube and be put on with care to have the smoothly cut slit straight and loose enough to close tightly. If the slit is placed about 90° from the opening in the tube, sufficient space will remain to permit the escape of the gas or liquid, but the moment the pressure outside becomes greater than that within, the rubber will be pressed tightly over this opening and thus a return made impossible. When dry the valve was found not to resist high pressure perfectly; but when wet, or better when both glass and rubber, including the slit, were moistened with glycerin, a column of mercury 730^{mm} high was held for several days without changing more than the barometer. The valve thus lubricated with glycerin when used as a protection in an ammonia wash-bottle, will prevent absolutely the access of ammonia to the mouth, and if made according to the directions will act with very little pressure. Placed in the connection between the vacuum flask and water pump ordinarily used in filtration, it has been found a valuable check on the valve of the pump, and when the latter was impotent this device prevented any water being drawn into the filtrate. In a process soon to be published, in which a partial vacuum is used, this valve holds the vacuum in continual readiness and adds greatly to the convenience of the process.

3.



Force Pump.—By adjusting two of the valves just described to the opposite extremities of a T-tube, with the horizontal limb enlarged or sealed to a larger tube so as to permit the attachment of a large and stout piece of rubber tubing closed at one end, as shown in fig. 3, a convenient and powerful little force pump is obtained. A small bore, stout T-tube is cut off short at the two ends at right angles to one another: to one is sealed a tube just large enough to permit the insertion of a valve; to the other, a large tapering tube, slightly lipped so as to hold a piece of rubber tubing firmly and allow of tying the latter if necessary. Of the third end of the tube, a valve like that shown in fig. 2 is made. The compressing rubber should not be of greater length than the hand is able to cover completely and may be closed with a glass stopper selected to fit tightly. Providing the space through the T-part is kept at a minimum compared with that of the compressing rubber, rapid pumping will be found possible and the power limited only by the strength of the user's grip. A column of water was quickly raised and forced from the top of a tube sixteen feet in length. The apparatus will be found convenient in the absence of a regular pump and can be quickly constructed of materials always at hand. Originally it was made, in about fifteen minutes, of a T-tube to which the necessary enlargements were connected by rubber tubing and the unused space filled by a glass rod. The valves may be inserted directly into the ends of the compressing rubber, but the form shown in the figure will be found more serviceable. By attaching the lower end to a tapering tube as shown, the pump is easily inserted into any sized perforation of a stopper and adds greatly to its convenience.

The pump has been found serviceable in various applications. For filling burettes it will be found more advantageous than the siphon plan. The standard solution bottles are fitted with two-holed stoppers from one of which a tube of sufficient length is bent so as to reach into the burette. The pump can be applied to various bottles by the adapter shown in the figure and the solutions forced into the burettes. To prevent any evaporation in the tube a glass stop-cock may be inserted. On several occasions it has been applied to a Kipp generator in which higher pressure was momentarily required. In various other ways it has been found a useful piece of apparatus.

ART. XVII.—*Contributions from the Gray Herbarium of Harvard University, New Series, No. IX;* by B. L. ROBINSON and J. M. GREENMAN.

I. *On the Flora of the Galápagos Islands, as shown by the collection of Dr. G. Baur.*

WHILE exploring the Galápagos Archipelago in the summer of 1891, Dr. George Baur secured, besides zoölogical specimens, a large collection of plants. The latter have recently been determined at the Gray Herbarium and for various reasons possess considerable interest. They furnish in several cases more copious material of hitherto imperfectly known forms and, as is to be expected, contain a certain number of new species. Furthermore Dr. Baur visited not only all the islands hitherto explored but extended his collecting to no less than eight others, from which, so far as can be learned, no plants have been secured, or at least reported. It is well known not only that the archipelago possesses a peculiar and remarkable vegetation, but that the different islands exhibit in their floras a striking individuality. It has been accordingly a matter of interest to compare the forms of the newly explored islands with those of the others for some time known through the collections of Darwin, Edmonstone, Macræ, Douglas, Scouler, Andersson and Agassiz.

While upon some of the smaller islands Dr. Baur collected only a few species, enough material is at hand not merely to confirm strongly the view that almost every island has its peculiar species and varieties, but to show clearly that even plants, which must pass as the same species, often exhibit, when found upon several islands, more or less striking racial differences. These facts, while in other respects noteworthy, derive a special interest from their relation to the probable origin of the flora of the group. Regarding the fauna Dr. Baur has in several recent articles called attention to peculiar harmonic relations existing between the forms of the different islands, and has argued from zoölogical grounds that the islands must at one time have been united, not only with each other but with the mainland near Central America. This view has been severely criticised by several writers, but no one has attempted to account for the peculiar distribution of differing, yet closely related forms upon the islands, and as the subject is one which merits further attention, it seems worth while to present the botanical data in some detail.

Perhaps no species to be found upon the different islands better illustrates the noteworthy racial divergence in related forms than *Euphorbia viminea* Hook. fil. This species differs markedly in foliage from any other known member of this large genus, and is characteristic of the Galápagos Archipelago. Being essentially a desert plant, it can subsist even upon those islands of the group which are of low altitude and do not attain the upper regions of moister atmosphere. It was first collected by Macræ upon Albemarle, rediscovered by Andersson on Charles Island, and has now been collected by Dr. Baur upon the following islands: Barrington, Chatham, Southern and Eastern Albemarle, James, Jervis, Bindloe, Tower, and Abingdon. Even the most cursory inspection of the forms from these different islands discloses marked variation in the contour, size, thickness, rigidity, and color of the leaves, as well as in the length of the internodes, color of the stems, etc., while more careful examination shows that these are not mere individual differences, due to chance, state of development, or individual environment, but each form appears in general to be restricted to a single island. Some forms, such as those of Abingdon and Tower Islands, differ rather strikingly from the rest, while others present slighter differences; in a few cases so slight, that a series of careful measurements is necessary to demonstrate their existence. But the examination of a considerable number of specimens, such as those secured by Dr. Baur, shows that the species, as it occurs upon each island, differs in some characteristics, slight or more considerable, from the forms of all or nearly all of the other islands, and furthermore each island appears to have *only one* form of its own.

The question at once presents itself, if this archipelago is composed of islands of elevation, built up from the sea-floor independently by volcanic action, how has such a distribution been effected. If the vegetation has been derived from the mainland by the chance transportation of seeds, it is quite impossible to believe that each island has received a slightly different form of the same species, and we are forced to the much more natural assumption that racial and varietal divergence has come about after the introduction of the species upon the islands. Now, continuing the supposition that these are islands of elevation, the seeds of *Euphorbia viminea* must have reached them in one of two ways; either each of the nine islands, where we know the species now to occur, must have received its seed directly from the mainland or, what is much more natural, seed must have reached one or more of the islands and from these spread to the rest. That the same species should have reached all these islands presupposes a considerable facility of transportation. But as soon as this is granted it is impossible to understand the highly individual development of the forms upon the different islands. For relative or complete isolation seems necessary to account for the racially divergent floras of the islands; and especially for the occurrence of only one form upon each island. It would thus appear necessary, in accounting for the present distribution, to assume that at one time in the remote past the islands were either united, or at least that the channels which separate them were less formidable barriers to seed-transportation than at present, so that a general distribution of species could have been effected; and that subsequently, as the islands separated, or as the channels through some change of currents, or other cause, became less easily passed, an era of *much* greater isolation of the floras of the different islands came about. The divergence of character of the vegetation would then begin at once and the otherwise unaccountable existence of a single and peculiar form upon each island would be readily intelligible.

While not prepared to make any positive assertion regarding the probable origin of the islands, the authors fail to see in the hitherto generally accepted theory of elevation any satisfactory explanation for the harmonic yet divergent floras of the different members of the group. Upon Dr. Baur's assumption of a former union between the islands, and subsequent separation by subsidence, not only is explanation possible, but the existing flora of the archipelago is just that which would most naturally result from such an origin. A former union of the islands would account at once for the occurrence of identical ancestral species upon the different members of the group, and the subsequent separation give the needed isolation for varietal and racial divergence, while the latter could not have come about if a continual interchange of seed were taking place from island to island.

Regarding a former land-connection with the continent, which would certainly offer much greater geological difficulties, the botanical evidence is still too vague to merit regard. The affinities of the vegetation of the upper, moister portions of the islands are doubtless, as has been assumed, with the floras of Columbia, Central America, Southern Mexico, and the West Indies, while much of the desert flora of the lower regions has doubtless been derived from the arid regions of Chili and Peru. But so far as botanical data are concerned this could have come about either by migration by land or by transportation by oceanic currents and, as the latter still exist, it seems unnecessary to assume the former. However, upon this point the evidence from the vegetation appears to be still wholly indecisive.

The harmonic relation of the floras of the different islands, which, as we have seen, appears to have such an interesting bearing upon the former possible connection of the islands with each other, is shown not only by *Euphorbia viminea*, but by various other endemic species and groups of species of the same and other genera and orders.

All the Galapageian species of *Euphorbia* for instance, with the exception of *E. amplexicaulis* Hook. fil., form a closely related group, doubtless having a comparatively recent common ancestry; but most of these forms are characteristic of particular islands. The same is eminently true of the different species of *Acalypha*. The *Borreriæ* of the Galápagos Islands also form, for the most part, a close group of very nearly related species, or perhaps better, varieties of one polymorphous species, all of which have probably diverged from a uniform parent stock after the separation of the insular floras from that of the mainland and from each other. Here, however, we find in some instances the same form upon two or more of the islands, as though transportation of the seed had offered somewhat less difficulties than in the case of *Euphorbia viminea*. The peculiar interest which attaches to the individual occurrence of these nearly related forms of various groups upon the different islands, certainly warrants the publication of the following more detailed descriptions and complete list of Dr. Baur's plants.

The forms of *Euphorbia viminea* Hook. fil. are as follows:

Forma Albemarlensis (typica). Internodes 4 to 5½ lines long: leaves of the stem and of the slender elongated branches 2 to 5½ lines long, half line broad, reddish in the dried state and usually paler beneath, linear with dilated rounded rarely retuse tip; margins except near the apex strongly revolute; leaves of the fascicles and scarcely developed branchlets similar but only 1 to 2 lines long and more distinctly retuse at the apex.—Albemarle Island; collected first by Macræ, and again by Dr. Baur on the southern end of the island in July, and on the eastern side in August, 1891.

Forma Jacobensis. Internodes 3 to nearly 6 lines long: leaves of the stems and branches 3 to 6 lines long, half a line broad, scarcely dilated at the apex; fascicled leaves as in the preceding. —Collected by Dr. Baur near Orchilla Bay, James Island, 1891. Distinguished from the last by its slightly longer and less dilated leaves.

Forma Castellana. Internodes 2½ to 4 lines long: leaves of stem and branches 3 to 4 lines long, three-fourths lines broad; a line in width at the dilated apex, truncate and retuse, much firmer and thicker than in any of the other forms, very pale above, whitened beneath; fascicled leaves very short, 1 to 1½ lines long. —Collected on Tower Island, by Dr. Baur, September, 1891.

Forma Chathamensis. Internodes from 3 to 5½ lines long: leaves of the stem and branches 4½ to 7 lines long, half line broad, slightly dilated at the truncate or often retuse tip, pale in the dried state; fascicled leaves numerous, $1\frac{1}{2}$ to 3 lines long, retuse.—Collected on Chatham Island, lower region, southwest end, by Dr. Baur, June, 1891.

Forma Carolensis. Internodes from 3 to 5 lines long: leaves of the stem and branches 5 to $10\frac{1}{2}$ lines long, narrowly linear, not at all dilated but merely rounded at the tip, more slender petioled than the preceding forms.—Collected on Charles Island, by Andersson, 1852.

Forma Barringtonensis. Closely approximating forma *Albemarlensis* but having leaves commonly longer, 6 to 12 lines in length.—Collected on Barrington Island, by Dr. Baur, July, 1891. Essentially the same form, although much paler, in the dried state, was collected on Bindloe Island by Dr. Baur, September, 1891.

Forma Jervensis. Internodes $3\frac{1}{2}$ to 6 lines long: leaves of the stems and branches narrowly linear, slightly dilated at the tip, 8 to 13 lines long, half a line broad; the fascicled leaves few and much shorter.—Collected on Jervis Island, by Dr. Baur, 1891. Chiefly distinguished from the other forms by its long narrow leaves, which in the dried state are very pale.

Var. Abingdonensis. Internodes from 5 to 10 lines long: leaves of stem and branches 10 to 15 lines long, linear spatulate, very gradually dilated, half a line broad near the base, $1\frac{3}{4}$ lines broad toward the rounded and indistinctly apiculate apex, pale above, whitened beneath.—Collected on Abingdon Island, by Dr. Baur, 1891. This form is so well-marked as to merit varietal rank.

In specimens of *Euphorbia articulata* Ands., collected on Charles, James, Albemarle and Bindloe Islands, no satisfactory formal or racial differences could be detected. The Acalyphas, with the exception of the new *A. Baurii*, belong to a small group of closely related forms, regarded by Andersson as species; but by Müller Arg. these so-called species are reduced to six varieties of *A. parvula* Hook. fil. From accounts of previous collectors and from numerous specimens in Dr. Baur's collection, it appears that none of these species, as distinguished by Andersson, have a general distribution; while *A. reniformis* Ands., *A. diffusa* Ands., and the typical *A. parvula* Hook. fil. are each confined to a single island. The other species in essentially the same form occur upon two or more islands.

In *Amarantus sclerantoides* Ands. a racial variation has been noted similar to that in *Euphorbia viminea*. The type of the former was collected on Charles Island by Andersson and has narrow linear leaves $3\frac{1}{2}$ to 8 lines long, scarcely a line broad, somewhat dilated at the apex. Two forms collected by Dr. Baur upon Chatham and Hood Islands differ perceptibly in foliage as follows :—

Forma Chathamensis. Leaves shorter and broader at the tip, 2½ to 5 lines long, a little over a line broad at the apex.—Collected on Chatham Island, lower region, southwest end, June, 1891.

Forma Hoodensis. Somewhat nearer to the above form than to the type but with leaves less dilated at the tip.—Collected on Hood Island, July, 1891.

Besides the forms mentioned, Dr. Baur's collection contains the following new or otherwise noteworthy species:

Hydrocotyle umbellata L. A form apparently of this species was collected in the upper region of Chatham Island at the southwest end, June, 1891. It differs from the typical form only in its shallowly repand dentate rather than crenate leaves.

Borreria Baurii. Slender, ascending: stems weak, a foot or so long, branched, terete, slightly woody at base, covered with a grayish cortex below; branches ascending, finely puberulent or nearly glabrous, 4-angled; internodes much exceeding the leaves: the latter sessile, spreading, ovate to ovate-lanceolate, acute, hispid-ciliate on the revolute margins, slightly scabrous or quite smooth above, paler and almost or quite glabrous beneath, 2½ to 3½ lines long, ¾ to 1½ lines broad, acutish and with short pungent mucronation: flowers minute, 3 or 4 in each of the axils of the upper leaves: calyx teeth ovate, acute, hispidulous, erect in fruit, a little exceeded by the corolla: lobes of the latter recurved: throat pubescent: fruit hispidulous: seeds black, strongly concavo-convex, finely pitted, shallowly and longitudinally channeled upon the dorsal surface.—Collected in the lower region of Chatham Island at the southwest end, June, 1891. Most nearly related to *B. ovalis* Ands.

Borreria Galapageia. Stems slender, ligneous, covered with roughish fuscous cortex; branches approximate, ascending, densely pubescent, leafy; internodes short but usually exceeding the leaves: the latter ovate-oblong, 2 to 3 lines in length, 1 to 1½ lines in breadth, with smaller ones fascicled in the axils, obtuse, covered upon both surfaces with dense grayish and somewhat scabrous pubescence; margins strongly revolute; midrib prominent beneath: flowers about 2 in each of the upper axils: calyx-lobes erect, acute, about equalling the corolla, rough-pubescent as is also the fruit.—Collected on Duncan Island, August, 1891. Apparently nearest *B. divaricata* Hook. fil.

Borreria Pacifica. Fruticose: stem terete, ligneous, covered with smoothish grayish brown cortex; branches many, elongated, ascending or widely spreading, mostly simple, with a close fuscous and scabrous puberulence, especially upon the four salient angles; internodes usually considerably exceeding the leaves: the leaves oblong-lanceolate, sessile, acute, mucronate, scabrous above, glabrous or nearly so beneath, 3½–6 (–8) lines long, scarcely a third as broad, and with smaller leaves fascicled in the axils; margins revolute; midrib prominent beneath; stipular sheaths with about 5 setaceous teeth upon each side: flowers 2 or 3 together in the axils: calyx-lobes lanceolate, acute, mucronate, 1 to 1½ lines long, about equalling the corolla: fruit with scattered grayish pubescence.—Collected on Indefatigable Island, south of Conway Bay, August, 1891.

The three species of *Borreria* here described were distributed as *Spermacoce Baurii*, *S. Galapageia*, and *S. Pacifica*, respectively.

Erigeron tenuifolius Hook. fil.? Specimens corresponding in most essential characters with Hooker's description (Enum. Pl. Galap., Trans. Linn. Soc. xx, 207), were secured on South Albemarle Island, July, 1891. The leaves, however, are 1½ to 3 inches long and ¾ to 1 line broad, being accordingly nearly twice as large as in the type. Furthermore the tubes of the disk flowers are glabrous. Without a comparison with the type it is impossible to say whether the present plant is identical with it or represents a species new at least to the islands.

An interesting but unfortunately sterile plant collected on Charles Island, is identical with the specimen of Andersson upon which it appears that Steetz based his description of *E. tenuifolius* in Andersson's Om Galapagos-öarnes Veg. 68. It is to be regretted that the present specimens are too imperfect to show the true position of this problematic plant, although they show pretty clearly that it is distinct from Hooker's species.

Acanthospermum lecocarpoides. Pubescent throughout and probably viscid: leaves ovate-oblong, irregularly laciniate or shallowly pinnatifid, with obtusely toothed segments, rounded sinuses, and tapering base, slender-petioled, 2 to 4 inches long: peduncles solitary in the forks, slender, 2 inches long: heads three-fourths inch or more in breadth; outer involucral scales about 4, ovate, acuminate, serrate or entire, 3 or 4 lines long, pubescent upon both surfaces; rays yellow, about 5, elliptic-oblong, minutely 3-toothed at apex: fruit (achene invested in inner bract) irregularly turbinate, somewhat compressed laterally, and developed dorsally, finely and densely pubescent and bearing near the summit 4 or 5 slender spreading straight or somewhat hooked spines: style with slender and spirally recurved branches: disk-flowers about 30, glabrous, with filiform empty achene, slender tube, ampliate throat, and 5-cleft limb: style filiform, entire: anthers subsagittate at base: chaff 1½ lines long, irregularly fringe-toothed at apex: disk conical.—Collected on Hood Island, July, 1891; said to be rare, at least upon this island. Although possessing all the important technical characters of the genus, this plant has more numerous disk-flowers than any hitherto known species. Both in this regard and in its outer involucre and foliage it bears a strong resemblance to *Lecocarpus*, a genus peculiar to the Galápagos Archipelago, doubtless nearly related, but with a very different and characteristic fruit.

Scalesia Baurii. Villous-pubescent: leaves pinnatisect to the middle, ovate in outline, acute, attenuate at the base, resinous-dotted, finely pubescent and slightly scabrous above, pubescent and somewhat villous upon the midrib beneath, 3 or 4 inches long, half as broad; segments about 7 pairs, irregularly toothed or again somewhat pinnatifid; petioles slender, about an inch long: peduncle solitary, slender, 1½ inches or more in length: head half inch or more broad; involucre campanulate: scales ovate, acutish, strongly pubescent on both surfaces: true ligulate flowers none, the marginal disk-flowers bilabiate and ray-like, bisexual; the others regular, 5-parted, pubescent on the outer surface of the tube: scales of the disk unequally 3-parted and strongly striate.—Collected on Duncan Island, August, 1891. Apparently near *S. incisa* Hook. fil., but differing from the description of that species in its slender peduncle and ovate acutish involucral scales.

Acnistus sp. Arborescent shrub: branchlets glabrous, covered with grayish bark, leaf-bearing at their ends: leaves obovate-elliptic, entire, rounded at the apex, 2 to 4 inches long, 1 to 1½ inches broad, attenuate at the base to slender petioles (half inch long), thin, bright green, puberulent and finely punctate above, paler and soft pubescent beneath: pedicels axillary, rather few in a fascicle, filiform, somewhat thickened toward their ends, spreading or pendulous, nearly an inch in length: calyx broadly cup-shaped, about 2 lines long and broad; the limb subentire: corolla funnel-shaped, about an inch long, externally pubescent; throat gradually ampliate; limb 5-lobed; lobes ovate, obtusish, ciliated: stamens inserted a little below the middle of the tube, included: stigma obscurely 2-lobed.—Collected on Chatham Island, June, 1891. Apparently near *A. ellipticus* Hook. fil., but differing in its pubescent leaves and in having a corolla about twice as long as described for that species.

Solanacea sp. Densely pubescent herb with habit, inflorescence, and foliage of *Datura:* leaves broadly ovate (in some cases broader than long), open cordate, shallowly sinuate-toothed, 2 to 3 inches in diameter, above green, glabrous or nearly so, under lens finely papillose-punctate, below pubescent upon veins, not paler; petioles pubescent, as long as the leaves: peduncles an inch or so long, axillary, solitary, 1-flowered, deflexed in fruit: calyx short-cylindric from an ovate base, densely pubescent, very obscurely angled, 4 to 5 lines long, persistent in young fruit; the limb of 5 erect unequal linear teeth: corolla funnel-formed; tube rather slender, 1½ inches long including the but slightly ampliate throat; limb spreading, very shallowly 5-lobed, inch in diameter: anthers longitudinally dehiscent: young fruit ovoid, smooth, 3 or 4 lines in length, loosely surrounded by the calyx.—Collected on Hood Island, July, 1891. A plant certainly new to the flora of the islands and of interesting, apparently somewhat anomalous generic affinities, possessing on the one hand the corolla, smoothish fruit, and more or less persistent calyx of *Nicotiana*, but the leaves, axillary inflorescence, and general habit of a *Datura*. Insufficient material prevents a more accurate disposition.

Verbena grisea. Densely and somewhat sericeously grayish tomentose, in parts brownish or ferrugineous in dried state: stem tetragonal, somewhat furrowed; internodes in specimens at hand considerably exceeding the leaves: the latter all opposite, petiolate, bipinnatifid, ovate or deltoid in outline, an inch or more in length; rhachis and segments very narrow, not a line in width, frequently curled, obtusish, so densely pubescent as to obscure completely the venation on both surfaces: inflorescence branched; flowers small, in slender loose elongating spikes; central spike floriferous almost from base; the others more or less pedunculate; bracts small, subulate, pubescent, $\frac{1}{3}$ to $\frac{2}{3}$ the length of the calyx: the latter cylindrical, a line long, hirsute-pubescent on the outer surface, 5-ribbed; limb very shallowly and obtusely 5-toothed: corolla nearly twice as long as the calyx, unequally 5-lobed, pubescent in the throat; segments rounded at the apex: anthers unappendaged.—Collected on Duncan Island, August, 1891. A species of § *Leptostachya* and with much the habit of *V. remota* Benth., but differing in pubescence and foliage.

ALTERNANTHERA RIGIDA. Fruticose, copiously and densely branched: cortex light yellow, lucid: branches opposite, rigid, spreading or divaricate; internodes short, glabrous or nearly so: leaves opposite and proliferous in their lanate axils, very small, subulate, pungent, entire, smooth and green, about two lines in length, three-fourths line in breadth at the sessile base: spikes capitate, ovate or oblong, terminal upon the branchlets, 4 to 6 lines in length, about 3 lines in diameter, bright white, slightly villous in the axils of the bracts, otherwise glabrous: bracts ovate, acute, two-thirds the length of the flower, white and scarious; bractlets 2, ovate-lanceolate, somewhat falcate, equalling the calyx: stamineal tube about as long as the antheriferous processes; sterile processes none: stigmas 2, erect, obtuse.—Collected on James Island, on Orchilla Bay, August, 1891. A noteworthy plant differing much in its erect firm habit and rigid subulate leaves from any species known to the writers.

FRŒLICHIA JUNCEA. Stem woody below, profusely branched above; branches opposite, ascending, slender, terete, finely striate, puberulent or glabrous; internodes elongated: leaves reduced to minute scales, scarcely half line long, ovate, acute, scarious toward the edges: inflorescence terminal, loosely spicate, slender and flexuous, 1 to $2\frac{1}{2}$ inches long; flowers sessile, scattered, solitary in alternate bracts; the lowest still more remote; bracts short, broader than long, obtuse, half line long, slightly if at all pubescent; bractlets broadly ovate, retuse, glabrous, scarious: calyx deeply 5-parted, in fruit ovoid, ribbed, slightly compressed, firm in texture, dark colored, a line long; divisions oblong-lanceolate, obtusish, scarious-margined: stamens included; anthers slightly exceeding the alternating obtusish sterile lobes of the stamineal tube.—Collected on South Albemarle and Barrington Islands, July, 1891. A species with the juncoid habit of *F. nudicaulis* Hook. fil., but differing much in its elongated scattered inflorescence, glabrous bractlets, etc. A doubtful and entirely sterile specimen was also collected on East Albemarle.

Euphorbia Galapageia. Ascending, a span high: stems slender, branching from near the base, terete, brown, under a lens finely and densely pubescent; cortex pealing off below; branches rather short, very slender, alternate, ascending: leaves opposite, glabrous, mostly erect, essentially entire, oblong, obtuse or roundish at the apex, obliquely cordate at the base, short-petioled, 3 to 6 lines long, half as broad, somewhat pellucid in the interstices of the veins; stipules minute, lanceolate, somewhat fringed: involucres alternately fascicled in the upper axils, on very short pedicels, very small, one-third line long; glands 4, unappendaged, not dark-colored: capsule ovate; cells finely crested upon their rather sharp dorsal keels, half line long; the three styles short, bifid; seeds yellowish-brown, finely sculptured.—Collected on Charles Island, June, 1891. A species with the habit of *E. flabellaris* Ands., but more slender: leaves mostly smaller, stem and fruit pubescent, glands smaller and not dark-colored, and styles much shorter.

Euphorbia nummularia Hook. fil. var. glabra. Glabrous throughout and somewhat glaucous: leaves nearly all unequally 2-lobed with an oblique sinus between the lobes: seeds slightly longer and a little more decidedly angled than in the type.—Collected at Cuevas Bay, Charles Island, July, 1891.

Acalypha Baurii. Herbaceous: stem and petioles densely pubescent-tomentose: leaves ovate, short-acuminate, rather regularly and somewhat doubly crenate-dentate, appressed-pubescent upon both surfaces, especially upon the veins beneath, 1½ to 3 inches long, two-thirds as broad, 5-nerved from the truncate or subcordate base; petioles ascending, 1 to 2 inches long; stipules small, subulate-setaceous: spikes axillary, slender, 2½ inches in length, androgynous; pistillate involucres commonly solitary, 2-flowered, sessile near the base of the spike, the slender staminate portion of the spike about a line in diameter, flexuous, loosely flowered below; rhachis densely grayish pubescent: bracts of the fertile flowers broadly ovate, somewhat unequally 9-dentate, cleft a third of the way to the base, villous, 2½ to 3 lines long, 4 lines broad: calyx deeply 3-cleft; segments ovate, acute, ciliate: styles laciniately many-cleft; capsule villous, nearly a line long; seeds ovate, very finely pitted.—Collected on the southwest end of Chatham Island, June, 1891. A single detached perhaps terminal inflorescence has several fertile involucres.

Aristida villosa. Annual: root a cluster of short delicate fibres: culms several, slender, ascending, nearly a foot in height; internodes minutely puberulent under a lens: blade of leaves thin, flat, narrowly linear, 2 to 5 inches long, 1 to 1¼ lines broad, also finely puberulent and slightly scabrous and hispid upon both surfaces; sheaths conspicuously silky-villous with soft white spreading hairs except near the base; the summit covered with more densely tufted hairs; ligules laciniately ciliate: panicles 1½ to 3 inches long, condensed and subspicate, 4 lines in diameter; lowest branchlets scarcely imbricated: sterile glumes nearly equal, lanceolate to linear, attenuate, shortly aristate, 3 lines long, closely puberulent, ciliate upon the keel; spreading aristæ of the flowering glumes 2 to 5 lines long; rhachis and rhachillæ finely puberulent.—Collected on Jervis Island, August, 1891.

Leptochloa Albemarlensis. Decumbent: culms 8 to 12 inches or more in length, slender, much branched, geniculate below; branches approximate, ascending; internodes glabrous, short: leaves somewhat scabrous; blade lance-linear, acute, divaricately spreading, 8 to 12 lines long, about a line broad; sheaths sparsely pilose with delicate white spreading hairs: panicle with slender alternate nearly divaricate branches (4 to 10 lines long); spikelets closely appressed, somewhat imbricated, $2\frac{1}{2}$ to 3 lines long, with about three perfect flowers and rudiment: sterile glumes somewhat unequal; the outer and larger one $2\frac{3}{4}$ lines long, acute, exaristate; flowering glumes $1\frac{1}{2}$ lines long, 3-nerved, slightly bifid and tipped with short awn, sometimes ciliate.—Collected on South Albemarle Island, July, 1891. From character this must be near *A. brachiata* Steudel.

The following is a complete list of Dr. Baur's plants. Those species which appear never to have been previously reported from the Archipelago are marked with an asterisk (*), and the new plants with a dagger (†). The Lichens have been determined by Miss Clara E. Cummings.

Names of Plants.	Chatham.	Charles.	Albemarle.	Hood	Duncan.	Indefatigable.	Jervis.	Barrington.	James.	Bindloe.
Cissampelos Pareira Linn.	×	×								
Drymaria cordata Willd. (=? *D. glaberrima* Bartl.)	×									
Polygala obovata Hook. fil. (forma *latifolia*)		×								
" *puberula* Ands.						×				
" *Galapageia* Hook. fil.	×	×	×							×
" *insularis* Bennett	×					×	×			
**Anoda acerifolia* DC.		×								
**Sida paniculata* L.		×								
" *rhombifolia* L.	×	×				×				
Abutilon Andersonianum Garcke. ?								×		
Gossypium Klotzschianum Ands.	×		×	×				×		
Waltheria reticulata Hook. fil.		×	×			×	×	×		×
Oxalis corniculata L.	×									
" *carnosa* Molina					×					
" *Agassizi* Rose		×		×		×				
Tribulus sericeus Ands.		×								
Xanthoxylon Pterota HBK.	×									
Castela Galapageia Hook. fil.	×	×	×		×		×			×
Maytenus obovatus Hook. fil.	×	×	×	×			×	×		
Discaria pauciflora Hook. fil.	×		×					×		
" sp.				×						
Cardiospermum corindum L.	×		×							
**Sapindus* (near *S. acuminatus* Willd.)			×							
**Dodonæa viscosa* Jacq.			×							
Spondias Edmonstonei Hook. fil.			×							

Names of Plants.	Chatham.	Charles.	Albermarle.	Hood.	Duncan.	Indefatigable.	Jervis.	Barrington.	James.	Bindloe.
Crotalaria puberula Hook. fil.	×									
Dalea parvifolia Hook. fil.		×				×			×	
" *tenuicaulis* Hook. fil.			×							
Tephrosia litoralis Pers.	×									×
**Stylosanthes scabra* Vog.		×				×	×			×
**Desmodium incanum* DC.	×									
" *molle* DC.		×		×		×	×			
* " *uncinatum* DC.	×									
* " *spirale* DC.										×
**Erythrina velutina* Willd.									×	
Phaseolus semierectus L.	×	×								
" *mollis* Hook. fil.							×			
Rhynchosia minima DC.								×		×
**Cœsalpinia Bonducella* Fleming			×							
Parkinsonia aculeata L.	×	×	×	×	×					
Cassia occidentalis L.	×									
Prosopis dulcis Kth.	×									
Neptunia Surinamensis Steud.	×	×				×	×			
Desmanthus depressus Benth. and Hook.	×			×						
Acacia tortuosa Willd.									×	
" *macracantha* Benth. and Hook.		×				×				
**Miconia* sp.	×									
Mentzelia aspera L.	×	×								
Passiflora fœtida Cav.	×									
" *suberosa* L. var.				×						
**Momordica Charanta* L.			×							
Sesuvium Edmonstonei Hook. fil.								×		
Trianthema monogyna L.		×								
Mollugo flavescens Ands.	×	×	×							
" *gracillima* Ands.									×	
**Hydrocotyle umbellata* L.	×									
Spermacoce tenuior Linn.	×									
**Borreria* (*Spermacoce asperifolia* Mart. and Gal.?)	×									
† " *Pacifica* Rob. and Greenm.						×				
† " *Baurii* Rob. and Greenm.	×									
† " *Galapageia* Rob. and Greenm.					×					
" *divaricata* Hook. fil.		×								
" *suberecta* Hook. fil.			×							
" *ericœfolia* Hook. fil.		×	×							
" *dispersa* Hook. fil.	×	×								
" *linearifolia* Hook. fil.			×					×		
Psychotria rufipes Hook. fil.	×									
" *angustata* Ands.				×						
Ageratum conyzoides Linn.		×								
Erigeron tenuifolius Steetz non Hook. fil.		×								
" *tenuifolius* Hook. fil. ?			×		×					
" sp.		×								
**Baccharis Pingrœ* var. *angustissima* DC.			×							
Lecocarpus pinnatifidus Dcne.		×								
†*Acanthospermum lecocarpoides* Rob. and Greenm.				×						
**Eclipta alba* Hassk.	×									
Scalesia Darwinii Hook. fil.		×								
† " *Baurii* Rob. and Greenm.					×					
" *decurrens* Ands.			×							
Blainvillea rhomboidea Ands.		×		×	×					

Names of Plants.	Chatham.	Charles.	Albemarle.	Hood.	Duncan.	Indefatigable.	Jervis.	Barrington.	James.	Bindloe.
Macrœa laricifolia Hook. fil.	×	×								
Bidens leucantha Willd.	×									
Porophyllum ellipticum Cass.	×	×		×			×		×	
Pectis gracilis Hook. fil.	×	×					×	×		
" *tenuifolia* DC.			×							
" *linearis* Ands.						×				
Plumbago scandens Linn.		×	×		×					
Vincetoxicum ?		×	×							
Cordia lutea Lam.	×	×		×	×		×	×		×
" *Scouleri* Hook. fil.	×									
" sp.					×					
" *linearis* Hook. fil.		×	×							
" *scaberrima* Ands.			×			×				
" *leucophlyctis* Hook. fil. ?									×	
Coldenia (*Galapagoa*) *Darwinii* Hook. fil.			×			×			×	×
" " *fusca* Hook. fil.	×			×						
Tournefortia psilostachya Cham.				×						
" *pubescens* Hook. fil.			×		×					
" *strigosa* Ands.			×							
" *rufo-sericea* Hook. fil.			×							
" *opaca* Ands.	×									
Heliotropium Curassavicum L.	×									
" *parviflorum* L.	×	×			×					
Ipomœa acuminata R. and S.	×									
" *pentaphylla* Jacq.				×		×	×			
" *Kinbergi* Ands.						×	×			
Evolvulus simplex Ands.	×	×								
" *glabriusculus* Choisy	×	×								
Cuscuta gymnocarpa Englm.			×							
**Solanacea*				×						
Lycopersicum esculentum Willd.			×	×						
Solanum nigrum Linn.			×		×					
Physalis pubescens Linn. (=? *P. angulata* L.)	×	×								
Capsicum annuum Linn.	×									
Acnistus n. sp. ? (near *A. ellipticus*)	×									
Lycium ?				×						
Scoparia dulcis Linn.		×								
Capraria biflora Linn.		×								
Lantana peduncularis Ands.		×	×		×		×			×
Lippia rosmarinifolia Ands.			×							
* " *nodiflora* Michx.	×	×								
" ?			×							
Bouchea sp.		×								
Verbena littoralis HBK.		×								
† " *grisea* Rob. and Greenm.			×							
Clerodendron molle HBK.	×	×	×							
Avicennia tomentosa Linn.		×								
Hyptis spicigera Lam.						×				
Salvia occidentalis Sw.	×	×								
Teucrium inflatum Sw.	×									
Boerhaavia hirsuta Linn.	×	×								
Cryptocarpus pyriformis HBK.		×		×				×	×	
Amarantus squarrulosa (Gray) U. and B.							×			
" *Caraccasanus* HBK.			×							
" *sclerantoides* Ands.	×			×						

Names of Plants.	Chatham.	Charles.	Albermarle.	Hood.	Duncan.	Indefatigable.	Jervis.	Barrington.	James.	Bindloe.
Telanthera vestita Ands.						×				
“ *angustata* Ands.	×		×							
“ *nudicaulis* Moq.			×						×	
“ *echinocephala* Moq.	×		×	×	×				×	
“ *flavicoma* Ands.	×			×						
†*Alternanthera rigida* Rob. and Greenm.									×	
“ *frutescens* R. Br.	×									
†*Frœlichia juncea* Rob. and Greenm.			×							
**Peperomia* sp.	×									
Viscum Henslovii Hook. fil.	×									
Euphorbia nummularia Hook. fil.	×									
† “ “ var. *glabra* Rob. and Greenm.		×								
“ *articulata* Ands.		×	×						×	×
“ *diffusa* Hook. fil.							×			
† “ *Galapageia* Rob. and Greenm.		×								
“ *flabellaris* Ands.						×				
“ *punctulata* Ands.				×	×					
“ *viminea* Hook. fil.	×		×				×	×	×	×
Phyllanthus Caroliniensis Walt. (=? *P. obovatus* Muhl.)	×									
Croton Scouleri Hook. fil.	×			×				×		
“ *incanus* Ands.		×								×
“ *Macræa* Hook. fil.			×						×	
“ *Xalapensis* HBK.	×									
†*Acalypha Baurii* Rob. and Greenm.	×									
“ *parvula* var. *flaccida* Müll. Arg.					×					
“ “ *procumbens* “	×	×								
“ “ *genuina* “			×							
“ “ *pubescens* “		×			×	×	×	×		×
“ “ *cordifolia* “ ?							×			
“ “ *strobilifera* “	×		×							
Fleurya æstuans Gaud. var. *tuberculata* Wedd.			×							
Pilea sp.	×	×								
**Tillandsia* sp.					×					
Hypoxis erecta Willd.	×									
Commelina agraria Kunth.					×					
Cyperus rubiginosus Hook. fil.	×			×	×					
“ *brachystachys* Hook. fil.		×	×							
“ *Mutisii* var. *plenus* Ands.	×									
* “ *fugax* Liebm.	×									
* “ *tristachyus* Böckl. ?	×									
**Kyllingia cæspitosa* Nees.		×								
**Dichronema leucocephala* Michx.	×									
**Hemicarpha subsquarrosa* Nees.	×									
**Scleria pratensis* Lindl.	×									
Paspalum conjugatum Berg.	×									
“ *canescens* Ands.			×							
“ *vaginatum* Sw. ?									×	
Panicum hirticaulon Presl.				×						
“ *fuscum* Sw.		×								
Oplismenus setarius Presl. (=? *O. Colonus* HBK.)	×									
Setaria Antillarum Kunth.	×									
Cenchrus platyacanthus Ands.				×						
“ *granularis* Ands.		×								
“ *distichophyllus* Griseb. ?				×						

Names of Plants.	Chatham.	Charles.	Albemarle.	Hood.	Duncan.	Indefatigable.	Jervis.	Barrington.	James.	Bindloe.
**Stenotaphrum Americanum* Schrank.	×									
Anthephora elegans Schreb.	×	×								
Aristida caudata Ands.						×				
" *divulsa* Ands.										×
" *subspicata* Rupr. and Trin.			×					×		
† " *villosa* Rob. and Greenm.							×			
**Chloris* sp.		×								
* " *radiata* Sw.		×								
Eutriana pilosa Hook. fil.			×				×			
Eleusine Indica Gærtn.	×									
* " *Ægyptiaca* Pers.				×						
Leptochloa Lindleyana Kunth.			×							
† " *Albemarlensis* Rob. and Greenm.			×							
Eragrostis ciliaris Link.	×	×							×	
Poa megastachya Koel.								×		
**Alsophila* sp.	×									
Adiantum Henslovianum Hook. fil.	×									
Cheilanthes microphylla Sw.	×									
Pteris pedata Linn.	×	×								
" *aquilina* L. var. *caudata* H. and B.	×									
Blechnum occidentale L.	×									
**Asplenium cicutarium* Sw.	×									
* " *farinosum* Willd.		×								
* " *auritum* Sw.	×									
Aspidium molle Sw.		×								
**Nephrolepis cordifolia* Presl.	×									
Polypodium Paradiseæ Langsd. and Fisch.	×									
* " *squamatum* L.	×	×			×					
**Gymnogramme leptophylla* Desv.		×								
* " *calomelanos* Kaulf.	×									
Acrosticum aureo-nitens Hook.		×								
**Lycopodium clavatum* L.	×									
Frullania atrata Nees.	×									
Roccella fuciformis (L.) Ach.		×	×	×						
" *intricata* Mont.		×								
Ramalina sp.		×	×	×						
" *Usneoides* (Ach.) Fr.		×								
Usnea barbata (L.) Fr.	×									
Theloschistes chrysopthalmus (L.) Norm. var. *flavicans* Wallr.	×									
**Zonaria lobata* Agh.	×									

The following species were collected on islands not mentioned in the above list; from Abingdon Island, *Borreria ovalis* Ands. (form), *Telanthera echinocephala* Moq., and *Euphorbia viminea* Hook. fil.; from Gardner Island, *Bastardia viscosa* HBK., and *Xanthoxylon Pterota* HBK.; from Tower Island, *Waltheria reticulata* Hook. fil., *Lantana peduncularis* Ands., *Euphorbia amplexicaulis* Hook. fil., *Euphorbia viminea* Hook. fil., *Croton Scouleri* Hook. fil., and *Eragrostis ciliaris* Link.

II. *New and Noteworthy Plants chiefly from Oaxaca collected by Messrs. C. G. Pringle, L. C. Smith and E. W. Nelson.*

Mappia Mexicana. A shrub, 5 feet in height: branches covered with a light grayish cortex, roughened by many small white lenticels: leaves oblanceolate, short-acuminate to an obtuse tip, cuneate at the base, $3\frac{1}{2}$ to $4\frac{1}{2}$ inches long, 1 to $1\frac{1}{4}$ inches broad, subcoriaceous, green and glabrous upon both surfaces; midrib prominent beneath; the lateral veins upon the lower surface each with a minute cavity just above the base; petiole puberulent, canaliculate, 4 lines long: flowers 4-5-parted, borne near the ends of the branches in short axillary pedunculate appressed-pubescent panicles (an inch or more in length): calyx minutely pubescent; teeth acutish: petals oblong, $1\frac{1}{4}$ lines in length, half line broad, entirely glabrous upon both surfaces, obtuse, mucronulate with incurved tip: disk shallowly lobed, glabrous upon both surfaces; ovary and style glabrous.—Collected by C. G. Pringle, in lowlands about Micos, San Luis Potosi, 8 December, 1891 (No. 5494). This plant agreeing rather closely both in habit and essential floral characters with *M. racemosa* Jacq. differs from any known species of *Mappia* in its glabrous petals. The genus appears to be new to Mexico.

Mimosa minutifolia. Branches smooth, grayish, often striated with brown, armed with two kinds of reddish brown spines; the stipular spines in pairs, straight, about 2 lines long; each internode also bearing a single strongly recurved spine: leaves cinereous, bipinnate, oblong in general outline, about an inch in length; petiole a line long; rhachis minutely winged, armed beneath with small spines; pinnæ 15 to 22 pairs, 2 lines in length; leaflets 10 to 20 pairs, elliptical, very minute, half line long, about two-thirds as broad, smooth and cinereous above, very minutely pruinous on lower surface, ciliated on the margin: peduncles solitary, half inch in length, finely pubescent; heads globose: calyx three-fourths line long; segments oblong, obtusish, two-thirds as long as the tube, somewhat thickened at the apex: pods oblong, narrowed at both ends, 14 to 18 lines long, 3 to 4 lines broad, cinereous-tomentose, and densely covered on the surfaces as well as the margins with weak straw-colored spines.—Fruiting specimen collected by C. G. Pringle, on rocky hills near Rio Blanco, Jalisco, 26 May, 1891 (No. 5142). This species belongs to the *Acanthocarpæ* and is most nearly related to *M. flexuosa* Benth. and *M. acanthocarpa* Benth. It is well characterized by its finely divided foliage. In each pinna the rhachis is provided with groups of minute dark-colored glands scarcely visible except under the compound microscope.

Sedum calcicola. Perennial, procumbent, nearly or quite smooth: stem nearly terete, somewhat ligneous near the base; the floriferous branches 8 to 12 inches high: leaves scattered, the lower oblong-lanceolate, acutish, 6 to 8 lines long, 3 lines broad; the upper thick, terete; nearly half inch long, falling off at touch: inflorescence terminal of about three divergent racemes; the latter 1½ to 2 inches long; pedicels less than a line in length: sepals green, oblong, obtusish, 1¼ lines long: petals lanceolate-attenuate, 2½ lines long: scales short and broad, truncate: stamens 10: carpels 5, united a third of their length, attenuate, many-ovuled, as long as the petals.—Collected by C. G. Pringle, on limestone ledges, Las Cuevas, San Luis Potosi, 30 October, 1891 (No. 5101). Habit of *S. Bourgœi* Hemsl. and from the character also of *S. Guatemalense* Hemsl. From the former it differs in its shorter sepals and shorter and much broader scales: from the latter in its much shorter pedicles, smaller flowers, and broader leaves.

PASSIFLORA PRINGLEI. Stem angulate, hispid with dark colored hairs: tendrils none: leaves 5-lobed to the middle, somewhat narrowed at the base, about 2 inches in diameter, finely pubescent above, paler beneath and sparingly pubescent upon the prominent reticulated veins; lobes ovate, acutish, finely ciliated, entire or more frequently sharply few-toothed; the middle lobe bearing upon the under surface near its base two small round sessile glands; petioles ascending, 6 to 9 lines long, hispid, bearing two stipitate glands at the summit; stipules lanceolate, acuminate, falcate, 2 lines long: peduncles somewhat exceeding the petioles, hispid, bearing 2 to 3 successive linear attenuate bracts and a single terminal flower (2 inches in diameter): calyx-tube broadly campanulate; lobes oblong-lanceolate, acute, 10 lines long, 3 lines broad, greenish white in a dried state: petals oblong-lanceolate, two-thirds as long as the sepals: outer crown of filaments free to the base, exceeding the petals; the middle crown membranous, plicate, inflexed, covering two inconspicuous inner rings: gynandrophore 5 lines long, glabrous, destitute of any fleshy urceola.—Collected by C. G. Pringle, on hills near Patzcuara, Michoacan, 23 July, 1892 (No. 5268).

PIQUERIA SERRATA Gray, var. ANGUSTIFOLIA. Shrubby, 3 to 6 feet high: leaves oblong-lanceolate, finely and rather remotely crenate-serrate, 4 to 5 inches long (including short petiole), 6 to 10 lines broad, gradually narrowed at the base.—Collected by C. G. Pringle, on the Sierra de San Felipe, altitude 9,500 feet, 24 September, 1894 (No. 4827).—With habit and floral characters of the type but differing rather strikingly in the outline and serration of the leaves.

OAXACANIA n. gen. of *Compositæ* (*Ageratecæ*). Heads homogamous, many-flowered. Involucre campanulate; bracts 4–5-seriate, 3-nerved, the outer shorter. Receptacle convex, chaff-bearing throughout. Corollas equal, regular, purplish, with slender tube, somewhat dilated above, and 5-toothed limb. Pappus obsolete or an inconspicuous crown of minute teeth. Achenes linear-oblong, 5-angled and rather strongly compressed laterally.—Bushy herbs or suffruticose. Leaves alternate, petiolate, dentate, palmately-nerved. Heads corymbose-paniculate, about 100-flowered.

O. MALVÆFOLIA. Densely and viscidly glandular-pubescent: stems branching, 3 to 4 feet long, very leafy: leaves varying greatly in size, the larger an inch in diameter on petioles of equal length ; the blade cordate, orbicular in outline ; the margin shallowly and palmately sinuate-lobed and lobes toothed : heads 8 to 9 lines in diameter.—Collected by C. G. Pringle, growing in crevices of dry cliffs, Tomellin Cañon, Oaxaca, altitude 3,000 feet, 22 December, 1894 (No. 6117). A plant nearly allied to *Alomia*, but differing in the form and arrangement of its leaves, larger heads, and flattened achenes. From *Trichocoronis* it differs among other characters in its chaffy receptacle.

Stevia elatior HBK. var.? decumbens. Stem strongly decumbent, leafy below, the erect portion nearly naked, 1 to 2 feet high : pubescence of the involucre very fine and appressed, not at all glandular : flowers 6½ to 7 lines long, purple ; aristæ of the pappus long, commonly crooked or bayonet-shaped.—Collected by C. G. Pringle, on dry hills near Oaxaca, altitude 6,000 feet, 13 October, 1894 (No. 4974). Perhaps distinct from but very nearly related to this species.

Eupatorium Pringlei. Fruticose, 8 to 12 feet high : branches terete, light-brown, glabrous : leaves all opposite, petiolate, deltoid-ovate, acutish to sub-acuminate, crenate-serrate, truncate at base, puberulent and slightly scabrous above, paler and soon becoming quite smooth beneath, 15 to 18 lines long, 12 to 14 lines broad : petioles 4 to 6 lines long : branches of the inflorescence opposite, axillary, thyrsoid and together forming a panicle a foot or more in length : pedicels glandular-puberulent : bractlets setose : heads 5 lines long, about 33-flowered : involucral scales lanceolate-oblong, acute, dark-purple, ciliated, glandular-tomentulose and not striate, loosely imbricated, sub-biseriate and not very unequal, about 3 lines long : corollas white or roseate as well as the pappus also.—Collected by C. G. Pringle, on Sierra de San Felipe, Oaxaca, altitude 9,500 feet, 24 December, 1894 (No. 6118). Resembling *E. Rafaelense* Coulter, but differing in its deltoid leaves, truncate at base, and in its thicker densely glandular-pubescent and non-striated involucral bracts.

Eupatorium collodes. Fruticose : essentially glabrous and more or less glutinous, 2 to 3 feet high : branches striate-angulate : leaves opposite, ovate, closely sessile, acuminate, rounded at base, sharply and finely serrate or serrulate, often purplish-tinged, paler beneath, 3-nerved, commonly somewhat vernicose, 12 to 16 lines long, a little more than half as broad, of rather firm texture : corymbs many-headed ; pedicels rather short : bractlets small with revolute tips : heads 20–25-flowered, purplish : scales of the involucres in 2 to 3 series, linear, attenuate, ciliate, purple-tipped : flowers considerably exserted, in dried state white or roseate : young achenes minutely ciliate on the angles.—Collected by C. G. Pringle, on hills, Las Sedas, Oaxaca, altitude 6,000 feet, 1 October, 1894 (No. 4941).

Brickellia nutans. Tall, 5 to 8 feet high : stems terete, striate, purple, pubescent : leaves chiefly opposite (only the uppermost alternate), broadly ovate, acuminate, cordate, serrate, green and puberulent above, paler and pubescent beneath, 2 to 2½ inches long, nearly as broad, 3-nerved at very base; lateral nerves soon branched: petioles 9 lines long, tomentulose: heads on short lateral leafy branchlets, slender-pedicelled, nodding or pendulous, 6 to 7 lines long, about 15-flowered: floral leaves ovate-lanceolate, acuminate or attenuate, serrate or subentire, subsessile: pedicels 4 to 6 lines long, tomentulose: involucral scales regularly imbricated in about 4 series, all obtuse, tomentulose and somewhat arachnoid-pubescent: achenes 2½ lines long, puberulent.—Collected by C. G. Pringle, on Sierra de San Felipe, Oaxaca, altitude 10,000 feet, 24 December, 1894 (No. 6114).

Brickellia lancifolia. Tall, 5 to 8 feet high: branches slender, terete, striate, tawny, tomentulose and slightly scabrous: leaves all opposite, lanceolate, acuminate, narrowed at the base, obsoletely serrulate, scabrous above, paler reticulated and soft glandular-tomentulose beneath, 2 to 3 inches long, 10 to 12 lines broad; petioles 4 to 7 lines long, fuscous-tomentulose: flowering branchlets opposite, 3–6-headed, shorter than or considerably exceeding the leaves; pedicels slender, glandular-pubescent: heads nodding, 12-flowered, 6 to 9 lines long: involucral scales glabrous except at the obtuse mucronate tip, purplish, finely striate, lucid, imbricated in 4 or 5 very unequal series: achenes villous, at least when young.—Collected by C. G. Pringle, on Sierra de San Felipe, Oaxaca, altitude 8,000 feet, 3 January, 1895 (No. 6109).

Grindelia squarrosa Dunal, var. hirtella. Branches and lower surfaces of the leaves covered with a fine slightly roughish pubescence; the type and other varieties being glabrous throughout and having the branches often lucid.—Collected by C. G. Pringle, on hills, Las Sedas, Oaxaca, altitude 6,000 feet, 16 August, 1894 (No. 4805).

Achyrocline deflexa. Stems erect, 3 to 4 feet high, strict, branching above, lanate: leaves oblong-lanceolate, acute at both ends, mucronate at apex, scarcely petioled at base, mostly deflexed or pendulous, sparingly arachnoid and green above, densely lanate and white beneath, 1½ to 3 inches long, 5 to 9 lines broad; margins somewhat revolute, irregularly subcrenulate: heads glomerate, about 5-flowered; glomerules corymbous; involucral scales about 9, oblong, obtusish to acutish, pale straw-color to silvery white: flowers all fertile, only one hermaphrodite: achenes ovate, glabrous.—Collected by C. G. Pringle, on Sierra de San Felipe, altitude 7,000 to 8,000 feet, November, 1894 (No. 6054). The other species of this genus hitherto attributed to Mexico have (acc. to descr.) much smaller, narrower leaves, and more deeply colored involucral scales, although the latter feature may very likely vary with age or change in drying.

Siegesbeckia repens. Perennial: stems several, decumbent and rooting at the base, sending out procumbent branches, ascending a foot or more in height, purplish, glandular-puberulent, about twice dichotomously forked; upper branches slender, erect: leaves ovate-elliptic, obtuse or obtusish, serrulate, nearly or quite glabrous, green above, paler beneath, 9 to 18 lines long, half as broad; winged petioles nearly as long; uppermost leaves lanceolate, sessile, acutish: heads few, half inch in diameter, on slender densely glandular-puberulent peduncles; outer involucral bracts lanceolate to linear-oblong, obtuse, 4 lines long, a line wide, inconspicuously 3-nerved; inner bracts ovate, acutish: ray-flowers about 11, bearing sterile stamens; ligules nearly 3 lines long, obtusely 3-toothed at the apex and provided at the base on the inner side with 2 smaller teeth: achenes oblique, smooth.—Collected by C. G. Pringle, in cold brooks, meadows of Sierra de Clavellinas, altitude 9,000 feet, 16 October, 1894 (No. 4987).

Gymnolomia tripartita. Stem slender, glabrous, nearly terete, pale brown, leafy, branched above: leaves partly opposite, others alternate, deeply 3-parted, dark green and scabrous above, much paler and grayish tomentulose beneath, 1 to 2 inches long, nearly as broad; segments oblong, obtuse, 2 to 3 lines broad, entire or with one or two irregular obtuse lateral teeth: petioles short, cuneate-winged: inflorescence corymbose; pedicels 8 lines to 1½ inches in length: involucral scales lanceolate, acute, 3-nerved, glabrescent: ray flowers about 11, yellow, oblong, 3½ lines long: disk conical, 4 lines in diameter: chaff strongly keeled, terminated by a short subulate tip.—Collected by L. C. Smith, at Cuicatlan, altitude 1,800 feet, 22 October, 1894 (No. 239).

Perymenium Jaliscense. Caudex short, thick, an inch in diameter, giving off numerous fibrous descending roots and several erect or decumbent slender scabrous furrowed stems about 2 feet high: leaves opposite, short-petioled, oblong to linear-lanceolate, obtuse, serrate or subentire, narrowed at the base, conduplicate, spreading and somewhat recurved, about 2 inches long, 3 to 6 lines wide, 3-nerved, scabrous; the lowest pairs considerably shorter and broader; petioles about a line long: heads about 3 together at the ends of the almost naked branches: peduncles very unequal: involucral scales in 3 series; the outer broadly ovate, obtuse, minutely cinereous-pubescent, ciliated upon the margin; the inner longer, about 2 lines in length: rays 8, unequal, about 3 lines long, more than two-thirds as broad, bright-yellow, minutely 3-toothed at the apex, ciliolate toward the base and upon the nerves on the outer surface: mature achenes about 1½ lines long, minutely pubescent toward the apex.—Collected by Dr. Edward Palmer, Rio Blanco, Jalisco, August, 1886 (No. 310), and also by C. G. Pringle, on rocky hills near Guadalajara, 23 August, 1893 (No. 5426). Dr. Palmer's specimen has been referred to *P. Cervantesii* DC. by Dr. Watson, Proc. Am. Acad. xxii, 427, but it has been compared with the type at Geneva through the kindness of Dr. Casimir De Candolle and Monsieur Buser and proves to be quite distinct, nor does it appear to be a form of *P. Mendezii* DC., as suggested by Dr. Watson, which has an umbellate inflorescence. The plant is habitally marked by its strongly conduplicate and somewhat recurved leaves.

Encelia (§ Geræa) hypargyrea. Shrub, 5 to 15 feet high: branches terete, striate, scabrous-pubescent: leaves opposite except the uppermost, ovate, acute or somewhat acuminate, cordate, obsoletely or more or less distinctly serrulate, thickish, densely gray-tomentose above, appressed sericeous-pubescent and silvery below, 3-nerved, 2 to 2½ inches long, three-fourths as broad; margins somewhat revolute; petioles about half inch long; floral leaves ovate-lanceolate, subsessile: heads corymbose, about 6 to 8 lines in diameter excluding the oblong yellow rays: the latter 10 to 12 in number: involucre campanulate; scales 2–3-seriate, oblong-linear, obtusish, roughish pubescent: chaff of the disk carinate, oblong, sub-3-dentate, puberulent: achenes 1½ lines long, densely sericeous-pubescent.—Collected by C. G. Pringle, in La Hoya Cañon, Oaxaca, altitude 3,000 feet, 2 November, 1894 (No. 6142).

Encelia (§ Geræa) glutinosa. A tall branching shrub, 10 to 15 feet high: branches covered with a roughish gray bark, somewhat white-woolly near the leaf-bearing summits: leaves alternate, approximate, short-petioled, ovate-lanceolate, acuminate, entire, nearly glabrous, but slightly papillose-scabrous, and almost lucid above, pubescent and not paler beneath, obtusish or scarcely acute at the base: 3 to 4 inches long, 15 to 16 lines broad; petioles densely pubescent, 3 lines in length: inflorescences terminal, corymbose, rather dense; heads nearly half inch in diameter (exclusive of rays), 7 lines in length, vernicose: involucre 2–3-seriate with the outer scales much shorter; scales thick, obtusish, somewhat striated: rays about 8, bright-yellow, fully half inch long: achenes linear-oblong, 4 lines in length, 2-awned, pubescent, and silky-ciliate.—Collected by C. G. Pringle, in La Hoya Cañon, Oaxaca, altitude 4,000 feet, 2 November, 1894 (No. 6024).

Encelia (§ Geræa) rhombifolia. Decumbent, densely pilose-pubescent with spreading white hairs, leafy to the middle: leaves (except the reduced uppermost) opposite, rhombic-ovate, acutish, harsh in texture, scabrous and tuberculate-hispidulous above, scarcely paler but more densely and softly pubescent and with frequent argenteous blotches beneath, serrate from below the middle, 3-nerved from above the base, 2 inches long, 12 to 15 lines broad, narrowed in the upper leaves to a sessile somewhat amplexicaul base, the lower short-petioled: inflorescence loose and irregular; heads half inch in diameter, short-peduncled, borne in irregular subracemose groups, 2 to 5 together at the ends of the almost naked branches: scales of the involucre 2–3-seriate, oblong-lanceolate, attenuate, grayish hirsute, the outer shorter: rays 8, yellow, 3½ lines long: achenes flattened, appressed-pubescent, ciliate on the edges; awns 2, with intermediate scales.—Collected by C. G. Pringle, on dry calcareous hills, Las Sedas, Oaxaca, altitude 6,000 feet, August, 1894 (No. 4813).

Leptosyne Pringlei. Rootstock short-oblong, thickish and woody; stems several, decumbent, simple and leafy nearly to the middle, a foot or more high, striate-angulate, puberulent below:

leaves pinnate, about an inch long, ascending, puberulent; rhachis and pinnæ narrow, linear, acute and slightly pungent; leaflets usually 3 pairs and an odd one, 3 to 6 lines long; the lower pairs gradually more elongated: peduncles slender, erect, 4 to 6 inches long, 1-headed: head 8 or 9 lines in diameter, often bracteolate; outer involucral bracts herbaceous, about 5, oblong, obtuse, 1½ to 2 lines long; the inner bracts scarious, yellow, ovate-oblong, obtusish, about 3 lines long: rays about 6, yellow, oblong, 3-toothed, fertile, 5 lines long, half as broad; the middle tooth the smallest; achenes obovate, dark-colored, 2 lines long, two-thirds as broad, glabrous, rounded and emarginate at the apex: disk-flowers apparently all fertile, distinctly annulate.—Collected by C. G. Pringle, on the Sierra de San Felipe, altitude 7,000 feet, 7 August, 1894 (No. 4871). Habit of *L. Mexicana* Gray.

Schkuhria platyphylla. Erect, stoutish annual: stem terete, striate, pubescent, purplish, simple below: leaves all alternate, broadly ovate, obtuse, coarsely and somewhat doubly crenate-dentate but not at all dissected, abruptly contracted to a 3-nerved cuneate base, densely puberulent upon both surfaces, 2 to 2½ inches long, nearly or quite as broad, slightly paler beneath: petioles pubescent, 4 to 10 inches long: panicle much branched, densely glandular-pubescent: involucral bracts about 5, obovate, rounded at apex, herbaceous but with thin purple margins, glandular-pubescent externally, 2½ lines long: ray flowers none, disk flowers about 20 in a head: scales of the pappus about 8; achenes upwardly pubescent especially near the base, 2 lines long.—Collected by C. G. Pringle, on Monte Alban, Oaxaca, altitude 5,500 feet, 8 October, 1894 (No. 4975). Exceptional on account of its broad undivided leaves.

Liabum Klattii. Shrub, 15 to 20 feet high, leaves falling before the flowers appear, deltoid-ovate, obliquely acuminate, cuspidate-serrulate, abruptly contracted to a somewhat cuneate base, glabrous above, gray and densely arachnoid-pubescent beneath, about 5 inches long and nearly as broad, 3-nerved from a point somewhat above the base: flowering branches terete, at first arachnoid but quite glabrate, opposite, recurving, terminating in dense thyrsoid inflorescences: heads 8 lines long: involucral scales lance-linear, attenuate, imbricated in about two unequal series, densely dark glandular-pubescent: flowers bright yellow: pappus nearly white: corolla 5 lines in length.—Collected by C. G. Pringle, on Monte Alban, near Oaxaca, altitude 6,000 feet, 24 November, 1894 (No. 6059). For a critical comparison of this plant with certain neighboring forms we are indebted to Dr. F. W. Klatt, to whom we take pleasure in dedicating the species in recognition of his valuable contributions to the knowledge of American *Compositæ*.

Senecio gracilipes. Herbaceous, perennial, erect, slender, 3 feet or more in height: stem simple up to the loosely paniculate inflorescence, striate, covered below with sparing arachnoid pubescence, above glabrate: leaves oblong in outline, deeply and regularly pinnatifid, green and glabrous above, paler and arachnoid-pubescent beneath; lateral segments in about 8 pairs, divaricate, lanceolate, acuminate, repand-dentate, about 1½ inches long, a third as broad; the terminal one scarcely larger, narrowly deltoid; lower leaves on slender petioles (7 inches long); the upper upon winged petioles, auriculate-clasping at the base; bracts of the diffuse panicle narrowly lanceolate, attenuate, sessile, auriculate-clasping: heads discoid, usually solitary at the end of the slender branches; bractlets subulate-filiform: involucre about 13-phyllous, 4 lines long, pubescent, 20–24-flowered; the scales minutely dark-tipped and tufted at the apex: flowers ochroleucous: corolla segments short: achenes glabrous.—Collected by C. G. Pringle, on the Sierra de Clavellinas, altitude 9,000 feet, 24 October, 1894 (No. 6010).

Senecio reticulatus DC. A plant of habit and foliage identical with an authenticated specimen of this species from De Candolle's herbarium, has been collected by Mr. Pringle on the Nevado de Toluca in the State of Mexico, 7 September, 1892 (No. 5262). The heads, however, have about twice as many flowers (8 rays and 26 disk flowers). The scales of the involucre are also more numerous, being about 16 in number.

Cacalia longipetiolata. Slender, 3 feet or more in height, apparently strict: stem terete, purplish and glaucous: leaves palmately 5–7-lobed, 3 to 4 inches in diameter, cordate with narrow sinus, green, puberulent and reticulated above, grayish-tomentulose beneath; lobes lanceolate, stellately divergent, denticulate, acute and mucronate; sinuses rounded; petioles slender, smooth, about 4 inches in length: heads few, large, about 9 lines in length, terminal upon the long slender almost naked branches of an open panicle; involucre calyculate with short loose spreading linear or subulate bracts, the inner erect bracts about 9, oblong, dark-colored with scarious margins, narrowed to an obtusish apex: flowers about 50 in a head; tube slender, thickened at the base; throat ampliate, very short; lobes rather long but recurved or coiled in anthesis: achenes smooth.—Collected by C. G. Pringle, on dry ledges of the Sierra de San Felipe, Oaxaca, altitude 7,000 feet, 10 October, 1894 (No. 5828).

Cacalia megaphylla. Tall, 6 to 10 feet high: stem terete, striate, ferrugineous-tomentulose: radical leaves large, centrally peltate, about 10-lobed, orbicular in outline, 1 to 2 feet in diameter, finely pubescent above, slightly paler and grayish-tomentose beneath; lobes ovate-lanceolate, sharply and unequally sinuate-dentate, usually 2–3-lobed toward the apex; secondary lobes only slightly divergent not divaricate with reference to the primary lobes, acute: panicle ample, pyramidal, bracts reduced, subulate; heads numerous, 5-flowered, 5 to 7 lines long, shortly and inconspicuously calyculate at the base or ecalyculate: involucral scales 5, ovate-oblong narrowed to an obtusish apex, densely tomentose, 4 to 5 lines long, nearly or quite 2 lines broad: akenes glabrous, stout, many-striate, light-colored.—Collected by C. G. Pringle, on hillsides near Guadalajara, 10 October, 1889 (No. 2490). Distributed as *Cacalia peltata* H.B.K., which however differs in its more numerously flowered heads, more leafy inflorescence, in the presence of long linear calyculate bracts, commonly exceeding those of the involucre, also in the more divaricately cleft lobes of the leaves.

Cacalia obtusiloba. Radical leaves subcentrally peltate, orbicular in outline, 6-lobed to the middle, green and glabrate above, somewhat paler and puberulent beneath, a foot in diameter; lobes broad, again irregularly and obtusely lobed and mucronate-denticulate; cauline leaves not seen: stem subsulcate, sordid-tomentulose: inflorescence thyrsoid-paniculate, tomentulose: heads many, 5-flowered, calyculate at base: involucral scales 5, oblong-linear, obtusish, green-backed, and tomentulose, 2½ to 3 lines long: flowers light colored.—Collected by C. G. Pringle, on the Sierra de San Felipe, altitude 6,000 feet, 17 November, 1894 (No. 5840).

Cacalia paucicapitata. Simple, slender, erect, 3 to 4 feet high: base tuberous, sending off a few stout fibres: stem terete, and as well as the petioles, pedicels, and under surface of the leaves densely white arachnoid-lanate; the indumentum being more or less deciduous: radical leaves sinuate-pinnatifid, 4 to 6 inches long, two-thirds as broad, green and glabrate above, lateral lobes in 3 to 5 divaricate pairs, oblong, acutish, subentire or again more or less divaricately lobed; petioles about equalling the blades; cauline leaves only one or two similar near the base: inflorescence a simple raceme: heads 6 to 8, large, 40–50-flowered, 9 or 10 lines broad, calyculate with loose linear scales: inner involucral bracts about 13, broadly oblong, narrowed to an obtusish ciliolate apex: corolla tube slender, 4 lines long, thickened at the base, throat short; segments narrow: achenes elliptic, densely silky-villous.—Collected by C. G. Pringle, on dry slopes under oaks, Sierra de Clavellinas, altitude 7,000 feet, 25 October, 1894 (No. 6018).

Cacalia silphiifolia. Radical leaves ovate-oblong, very deeply cordate, obtuse, shallowly and somewhat doubly sinuate-dentate, nearly a foot in length, 5 inches in breadth, glabrous, pinnately veined, scarcely paler beneath; midrib purplish; petioles wingless, purplish, striate, nearly a foot and a half in length, woolly at the base; lower cauline leaves unknown, the upper reduced to very narrow linear dried bracts, 6 lines to an inch in length: stem green, striate, puberulent; floral leaves filiform: heads very numerous in a much-branched compound corymb, about 8 flowered: scales of the involucre 6 to 8, oblong, acute, strongly carinate, 2½ lines long: corollas 5 lines long, segments two-thirds as long as the tube: achenes ribbed, nearly 2 lines in length.—Collected by C. G. Pringle, on the Sierra de las Crucis, State of Mexico, 21 August, 1892 (No. 5251). Radical leaves resembling in outline those of *Silphium terebinthinaceum* L. They are thinner and less strongly reticulated than in the related species, *C. pachyphylla* Sch. Bip. and *C. Palmeri* Greene, besides being of very different shape.

Cacalia tridactylitis. Tall, 8 feet high: stem leafy, sulcate-angulate, purplish, tomentulose: leaves trifid at least to the middle, green and puberulent above, paler and grayish-tomentose beneath, 3 to 6 inches long, nearly as broad, pinnate-palmately 5-7-nerved from somewhat above the cuneate base; lobes lanceolate, acute, somewhat incised-dentate: inflorescence a broad corymbous panicle leafy at base: heads very numerous, 5 lines in length, about 10-flowered, calyculate: involucral scales about 7, oblong-linear, acute, somewhat keeled, scarious margined, glabrate: flowers white, considerably exceeding the involucres: achene ribbed, glabrous.—Collected by C. G. Pringle, on the Sierra de San Felipe, Oaxaca, altitude 6,000 feet, 19 November, 1894 (No. 5841).

Cnicus imbricatus. Slender, 3 to 5 feet high: radical leaves narrow and elongated 10 to 18 inches long, an inch wide, divided to the rhachis; the broadly ovate, angulate spinose-dentate lobes very numerous, about 80, mostly attenuate and regularly imbricated, green and puberulent, glabrate above, grayish-arachnoid beneath; cauline leaves narrowly oblong, pinnatifid, decurrent at the base, 2 to 3 inches long; lobes short, spinose-dentate: heads terminal and solitary on long slender branches, nodding, depressed-globose, 1¼ inches in diameter: involucral scales linear-lanceolate, spinose-tipped, the outer spinose-ciliate, the inner elongated, densely purplish-lanate.—Collected by C. G. Pringle, in wet meadows, Sierra de Clavellinas, altitude 9,000 feet, October, 1894 (No. 6006). A very attractive species.

Urostephanus n. gen. of *Asclepiadaceæ* (*Gonolobeæ*). Calyx 5-parted, glanduliferous at the sinuses within. Corolla rotate, 5-parted; tube short; lobes flat, ovate or oblong, with dextrorsely imbricated margins. Corona borne upon the lower part of the column, tubular, nearly equalling the gynostegium, shallowly parted at the summit into 5 internal hornlike processes opposite the stamens and five external lobes alternating with them and produced on their outer surface and just beneath the apex into two filiform flexuous tails. Stamens united with the base of the corolla; filaments connate into a very short tube; anther-cells oblique; pollinia solitary in the cells, almost pendulous. Stigma depressed. Fruit and seeds unknown.—Twining. Leaves opposite, ovate, cordate. Flowers umbellate-cymose.

U. gonoloboides. Hirsute with somewhat tawny hairs subappressed on the leaves and reflexed on the slender stem: leaves ovate, entire, acuminate, cordate with a narrow sinus and rounded lobes, scarcely paler beneath, 2 to 2½ inches long, half as broad; petioles half to three-fourths inch in length: peduncles 2 lines long, 1–5-flowered; pedicels of equal length: lobes of the calyx ovate-lanceolate, acute, nearly 2 lines long; pilose externally, glabrous within: corolla in dried state olive green, pilose externally and covered at the throat within, with a short dense wool;

lobes ovate-oblong, obtusish, 4 to 5 lines long, 2½ lines broad at base: corona black.—Collected by C. G. Pringle, on hills above Oaxaca, altitude 6,000 feet, 6 August, 1894 (No. 4753).

Buddleia floccosa Kunth. Two forms of this species are shown by Mr. Pringle's 6025 (=6139) and by his 4925 from Oaxaca. The former numbers represent the typical form with rounded, deflexed interpetiolar appendages, while in the latter number these stipular structures are obsolete. No other differences have been noted. The unappendaged form has also been secured in Guatemala by Donnell-Smith and von Tuerckheim.

Ipomœa bracteata Cav. var. pubescens. A woody vine loosely twining to 15 feet: branches and petioles pubescent: leaves irregularly few-toothed, appressed sericeous-pubescent upon both surfaces.—Collected by C. G. Pringle, on barrancas near Guadalajara, altitude 4,500 feet, 3 May and 9 July, 1894 (No. 4734).

Ipomœa suffulta Don. (*Convolvulus suffulta* HBK. Nov. Gen. et Spec. iii, 102, t. 211). So far as we can learn this species has never been collected since it was first found upon the volcano Jorullo by Humboldt and Bonpland. It has now been rediscovered in Oaxaca, having been secured by C. G. Pringle (No. 4755); on Monte Alban, altitude 5,800 feet by L. C. Smith (No. 141); and Valley of Oaxaca, altitude 6,500 to 7,800 feet, by E. W. Nelson (No. 1541). The root, apparently not seen by Kunth, is thick and woody: the stems many, slender, prostrate-ascending.

Jacquemontia Smithii. Suffruticose at base: much branched: stems procumbent: branches puberulent, ascending, 2 to 3 feet high, not twining: leaves ovate, acutish, mucronate, cordate, entire, puberulent upon both sides, the larger 1½ to 2 inches long, two-thirds as broad; petioles 1 to 9 lines long: peduncles slender, 1 to 2½ inches long, loosely 2–5-flowered: pedicels 3 to 4 lines long: outer sepals rhombic-ovate, acuminate, about 3 lines long; the inner narrowly ovate, acuminate: corolla 6 lines long: lobes of the stigma thick, subglobose.—Collected by L. C. Smith, at Cuicatlan, Oaxaca, altitude 1,800 feet, 22 October, 1894 (No. 246); by C. G. Pringle, on dry calcareous soil, San Antonio, altitude 2,500 feet, 1 September, 1894 (No. 4848); and by E. W. Nelson, six miles above Dominguillo, Oaxaca, altitude 6,500 feet, 22 October, 1894 (No. 1600). Foliage and flowers much as in *L. violacea* Choisy, but stem not twining, inflorescence looser, and lobes of stigma strikingly different, being in the latter species slender and almost linear.

Solanum Pringlei. Herbaceous, unarmed, with a soft gray pubescence; hairs simple, those of the stem and petioles spreading, of the leaves appressed: leaves single below, geminate above, ovate, acuminate, abruptly contracted to an acute base, 2 to 5 inches long, two-thirds as broad; petioles 4 to 12 lines long: flowers an inch in diameter, blue, axillary in pairs; pedicels an inch or more in length: calyx urceolate with 5 or 10 small obtuse dark-colored prominences below the thin shallowly and bluntly

3–4-lobed rim: corolla rotate, pentagonal, nearly entire: stamens erect, unequal, one longer: fruit globose, bright red, nearly half inch broad.—Collected by C. G. Pringle, in mountain cañons near Guadalajara, 18 November, 1892 (No. 5343).

CHAMÆSARACHA POTOSINA. Densely glandular-pubescent, freely branched: stems and branches subterete, finely striate: leaves geminate, ovate-lanceolate, acute, contracted below to a shortly cuneate base, thin in texture, the larger ones 18 to 22 lines long, half as broad: pedicels solitary or less frequently in pairs, 4 lines long in anthesis: calyx 5-toothed almost to the middle, nearly enveloping and closely appressed to the fruit, but finally ruptured and more or less reflexed, teeth ovate, acute, ciliated: corolla rotate, 5-toothed, nearly to the middle, 4 lines broad, pale yellow, pubescent in the throat; segments ovate, acute, pubescent upon the outer surface near the tip and ciliate: filaments nearly twice as long as the oblong anthers: fruit globose, red, the size of a pea.—Collected by C. G. Pringle, in Tamasopo Cañon, San Luis Potosi, 25 November, 1890 (No. 3654). Leaves quite entire, thinner than in the other Mexican species, and corollas smaller and more deeply divided.

SARACHA GRANDIFLORA. Densely cinereous-pubescent: stems angulate, tomentose: leaves single or geminate, ovate, undulate or somewhat sinuate-dentate, obtusish, appressed-villous upon both surfaces, pale beneath, 2½ inches long, 2 inches broad, abruptly contracted at the base but decurrent into tomentose petioles 6 to 7 lines in length: peduncles axillary, 3 to 7 lines long, about 3-flowered; pedicels 7 to 9 lines in length: calyx appressed-villous, about 10 lines broad in anthesis, 1¼ inches in fruit, with 5 shallow triangular blunt lobes: corolla pentagonal, scarcely lobed, pubescent on the outer surface, conspicuously ciliated, 14 lines in diameter: stamens rather close in the throat; filaments nearly or quite glabrous but a line or two long: fruit globular, 5 lines in diameter.—Collected by C. G. Pringle, on hills near Patzcuaro, Michoacan, 22 July, 1892 (No. 5273).

JUSTICIA LINEARIS. Tomentulose, fruticose: leaves linear, crowded near the ends of the ascending cinereous branches, erect, an inch in length, a line in breadth, 1-nerved, sessile; margins strongly revolute: flowers sessile, axillary: calyx deeply 5-parted; segments sub-equal, linear, attenuate, 4 lines long: corolla pubescent upon the outer surface especially upon the veins, about 9 lines in length with an ampliate throat, the upper lip very shortly bifid; the lower more deeply 3-parted, the segments rounded, the middle one the largest: stamens of the genus: styles slightly pubescent below, minutely and unequally bidentate at the apex; valves of the capsule half inch long.—Collected by C. G. Pringle, upon dry hills, Las Tablas, San Luis Potosi, 5 August, 1891 (No. 5038). This species showing all the floral characters of *Justicia*, is very distinct in habit from any species known to us. It was collected in a season of especial drought and only a very limited quantity of material secured.

Lippia nutans. Shrub with grayish glabrate stems and pale brown angulate sparingly puberulent branchlets: leaves ovate-acutish, cuneate at the base, thickish, strongly rugose-warty, hispidulous and slightly lucid above, paler and rather densely pubescent beneath, an inch long, two-thirds as broad; petioles about 2 lines long, canaliculate and hispid pubescent above: peduncles slender, commonly recurved and nodding, opposite in the upper axils, pubescent, about 9 lines long: heads globose, an inch in diameter: bracts ovate, obtuse, reticulated, glandular-pubescent upon both surfaces and ciliate, thin, pale, and sub-chartaceous, the lowest ovate; the upper more elliptic, 4 to 6 lines long, half as broad: flowers shortly pedicellate, 3½ lines long: calyx densely pubescent.—Collected by C. G. Pringle, in Las Hoyas Cañon, Oaxaca, altitude 4,500 feet, 2 November, 1894 (No. 5650).

Lippia Oaxacana. Shrub, 3 to 5 feet high: stems cinereous, smoothish, subterete; branchlets canescent-tomentose: leaves ovate-oblong, obtuse or rounded at the base, acute or obtuse at the apex, 10 to 18 lines long, half as broad, very rugose and densely pubescent above, paler and tomentose beneath, crenulate-serrulate, short petiolate: inflorescences terminal on the branches, rather dense and spike-like, 2 inches long, nearly an inch in diameter, somewhat looser and rarely branched below: bracts rhombic-obovate, yellowish green, 4 lines long, half as broad, abruptly acuminate, pubescent upon the outer surface, ciliate upon the margin, 1-flowered; flowers 2¼ lines long: calyx 2-lobed, densely pilose-pubescent: corolla 4-lobed, 1½ lines long, sparingly pubescent externally: fruit pear-shaped.—Collected by C. G. Pringle, on dry limestone hills, Las Hoyas Cañon, Oaxaca, altitude 5,000 feet, 1 November, 1894 (No. 6021); and by E. W. Nelson, six miles above Dominguillo, altitude 5,000 to 6,000 feet, 3 October, 1894 (Nos. 1586 and 1841).

Stachytarpheta Nelsonii. Fruticose: branches cinereous: branchlets more or less distinctly 4-angled, sordid-tomentulose: leaves opposite, or nearly so, rhombic-ovate, serrate-dentate from below the middle, acutish, rather abruptly contracted at the base and then decurrent upon the petiole, appressed-pubescent above, paler and tomentulose beneath, 1 to 1½ inches in length, 6 to 8 lines in breadth: spikes 2 to 4 inches long, 4 lines in diameter: bracts lance-linear, acute, pubescent upon both surfaces, not strongly ciliated, 3 lines long, a line broad below: calyx split two-thirds of the way to the base on the ventral side, 4 lines long; externally pubescent, teeth cohering: corolla curved and nodding, 7 lines long, externally glabrous, pubescent in the throat, purple. —Collected by E. W. Nelson, six miles above Dominguillo, Oaxaca, altitude 5,000 to 6,500 feet, 30 October, 1894 (No. 1590). Habit nearly as in *S. acuminata*, DC., which was also collected by Messrs. Pringle and Nelson. The latter species is much less pubescent and has longer and conspicuously ciliate bracts.

SALVIA LITTÆ Vis. Specimens have just been received which agree in all essential characters with Bentham's description of the above species in DC. Prodr., but the plant differs, however, in being herbaceous, as noted by the collector, and also in having a sparingly pubescent style. Without access to the type it is impossible to say, with absolute certainty, whether or not this plant is the same.—Collected by C. G. Pringle, on Sierra de Clavellinas, Oaxaca, altitude 9,000 feet, 18 October, 1894 (No. 4991); also by E. W. Nelson 18 miles southwest of the City of Oaxaca, altitude 7,500 to 9,500 feet, 10–20 September, 1894 (No. 1342).

SALVIA VITIFOLIA Benth. Excellent specimens, agreeing in all points with the original description, show the root-character not hitherto described. From a knotted root-stock, fleshy fusiform fibres are given off which in the material at hand are a third of an inch in diameter.—Collected by C. G. Pringle, on the Sierra de San Felipe, Oaxaca, altitude 7,500 feet, 26 May, 1894 (No. 4659); also by E. W. Nelson, in the same locality, 1 September, 1894 (No. 1169); and by L. C. Smith, San Juan del Estado, altitude 7,000 feet, 4 June, 1894 (No. 169). Here also should be placed Mr. Seaton's No. 376 from Maltrata.

SALVIA THYRSIFLORA Benth. A shrubby plant with a beautifully thyrsoid inflorescence has been collected by Mr. Pringle on mountains near Patzcuaro, 21 December, 1891 (No. 4097), which corresponds in all particulars to Bentham's description of this species except in having somewhat larger acute leaves (2 inches long) and a calyx puberulent but not glandular-pubescent.

SCUTELLARIA AUREA. Stem branched, densely grayish pubescent: leaves broadly ovate, shortly and acutely acuminate, coarsely crenate-dentate, thin, green and puberulent, much paler and pubescent especially upon the veins beneath, rounded or subcordate at the base, 3 to 4 inches long, 2 to $2\frac{3}{4}$ inches broad; petioles 8 to 15 lines long, densely pubescent: flowers in pairs subtended by small ovate acuminate bracts and forming several elongated simple racemes; pedicels a line long: calyx green, puberulent, ciliate upon the margin, in anthesis 2 to $2\frac{1}{2}$ lines long: corolla an inch in length, puberulent, orange-colored, paler ventrally; the slender proper tube densely and retrorsely pubescent within, throat more or less ventricose; lateral lobes united with the dorsal pair to form the upper lip; the lower lip of a single emarginate lobe.—Collected by L. C. Smith, Rancho de Calderon, Oaxaca, altitude 6,500 feet, 13 August, 1894 (No. 173).

LORANTHUS INORNUS. Stems slender, terete or nearly so, glabrous, scoparious, flexuous, branched: branches spreading, not enlarged at the nodes, essentially terete: leaves alternate, mostly reduced and subulate, the larger 8 lines long, $1\frac{1}{2}$ lines broad, oblanceolate, acutish, cuneate at base, nerveless: flowers axillary, sessile, usually in pairs or solitary, $1\frac{1}{2}$ lines long: calyx cupulate, entire: divisions of the corolla 4, oblong, acutish, caducous and early disclosing the persistent style: fruit ovoid, $1\frac{1}{2}$ lines long, two-thirds as broad.—Collected by L. C. Smith, at Cuicatlan, altitude 2,000 feet, 27 August, 1894 (No. 122). The *Loranthus*, which in character most nearly approaches this is *L. inconspicuus* Benth., which is said to have ancipital branchlets and obovate oblong obtuse obscurely 3-nerved leaves.

PEDILANTHUS TOMENTELLUS. Tall, 5 to 8 feet in height, rusty tomentulose: branches stout, terete: leaves short-petioled, ovate-oblong to oblong-lanceolate, narrowed at both ends, obtusish, tomentulose upon both surfaces, 2 inches long, an inch broad; cymes terminal, twice dichotomously forked, about 2 inches in diameter, outer floral leaves and those at the forks large, bright red, sessile, broadly ovate or suborbicular, cordate, shortly acuminate, tomentulose, 12 to 15 lines long, inclosing the smaller inner bracts and involucres, thus giving the cyme a somewhat 2-headed appearance: involucres half inch in length, tomentulose, unequally 5-cleft at the mouth, the divisions rounded to subtruncate with an erose or fimbriated margin, the 3 posterior much smaller, linear-oblong; the appendage deeply 2-cleft; divisions about 3½ lines long, lanceolate-obtuse, thickened at the apex: glands 2 or 4: pedicels of the ♂ flowers glabrous; filaments and anthers pubescent; pedicel, ovary, and style of the ♀ flower ferrugineous-tomentose; style 2½ lines long, the 3 divisions 2-cleft.—Collected by C. G. Pringle, in fence-rows, near the City of Oaxaca, August, 1894 (No. 4912); and by E. W. Nelson, 40 miles northeast of the City of Oaxaca, altitude 5,500 feet (No. 1201).

EUPHORBIA MACROPODOIDES. Low, somewhat succulent, 2 to 5 inches high, springing from a dark rough tuber: the latter at first fusiform but becoming much thickened and irregular, 1½ inches in diameter, sending off occasional fibres: stem smooth, weak, hollow, pale and leafless below as though subterranean; copiously dichotomously or alternately branched; branches crowded, leafy: leaves chiefly alternate (a few sub-opposite), slender-petioled; suborbicular to short-oblong, regularly but obscurely serrulate, rounded both at the apex and at the nearly equal base, 2 to 3 lines in diameter, sparingly pubescent or almost glabrous, slightly paler beneath; petioles 1 to 1¾ lines long: involucres solitary, axillary, sparingly pubescent, a little over 1 line in diameter, on slender peduncles (3 to 4 lines long); glands 5, reniform with ovate obtuse appendages; lobes of involucre slightly fimbriate: capsule strongly 3-angled, glabrous; styles bifid, spreading; seeds ovoid, grayish, a line long.—Collected by C. G. Pringle, on the Sierra de San Felipe, Oaxaca, altitude 10,000 feet, 26 June, 1894 (No. 4713). Habitally and in floral characters very near *E. macrocarpus* Boiss., but with leaves rounder, longer-petioled, smoother and serrulate.

ACALYPHA GLANDULIFERA. A monœcious shrub, 5 to 8 feet high: branches terete, brownish, finely pubescent: leaves ovate, cordate, tipped with a short caudate point, serrate-dentate, appressed-pubescent above, more densely pubescent or grayish-tomentose beneath, 2 to 3 inches long, two-thirds as broad;

petioles 8 to 16 lines long, densely pubescent; stipules subulate, reflexed, pubescent upon the lower surface, about 2 lines long, at length deciduous: staminate inflorescence elongated flexuous, about 4 inches long, upon peduncles 1 to 4 lines in length: pistillate spike oblong, rather loose-flowered, $1\frac{1}{4}$ to $1\frac{1}{2}$ inches long, about two-thirds as broad, peduncles slender, rather rigid, ascending, an inch and a half long, cinereous-pubescent below, glandular-pubescent above; bracts 1-flowered, 7-parted; each segment lanceolate and green at the base, elongated to slender purple filiform tips, 4 to 6 lines in length, bearing numerous divaricate glanduliferous hairs: ovary hispid-pubescent toward the apex; styles multifid, reddish-purple.—Collected by C. G. Pringle, wet cañons, Sierra de San Felipe, Oaxaca, altitude 7,500 feet, 13 August, 1894 (No. 4789); and by E. W. Nelson, in the vicinity of Sierra de San Felipe, altitude 9,500 to 11,000 feet, 1 September, 1894 (No. 1165).

Parietaria macrophylla. Suffrutescent and decumbent at base, 1 to 2 feet high, finely pubescent: stem subterete, striate: leaves thin, lanceolate, narrowed both ways, mostly caudate-attenuate to an obtusish falcate secund tip, punctate, nearly glabrous, dark green above, scarcely paler beneath, of variable size, the larger 5 inches long, $1\frac{1}{4}$ to $1\frac{1}{2}$ inches broad, mostly 3-nerved from the base, on thickish petioles 2 to $2\frac{1}{2}$ inches in length: inflorescence at first glomerate, becoming looser; the axillary cymes 6 to 8 lines long, spreading, very pubescent: lobes of the calyx 4, lanceolate, acuminate, about a line long, twice the length of the tube, nearly glabrous: fruit becoming black and shining, nearly half line in length.—Collected by E. W. Nelson, on the top of the Sierra Madre near Chilpancingo, Guerrero, altitude 9,000 to 10,200 feet, 24 December, 1894 (No. 2231).

Spiranthes eriophora. Roots several, oblong, fleshy, tuber-like: base of stem surrounded by the sheaths of old leaves: leaves radical, narrowly oblong-lanceolate, acute, 3 to 4 inches long, 3 to 4 lines wide, glabrous: stem a foot to a foot and a half high, glabrous below, densely ferrugineous-lanate above, covered throughout its whole length by white and scarious ovate-lanceolate attenuate striate bracts: spike 4 to 6 inches long, 5–10-flowered; floral bracts similar in texture to those of the stem, more ovate, exceeding the flowers: flowers sessile: the erect ovary as well as the external surface of the outer divisions of the strongly deflexed perianth pubescent: the upper sepals oblong-lanceolate, acute: the lateral linear-lanceolate, acuminate, about 7 lines long: lateral petals adnate to the upper sepal; labellum panduriform; margins involute; lateral lobes very short, almost obsolete.—Collected by C. G. Pringle, in pine woods, Sierra de San Felipe, Oaxaca, altitude 9,000 feet, 31 May, 1894 (No. 4682).

Spiranthes rubrocalosa. Tuberous roots 2 to 4, oblong, covered with minute fibres: radical leaves 2, narrowly lanceolate, acuminate both ways, glabrous, 3-nerved, including the petiole 4 to 5 inches long, half inch broad: stems a foot or more in height, smooth or somewhat pubescent: scales oblong-lanceolate, sharply acuminate: floral bracts ovate to elliptic-lanceolate, acuminate, 4 to 6 lines long, about equalling the ovary: spike many-flowered, 4 to 7 inches long; lower flowers sometimes scattered; the upper imbricated; perianth nodding; sepals narrowly oblong, obtuse, 3-nerved, 2 lines long, not noticeably decurrent upon the ovary; lateral petals spatulate, obtuse, 1-nerved, equalling the sepals; labellum shortly unguiculate, oblong, obtuse, 2 lines long; the blade shortly and inconspicuously auricled at the base; margin slightly wavy, inflexed near the apex; callosities 2, two-thirds the length of the labellum, bright red: fruit 5 lines long.—Collected by C. G. Pringle, chiefly under *Arbutus*, in cool porphyritic gravel, Sierra Madre, Chihuahua, October, 1887 (No. 1373); and on dry ledges under firs, Sierra de las Crucis, 20 August, 1892 (No. 5326). Mr. Pringle's two plants differ only in the fact that in the first mentioned the stem and inflorescence is sparingly pubescent, in the other quite glabrous.

SISYRINCHIUM ALATUM Hook. var.? ANGUSTISSIMUM. Erect 1½ feet high: root a cluster of elongated tough fibres somewhat thickened below: stems scarcely at all flexuous, only 1 to 1½ lines in breadth: cauline leaves 4 to 12 inches long, 1½ to 2 lines broad, erect: flowers and fruit as in the typical form but spathes more slender.—Collected by C. G. Pringle, on the Sierra de San Felipe, altitude 9,500 feet, 22 June and 29 August, 1894 (No. 4703). The tall slender erect stems and narrow elongated leaves are so different from the original form of the species that the present plant would have appeared distinct but for the occurrence of a good intermediate in Mr. J. Donnell-Smith's No. 1297 from Guatemala, and the well known polymorphous character of the species.

SISYRINCHIUM EXALATUM. Erect, 1½ to 2 feet or more in height: root a cluster of long stout but scarcely tuberous fibres; stem terete, smooth, 3–5-leaved, ending in several dichotomous flexuous branches, subtended by linear-lanceolate bracts: leaves linear attenuate; the outermost basal 2 to 4 inches long, 2 lines broad, flat; the inner basal and lower cauline elongated, 8 to 18 inches long, 2 to 3 lines broad; the upper shorter, bractlike: clusters of flowers solitary, terminal on the branches, 3–5-flowered; outer spathes 14 to 22 lines long, exceeding the inner: perianth golden yellow; the outer divisions obovate, short-acuminate, about 4 lines long, 2 lines broad; the inner slightly smaller: filaments united for about a third of their length; anthers oblong-linear, about 3 lines in length: young capsule pubescent, short-obovoid, 3 lines long.—Collected by L. C. Smith on the Cuilapan Mountains, Oaxaca, altitude 7,000 feet, 27 June, 1894 (No. 52).

SISYRINCHIUM POLYCLADUM. Tall, much branched and very leafy above, 1½ feet high, drying green: root fibres numerous, 2 to 4 inches long, fusiform-thickened near the ends: stems erect, rather slender, nearly terete and leafless up to the first fork: branches flattened and narrowly winged, scarcely a line in breadth, flexuous, several times forked: radical leaves 6 to 8 inches long, a line wide, surrounded at the base by fibres of decayed leaves; cauline leaves 2½ to 4 inches long, 1½ to 3 lines broad, often falcate: spathes solitary, terminal upon the ultimate divisions of the branches, 2(–3)-flowered, 8 to 10 lines long, slender and not ventricose: flowers 8 lines in diameter, yellow, exserted upon slender pedicels: divisions of perianth elliptic: stamens connate only at the base: capsule shortly obovate-oblong, somewhat triquetrous, puberulent when young but quite glabrate, at maturity nearly 4 lines in length.—Collected by C. G. Pringle, on rocky banks, Sierra de San Felipe, Oaxaca, altitude 7,500 feet, 11 September, 1894 (No. 4902).

NEMASTYLIS DUGESII Watson, Proc. Am. Acad. xxiv, 86. Add syn. *N. flava* Robinson, ibid. xxix, 323. Dr. Watson's species, described from drawings and somewhat fragmentary material, was not at once recognized upon its subsequent collection in more perfect specimens.

HECHTIA PRINGLEI. Leaves fifteen or twenty, clustered at the base, linear-oblong from an ovate base, spinose-tipped and pungent, about 8 inches long, remotely serrate with firm curved reddish spines; margins repand and in dried state involute; both surfaces but especially the upper argenteous, scurfy: stem 2 to 4 feet high, half inch thick, simple, scape-like: panicle a foot in length, cylindric, mealy-puberulent: bracts attenuate from an ovate base: rhachis flexuous, branches numerous, mostly simple, spike-like, ascending or somewhat flexuous and more or less spreading: bractlets ovate, acute, erose, each subtending a single flower: the ♂ flowers subsessile, outer divisions of the perianth ovate-rotund, 3-nerved, scarious-margined, somewhat puberulent on the outer surface, a line long, the inner a third longer, elliptic-oblong, obtuse: anthers slightly exserted, apiculate: ♀ flowers sessile; outer divisions of perianth deltoid, acuminate; the inner longer, lanceolate, attenuate.—Collected by C. G. Pringle, on the east side of the valley of Oaxaca, abundant, sometimes growing in patches or masses, May, 1894 (No. 4637).

DIOSCOREA CAPILLARIS Hemsl. Specimens corresponding in all essential points to Hemsley's description of this species, have been collected by Mr. Pringle, at El Parian, Oaxaca; altitude 5,000 feet, 3 October, 1894 (No. 5700), and on dry ground in the Sierra de San Felipe, altitude 7,000 feet, 11 October, 1894 (No. 5829). In the latter locality the hitherto undescribed fruit was secured, furnishing the following supplementary characters: fertile spikes simple, 1 to 4 inches long; capsules deflexed, elliptical, 6 to 7 lines in length, half as broad, tipped with the persistent styles and stigmas.

DIOSCOREA CONVOLVULACEA Cham. and Schlecht. Specimens agreeing well in other respects with this species but having very large flowers (5 lines in diameter) were secured by Mr. Pringle on the Sierra de San Felipe, Oaxaca, altitude 7,500 feet, 13 August, 1894 (No. 5672). The segments of the perianth are deep purple, almost black, but sometimes tipped with yellow.

ANTHERICUM LEUCOCOMUM. Root-fibers numerous, long, simple, enlarged and fusiform near their ends: base of the stem surrounded by persistent fibrous remains of earlier leaves: radical leaves 8 to 12, lance-linear, 3 to 4 inches long, 3 to 4 lines broad, acute, entire, narrowed at the base, conspicuously and densely white-pilose upon both surfaces, 13–15-veined; margins ciliated: stem somewhat compressed, pilose at least toward the base, leafless, 6 inches to a foot high: bracts scarious, attenuate, the lower 6 to 8 lines long: inflorescence a simple or branched raceme, 1½ to 8 inches long: pedicels 2 to 4 lines long, articulated in the middle: flowers usually 3 in each bract; perianth yellow; divisions oblong-lanceolate, acute, 3-nerved, 6 lines long: filaments smooth: capsule short-oblong, 3½ lines in length, glabrous. —Collected by C. G. Pringle, in Oaxaca, 1894 (No. 4783), and by L. C. Smith, at Cuilapan, Oaxaca, altitude, 6,000 feet, 27 June, 1894 (No. 63).

SCHŒNOCAULON TENUIFOLIUM. *Veratrum tenuifolium* Mart. and Gal., Bull. Acad. Brux. ix, 380 (reprint, p. 9). *Asagræa? tenuifolia* Kunth, Enum. iv, 700. This species, now rediscovered by Mr. Pringle, proves quite distinct from *S. officinale* Gray, with which it has been united by recent authors. The original description may be supplemented as follows: Caudex erect, cylindrical, 4 to 10 inches long, surrounded by a dense envelope of dark fibers: leaves linear, attenuate, 2 feet or more in length, 3 lines in breadth, smooth upon the surfaces, obscurely or obsoletely denticulate, about 11-nerved: naked scape 6 to 8 inches high, terete, smooth: inflorescence dense, 3 to 4 inches long: bractlets broadly ovate, obtuse, scarious, shorter than the sessile flowers: divisions of the perianth obovate or sub-rotund, 7–9-nerved, green tipped with red, 2¼ lines long; margins erose: fruiting spike very broad, 2 inches in diameter, fertile only near the base: valves 6 to 8 lines long.—Collected by C. G. Pringle, on summit ridges, Sierra de San Felipe, Oaxaca, altitude 10,200 feet, 22 May (in flower) and 21 August (in fruit), 1894 (No. 5857).

III. *A Synoptic Revision of the Genus Lamourouxia.*

LAMOUROUXIA HBK. (Dedicated to *J. V. F. C. Lamouroux*, professor of natural history at Caen, born 1773, died 1825.)—Calyx campanulate, 4-cleft; segments subequal or connate in pairs (in one species the ventral cleft much deeper than the others, giving the calyx a unilateral and spathe-like form). Corolla long, much exceeding the calyx; throat elongated and more or less ventricose, laterally compressed; limb bilabiate; posterior lip erect, somewhat galeate, entire or emarginate; the lower usually shorter, ventricose, 2-plicate and with 3 small more or less spreading lobes. Stamens 4, didynamous, usually included and ascending under the galea, rarely exserted, all fertile or the posterior pairs with reduced sterile or obsolete anthers; fertile anthers contiguous or sometimes coherent in pairs, densely woolly; cells distinct, parallel or oblique, often calcarate at the base. Style undivided; stigma terminal. Capsule ovoid, loculicidal; valves entire, with central placentæ. Seeds very numerous, small, minutely roughened or reticulated. —Chiefly perennial herbs exclusively of subtropical and western tropical America, extending from Northern Mexico to Peru, growing chiefly upon the mountains and at middle altitudes. Habit erect, decumbent, or rarely somewhat scandent. Leaves opposite, entire, dentate, serrate, crenate, or in one species dissected. Flowers orange to crimson, showy, spicate- or racemose-paniculate, or somewhat corymbous.—Nov. Gen. et Spec. ii, 335, t. 167–169; Benth. in DC. Prodr. x, 539.

§ 1. EUPHRASIOIDES Benth. l. c. Fertile stamens 4, equal or nearly so; a very rudimentary fifth sometimes present.

* Leaves bipinnatifid.

1. L. MULTIFIDA HBK. Perennial, well-marked in the genus by its dissected foliage, scabrous-puberulent to densely and somewhat glandularly pilose: base a small woody tuber: flowers in the typical form 12 to 16 lines in length.—HBK., l. c., 339. *L. laciniata* Mart. and Gal., Bull. Acad. Brux. xii. 2, 32 (incl. var. *pilosa*, the commoner form).—Common at moderate altitudes (2,500 to 8,000 or even 11,000 feet), throughout Central and Southern Mexico to Guatemala; San Luis Potosi, *Parry* and *Palmer*, 687; Jalisco, *Pringle*, 2833; Valley of Mexico, *Bourgeau*, 612; Mexico, without locality, *Graham;* Chiapas, *Ghiesbrecht*, 704; Guatemala, Pl. Guat. *Donnell-Smith*, 813, 4013; Orizaba, *Seaton*, 134; Sierra de San Felipe, Oaxaca, *Pringle*, 4829, and *Nelson*, 1098, 1798.

VAR. GRANDIFLORA Benth. Flowers considerably larger, becoming 2 inches in length.—Benth., l. c., 540. *L. grandiflora* Benth., acc. to Linden, Cat. n. 10 (1855), 6.—Jalisco, *Hartweg*, 187; State of Mexico, *Pringle*, 3149; Guanajuato, *Dugès*, 385. Intermediate forms passing to the type are represented by *Ghiesbrecht's* 84 from Chiapas and his unnumbered specimen from the Plateau of Mexico, as well as by *Coulter's* 1356, without exact locality.

* * Leaves serrate, crenate, or entire.

+ Anther-cells conspicuously calcarate at base.

++ Calyx-teeth subulate: leaves entire or nearly so.

2. L. LONGIFOLIA Benth. Calyx 5 to 7 lines long: leaves oblong-linear, attenuate at both ends, acute, the larger 2 inches long, 1½ to 2½ lines broad; margins recurved.—Pl. Hartw. 22, and in DC. Prodr. x, 540.—Northwest Mexico in the Sierra Madre, *Seemann;* Jalisco near Balaños, *Hartweg*, 188.

3. L. HYSSOPIFOLIA Gray. Calyx 3 to 4 lines long: leaves mostly shorter and broader, oblanceolate to spatulate, acute or obtusish, 9 to 18 lines long, 2½ to 3½ lines broad.—Proc. Am. Acad., xxi, 404.—Southwestern Chihuahua, *Palmer*, 266.

++ ++ Calyx-teeth oblong, obtusish: leaves serrate.

4. L. PRINGLEI. Tomentulose, 3 to 5 feet high, branched from a somewhat ligneous base: stems terete: leaves elliptical, obtuse, 4 to 9 lines long, nearly half as broad, obtusely serrate from the middle, narrowed and shortly petiolate at the base: racemes several, rather dense; pedicels only a line or two in length: flowers 2 inches or more in length.—Garden and Forest, viii, 275, t. 39.—On cold ledges of Sierra de San Felipe, altitude 10,000 feet, 25 September, 1894, *Pringle*, 4927; and near Tamazulapam, altitude 7,800 feet, 13 November, 1894, *Nelson*, 1953.

+ + Anther-cells obtuse or acute at base, but not distinctly spurred: leaves serrate.

++ Flowers small: corolla 7 to 10 lines long.

5. L. BREVIFOLIA Benth. Pubescent throughout: flowers subsessile.—Benth. in DC. Prodr. x, 540.—Chachapoyas, Peru, *Mathews*, 3138.

6. L. PARVIFLORA Hemsl. Glabrous or glabrate: flowers short-pediceled.—Biol. Cent.-Am. Bot., ii, 465. "Mexico, without locality, *Tate*, 31, *Mairet*, 56."

++ ++ Flowers larger; corolla 14 lines to 2½ inches long.

= Calyx very irregular, deeply cleft anteriorly; lobes lanceolate, usually acute.

7. L. XALAPENSIS HBK. Calyx slender, spathe-like, 6 to 8 lines long: corolla 15 to 18 lines long.—Nov. Gen. et Spec., ii, 388. *L. spathacea* Benth., l. c., 539.—Jalapa, *Humboldt* and *Bonpland;* Orizaba, *Botteri*, 383, 1169. Bentham's *L. Xalapensis* of the Podromus exclusive of Humboldt's specimen may well have been the following.

= = Calyx less irregular: lobes usually broad, ovate or oblong, obtusish, or in the first linear-oblong and acutish.

8. L. EXSERTA. Puberulent: stem subtetragonal, copiously branched above: leaves narrowly lanceolate, sharply serrate, acute to acuminate, 1 to 2½ inches long, 3 to 5 lines broad, narrowed at base to slender petiole: racemes lax and secund; pedicels 2 to 4 lines long: calyx glabrous, 4 to 6 lines in length; the lobes narrowly oblong: corolla 1 to 1½ inches long, densely pubescent: stamens conspicuously exserted.—Valley of Mexico, *Bourgeau*, 986, *Schaffner*, 367; and in rich ravines of Sierra de Clavellinas, Oaxaca, altitude 9,000 feet, 18 October, 1894, *Pringle*, 4995; also on top of Sierra Madre near Chilpancingo, altitude 9,000 to 10,200 feet, 24 December, 1894, *Nelson*, 2216, and at Tlalixtaquilla, *Nelson*, 2261.

9. L. DEPENDENS Benth. Hirsute: leaves ovate-lanceolate: calyx-lobes broad and often serrate: flowers rather long-pediceled, 1½ inches long: flowering branches pendulous.—Benth., l. c., 539.—"Guatemala, *Skinner*." *Ghiesbrecht's* 74, 173, 176, and 706 from Chiapas may be doubtfully placed here, and *J. Donnell-Smith's* 2162, which we have not seen, has also been referred to this species.

10. L. MACRANTHA Mart. and Gal. Pubescent with soft spreading articulated hairs: stem rather stout, erect from a somewhat decumbent base: leaves ovate, subsessile, doubly and rather deeply crenate-serrate, obtuse: racemes erect: calyx-lobes entire: corolla 2½ inches long, red dorsally and yellow ventrally: stamens not produced beyond the galea.—Bull. Acad. Brux., xii, 2, 32. *L. betonicæfolia* Benth., l. c.—South Mexico, 7,500 to 10,200 feet altitude, on Sierra de San Felipe, Oaxaca, *Pringle*, 4854, *Nelson*, 1070, 1343. Originally collected in Orizaba by *Galeotti*.

11. L. OVATA Mart. and Gal., l. c., 33. Similar to the last, but with flowers much shorter, 1¼ to 1½ inches long: inflorescence more leafy: calyx-lobes more or less serrulate.—Oak woods, Sierra de San Felipe, Oaxaca, *Pringle*, 4762; in neighboring locality, *Nelson*, 1118. Originally collected in the same general region by *Galeotti*, 989.

§ 2. HEMISPADON Benth. Fertile stamens only 2, or the posterior pair at least much shorter and with reduced anthers.

* Leaves ovate or oblong, broad at base, sessile or nearly so; Mexican and Central American species.

+ Some or all of the calyx-lobes serrate.

12. L. RHINANTHIFOLIA HBK. Leaves very sharply and doubly serrate: flowers not densely aggregated: tube of the calyx short, campanulate, obscurely 2-3-nerved at each sinus.—Nov. Gen. et Spec., ii, 337, t. 169.—Common: San Luis Potosi, *Schaffner*, 750; *Parry* and *Palmer*, 686; Valley of Mexico, *Bourgeau;* Zimapan, *Coulter*, 1357; Orizaba, *Seaton*, 464; State of Mexico, *Pringle*, 5335; Guanajuato, *Dugès*, 387; Oaxaca, *Pringle*, 4661;

Nelson, 1040, 1131. *Andrieux'* 158, from Gonocatepec, referred by Hemsley to *L. viscosa*, has the pubescence, serrulate calyx-lobes, and elliptical rameal leaves of the present species, of which it is probably only a small and more densely-flowered form.

+ + Calyx-lobes entire: corolla tubular, scarcely ventricose.

++ Inflorescence loose.

13. L. Smithii. Habit of the preceding: leaves of the stem ovate, sharply serrate, acute, somewhat larger, 2 inches long, an inch broad; the rameal ovate, subcordate, sessile, not elliptical and shortly petiolate as in the preceding: inflorescences considerably branched: calyx-tube short-cylindrical, 3 lines long; lobes lanceolate, acute, entire, about equal in length; nerves from the sinuses distinct, single or double: corolla 2 to 2¼ inches long.—Mountains of Jayacatlan, Oaxaca, altitude 5,000 feet, 13 August, 1894, *L. C. Smith*, 155.

++ ++ Inflorescence dense.

14. L. viscosa HBK. More or less glandular-tomentose: stem rather rigid, terete: leaves ovate-oblong, thickish, sharply-serrate.—HBK. l. c., 338. *L. cordata*, Cham. and Schlecht. Linnæa, v, 103. *L. coccinea*, Gray, Proc. Am. Acad., xxi, 404 (only a less pubescent form).—One of the commonest species throughout the whole length of Mexico; Sonora, *Lloyd*, 437; Chihuahua, *Palmer*, 258; *Pringle*, 656; Jalisco, *Palmer*, 578; *Pringle*, 2133, 2339; Zacatecas, *Hartweg*, 189; Huasteca, *Ervenberg*, 112; Zimapan, *Coulter*, 1358; Orizaba, *Bourgeau*, 2424; *Bilimek*, 285; *Botteri*, 86, 149; *Seaton*, 135; Oaxaca, *Pringle*, 4879; *Nelson*, 1199, 1245; Chiapas, *Ghiesbrecht*, 96, 703; Guatemala, *J. Donnell-Smith*, 4016; Mexico without locality, *Sumicrast*. So far as the characterization shows, *L. Viejensis* Oerst., Vidensk. Meddel. Kjöben., 1853, 28, from Nicaragua is also the same.

* * Leaves lanceolate, narrowly oblong, elliptical or linear, narrowed at the base, and often petioled.

+ Posterior filaments bearing reduced villous anthers.

++ Corolla short for the genus, 8 or 9 lines long: leaves incisely serrate: species of Ecuador.

15. L. subincisa Benth. "Habit of *L. brevifolia*: leaves lanceolate, an inch or less in length."—Benth. l. c., x, 540.—Andes of Quito, *Jameson*.

++ ++ Corolla longer, an inch or more in length.

= Calyx-lobes serrulate.

16. ? L. sylvatica HBK. "Somewhat twining: leaves lanceolate, acute, narrowed at base: corolla roseate."—HBK. l. c., ii, 337.—Near Ayavaca, Peru, *Humboldt* and *Bonpland*. A very

dubious species, founded upon imperfect material, but, if correctly described, belonging here.

= = Calyx costate; segments entire.

a. Mexican species.

17. L. TENUIFOLIA Mart. and Gal. l. c. Stem copiously branched above; branches simple, slender, ascending, very leafy: leaves narrow, lance-linear, 6 to 10 lines long, crenate-serrulate; margins recurved: inflorescence dense.—Walpers, Rep. vi, 652. *L. linearis*, Benth. l. c., x, 541.—Valley of Mexico, *Bourgeau*, 1113; *Schaffner*, 368; Chiquihuite, *Bilimek*, 284; Tula, *Berlandier*, 1261; San Luis Potosi, *Parry* and *Palmer*, 673. Originally collected in E. Oaxaca by *Galeotti.*

b. South American species.

18. L. VIRGATA HBK. Leaves linear-lanceolate, sharply but finely serrate: calyx-lobes lanceolate, acute, longer than the tube. —HBK. l. c. ii, 336, t. 167.—Near Quito, *Humboldt* and *Bonpland*, *Hall*, *Jameson*, *Hartweg*, *Couthouy.*

19. L. LOXENSIS Benth. Leaves linear-lanceolate: segments of the calyx scarcely longer than the tube.—Pl. Hartw. 147, and in DC. Prodr. x, 541.—Mountains of Loxa, United States of Columbia, *Hartweg*, 824. A doubtful species, intermediate between the preceding and following.

20. L. SERRATIFOLIA HBK. Leaves linear-lanceolate, conspicuously and incisely serrate with short divergent teeth.—HBK. l. c. ii, 336, t. 168.—Near Bogota, *Humboldt* and *Bonpland*, *Goudat.*

+ + Posterior filaments glabrous at the summit and anantherous or nearly so.

++ Leaves quite entire.

21. L. INTEGERRIMA Donnell-Smith. Nigrescent in drying: leaves narrowly lanceolate, attenuate at both ends, ¾ to 1½ inches long, 1½ to 2½ lines wide, conspicuously 1-nerved; veins very obscure: calyx indistinctly 8-costate.—Bot. Gaz. xiii, 189.—Pansamala, Alta Verapaz, Guatemala, altitude 4,000 feet, *von Tuerckheim* (Donnell-Smith's Pl. Guat.), 1112.

++ ++ Leaves serrate, serrulate, or crenate.

= Leaves an inch or more in length.

22. L. LANCEOLATA Benth. Whole plant nigrescent in drying: branches divaricate: leaves narrowly lanceolate, finely, sharply and irregularly serrate, 1 to 1½ inches long, 1½ to 2½ lines wide: calyx conspicuously 12-costate; segments linear-lanceolate, acute, spreading or even reflexed.—Benth. in DC. Prodr. x, 542.—South Mexico, Chiapas, *Ghiesbrecht*, 144, 705; Guatemala, *Donnell-Smith's*, 398, 3100.

23. L. Nelsonii. Pubescent, drying green : leaves thin, oblong, acute, irregularly dentate, the larger 2 to 3 inches in length, 4 or 5 lines broad : calyx pubescent, not distinctly ribbed, 6 lines long : segments lanceolate, acute, erect : corolla over 2 inches long, red, paler and yellowish toward the base.—Six miles above Dominguillo, Oaxaca, altitude 4,500 to 5,000 feet, 30 October, 1894, *Nelson*, 1833.

= = Leaves half inch or less in length.

24. L. microphylla Mart. and Gal. Leaves oblong, crenate-serrulate, 3–4 (–6) lines long, a line broad; those of the branches reflexed : calyx glabrous; teeth very short.—Bull. Acad. Brux. xii, 2, 31. *L. parvifolia*, Benth. l. c. x, 542.—Oaxaca, *Galeotti*, 1005; and on granitic hills at base of Sierra de Clavellinas, altitude 6,000 feet, *Pringle*, 6000.

25. L. Gutierrezii Oerst. Shrub, 3 to 4 feet high, somewhat scandent: leaves lanceolate-elliptical, 6 to 10 lines long, 2 lines broad, somewhat scabrous : calyx somewhat villous, teeth much shorter than the tube, and (from figure of Seemann) entire.—Vidensk. Meddel. 1853, 29. *L. scabra* Benth. in Seem. Bot. Herald, 177, t. 33.—Mountains between Cartago and Candelaria, Costa Rica, *Oersted;* Volcano of Chiriqui, Veraguas, *Seemann.*

This species in the Index Kewensis is incorrectly said to be Venezuelan. Bourgeau's 101, referred hither by Hemsley, is *L. rhinanthifolia.*

26. L. gracilis. Scarcely shrubby, 1 to 1½ feet high: stems slender, terete, puberulent in lines: leaves elliptic-oblong, obtuse, narrowed at the base to short slender petioles, crenate-dentate, thin, not at all rugose, nearly or quite smooth, the larger ones 9 lines long, 3 lines broad : racemes simple, rather loose, leafy to the apex: segments of the calyx ovate-oblong, obtuse, nearly always crenate-dentate: corolla 1¼ to 1½ inches long, red with yellowish throat, moderately ventricose.—Summit of Sierra Madre near Chilpancingo, Guerrero, altitude 9,000 to 12,000 feet, 24 December, 1894, *Nelson*, 2234.

The following distributed as species of *Lamourouxia* belong elsewhere :

Mandon's 479 = *Gerardia* sp.
Bang's 543 = *Gesnera* sp.

IV. *Miscellaneous New Species.*

Unona Panamensis Robinson. A small tree, 15 to 20 feet high: branches brown with lighter colored lenticels; the young parts finely rufous-tomentose with simple hairs: petioles a line or two in length: leaves oblong or elliptic, shortly acuminate, somewhat narrowed at the base, entire, 4 to 8 inches long, about a third as broad, glabrous above, covered beneath especially upon the veins with an appressed rufous silky pubescence: peduncles opposite the leaves, rather short, 4 to 6 lines in length, bearing at the summit a suborbicular cordate bract half inch in diameter (rarely larger and more like the leaves, rarely absent) and 1 or 2 elongated curved pedicels, slightly thickened near their summits and 3 to 3½ inches long: calyx-segments ovate-triangular, a line in length: petals 6, equal, lance-linear, nearly erect, finely pubescent upon the outer surface, minutely granulated within, 6 to 8 lines long; the edges revolute; the tips incurved: maturing carpels 5 to 12, oblong, a little over half an inch in length, 5 lines in diameter, very slightly torulous, rounded at each end; stipe slender, 3 to 4 lines long: seeds about 6, disk-shaped.—Collected by Sutton Hayes in woods near Gatun Station on the Panama Railway, 30 July, 1860.

Unona bibracteata Robinson. Branchlets light brown, nearly or quite glabrous: leaves lance-oblong, narrowed to an obtuse apex, contracted below to a very short thickish petiole, green and glabrous upon both surfaces, 2¼ to 3 inches long, an inch in breadth, firm but not coriaceous in texture: peduncles opposite the leaves, bearing two very unequal suborbicular cordate bracts; the lower one a third to half inch, the upper only a line in diameter; pedicel recurved, slender, about an inch in length: segments of the calyx ovate, 2 lines in length: petals linear-oblong, obtusish, 8 lines in length: maturing carpels about 15, glabrous, two-seeded, 4 lines long, 3 lines in diameter, subtruncate at apex and base, somewhat constricted in the middle; stipes slender, 3 lines in length; seeds disk-shaped, 1½ lines thick. —Collected by Charles Wright in Nicaragua upon the U. S. North Pacific Exploring Expedition in 1855.

The only other *Unona* reported from Central America, the rather doubtful and imperfectly described *U. violacea* Dunal, has according to the original figure in Dunal's monograph a considerably larger flower with broader petals and no bracts. All efforts to identify the two species here described with those of the Old World have failed and their occurrence does not suggest an introduced character.

Malvaviscus Pringlei E. G. Baker. Caule ligneo, foliis membranaceis viridibus cordatis acute palmate-5-lobatis, lobo medio majore, præcipue junioribus utrinque stellato-pubescentibus serratis petiolatis, floribus maximis axillaribus solitariis vel ad extremitatem ramulorum subracemosis, bracteolis ligulatis calyce brevioribus, sepalis triangularibus vel ovatis acutis intus margine cinereo-pubescente, columna staminea exserta petalorum longitudinem dimidio excedente, carpellis nigrescentibus vel subnigrescentibus superne in medio sulcatis inferne carinatis.—Collected by C. G. Pringle, on rocky hills bordering Lake Cuitzeo, Michoacan, 20 July and 26 October, 1892 (No. 4132). Stem 10 to 20 feet high, woody, younger branches at the extremities covered with a scurfy cinereous pubescence. Leaves membranous, green, cordate; palmately 5-lobed, middle lobe longest, serrate, pubescent on both surfaces especially the young leaves, length of leaves on specimen 3–3½ inches, breadth 3–4 inches, petioles 1½–3 inches long covered with cinereous pubescence. Flowers axillary, solitary or at the end of the branches somewhat racemose. Bracts strapshaped, half inch long, shorter than the sepals. Calyx three-fourths inch long, sepals triangular or ovate, acute, inside the margin cinereous-pubescent. Petals convolute, 2¾ inches long. Stamineal tube exserted 1½ inches. Styles 10, capitately stigmatose. Fruiting peduncles straight, stiff, terete, generally slightly bent just below the fruit. Carpels 5, black or brownish, black on the back, grooved above, the groove gradually passing into a ridge below, third inch long.

This plant was distributed as *Malvaviscus acerifolius* Presl, of which there is a specimen gathered by Hænke in Mexico in the Herb. Mus. Brit. *M. Pringlei* differs from *M. acerifolius* Presl, in its leaves, bracts and flowers. The leaves are much deeper lobed in the former than in the latter and in *M. Pringlei* the bracts are shorter than the calyx and the petals nearly 3 inches long; in *M. acerifolius* the bracts are the same length as the calyx and the petals an inch long. *M. Pringlei* differs from *M. cinereus* Bak. fil. MS. in the texture of its leaves and its much larger flowers. I have named this very showy plant in honor of Mr. C. G. Pringle, who has done so much to further our knowledge of the Mexican flora.

Laphamia Toumeyi Robinson and Greenman. Many-branched from a knotted woody base, densely glandular-puberulent; branches about 4 inches long, erect, terete, striated, simple or again branched, rather cinereous: leaves spatulate, including the petioles 3 to 5 lines long, a line to a line and a half broad; entire, obtuse, thickish, cinereous; the petiole channelled above; heads discoid, 2½ to 3 lines high, equally broad, about 35-flowered, terminal upon the branchlets, together forming a pyramidal or subcorymbous inflorescence; involucral scales sub-biseriate, nearly equal, acute, the outer thickish, carinate, densely puberulent, the inner thinner and flatter: pappus of a single awn: tube of the corolla glandular-pubescent: achenes compressed, oblong-linear, about a line long, puberulent.—Collected by Prof. J. W. Toumey, in the Grand Cañon, 12 July, 1892 (No. 645).

Art. XVIII.—*Thomas Henry Huxley.*

In the present half century of English science, four names stand forth preëminent; Darwin, Huxley, Spencer, and Tyndall, and of these masters Spencer alone survives. It has been my good fortune to know each of these men, under circumstances that brought out their prominent characteristics, intellectual and social, and my intercourse with each and all of them I recall as among the brightest spots in my life. Darwin I saw only at his own country home, but the others I met more frequently in London, and held still closer relations with them during their visits to this country. With Darwin and Huxley, as the leaders in modern natural science, my associations were more intimate than with the others, while Huxley was to me a guide, philosopher, and friend, almost from the time I made choice of science as my life work. For this reason, I cannot now bring myself to attempt an estimate of the loss to science and to the world occasioned by his death. I can only at present place on record a few facts of his life, and add something about the man himself as he appeared to me.

Thomas Henry Huxley was born at Ealing, Middlesex, England, May 4, 1825. His early education was obtained mainly at home, and in the Ealing school of which his father was one of the masters. He began his scientific studies in 1842, at the medical school of Charing Cross Hospital, and passed the M.B. examination at the University of London in 1845. In the following year, he entered the medical service of the Royal Navy at the Haslar Hospital, and from there was appointed to the post of assistant surgeon to H. M. S. *Rattlesnake*, then preparing for a surveying voyage to the South Seas. The ship left England in 1846 and returned in 1850, having surveyed the inner route between the barrier reef and the east coast of Australia and New Guinea, and also completing a voyage around the world. Huxley's scientific work during this voyage is well known, and in recognition of it he was elected, in 1851, a fellow of the Royal Society. He left the naval service in 1853, having failed to obtain from the government the publication of his researches during his voyage. This was afterwards done by the Royal Society.

In 1854, Huxley was appointed naturalist to the Geological Survey, and in the same year was made professor of natural history in the Government School of Mines, a position which he filled with marked success until his retirement in 1885. He was appointed in 1854 Fullerian professor of physiology in the Royal Institution, and also became examiner in physiology and comparative anatomy to the University of London.

From 1863 to 1869, he was Hunterian professor at the Royal College of Surgeons, and was president of the Geological Society of London in 1869 and 1870. For three years, beginning with 1872, he was Lord Rector of Aberdeen University, and in 1875 and 1876 was acting professor of natural history in the University of Edinburgh. In 1870, he was president of the British Association for the Advancement of Science. From 1870 to 1872, he was a member of the London School Board, where, as chairman of the educational committee, he rendered important services. He was elected president of the Royal Society in 1883, having previously served as its secretary. From 1881 to 1885, he was Inspector of Salmon Fisheries. He resigned this and other offices in 1885, owing to impaired health, and shortly after removed from London to Eastbourne, on the Sussex coast, where he passed the remainder of his life.

The ten years after his return to England in 1850 were devoted to brilliant investigations in several departments of natural science and to many popular lectures, which won for him high rank in the scientific world. With this came various official positions, the arduous duties of which he faithfully performed. His publications during this period were numerous and important, but need not be enumerated here.

With the appearance of Darwin's great work on the Origin of Species, a new field was opened to Huxley, which he entered with masterly zeal. He accepted at once the theory of Natural Selection, and applied it to the evolution of the human race, giving his first results in his lectures to working men, in 1860, at the Museum of Practical Geology. These lectures, which led to bitter controversy, were published in 1863, under the title, Evidence as to Man's Place in Nature. For several years, the battle over Darwin's views raged fiercely, and Huxley was the leader who repelled the assaults of both theologians and scientific conservatives. After this victory was won, he still continued the struggle by carrying the war into new fields, involving all the relations between science and religion, and this contest he carried on vigorously until failing health caused him to give up all intellectual work.

Haeckel, the leading biologist on the Continent, ably reviewed, in 1874, Huxley's scientific work up to that time, and the following brief extracts will serve to indicate his appreciation of it:

"When we consider the long series of distinguished memoirs with which, during the last quarter of a century, Prof. Huxley has enriched zoölogical literature, we find that in each of the larger divisions of the animal kingdom we are indebted to him for important discoveries.

"From the lowest animals, he has gradually extended his investigations up to the highest, and even to man. His earlier labours were, for the most part, occupied with the lower marine animals, especially with the pelagic organisms swimming at the surface of the open sea."

"More important than any of the individual discoveries which are contained in Huxley's numerous less and greater researches on the most widely different animals are the profound and truly philosophical conceptions which have guided him in his inquiries, having always enabled him to distinguish the essential from the unessential, and to value special empirical facts chiefly as a means of arriving at general ideas."

"After Charles Darwin had, in 1859, reconstructed this most important biological theory, and by his epoch-making theory of Natural Selection placed it on an entirely new foundation, Huxley was the first who extended it to man, and in 1863, in his celebrated three Lectures on "Man's Place in Nature," admirably worked out its most important developments. With luminous clearness, and convincing certainty, he has here established the fundamental law, that, in every respect, the anatomical differences between man and the highest apes are of less value than those between the highest and lowest apes. * * * * * Not only has the Evolution Theory received from Prof. Huxley a complete demonstration of its immense importance, not only has it been largely advanced by his valuable comparative researches, but its spread among the general public has been largely due to his well-known popular writings. In these he has accomplished the difficult task of rendering most fully and clearly intelligible, to an educated public of various ranks, the highest problems of philosophical Biology. From the lowest to the highest organism, * * * he has elucidated the connecting law of development.

"In these several ways he has, in the struggle for truth, rendered Science a service which must ever rank as one of the highest of his many and great scientific merits."

The above refers only to Huxley's biological work up to 1874. During the next twenty years, his scientific labors were equally fruitful, but embraced a much wider field. The results will be estimated in so many special reviews by those familiar with each department of science he treated, that they need not be especially mentioned here.

Huxley has himself placed on record, in the following words, the main objects he kept in view during his whole scientific career:

"To promote the increase of natural knowledge and to forward the application of scientific methods of investigation to all the problems of life to the best of my ability, in the conviction which has grown with my growth and strengthened with my strength, that there is no alleviation for the sufferings of mankind except veracity of thought and of action, and the resolute facing of the world as it is when the garment of make-believe by which pious hands have hidden its ugliest features is stripped off.

"It is with this intent that I have subordinated any reasonable, or unreasonable, ambition for scientific fame which I may have permitted myself to entertain to other ends; to the popularisation of science; to the development and organisation of scientific education; to the endless series of battles and skirmishes over evolution; and to untiring opposition to that ecclesiastical spirit, that clericalism, which in England, as everywhere else, and to whatever denomination it may belong, is the deadly enemy of science.

"In striving for the attainment of these objects, I have been but one among many, and I shall be well content to be remembered, or even not remembered, as such."

Huxley was a man of strong moral nature, with a tender conscience, but he could not accept authority when his reason did not approve. The following quotation will make clear his views on religious subjects, which have been much misunderstood:

"When I reached intellectual maturity and began to ask myself whether I was an atheist, a theist, or a pantheist; a materialist or an idealist; a Christian or a freethinker; I found that the more I learned and reflected, the less ready was the answer; until, at last, I came to the conclusion that I had neither art nor part with any of these denominations, except the last. The one thing in which most of these good people were agreed was the one thing in which I differed from them. They were quite sure they had attained a certain "gnosis,"—had, more or less successfully, solved the problem of existence; while I was quite sure I had not, and had a pretty strong conviction that the problem was insoluble. * * * * * So I took thought, and invented what I conceived to be the appropriate title of "agnostic." It came into my head as suggestively antithetic to the "gnostic" of Church History, who professed to know so much about the very things of which I was ignorant."

One thing that will always be of special interest to Americans is Huxley's visit to this country, in 1876. One object of this visit was to deliver a series of lectures in New York, but he came mainly to see America and its people, and what they were doing for science. The Exposition that year in Philadelphia was also an inducement, and last, but not least, he wished to see a sister, who for many years had resided in the South. During his visit, which extended over seven weeks, he attended the American Association for the Advancement of Science at Buffalo, gave the opening address at the Johns Hopkins University at Baltimore, another discourse in Nashville, where his sister resided, and after visiting the principal scientific centers of the country, he delivered three lectures in New York on the eve of his departure. These lectures, with his other discourses in this country, were subsequently published under the title, American Addresses.

On his arrival in New York, in August, I met him there by appointment, and a day or two later, he came to New Haven to make me a long promised visit, and see my fossil treasures from the West. These he wished to examine before delivering his course of lectures, and he devoted a week of hard labor to this object, during which time I gained new insight into his methods of work and the noble nature of the man himself. One instance, which illustrates both these points, I am glad to place on record here.

One of Huxley's lectures in New York was to be on the genealogy of the horse, a subject which he had already written about, based entirely upon European specimens. My own explorations had led me to conclusions quite different from his, and my specimens seemed to me to prove conclusively that the horse originated in the New World and not in the Old, and that its genealogy must be worked out here. With some hesitation, I laid the whole matter frankly before Huxley, and he spent nearly two days going over my specimens with me, and testing each point I made. He then informed me that all this was new to him, and that my facts demonstrated the evolution of the horse beyond question, and for the first time indicated the direct line of descent of an existing animal. With the generosity of true greatness, he gave up his own opinions in the face of new truth, and took my conclusions as the basis of his famous New York lecture on the horse. He urged me to prepare without delay a volume on the genealogy of the horse, based upon the specimens I had shown him. This I promised, but other work and new duties have thus far prevented.

During Huxley's sojourn in America, I was fortunate enough to be with him on many occasions when he met all classes of the American people, many of whom had read his works and held him in high esteem. The impression he made upon rich and poor alike was a most agreeable one, and he returned home with a deep interest in America and its people and great hopes for its future. What seemed to impress him most of all, as an ethnologist, was the identity of the American race, especially in New England, with that of his own country, and he could detect no signs of that physical deterioration which our climate was supposed to have caused.

The lifelong friendship that existed between Huxley and his colleagues, Darwin, Spencer, and Tyndall, men of widely different views on many subjects, is a noteworthy fact. The intimacy between Huxley and Tyndall has been recorded on many pages, and I recall many illustrations of that of Huxley and Spencer, the last at one of the long-to-be-remembered dinners of the X Club, of which Huxley was then president.

As an illustration of the warm friendship existing between Huxley and Darwin, I may perhaps be permitted here to refer to an incident that occurred during one of my visits to England. I was passing a memorable day with Darwin, during which he spoke freely of many scientific men. Referring to Huxley, he said with more than usual earnestness, "Huxley is the king of men!" A few days later I mentioned this to Huxley, and he was deeply moved by it. His reply I shall never forget: "Now you can understand why we who know Darwin all have such an affection for him, and when his enemies reviled the noble man, why my right arm was so heavy in his defense."

How kind Huxley was to every one who could claim his friendship, I have good cause to know. Of the many instances which occur to me, one will suffice. One evening in London, at a grand annual reception of the Royal Academy, where celebrities of every rank were present, Huxley said to me, "When I was in America, you showed me every extinct animal that I had ever read about, or even dreamt of. Now, if there is a single living lion in all Great Britain that you wish to see, I will show him to you in five minutes." He kept his promise, and before the reception was over, I had met many of the most noted men in England, and from that evening, I can date a large number of acquaintances, who have made my subsequent visits to that country an ever increasing pleasure.

Another characteristic remark of Huxley's, at a later date, comes back to me as I write. Speaking of the many interruptions and distractions of his life in London, which claimed the greater part of his time, he said to me feelingly, "If I could only break my leg, what a lot of scientific work I could do!"

My latest message from Huxley came last Christmas, and with it the complete new edition of his revised works, which I shall always treasure as his parting gift, the last of many tokens of his friendship.

Honors fell thick and fast upon Huxley, especially during his active life. They were all deserved, and he estimated them at their true value. A mere list of his titles would extend the present notice much beyond the limits assigned to it.

Huxley's life work extended over so wide a range, and was of such high character, that no one man now living is qualified to place a true estimate upon it. The more important of his published works are as follows: Oceanic Hydrozoa, 1859; On the theory of the vertebrate skull, 1859; Evidence as to man's place in nature, 1863; Elementary physiology, 1866; On the physical basis of life, 1868; Introduction to the classification of animals, 1869; Lay sermons, 1870; Manual of the anatomy of vertebrated animals, 1871; Critiques and addresses, 1873; American addresses, 1877; Physiography, 1877; Manual of the anatomy of invertebrated animals, 1877; The crayfish, 1879; Hume, 1879; Science and culture, 1882; Essays on some controverted questions, 1892; Evolution and ethics, 1893. A new edition of his more popular works, in nine volumes, with his latest notes and additions, was published in 1894.

The limited space and time at my command have left little opportunity to say what I wish about Huxley himself. As I recall the hours spent with him, first of all the memory of his charming personality presents itself, and in this respect, no man I have ever met surpassed him. To go further and name his chief characteristics, I should place his ability, his honesty, and his courage, next in order. His marvellous ability no one will question. One qualified to judge has said, that, in his intellectual grasp, Huxley was the greatest man of the century. His honesty, in the broadest sense of the word, was the dominant feature of the man. His love of truth for its own sake, wherever it might lead him, was one of the strongest elements in his character, and this resulted not only in his well-known intellectual honesty, but also in his hatred of the opposite, wherever found. His courage, especially the courage of his convictions, is known to all, and has borne good fruits. Every man of science to-day is indebted to Huxley for no small part of the intellectual freedom he enjoys.

Huxley was especially fortunate in his home life, and a happier family circle I have never known. Mrs. Huxley, whom he won in his student days, was a most charming companion and helpmate in all his work, while his two sons and four daughters are all worthy of such a parentage.

Huxley passed quietly away on the afternoon of June 29, at his home in Eastbourne, after an illness of several months, which came at the end of years of feeble health. He was buried July 4, in St. Marylebone Cemetery, East Finchley, where he wished to lie. His friends proposed an interment in Westminster Abbey, where Darwin was entombed, but his own wishes were respected. His works are his best monument.

O. C. Marsh.

Yale University, July 20th, 1895.

Art. XIX.—*Daniel Cady Eaton.*

Daniel Cady Eaton, Professor of Botany in Yale University, died at his home in New Haven on June 29th.

He was of old New England stock, and the name has been associated with the progress of botany in this country for more than eighty years. His grandfather was that pioneer of American science, Prof. Amos Eaton, who perhaps more than any other one man stimulated the study of natural history in this country during the second and third decades of this century.

Several of his children were educated in scientific pursuits. One son, Amos B. Eaton, although sharing the scientific tastes of the other children, was trained for the army and graduated at West Point in 1826. He was in the Seminole, Mexican and the Civil War, and rose to the rank of Brigadier General.

General Eaton married Elizabeth Selden, who also was of New England stock, and Daniel Cady Eaton, the subject of this sketch, was born at Fort Gratiot, in Michigan, September 12th, 1834. In the changes incident to the military duties of the father, the family, during the youth of the son, had no very permanent place of abode. The mother was a sister of the eminent jurists, Samuel L. Selden and Henry R. Selden of Rochester, N. Y., and she lived in that city during a part of his boyhood, and until the close of the Mexican war. Later, he was for a while a student in the Rensselaer Institute at Troy, and still later, in Gen. Russell's Military School at New Haven.

He entered Yale College in 1853, and was graduated in 1857, having among his classmates an unusual number of persons who have since become eminent as professors in colleges. He was already a zealous student in botany, and published his first paper "On Three New Ferns from California and Oregon" in this Journal in 1856, while a junior in college.

After graduation he studied botany with Prof. Gray at Harvard for three years, and received in 1860 the degree of B.S. in that institution and that of M.A. in course at Yale.

He was a diligent student and published during this period papers on some New Filices from Japan; An Enumeration of Ferns collected by Mr. Charles Wright in Cuba; Equisetaceæ, Filices, etc., of the United States and Mexican Boundary Survey; contributed the description to the Filices in Chapman's Flora of the Southern States; and as a graduation thesis, Filices Wrightianeæ et Fendlerianæ, including some ferns from Panama, collected by Messrs. Schott and Hayes.

During the Civil War his father becoming Quartermaster-General, he went into the commissary department in New York as inspector of stores. In this capacity he became very expert, and ever after retained a special interest in certain vegetable products which had been under his study and inspection. These duties, while interrupting botanical work, did not prevent it absolutely. He botanised about New York, he became acquainted with the local botanists there, he delivered some lectures on botany and studied some small collections of ferns sent from various places, but he published nothing more until the close of the war.

In July, 1864, he was elected Professor of Botany at Yale at the same time with the writer of this sketch. As with his colleague, the late Wm. D. Whitney, the professorship was on a university foundation, not specially attached to any one department of the institution but practically his labors were chiefly in the Sheffield Scientific School, where he was a member of the Governing Board, and in which he was an active and successful teacher for thirty-one years. Regular classes in botany in the Academic department only began many years later, but from the first he gave instruction to such advanced students as wished it, and a considerable number have enjoyed this privilege.

As a teacher he was intensely conscientious, sympathetic, courteous, kind, and helpful in the extreme to those who wished to learn. Compelling students to learn was very distasteful to him, although he was patient to a fault with those who were indolent or indifferent.

During his professorship he published fifty botanical papers, works or contributions which are enumerated in the "Yale Bibliographies," and this list need not be repeated here. They related mostly to Ferns and Acrogens. The number but illy describes the work. Some of the contributions consisted of several parts of some larger work, and some were complete works of themselves. He prepared the Compositæ for the Report on the Botany of the Geological Exploration of the 40th Parallel, as well as the Acrogens, and both are enumerated as but one title in the published list cited.

His largest single contribution to botany was his "Ferns of North America," a sumptuous quarto in two volumes, published in 1879–'80, and dedicated to his old instructor, Prof. Gray, for whom he always had a strong affection. The work is beautifully illustrated with colored figures, from drawings by Emerton and Faxon. It gives technical descriptions and full synonomy, as well as a popular discussion of each species in his own charming style. This work is classic in the botanical literature of this country.

Most of his publications relate to Ferns, but he made a study of the Algæ and Mosses. While he printed but little pertaining to the Algæ, he, associated with Professor W. G. Farlow of Harvard University and Dr. C. L. Anderson of California, prepared and distributed numbered sets of specimens of North American sea weeds, under the title of "Algæ Boreali-Americanæ," a timely contribution to this department of our botany. It was the first considerable set authoritatively sent out, and is the most important of its kind yet published. Many of the specimens found on our Atlantic coast he collected, and this work with that of their preparation and the incident correspondence necessitated an amount of labor only appreciated by those who have attempted similar work. During the later years of his life he devoted more time to the Mosses, and for some years he had been making a critical study of the Sphagna, especially the North American species. In coöperation with Mr. E. Faxon he was preparing sets of specimens of North America Sphagna for distribution. It is a great loss to science that death cut short this work. He was at work on it to almost the very last, and the examination of the new specimens he collected last summer or received since, cheered him during his long and painful illness. He had been very desirous to obtain specimens from the far north for these sets, and the writer made special effort to collect such for him last summer. Their loss by shipwreck he deeply regretted, returning to the subject the last time I saw him, scarcely two weeks before his death, "What a pity I cannot add those Greenland specimens to the sets."

His preparation of the descriptions of the Ferns in Chapman's Flora of the Southern States, in Gray's Manual of the Botany of the Northern States, and in Gray's Field and Forest Botany and in Brewer and Watson's Botany of California are too well known to need more than reference here.

He was careful, accurate, and intensely conscientious in all his botanical work. Neither time nor patient work was spared, if by them the conclusions arrived at might be made more certain and sound. He saw the number of described species of American Ferns greatly enlarged during his career, of which he described about a dozen new species. His published work relates almost entirely to systematic botany. The anatomy and physiology of plants he considered a separate specialty, and he pursued it only so far as was necessary for an understanding of the completed organism.

He was a person of keen literary and artistic tastes, and these profoundly influenced his scientific work. His large private herbarium was arranged and kept with scrupulous care. Each sheet of specimens was as carefully prepared and as fondly cherished as if it were a precious work of art. His library was rich in rarities, and undoubtedly the fullest in the country in the literature of ferns. He was emphatically a student of plants and his zeal and pleasure in their study was enhanced by his strong love of nature. He loved a plant because it was a plant, and he saw beauty as well as interest in its every feature and organ. The writer long ago came to the opinion that Professor Eaton had chosen his specialty largely because of the intrinsic beauty of the plants of those orders. The delight with which he would call attention to the special beauty of the foliage of some moss under the microscope, or the delicate tracery of some fern indicated the pleasure their contemplation and study afforded him. They had to him not merely a scientific interest, studied for description and classification, but he contemplated them also with much the pleasureable emotion that an artist contemplates a great painting or statue, as an object of beauty. Some species he seemed to regard much as other persons regard pets, whose very presence was a pleasure to him. Representations of the walking fern and the climbing fern embellished his study, and one of the first botanical walks the writer had with him was to a locality near New Haven where the walking fern grew.

In technical descriptions his style was clear, and in popular writing it was smooth and genial. It was his aim to so write that there might be no misunderstanding as to what he meant. His carefulness in this matter may be illustrated by a remark he once made to the writer: "I never send a telegram that I cannot parse." But careful as he was as to style, language was to him but an instrument, and he was strongly on the conservative side in the revolution that is being attempted in botanical nomenclature. Botany was to him a study of plants, not a quibble over names. When a plant had long been known by some botanical name under which it had been most studied and by which it was generally known in speech and in literature, he decidedly objected to changing that name merely to satisfy some newly made and arbitrary rule. Language in its growth and use had heretofore refused to be so fettered, and he believed that the slight gain which might arise by strictly following the newly proposed rules would not compensate for the loss that he thought would come by the additional confusion introduced into botanical literature, and the unsettling of what was sufficiently established for practical use. If there was a more cordial agreement between the American and European botanists he would accept it although regretfully, but as the matter actually stood, he resisted the change.

Other than as incident to his scientific work, Professor Eaton published but little of what is usually termed "popular" botany. He, however, between 1868 and 1890, delivered twenty of the public "Lectures to Mechanics" given in annual courses at the Sheffield Scientific School. They were all upon subjects related to botany, such as Trees of New England; Our Common Weeds; Seaweeds; Mosses; Hybridism in Plants; Oaks; Water Lillies, etc. These lectures were written in his genial style, and were very popular.

The most of his botanical work was done in his study or in the fields and woods about New Haven. In connection with the work of The Geological Survey of the 40th Parallel, he spent a part of the summer of 1869 in Utah, and was intensely interested in the study and aspects of the vegetation of that part of the Great Basin. He spent much of the year 1866 in Europe, and then took occasion to consult and examine specimens in several of the herbaria there.

Professor Eaton was fond of literature, and retained a love for the ancient classics. He became deeply interested in historical and genealogical studies, and was an officer in several societies devoted to these subjects, and was also the secretary of his college class. He carried on a wide correspondence, and published several papers relating to these subjects. Of the sixty-four titles given under his name in the "Yale Bibliographies," fifty-six were botanical. Reviews of botanical books, published in the Nation, some of which might rank as scientific "papers," are not included.

Regarding his personal qualities I cannot do better than quote the language of another. "An ardent enthusiast in his chosen science, ever ready to aid those seeking its lights, Professor Eaton owned as a natal gift a most graceful and winsome personality. He was singularly but unobtrusively helpful in every social relation, generous and tender in his charities, always eager with some self-sacrificing act of neighborly kindness. He took keen interest in the politics of city, state and nation. He loved intensely the out-door life of woodland and field, and was fond of out-door sports."

He appeared in his usual good health until last year. While botanizing for mosses and particularly sphagna in the White Mountains in the summer vacation, a malady before unsuspected began to acutely manifest itself. Although the disease was very painful, he did some botanical work in the autumn, but he attempted no college work after the Christmas recess. He endured his sufferings with Christian resignation, and passed away with the college year, two days after Commencement.

He married, February 13th, 1866, Caroline, daughter of Treadwell Ketchum, of New Haven. She, a son and a daughter survive him.

Wm. H. Brewer.

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ERRATUM.

In the paper by M. Carey Lea on the *Color relations of atoms, ions and molecules* published in the May number of this Journal, by an unfortunate mistake on the part of the printer, the groups in the table on page 362 have been transposed so that groups three and four take the place of groups five and six and conversely. On page 361 the groups appear in their proper order.

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[THIRD SERIES.]

Art. XX.—*On the Distribution and the Secular Variation of Terrestrial Magnetism, No. II;** by L. A. Bauer, Ph.D.

In the present communication it is the intention to endeavor to *localize* the chief cause of asymmetry or distortion in the earth's magnetic field. In a subsequent paper a similar attempt will be made with respect to the secular variation.

How shall we formulate our problem? We do not as yet know conclusively *whether the earth is a magnet or an electro-magnet*—i. e., whether the earth acts upon a freely suspended magnetic needle as a permanently magnetized body, with definite magnetic poles or centers of attraction, or whether it acts like a soft piece of iron rendered temporarily magnetic by a current of electricity circulating around it. To put the matter tersely, no satisfactory answer has as yet been given to the question: "*Is the earth's magnetism permanent or induced?*"

A priori one might be led to the latter opinion. For if we recall that the intensity of the magnetization of the earth can be easily compared with that which we produce with great difficulty in steel magnets and consider the force necessary to increase the magnetization or diminish it, it would seem that the mighty disturbances, termed magnetic storms, which at times simultaneously affect the whole geomagnetic field, would not so readily result if the greater part of the earth's field were in a permanent state. We must have apparently a more sensitive field—one readily susceptible to change.

Peter Barlow in reviewing Biot's, Kraft's and his own researches in 1831 arrived at the following conclusions:—†

* See foot note to No. I in August number of this Journal, Art. XII., p. 109.

† Phil. Trans. Roy. Soc., 1831, Art. VI., p. 102.

a. "That the laws of terrestrial magnetism are inconsistent with those which belong to a permanent magnetic body."

b. "That they are perfectly coincident with those which appertain to a body in the transient state of magnetic induction."

He based these conclusions chiefly upon these facts: Biot (1804) and Kraft (1809) found that by taking a variable distance between the earth's magnetic poles or centers of attraction, supposing them situated on a line through the earth's center at right angles to the magnetic equator, considered as a circle, the accord between observed and computed dip became the more perfect the closer the two poles were made to fall together with the center of the earth. By supposing the centers of magnetic attraction to be coincident with the earth's center, this law was found:

$$\tan I = 2 \tan \varphi \tag{1}$$

I being the inclination and φ the *magnetic* latitude.

Barlow obtained this identical law both empirically and theoretically when considering the deflections in an inclination needle caused by a soft iron sphere inductively magnetized.* He hence concluded that the earth acts like an inductively magnetized body.

It will be recalled that formula (1) is identical with the law governing the mean inclinations along parallels of latitude as given in conclusion II of the preceding paper.† In the succeeding it will be shown that the same law is obtained on the assumption that the earth is a *permanent uniformly* magnetized sphere. Barlow's deduction does not then necessarily follow.

But let us assume that the earth's field *is* for the greater part an induced one. The next question that might fairly be asked is: *What induces the earth's magnetism?*

Helmholtz characterized the earth's magnetism as one of the most puzzling of natural forces. A volume of very respectable dimensions could be written upon the many theories that have been advanced to account for the origin of telluric magnetism. It seems questionable to me, however, whether this problem as to the *origin* can ever be solved, owing to our inability to form an adequate conception of the earth's condition anterior to all observation. That theory, however, that will explain to us those phenomena that impress themselves forcibly upon us at present, viz., the variations, periodical and non-periodical, will probably be the basis of the one ultimately accepted. In a word, we must investigate the *variations* of geomagnetism and endeavor first to account for them before

* See his "Essay on Magnetic Attractions," 1st ed., 1820, 2nd ed., 1823.

† See this Journal, August, 1895, Art. XII.

attempting the unraveling of the greatest secret of all—the origin of the so-called permanent magnetism.

Thus many plausible theories advanced by eminent and careful philosophers have been shown to be inadequate. Very frequently electrical hypotheses have been proven false by reason of the fact that the theoretical induced currents would not proceed in the requisite direction. As Ampère first pointed out, the observed approximately northward direction of the magnetic needle necessitates electric currents (if they be the cause of the needle's polarity) flowing in an east-west direction. As yet no satisfactory theory has been advanced to account for such induced east-west currents. The thermo-electric hypothesis met with considerable favor at one time and was adopted by eminent geomagneticians. It has, however, been discarded by prominent physicists.

If we have induced currents, then it would appear that according to Gauss's Potential Theory of Terrestrial Magnetism, we must look for them in the earth's crust, not in the atmosphere. It will be recalled that his beautiful investigations proved:

First, that by far the greater portion of the earth's magnetic force possesses a potential.

Second, that the seat of the so-called permanent magnetic force is *within* the surface.

It is a well-known fact that we have earth currents, directed roughly N.E. to S.W., which experience fluctuations concomitant, or nearly so, with a freely suspended magnetic needle. A number of investigators believe themselves to have shown conclusively that these earth currents are *not* sufficient to produce the observed phenomena of the earth's magnetism. This is a matter of difficult experimental determination. A fact clearly indicated, however, is *that earth (and atmospheric) current observations should be more carefully and more frequently made than hitherto and that they should form as much a part of the regular work of a magnetic observatory as the observations of the deflections of a magnetized needle.*

Enough has been given in the preceding remarks to show how infinitely complex and well-nigh hopeless is the solution of the question as to the *origin* of the earth's magnetic field. It is not any more necessary, however, for us to answer this puzzling enigma in order to make headway in the study of terrestrial magnetism, than it is for the astronomer to know, for example, the origin of the moon. He knows the moon exists, and so he determines its disturbing influences upon the earth's motions.

Just so is it with geomagnetism. We do not know the whence but we know its existence. Let us then accept it as part and parcel of our earth and endeavor to find out the function it plays in the economy of nature's household.

To-day the magnetic earth is rotating about an eccentric axis.* *What has caused this eccentricity?* The relevancy and importance of this interesting question can best be seen from the following extract taken from Prof. Rees's paper on "Variation of Latitude."†

"In an address made before Section A, of the British Association, in 1892, Professor Schuster stated that he believed the evidence at hand was in favor of the view that there was sufficient matter in interplanetary space to make it a conductor of electricity. This conductivity, however, must be small, for if it were not, he said, the earth would gradually set itself to revolve about its magnetic poles. *However, changes in the position of the magnetic poles would tend to prevent this result.*‡ Perhaps the investigator in the near future, working on the suggestion of Prof. Schuster, may find some connection between the earth's magnetism, rotation-time and position of rotation-axis."

Let us assume that the earth's field was originally uniform and symmetrical about the geographical axis. The magnetic poles (whether defined as the points of vertical dip or of maximum or minimum potential) fall together with the rotation poles. At every point on the earth the compass points truly north and south. In every parallel of latitude, the potential, the intensity, and the inclination are constant, though varying according to definite laws from parallel to parallel. The line of zero equipotential, the line of no dip and the line of maximum horizontal intensity fall together with the geographical equator. Let some cause operate now to deflect the magnetic axis or to tilt the primary uniform field until at some given date the magnetic axis is observed to make a definite angle with the rotation axis. We will suppose, for the present, that the field is still uniform about the new magnetic axis. If we were now to determine the difference of inclination, for example, at various points along a parallel of latitude caused by the change in the magnetic axis, and imagine perpendiculars erected at the points of observation proportional to the observed inclination differences, having due regard to sign, then would the surface passing through the ends of the perpendicu-

* The term "magnetic axis" is used throughout in the Gaussian sense, i. e., that straight line with reference to which the earth's magnetic moment is a maximum. This is the only precise definition that can be given this term in the case of such a heterogeneously magnetized body as the earth. According to the latest computation (Neumayer-Petersen's), the magnetic axis makes an angle of 11°·7 with the geographical axis.

† "Science," May 24, 1895, pp. 563-564.

‡ The italics are my own.

lars give us a clue as to the location of the operating cause. Sometimes the secondary inclination would be greater, sometimes less than the primary. Some of the differences would be plus and some minus. Hence, on certain parts of the earth's surface the perpendiculars will point *above* the surface, at others *below*. The result will be that the enveloping surface will lie partly above the earth, partly below. The difference between this surface and the earth's will everywhere give us a measure of the deflecting forces, the maximum departure of the surfaces occurring over the seat of the forces. The curve of intersection of the surface with the earth will pass through all the points on the earth where the deflecting forces have neutralized each other and where in consequence, the particular element, under consideration, has suffered no change.

This is precisely the method we would adopt in making a thermic survey of a region in order to locate the cause of disturbance in a uniform heat distribution. We observe the temperature at various points, imagine perpendiculars erected, lay off on them proportionately the temperature observed and imagine a surface passing through the ends. The seat of heat disturbance would then be indicated on this model by a hillock or peak.

Instead of considering one element alone it would be preferable to include all three at the same time, viz : declination, inclination and intensity, and combine them into vector quantities. These latter could in turn be broken up into three rectangular components, or if the earth's magnetic force possesses a potential, as in fact the greater part seems to do, be treated as functions of a potential. For my purposes, however, it seems preferable to consider the observed elements separately, but simultaneously, and to begin with the dip. The special reason why this path appears better is that I shall have to carry out the idea referred to in the foregoing for various dates, some of them anterior to intensity observations. When considering the secular shift of the disturbing forces, we are, namely, restricted to angular quantities, declination and inclination. In order then to have all my results strictly comparable, I shall have to deal almost entirely with these two elements.

On the supposition that the earth is uniformly magnetized about the geographical axis, we shall get the following value of the potential at any external point P if the X axis of a rectangular system of coördinates is taken coincident with the magnetic or geographical axis, and the origin at the earth's center :*

* See Encyclopædia Britannica, Article Magnetism, p. 232, eq. xxx.

$$(1) \qquad \Psi = \tfrac{4}{3}\pi\mu\, a^3 . \frac{x}{r^3}$$

a, is the mean radius of the earth, r the distance of P from the origin, and μ the intensity of magnetization per unit of volume. For points on the earth's surface (1) reduces to

$$(2) \qquad \Psi = \tfrac{4}{3}\pi\mu a . \cos u = c . a \sin \varphi$$

u being the geographical polar distance, $\varphi = 90° - u$, or the geographical latitude and $c = \tfrac{4}{3}\pi\mu$, a constant for any particular time and perhaps for all historic times.* Since for the case supposed the horizontal component, H, of magnetic intensity is directed tangentially along the meridian, we obtain by partially differentiating Ψ according to the variable $u' = a . u = a (90° - \varphi)$:

$$(3) \qquad H = -\frac{\partial \Psi}{\partial u'} = \frac{\partial \Psi}{a \partial \varphi} = c . \cos \varphi$$

And for the vertical component, V, directed radially:

$$V = -\frac{\partial \Psi}{\partial r} = -\frac{\partial}{\partial r}\left(\tfrac{4}{3}\pi\mu a^3 . \frac{r \cos u}{r^3}\right) = 2\, c . a^3 \sin \varphi . \frac{1}{r^3}$$

Putting $r = a$, we get:

$$(4) \qquad V = 2c . \sin \varphi$$

$$(5) \qquad \text{Total force, } F = \sqrt{H^2 + V^2} = c . \sqrt{1 + 3 \sin^2 \varphi}$$

If I be the inclination, then is

$$(6) \qquad \tan I = \frac{V}{H} = 2 \tan \varphi$$

Furthermore for all points on the earth the declination D:

$$(7) \qquad D = 0$$

Formulæ (3), (5) and (6) will be recognized by every nautical geomagnetician. They were deduced empirically, theoretically (in a different way than above) and practically applied to the determination of the compass deviation due to iron on board

*Prof. W. von Bezold in an admirable paper entitled "Uber Isanomalen des erdmagnetischen Potentials," Sitzungsberichte d. Kgl. Preuss. Akad. d. Wiss. zu Berlin, Phys. Math. Classe, April 4, 1895, has deduced the expression

$$\frac{\Psi}{a} = c . \sin \phi$$

empirically with the aid of the mean values of the potential along geographical parallels of latitude. The value of his empirical coefficient was found to be 0·330 for the date 1880. He regarded this empirical formula as one of the most important contributions of his paper.

ship, by Peter Barlow.* By turning back it will be seen that (6) is identical with Biot's and Kraft's formula which these investigators found empirically when considering the magnetic action of the earth. In obtaining (6) the only assumption made was that the earth was *uniformly* magnetized about the geographical axis. Barlow's argument, based on equation (6), that the earth is *inductively* magnetized is, consequently, not necessarily true.†

From (1) it will be seen that if we substitute for $\frac{4}{3}\pi\mu a^3$, M, the magnetic moment of the earth, the external action of the uniform magnetized sphere is identical with that produced by an infinitely small magnet having the same magnetic moment, and situated at the center of the earth. This explains Biot's and Kraft's result that the computed dip became the more perfect the nearer the magnetic poles were moved to the center of the earth.

Inside the sphere the potential will reduce to

$$\Psi^1 = \tfrac{4}{3}\pi\mu . x \tag{8}$$

from which it appears that the force $-\frac{\partial\Psi'}{\partial x} = \frac{4}{3}\pi\mu$ is everywhere constant in direction and intensity, i. e. inside the sphere the field is uniform.

Now let us see how closely the above theoretical results will give us the mean values of the various elements along geographical parallels of latitude. To obtain the computed values below I have adopted provisionally for the value of c von Bezold's empirical coëfficient, viz: 0·330. The observed values are the means of equidistant scalings of magnetic charts along parallels of latitude. The values for D and I have been taken from Table I of my former paper (No. I). Those for Ψ, H, V and F have been borrowed from General A. von Tillo.‡

* See his "Essay on Magnetic Attractions."

† This formula (6) is very significant. It tells us that the inclination is independent of c, or the intensity of magnetization. Hence changes in c will not affect I as long as the axis of magnetization coincides with the geographical axis. Any change in I will have to be referred to a change in direction of magnetic axis. Compare Table I of No. I of these contributions (August number) and see how nearly the mean inclination for a geographical parallel has remained constant for a century. It will be doubly interesting now to determine definitely whether the slight fluctuation exhibited is real and not to be described to inaccuracy of chart data.

‡ Comptes Rendus No. 15 (Oct. 8, 1894): Magnétisme moyen du globe et isanomales du magnétisme terrestre. Note by M. Alexis de Tillo.

Lat.	D Obs'd	D Comp'd	I Obs'd	I Comp'd	Ψ/a Obs'd	Ψ/a Comp'd	H Obs'd	H Comp'd	V Obs'd	V Comp'd	F Obs'd	F Comp'd
					C. G. S.		C. G. S.		C. G. S.		C. G. S.	
60° N	+2°·6	0°·0	+75°·2	+73°·9	+0·285	+0·285	+0·14	+0·165	+0·55	+0·572	+0·56	+0·594
40	+0·9	0·0	+59·6	+59·2	+0·21	+0·212	+0·24	+0·253	+0·43	+0·424	0·50	0·495
20	+0·3	0·0	+34·4	+36·1	+0·11	+0·113	+0·32	+0·310	+0·23	+0·226	0·41	0·383
0	+0·7	0·0	− 2·3	0·0	0·00	0·000	+0·34	+0·330	−0·02	0·000	0·35	0·330
20	+1·6	0·0	−36·0	−36·1	−0·11	−0·113	+0·30	+0·310	−0·23	−0·226	0·39	0·383
40	+3·2	0·0	−57·6	−59·2	−0·20	−0·212	+0·24	+0·253	−0·40	−0·424	0·47	0·495
60 S	+2·8	0·0	−70·6	−73·9	−0·275	−0·285	+0·18	+0·165	−0·53	−0·572	0·57	0·594
Mean	+1·7	0·0	+ 0·4	0·0	+0·004	0·000	+0·251	+0·255	+0·004	0·000	+0·464	+0·468

It will be seen that the accord is very good throughout. This is all the more remarkable when we consider the great changes encountered in the values of the magnetic elements in going along a parallel of latitude; as, for example, along 60° North, the inclination suffers a total change of 82°·5 and the declination along the equator a total change of 50°·7! Notwithstanding these great changes, the mean or normal elements correspond very closely to those obtained on the assumption that the earth is uniformly magnetized about the rotation axis. Why is this? Why should the "anomalies" in the distribution so nearly cancel each other in going along a geographical latitude? This is certainly not a result we should expect *a priori* if the asymmetrical distribution of land and water be the cause of the present distribution of telluric magnetism.

We now see the theoretical significance of von Bezold's empirical formula governing the mean value of the potential from latitude to latitude, likewise, that of the empirical deduction, tan I = 2 tan φ given in conclusion II of preceding paper.

What does the empirical factor, 0·330 imply? According to equation (2) we have:

$$c = 0{\cdot}330 = \tfrac{4}{3}\,\pi\mu$$

If M is the magnetic moment of the earth, then is

$$M = \tfrac{4}{3}\pi a^3 \,.\, \mu = c \,.\, a^3$$

i. e. volume of sphere times the intensity of magnetization per unit of volume. With value of $c = 0{\cdot}330$ we then get a value of $M = 0{\cdot}330\, a^3$ or $8{\cdot}52 \times 10^{25}$ (C. G. S. units) against $8{\cdot}55 \times 10^{25}$ as determined by Gauss.* Hence we have the theoretical interpretation of this factor.

Furthermore, if we know the mean value of H along a parallel we can rapidly determine with the aid of equation (3) a fair value of the earth's magnetic moment, without making use of the laborious Gaussian computation. To illustrate:

* Gordon's "Physical Treatise on Electricity and Magnetism," 2d ed., vol. I, p. 155.

Latitude.	Date, 1885. Mean H.	M.
40° N.	0·245	0·320 a^3
20	0·327	·348
0	0·341	·341
20	0·292	·311
40 S.	0·232	·303
	Mean	0·325 a^3

The Neumayer-Petersen re-computation of the Gaussian coefficients gave a value for M of 0·322 a^3. Our value then is in fair accord. H was obtained from 18 equidistant scalings of Neumayer's isodynamic chart for 1885.

Is *c or M subject to a secular change?* Below are the values* of M obtained thus far with the aid of the Gaussian theory:

Year.	Computer.	M.
1829	Erman-Petersen	0·327 a^3
1830	Gauss	0·331
1880	Icilius	0·340
1885	Neumayer-Petersen	0·322
	Mean	0·330 a^3

These figures do not tell anything conclusive as yet. We shall consequently for the present assume that the magnetic moment of the earth does not suffer a secular change and adopt as our coëfficient in above theoretical formulæ the value 0·330.

We are now ready to take up the chief object of this paper —the localization of the causes of the present distribution of geomagnetism. I will *assume* that if these causes were *not* operating the value obtained from the foregoing formulæ would be the actually observed values. I shall consider in this paper, the distribution in *the dip* for the year 1885, scaling the inclination from Neumayer's isoclinic chart at every 20° of longitude along parallels ±60°, ±40°, ±20°, ±10° and 0°. For this purpose I determine the departures of the inclinations thus found from those derived by formula (6) and imagine the ideal surface referred to above constructed with the aid of these departures. To give a representation of this surface, the topographer's method of mapping a hilly country by means of contour lines could be adopted. That is, the curves of intersection of equidistant geo-concentric spherical surfaces with the ideal surface could be drawn. The crowding together of these lines would indicate the position of the highest and lowest points of the surface or the seat of the disturbing forces.

* G. Neumayer, "Atlas des Erdmagnetismus," p. 19, Gotha, 1891.

What we actually do, however, is simply to draw lines through all the places on the earth's surface having the same departure from the normal or computed dip. Such lines, I call lines of equal-departing inclination or briefly, "isapoclinics."* On the diagram opposite they have been drawn for the year 1885.

The sign of the differences, ι, is determined in accordance with the formula:

$$\iota = \text{I obs'd} - \text{I comp'd}$$

regarding dip of north end of needle *below* the horizon as positive, above as negative. A plus ι means then that the dip of the north end of the needle has been *increased* by the disturbing force, or the *north* end of the needle has been attracted; a minus ι signifying, that dip of north end has been *diminished*, or the *south* end attracted.

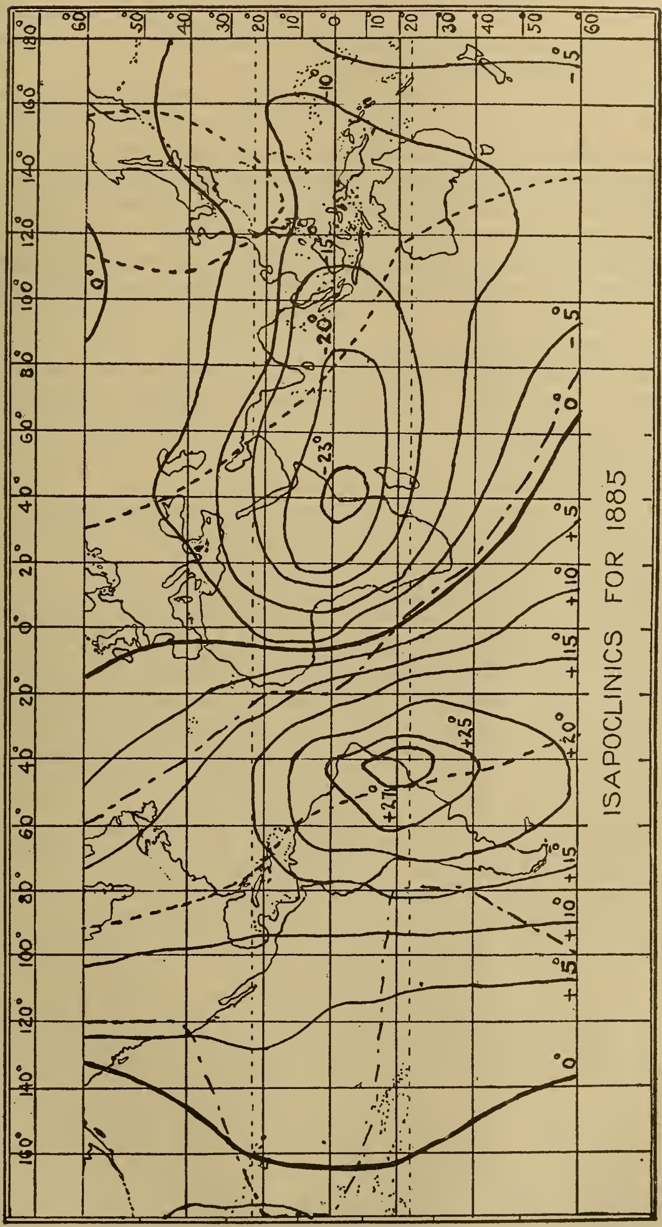
The two heavy lines marked zero, which are but branches of the same closed curve, mark out all those places where $\iota = 0$, or where the dip has the value assuming the earth to be uniformly magnetized about the rotation axis. The region between them on the left has everywhere plus departures, i. e. over this part of the earth the deflecting force attracts the *north* end of the needle. It is seen that these plus isapoclinics encircle a focus, approximately in latitude 20° S. and in longitude 40° W. Here the inclination attains a value of $-7°{\cdot}5$ instead of $-36°{\cdot}1$ prescribed by formula, hence

$$\iota = -7°{\cdot}5 - (-36°{\cdot}1) = +28°{\cdot}6$$

or the north end of the dipping needle is drawn downwards at this point about 29°—this being the maximum plus deflection produced by the disturbing force. *We might regard then this point as the* SEAT *of the force which deflects the north end of the dipping needle from its normal amount, or briefly a secondary north magnetic pole.*

Similarly, the curves of negative departures on the right lead up to a focus in about latitude 5° S. and longitude 40° E. Here the *south* end of the dipping needle is drawn downwards by about 24°. *Hence this focus marks the seat of the south end disturbing force and corresponds thus to a secondary south magnetic pole.*

* The analogous terms for the other elements would be, "isapogonics," "isapodynamics" and "equiabspotentials." These lines are not quite, though nearly, the same as the "isanomalous lines" successfully introduced in terrestrial magnetism by von Bezold and von Tillo which are the equal departing lines, taking the *mean* elements for a parallel of latitude as the normal ones. I have been obliged to adopt the above method for my purposes because: First, it enables me to draw "equal departing lines" without the aid of magnetic charts, since I can *compute* the normal elements for any latitude. This is important when considering the secular variation. Second, it enables me to give precision to the interpretation of the residual or secondary field obtained with the aid of these lines.


ISAPOCLINICS FOR 1885

It will be noticed that the zero isapoclinics, or secondary magnetic equators as they might be termed, lie midway between the secondary magnetic poles.

It is certainly surprising that these two secondary poles which represent the centers of the forces producing the asymmetrical distribution of the earth's magnetism should be on the *same* side of the equator and so nearly on it, instead of on *opposite* sides. Consider now the very asymmetrical distribution of land and water with regard to the equator and it hardly seems possible that this should be the main cause of asymmetry of the earth's magnetic field. In this case one might expect the attracting centers to be either farther north or farther south, as the case may be.

Another remarkable result is the close proximity of these secondary dip poles. They are only 80° apart in longitude. Here we may have an effect due to the heterogeneity in the earth's composition.*

It would appear then that:

The chief cause of distortion of the primary symmetrical field can be represented as due to a secondary polarization approximately equatorial in direction.

The question might fairly be asked what has been gained by assuming that the earth has a primary polar field, uniform and symmetrical, and referring all distortions to a secondary complex field, only approximately equatorial in direction? The answer is, we have placed the disturbing centers where we can *operate* upon them. We have observations of declination and inclination running back in this region for three centuries. It will be investigated in the next number whether we can

* Prof. W. von Bezold in the paper already cited drew the "lines of equal departing potential," or as he terms them "isanomalous lines of geomagnetic potential." He fully develops the theory of these lines and constructs them for 1880, making use of Quintus Icilius's re-computation of the elements of terrestrial magnetism as based upon Gauss's potential theory. He regarded the mean values of the elements along parallels of latitude as the normal ones. He finds that the lines close around two foci, one, the north end attracting, in 26° S. and long. 44° W., the other, the south end attracting, in 49° S. and 140° E. The positions of our secondary north poles agree very well but those of the secondary south poles are very different, though they are roughly in the same region. Just why this is, is difficult to tell at present. The theory of the potential does not prescribe that the vertical dip poles and the foci of maximum or minimum potential should coincide; this depends upon the geometric nature of the equipotential surfaces. Furthermore, my secondary field is derived directly from observation and includes such effects as would not be embraced in the potential theory. Still the prime cause of want of coincidence of our south poles must be referred, doubtless, to the form of the secondary equipotential surfaces. As we proceed in the differentiation of this field, this matter may become clearer. The main fact, however, that the secondary polarization is apparently directed roughly east–west is sufficiently borne out by both investigations. Von Tillo moreover in his paper already cited has found that with respect to all the elements, the isanomolous lines can be referred to an east and to a west hemisphere. It is very much hoped that von Tillo's charts will soon be published.

refer the secular variation to the secular shift of these secondary poles.

I shall now show that these secondary magnetic dip poles are as truly magnetic poles as those which we believe to be in the arctic and antarctic regions. The following main condition must be fulfilled:

In going along a magnetic meridian of the secondary system with a dip needle having its plane in that meridian the north end of the needle must point vertically downwards over the secondary north pole (i. e. over the west focus), at the magnetic equator (the zero isapoclinic), the needle must be horizontal and over the secondary south pole (east focus), the south end must point vertically downwards.

Let us assume for simplicity, that the secondary magnetic dip poles are exactly on the equator, as they are in fact very nearly. The equator will then be a magnetic meridian of the secondary system. The formula for reducing a dip observed in the actual magnetic meridian to the plane passing through the secondary magnetic meridian will be on the assumption made:

$$\tan I_e = \tan I_m \,.\, \operatorname{cosec} D$$

I_e being the dip in the equatorial plane and I_m the dip in the actual magnetic meridian and D the observed declination. From this it follows that the points where D is zero and I_m not zero, $\tan I_e = \infty$ or $I_e = 90°$. In other words, the intersections of the agonic lines with the equator mark the places of vertical dip in the equatorial plane. The dotted lines on the diagram are the agonics. It will be noticed that they pass nearly through the secondary magnetic poles.

The points where the dip needle would be horizontal in the equatorial plane are found with the aid of the above formula, to be in long. 188° E. and 2° W. See how closely these points come to the intersections of the secondary magnetic equator (zero isapoclinics) with the geographical equator.

Since the horizontal component of intensity directed equatorially, H_e, can be derived from the formula

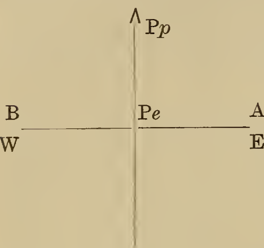
$$H_e = H_m \sin D$$

H_m being the observed horizontal component in the actual magnetic meridian, it follows that where D is zero H_e is zero. We have already seen that these points fall in the neighborhood of the secondary poles.*

Again, let us suppose that we have really two magnetic fields instead of one and that they are at right angles to each other, the

* If we construct the isapodynamics with the aid of values of the horizontal intensity scaled from Neumayer's isodynamic chart for 1885, we shall find that the departure of observed intensity from computed intensity is zero for the following two points along the equator, 73° W. and 60° E.

first being the primary polar field, the other the secondary equatorial. Were only the *polar* field present, then would the compass everywhere point due north and south. Were but the *equatorial* field present, the needle would everywhere point east and west. Under the combined action of the *two* fields, the needle takes up an intermediate position. As we proceed along the equator the north end of the compass alternately points E. or W. of N., the points of change from E. to W. or vice versa being over the equatorial poles.



Thus, in the figure, let P*p* represent the north magnetic pole of the polar field, P*e* the same for the equatorial. At A under the combined influence of *Pp* and P*e* the north end of the compass points W. of N. As we proceed from A towards P*e*, the westerly declination diminishes until over P*e* it vanishes entirely, the component of horizontal intensity of the secondary field vanishing over P*e*. As we leave *Pe* and proceed towards B the needle points E. of N. That is, over the equatorial poles the declination is zero, to the right of the equatorial magnetic north pole, the declination is westerly, to the left, easterly; for the equatorial south magnetic pole, a precisely reverse condition of things obtains.

Hence, if two such systems are present on the earth the actually observed declination ought to be westerly *between* the two isapoclinic foci, and beyond, easterly. Now as a matter of fact over the region *between* the agonics given on the diagram, the declination *is* westerly and beyond them easterly. It will be seen that this region is nearly identical with that prescribed by the foci! In other words, without the knowledge of a single declination observation we might have delineated roughly the region where the declination is westerly or easterly with the aid of the isapoclinics.

It seems to me that the proof is overwhelming that these isapoclinic foci are magnetic dip poles just as truly as the one supposed north of Hudson's Bay. I do not see how we can escape the fact that we have secondary magnetic dip poles situated approximately in the equator. The field that we actually observe is the resultant of the two systems—the polar and the equatorial.

Hence, perhaps the prime reason why a declination needle does not point truly north is because of a secondary polarization approximately equatorial in direction.

To give further proof that the isapoclinics are not random lines but the isoclinics of a definite magnetic system and hence subject to the laws of such a system, I have drawn on the diagram (p. 199) the lines connecting the places of maximum west and east declination along parallels of latitude. These lines are indicated thus: —— . ——. The one on the left connects the places of maximum easterly declination; the other, skirting the west coast of Africa, passes through the places of maximum westerly declination. If the foregoing deduction is true that the secondary system causes the deflection of the declination needle, then since the horizontal intensity component of the secondary system is a maximum along the secondary magnetic equator, the lines of maximum declination should follow somewhat the zero isapoclinies. It will be noticed that this is roughly true. Exact coincidence must not be expected, since the magnetic intensity equator and dip equator do not necessarily fall together on account of the complexity of the secondary system.

Let us compare roughly the maximum horizontal intensities of the two systems. For the total uniform system we obtain the maximum value of 0·330 C. G. S. in the geographical equator (see table, p. 196).

If we resolve the observed horizontal component in the geographical equator into two components, one directed due north (X component) and the other, directed west (Y component) we shall get these values near the secondary magnetic equator:

Long.	X	Y	$\frac{X}{Y}$
40° W.	·293	+·049	6·0
20 W.	·276	+·106	2·6
0	·283	+·097	2·9
20 E.	·293	+·069	4·3
160 E.	·365	—·047	7·8
180	·364	—·056	6·5
160 W.	·357	—·041	8·7
Mean			5·6

Or, the polar field is on the average about 5 or 6 times stronger than the equatorial. *In other words, if the magnetic moment of the resultant system be taken as* $0{\cdot}330 \times a^3$, *that of the primary is roughly,* $0{\cdot}325 \times a^3$, *and of the secondary* $0{\cdot}060 \times a^3$.

In consequence of this secondary magnetic moment attached to the primary, roughly at right angles, the axis of the resultant magnetic system must incline towards the equator by an amount u computed thus:

$$\tan u = \frac{0{\cdot}058 \times a^3}{0{\cdot}325 \times a^3} = \frac{1}{5{\cdot}6} = 0{\cdot}1786$$

$$\text{hence } u = \quad 10^\circ{\cdot}1$$

or the equatorial inclination of the actual magnetic axis would be about 80°. The latest computation based on the Gaussian potential theory gave a value of 78°·3. The close coincidence is certainly striking.

Hence,

The principal phenomena of the distribution of terrestrial magnetism can be regarded as produced by two rectangular magnetic systems, a polar and an equatorial, the former of about 5 or 6 times the strength of the latter.

Since, in going around the earth along a geographical parallel of latitude, the deflections due to the secondary system almost balance each other, as shown by the fact that the mean elements so nearly agree with the computed ones of the primary polar system (see table, p. 196), the inference might be drawn *that the secondary field is in some way connected with the earth's rotation.*

In a subsequent number of these contributions, this matter will be examined in detail from a theoretical standpoint. For this reason, I shall make no attempt in the present paper to resolve the complex secondary magnetic system shown on the diagram into its components. The field as exhibited may really be a resultant one of three—a theoretical equatorial field, a field due to electric currents piercing the earth* and a third, due to the heteorogeneity of the earth's composition.

*Such currents have been made probable by Dr. A. Schmidt's beautiful researches. (See his brief note in Report of the Brit. Ass. for Adv. of Science, for 1894, p. 570.) They may be due to the following reason:

If an arbitrarily magnetized sphere rotates in a conducting fluid, the surface of contact of sphere and fluid being also conducting, currents will be incited in the fluid which pass into the sphere, suffer a deflection and then pass out again. While in the case of the earth, there is perhaps no fluid with respect to which the solid earth performs a *complete* differential rotation, there are *partial* differential rotations, due to moving streams, ocean currents, tidal waves and air currents. In the latter case it is also quite possible to have complete differential rotations if we take into consideration the mighty polar whirls of the primary atmospheric circulation. See also quotation with respect to Professor Schuster's work, p. 192.

Washington City, June 4, 1895.

ART. XXI.—*On Outlying Areas of the Comanche Series in Kansas, Oklahoma and New Mexico;* by R. T. HILL.*

THE Tertiary Plains formations of western Kansas, Texas and eastern New Mexico constitute the summits of extensive levels or plateaus. The eastern border has an average altitude of 2000 feet in Kansas and 2500 feet in Texas.

The Medicine Lodge, Cimarron, Canadian, Red, Brazos, and Colorado rivers originate along the eastern escarpment of the Great Plains and are rapidly destroying them by head-water erosion. These streams are types of the valleys of the rivers of the central denuded region which rise in the eastern margin of the plains, as distinguished from the rivers of the plains such as the Republican and Smoky Hill, which rise and flow upon the plains formations, and from the rivers of the mountains which transect the plains.

The sources of these marginal rivers consist of many digitate branches along the eastern border of the plains. These streams soon cut through the Tertiary formations composing the surface of the plains, down into the underlying red beds of undetermined age, which are the chief components of the underlying floor. These valleys are bordered by mural escarpments of red beds, capped by remnantal patches of the Plains formation between which are preserved occasional patches of the Cretaceous formations.

In proceeding southward the first region of the breaks of the plains with their escarpments of picturesque Red Bed scenery, is the valley of the Medicine Lodge River of Kansas—the so-called "Gypsum Hills" country of many writers.

This region, which lies along the south central border of Kansas in the counties of Harper, Barber, Comanche and Meade, abounds in data throwing light upon the problems of the Pleistocene, Tertiary, Cretaceous and Permo-Trias history. Its geology has been mentioned by earlier writers, especially Professors O. P. St. John† and Robert Hay.‡ The latter has given an interesting and graphic description of the structure and scenery and pointed out the great denudation which preceded the Tertiary sedimentation.

Near the head-waters of this river a thin group of Cretaceous formations lies between the Tertiary and the Red Beds. To the east the Plains formations rest directly upon the Red

* Published by permission of the Director of the United States Geological Survey.

† Notes on the Geology of Southwest Kansas, by O. P. St. John, Fifth Biennial Report, Kansas State Board of Agriculture, Topeka, 1887, Part II, pp. 132, 152.

‡ A Geological Reconnoissance in Southwestern Kansas, by Robt. Hay, Bull. 57, U. S. Geological Survey, 1890.

Beds, the intervening Cretaceous deposits having there been denuded in early Tertiary time.

There has been a diversity of opinion as to the age and affinities of the Cretaceous beds of this region. St. John* referred them with the overlying sandstone to the Dakota, but notes certain dissimilarities of structure and fauna from the Dakota as he had seen it elsewhere.

Prof. Robert Hay† has pointed out their dissimilarity to other outcrops of the Cretaceous, and while judiciously not committing himself, said:

"With reserve, we are inclined to place the stratum called the shell bed in the Fort Benton group. . . . Before giving up the Dakota age of the sandstones (one bed in particular) I will have to re-examine the region."

In a later paper,‡ after reviewing subsequent discoveries he says: "There seems no doubt but that they belong to lower horizons than the Kansas Dakota. There is no reason why the Texas names given to the beds [by Prof. Cragin,] Trinity for the lower sandstone, and Comanche Peak for the upper, should not be permanent."

Prof. Cragin has written more voluminously upon the region and its formation than any other writer, and he it was who first brought out the important fact that a portion of the beds were of pre-Dakota age,§ and belonged to the lower-lying Comanche Series which has its typical development in central Texas.

It is impossible in this short paper to give all the reference to Prof. Cragin's age determination of these beds, but in general he has classified the Cretaceous deposits into three conspicuous divisions: a basal member which he has named the Cheyenne sandstone; a group of intermediate shales which he has until lately called the Neocomian shales, and recently terms the Kiowa shales, and an upper sandstone which he calls the Dakota. He has correlated the Cheyenne sandstone with the Trinity sands of Texas and Arkansas, and the Kiowa shales with the Fredericksburg division, and the Dakota with the Dakota. Furthermore, he has generally spoken of the shales as the "Neocomian shales of Kansas." As a result of this classification, the Dakota sandstone was supposed in Kansas to rest directly on the beds of the Fredericksburg division, without the interposition of the sediments of the Washita subepoch.

* Kansas State Board of Agriculture, Fifth Biennial Report, Part II, pp. 142–144, Topeka, 1887.

† Bull. 57, U. S. Geol. Survey, 1890, pp. 29–30.

‡ Geology and Mineral Resources of Kansas, Topeka, 1893, pp. 12–13.

§ See Bull. Washburn Laboratory of Natural History, vol. i, No. 3, vol. ii, Nos. 9, 10, 11. American Geologist, July, 1894, etc.

The writer naturally felt interested in the extension northward into Kansas of the supposed equivalents of the Comanche series of the Texas region as announced by Prof. Cragin, and in August, 1894, proceeded to the region in company with Mr. C. N. Gould, a promising young local student, and Mr. G. B. Shattuck of the post graduate department of Johns Hopkins University. We made minute studies and sections of the localities in Barber and Comanche counties. The present observations are based upon extensive studies and collections made upon this trip.

Four miles west of Sun City a small remnant of the Cretaceous, hardly 100 feet long, 50 feet broad, and not over 40 feet thick, forms a cap to a Red Bed butte. This is the easternmost Cretaceous formation interpolated between the Red Beds and Tertiary, as seen by the writer on this journey.* This outcrop is the remnantal base of the Cretaceous formations, more fully developed to the westward.

About two miles west, upon the northeast land section of Comanche county, a more extensive and thicker outcrop of the Cretaceous formation occurs. This locality is the "Black Hills" of St. John, Hay and Cragin, so-called from the black color of the shale composing the buttes, as distinguished from the predominant red color of the buttes of the Gypsum Hills region lower down the river. This locality is the easternmost of a continuous series of outcrops exposed from here to west of Belvidere. A minute study was here made of the section, which is as follows, beginning at the bottom:

Section at Black Hills, Northeast Corner of Comanche Co.

	Ft.	Ins.
I. The Red Beds.		
1. Friable beds of finely comminuted sand and clay of intense vermilion color constituting the slopes and base of the butte. Some 400 feet of this formation are exposed. This is the problematical formation known as the Red Beds. Triassic of various writers	300	
II*a*. The Cheyenne Sandstone.		
1. White pack sand, sometimes irregularly cross-bedded, consisting of the loosely or unconsolidated sand known in the Texas region as "pack sand" with occasional fine silicious pebbles. In its upper and exposed portion this sand ultimately becomes ferruginated into light-colored limonitic tints, but sometimes it reveals blotches of vermilion hematitic coloring. The ultimate oxidation, however, is a dark blackish brown. Some kaolinized pebbles were occasionally seen in layers of gravel three inches thick. The total thickness of this formation is	57	

* Prof. Hay notes having seen a patch of these beds in the hills north of Sharon, which are thirty miles east of this locality.

	Ft.	Ins.
2. Blue-black sandy clay shale with limonitic seams. This begins rather abruptly above the sandstone, but its sandy nature indicates that it is a transition and not an unconformity, which is further attested by the occurrence upward in these shales of bands of sand similar and identical in material with the lower sandstone. The shale contains crystals of selenite and dicotyledonous leaf impressions	10	
3. The shale No. 2 in its upper part grades by gradual transition into a bed of sand which superficially indurates into a hard series of layers aggregating four feet in thickness. In these sandstones and shales (No. 2) immediately below it were found the dicotyledons to be mentioned later	4	
II*b*. The Belvidere Shales.		
4.* A persistent stratum of small Gryphæate oysters superficially resembling the Comanche Peak variety of *G. pitcheri*. A closer study shows it to be a small form *Gryphæa pitcheri* Morton (*G. dilatata*, var. *tucumcarii* Marcou) imbedded in a sandy shaly matrix not exceeding	1	6
5. A thin white shaly sandstone with plant and molluscan remains		3
6. Thin black sleek paper shale with impressions of mollusca in its lower part	15	6
7. Indurated bed in the shale with occasional minute pebbles	2	
8. Shale like No. 6	4	
9. Sandy induration in shale	2	
10. Shale	5	
11. Indurated shale with Gryphæas	1	
12. Black shale	5	
13. Indurations with var. of *Gryphæa pitcheri* (*G. roemeri* Marcou, *G. forniculata* White), Cyprimeria and Turritella, alternating with shales for a thickness of	20	9
14. Blue shale as above.		
15. Indurated beds with *Exogyra texana* Roemer, Trigonia, sp. Cyprimeria, Turritella and Gryphæas of large size. The upper horizon of 15 containing vertebrates bones, Lingula, etc. Total of Nos. 15 and 16	17	

* Above this oyster bed to the summit of the section, the formation consists mostly of blue papyraceous shales with occasional indurated bands and presenting many fossiliferous horizons, all of which, however, are portions of the same continuous deposition and fauna.

	Ft.	Ins.
16. Fossiliferous shale	16	
17. From No. 16 to the top of the large butte $\frac{1}{8}$ mile to the west the thickness of shale is	32	
Making of blue shale with indurated fossil layers a total of	106	

In the shale near the summit of this butte specimens of the large *Gryphæa dilatata* var. *tucumcarii* Marcou, were found.*

As we approach Belvidere the Cheyenne sandstone begins to form the principal slope of the river basin, and west of that village the bed of the river rises until it is upon the Cheyenne sandstones, while some bluffs and castellated remnants of the sandstones are beautifully exposed in the north side of the valley.

Five miles west of Belvidere the railroad has made magnificent cuts into the beds so that they are there seen better than at any other locality. Here the comparatively steep wall of the valley affords a fine section from the old deposition plane of the Great Plains Tertiaries down into the Cheyenne sandstone, the buttes on the south margin of the river valley being remnants of the main body of the plains to the northward. It is here that Prof. Cragin made his Blue Cut mound section,† omitting from it, however, the basal sandstones which are revealed in the floor of the valley near by. Following is the section as measured by Mr. Gould and the writer :

Blue Cut Section.

	Ft.	Ins.
II. The Cheyenne Sandstone—bottom not exposed.		
1. The Cheyenne sandstones are well shown west of Belvidere in the bluffs on the north side of the river valley, especially in the cliffs of Thompson's Creek. About two and one-half miles west of Belvidere a small creek from the south emptying into the river makes good cuts through the sandstone, showing the same general detail as at Black Hills section.		
2. Sandy shale band above the basal sandstone the same as No. 2 of Black Hills section	8	
3. Thin sandstone layers of the plant beds‡ of Nos. 3 and 4 of the Black Hills section	6	

* See remarks on this species, p. 38.

† Bull. Washburn Laboratory, vol. ii, No. 11, p. 77, 1890.

‡ These beds constitute a low bench immediately adjacent to the river, and the clay shales succeed them, forming the higher outer slope of the valley. I made a general study of the section to the summit; Mr. C. N. Gould made the succeeding accurate measurements and minute collections.

		Ft.	Ins.
IIa. Belvidere Shale.			
5.	Black or blue shale	26	
6.	Oyster bed, sandy matrix		2
7.	Black shale	3	6
8.	Oyster bed, in shale		8
9.	Black shale	1	
10.	Oyster bed, in shale		3
11.	Black shale	3	
12.	Oyster bed, in shale		8
13.	Lower part, black shale with much gypsum 3 } Upper part quite ferruginous . 4 }	7	
14.	Oyster bed with much gypsum		8
15.	Black shale	5	
16.	Oyster bed weathered	1	
17.	Black shale weathered	3	
18.	Oyster bed, cap on top of cut	2	
19.	From top of cut to top of next Gryphæa bed	20	
20.	To top of next Gryphæa bed	12	
21.	To top of next Gryphæa bed	4	
22.	To top of next Gryphæa bed	12	
	Total,	102	
III. The "Dakota" Sandstone.			
23.	A small nipple of nearly black ferruginous sandstone, consisting of coarse oölitic-like grains, and containing stems of plants. This is the character of sandstone generally called Dakota in Kansas	20	
IV. Plains Tertiary :			
24.	White mortar-like rock with calcareous matrix enclosing fine grains of sand	11	

Thirty rods north of the line of the section the Tertiary (No. 24) rests directly on the Belvidere shales, the Dakota (No. 23) having been eroded.

These two sections, taken some miles apart, are sufficient to show the general character of the structure and sedimentation of the beds. They practically agree in thickness and character with the sections of the Belvidere region previously given by Prof. Cragin.*

Reviewing both these sections above the Red Beds (No. 1) and below the Dakota (III), they consist of continuous deposits of shallow marine sedimentation, showing (I*a*) a group of the sand beds at the base (the Cheyenne sandstones of Cragin) grading into an upper portion of thin blue and black shales (II*b*). These shales resemble lithologically the similar blue and black shales of the Meek and Hayden section as seen in the plains and Rocky Mountains of the northwest, and not those of the beds

* Bulletin Washburn Laboratory, vol. ii, No. 11, pp. 75–76, 1890.

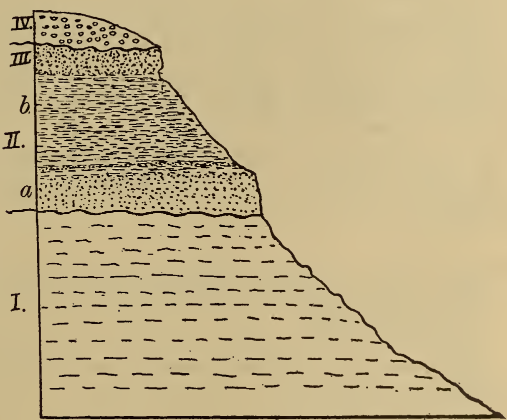
of the Lower Cretaceous of the Central Texas region, which are of a light-colored marly nature.

Although the occurrence of the secondary beds of sandstone, No. 2, 3, and 4, immediately above the main body of that material, is quite persistent both at Black Hills and Blue Cut, Prof. Cragin has not noted its occurrence in his sections of these localities. Whether he failed to observe them, or merely considered them portions of the Cheyenne sandstone to which they logically belong, rather than the shale series above, cannot be stated. That he considered the Cheyenne sandstone and overlying shales a continuous sequence of sedimentation, is clearly shown in his discussion of the Vanheim section, where he finds a band of Cheyenne-like sandstone ten feet thick, intercalated between ninety feet of shale beneath and forty above. The shales overlying No. 4 we call the Belvidere shales from the town near which they can best be seen.*

These formations may be grouped into a generalized section characteristic of the bordering breaks of the Plains in southern Kansas, western Oklahoma, and northeastern New Mexico, which we may appropriately call the Plains section.

This section is as follows:

IV. Plains Tertiary.
III. "Dakota" Sandstone.
II. Belvidere Beds.
b. Blue and black shale with fossils.
a. Cheyenne Sandstone grading upward into *b.*
I. "Red Beds."



In this section there are two conspicuous time unconformities, indicative of long periods of erosion, one between the Red

* Since writing this paper Prof. Cragin has proposed the name Kiowa for the shale beds. The name would no doubt have priority over the one herein used by me, but owing to doubt as to which subdivision Prof. Cragin would have included the beds 2, 3 and 4, I prefer to retain for the present the term Belvidere shales. Although the relations of the Cheyenne sandstones and Belvidere shales are transitional, the writer draws the line of demarcation between the Belvidere shales and the Cheyenne sandstone immediately above this highest sandy layer No. 4, in the sections given.

Beds and the Cretaceous—the other between the Cretaceous and the overlying Tertiary.

Owing to the great erosion which took place between the close of the Cretaceous and the deposition of the plains Tertiary (Miocene and later), any or all of the Cretaceous may be missing in some localities as between the Canadian and Brazos; while south of the head of the Brazos the plains Tertiary rests on the limestones of the Fredericksburg and Trinity divisions of the Comanche series instead of the beds of the Washita division to the northward.

Paleontology: The fossil mollusca was submitted to Mr. T. W. Stanton of the United States Geological Survey, and the fossil plants to Prof. F. H. Knowlton, for determination and study. Their reports are included in the following discussion.

The Cheyenne Sandstone.—Prof. Cragin, as before noted, reported the occurrence of one species of a plant from these beds. This he described as *Cycadoidea munita.** It can be stated that later information concerning the specimens in question, throws doubt as to its occurrence in this identical horizon.

In the lowest sandstone No. 1, only plant stems and small pieces of lignite were found. A well defined flora was found in the sandy shale (No. 2) and the layers (3, 4) immediately overlying the main basal sandstone, and which are genetically related to No. 1, marking the cessation of the initiatory sandy beds of the series; two large boxes of these specimens were collected at Black Hills and submitted to Professor Knowlton, whose appended report speaks for itself. Similar plant remains were observed in the same sand layer near Blue Cut Mound, but night coming on a detailed collection could not be made there.

Report upon a Small Collection of Fossil Plants from Black Hills, near Belvidere, Kansas, collected by Prof. R. T. Hill in August, 1894.

This material has been carefully examined and the following species identified:

Rhus Uddeni Lx.
Sterculia Snowii Lx.
Sassafras Mudgei Lx.
Sassafras cretaceum Newby., var. *obtusum* Lx.
Sassafras, n. sp.
Glyptostrobus gracillinus Lx.
Sequoia sp.

The above species have, according to Lesquereux, the following distribution:

* Bull. Washburn Laboratory, vol. ii, No. 10, p. 65.

Rhus Uddeni Lx.—The locality for this species is simply "Kansas." It is said to have been presented to the U. S. National Museum by the collector, Prof. J. A. Udden, but according to the records it is not now and has never been in this institution. I have lately written to Prof. Udden to find where it came from, and he replies that it is "from the west slope of the Smoky Hill Buttes, near Salemsburg Post Office, Saline county, Kansas."

Sterculia Snowii Lx.—From Ellsworth Co., Kansas, where it is very abundant. It was reported by Mr. W. F. Cummins from the "upper sandstone of the Tucumcari beds, four miles west of Big Tucumcari mountain, New Mexico," and described by him under the name of *Sterculia Drakei*. 3d Ann. Rep. Geol. Survey of Texas, p. 210.

Sassafras Mudgei Lx.—Found on hills along the Salina river, Kansas.

Sassafras cretaceum var. *obtusum* Lx.—Also found on bluffs along the Salina valley, Kansas.

Sassafras n. sp.—This is a small leaf differing from any heretofore described. It, however, approaches to certain well known forms from Kansas.

Glyptostrobus gracillinus Lx.—Found near Sioux City, Iowa, at the mouth of Iowa creek. The collection from near Belvidere contains a number of fairly well preserved examples and there can be no question of its correct identification.

Sequoia ? sp.—The collection contains a number of fragmentary cones which appear to belong to this genus. I have not been able to identify them with any known species, and they may be new, although it is hardly safe to found species on such imperfect material.

Indeterminable dicotyledons.—Besides the forms enumerated above, there are a number of fragmentary leaves that it is impossible to determine with satisfaction. They are undoubtedly dicotyledons, but are only fragments with hardly a trace of nervation preserved.

All the above mentioned species belong to the Dakota group as it is usually accepted, but as a matter of fact no detailed stratigraphic work has yet been done with a view to ascertaining the range and association of the fossil plants referred to this formation. It would be natural to suppose that a formation of great thickness and wide areal extent, would have horizons capable of differentiation by means of the fossil plants, but they have not yet been worked out.

If it is shown by stratigraphic and paleontologic data that these leaves come from a horizon lower than that usually recognized as the Dakota group, it would be quite in accord with what should be expected of the Dakota flora. This flora, for years supposed to be the oldest of its type in North America, is made up of a great number of highly differentiated forms, that must have had an anterior period of development. That is, the flora could not have sprung into existence in so abrupt a manner as would seem to be indicated by previous studies, If more were known of the chronologic sequence of the Dakota flora, it would possibly be found that the plants identified above belonged to lower or older beds. But all that can now be stated is that these species belong to the Dakota group as it has usually been accepted, and have never before been identified outside of it.

Very respectfully,
(Signed) F. H. KNOWLTON,
Ass't Paleontologist.

III. *The Belvidere Shales.*—The fossils enumerated by Prof. Cragin from these shales, especially in his earlier writings, were determined under difficult conditions, remote from large libraries and typical collections, and his synonymy is greatly in need of revision.

From "the Neocomian shales," (the Belvidere shales)—the shales lying between the "Dakota" (No. IV) sandstone at the top and the highest layer of the Cheyenne sandstone, as above defined, Prof. Cragin in his various papers has reported the following fossils.*

Astrocœnia nidiformis Cragin, 7.
(? Nereis incognita Cragin, 6.
Ostrea anomioides Meek, 2.
Ostrea franklini Coquand, 4.
Ostrea diluviana Lam., 2, 4.
Gryphæa bryani Gabb, 2.
Gryphæa pitcheri Morton, 2, 4.
" " var. forniculata White, 4.
Gryphæa vesicularis White, 4.
Exogyra columbella Meek, 2.
" flabellata Goldf, 4.
" forniculata White, 2, 4.
" texana Roemer, 2.
A. argentaria Mort., 4.
Anomia tellinoides Mort., 4.
Plicatula arenaria Meek, 4.
" senescens Cragin, 6.
Neithea quinquecostata Sowerby, 2, 4.
Avicula belviderensis Cragin, 6.
Gervillia sp. allied to G. anceps, 4.
Modiola burlingtonensis Whitfield, 4.
Inoceramus comancheana Cragin, 7.
Inoceramus sp., 3.
Pinna comancheana Cragin, 7.
Cucullæa (Idonearca) terminalis var. recedens Cragin, 6.
Idonearca ? tippana Con., 4.
I. vulgaris Con., 4.
Limopsis sp., 4
" subimbricatus Cragin, 6.
Nucula catherina Cragin, 6.
" sp., 4.
Trigonia emoryi Conrad, 2, 3.
Remondia ferrissii Cragin, 4, 6.
Cardita belviderensis Cragin, 6.
Gouldia sp. "Prof. Marcou thinks it an Astarte."

* The figures appended to the names in the list refer to the publications of Prof. Cragin in which they have been used, as follows:
1. Bull. Washburn Laboratory, vol. i, No. 3.
2. Bull. Washburn Laboratory, vol. ii, No. 9.
3. Bull. Washburn Laboratory, vol. ii, No. 10.
4. Bull. Washburn Laboratory, vol. ii, No. 11.
5. Invertebrate Paleontology of the Texas Cretaceous, Austin, June, 1893.
6. Neocomian of Kansas, American Geologist, 1894.
7. Colorado College Studies, 1895.

Cardium belvederi Cragin, 3. (Not described.)
Cardium hillanum Sow. ? 4.
" kansaense, 3.
(?) " mudgeii Cragin.
" (Nemocardium) bisolaris Cragin, 6.
Cyprina ovata M. & H., 2, 3.
Tapes belviderensis Cragin, 6.
Roudaria quadrans Cragin, 4.
Cyprimeria crassa Meek, 2, 4.
" gradata Cragin, 3. (Not described.)
Leptosolen belvederi Cragin, 4. (Not described.)
Leptosolen otterensis Cragin, 6.
Pholadomya ? elegans ? 4.
" sancta sabæ Roemer, 4.
Homomya alta Roemer, 4.
Liopistha protexta Con., 4.
Mactra antiqua Cragin, 6.
Corbula crassicostata Cragin, 7.
Dentalium, 4.
Trochus texanus Roemer, 6.
Margarita marcouana Cragin, 6.
" (Solariella) Newberryi Cragin, 6.
Neritina sp., 4.
Serpula iintrica White, 2.
Vanikoro propinqua Cragin, 7.
Scalaria sp. (?) 4.
Turritella marnochii White (probably T. seriatim granulata Roemer), 2.
Turritella marnochii White "typical" Cragin, 4.
Turritella marnochii White, var. belvideri Cragin, 4.
Anchura kiowana Cragin, 7.
Globiconcha elevata Shum., 4.
Neritoma marcouana Cragin, 7.
Ammonites acutocarinatus Shum., 3, 4.
A. pedernalis Roemer, 4.
Petersia Medicinensis Cragin, 6.

The large and abundant collections of invertebrate fossils, made by Mr. C. N. Gould and the writer from the shale beds overlying the sandstone from which these fossil plants were collected and grading into them, were determined by Mr. T. W. Stanton, Paleontologist of the U. S. Geological Survey, who reports upon them as follows:

Washington, Jan. 25, 1895.

Mr. R. T. Hill, U. S. Geological Survey.

Dear Sir.—I have the honor to submit the following report on the fossils collected by you last season in southern Kansas.

The collection includes fossils from three different localities, which, according to the labels, are Black Hill, Blue Cut Mound, and hill four miles west of Sun City, Kansas, all of which are in Comanche and Barber counties. The collections from the first two localities are from several different horizons, but as they all evidently belong to one fauna they have all been combined in one annotated list, though the separate lists for each locality and layer are also appended in order that the record may be complete. In connection with the examination I have made a preliminary study of your Washita collection from the Denison section for comparison.

List of Species.

Enallaster sp.—Fragments of an Echinoid referred to this genus by Dr. W. B. Clark. It is not known in beds later than the Comanche series in America.

Ostrea sp.—This species is probably a new form. In size and outline it resembles some specimens of *O. franklini* to which Prof. Cragin referred it, but there are noteworthy differences especially in the beaks and the cartilage pit sufficient for specific separation. This species is very abundant in the shales.

Gryphœa pitcheri Morton.—A few specimens from No. 2 of Blue Cut Mound section seem to belong to this species, though they may be the young of one of the related forms.

Gryphœa forniculata (White).—It is abundant in certain layers. It occurs in the Washita beds at El Paso and the Kiamitia beds of the Washita at Denison and many other places in Texas.

Gryphœa tucumcarii Marcou.—Abundant in the upper part of the section at Blue Cut Mound. It is interesting to note that this form, supposed by Prof. Marcou to be Jurassic, here occurs *above G. forniculata*, which he considered Neocomian, though there is only a few feet difference in the beds and they seem to be connected by intermediate forms. The geographic distribution of the two species is about the same.

Exogyra texana Roemer.—There are only three specimens in the collection. It is abundant at El Paso in beds that are supposed to be Washita and it also occurs at Tucumcari Mountain, New Mexico.

Plicatula senescens Cragin.—Originally described from this region. The material is not sufficient for critical comparison.

Pecten sp.—A small smooth form like one that occurs in the Paw Paw beds of Denison.

Avicula belviderensis Cragin.

Avicula leveretti Cragin ?—Several specimens were collected in the shales of Blue Cut Mound, that agree fairly well with the figure and description of that species from the Kiamitia beds on Duck Creek, Texas.

Inoceramus comancheana Cragin ?—Fragmentary impressions of a form closely related if not identical with this species from the Duck Creek beds.

Lithophagus sp. nov.—Abundant burrowing in *Gryphœa forniculata.*

Nucula catherina Cragin.

Nucula sp.—Casts.

Leda sp.—Casts.

Trigonia emoryi Conrad.—This widely distributed species occurs at Tucumcari, El Paso, etc., and seems to have a great vertical range. It is found in the uppermost Washita beds at Denison and is reported from the Fredericksburg.

Cardita belviderensis Cragin.

Cardium mudgei Cragin?

Cardium bisolaris Cragin.

Cardium (Protocardia) *texanum* Conrad.

Roudaria [?] *quadrans* Cragin.—The Museum contains an example of this species collected by Prof. A. Hyatt at Tucumcari.

Cyprimeria sp.—This abundant species is evidently not *C. crassa*, as Prof. Cragin thought. Our collections of the Texan forms of this genus are not yet large enough for a revision of the species.

Cytherea? sp.—A few casts of an indeterminate Venerid.

Tellina? sp.

Mactra antiqua Cragin.

Corbula crassicostata Cragin, also occurs in the Paw Paw beds.

Dentalium sp.—Represented by fragments.

Natica sp.—A few small casts.

Turritella sp. related to *T. seriatim-granulata* Roemer.—This abundant species does not exactly agree with Roemer's figure nor with any of the four or five other similar species that have been described from Texas. The group needs careful study with large collection from the entire area in order to determine whether we are dealing with several species or only one or two variable forms. The variety now under consideration occurs at Tucumcari.

Anchura kiowana Cragin.—A small form represented by several imperfect specimens. It is closely related to *Anchura mudgei* White, which occurs in the Paw Paw beds, but is apparently not identical with it.

Trochus texanus Roemer.—Two specimens that are doubtless like the one referred to this species by Prof. Cragin. They are somewhat smaller than Roemer's figure, but agree well in sculpture and form.

Schlœnbachia peruviana von Buch.—Two or three characteristic fragments. The species is abundant in the Duck Creek and Kiamitia beds at Denison. It also occurs in the Washita division at El Paso and is said to occur as low as the Walnut clays of the Fredericksburg.

Sphenodiscus sp.—Fragments of a form that differs from *S. pedernalis* von Buch in that it has a truncated periphery. *S. emarginatus* Cragin and *S. rœmeri* Cragin are both related forms from the Fredericksburg and Trinity divisions, respectively, but they do not agree with each other nor with this form in the details of the septa.

A critical examination of the above list will show conclusively that the beds from which the fossils came belong to the Comanche series and probably to the upper half of that series. To make closer correlation with the subdivisions of the Texas section is more difficult because the association of species is not exactly the same as in any one of those subdivisions and some of the species common to the two regions are known to have a considerable vertical range. Taken altogether, the evidence seems to indicate about the horizon of the Kiamitia. The absence of limestone in the Kansas section adds another element of difficulty in the correlation, because a fauna occurring in shales is often more closely related to a slightly earlier or slightly later fauna in beds of the same lithologic character than it is to a strictly contemporaneous fauna in limestone or sandstone. That is, differences in local faunas are often in part due to differences in depth of water and in character of the sea bottom.

The similarity of the faunas in Kansas, at Tucumcari, New Mexico, and near El Paso, Texas, will allow greater confidence in correlating the beds at these three places.

Very respectfully,
(Signed) T. W. STANTON.

List of Fossils from Black Hills, Kansas.

No. 4. Gryphæa forniculata White. Small specimens—young or depauperate examples of this species.
No. 2, 5 and 9, contain indeterminate fragments of fossils.
No. 6. Corbula crassicostata Cragin.
Ostrea sp.
Gryphæa forniculata White.
Exogyra texana Roemer.
Nucula sp.
Cardium mudgei Cragin?
Cardium bisolaris Cragin.
Roudaria? quadrans Cragin.
Cytherea ? sp.
No. 11. Tellina ? sp.
Mactra antiqua Cragin.
Corbula crassicostata Cragin.
Dentalium sp.
Natica sp.
Anchura kiowana Cragin.
Trochus texanus Roemer.
Turritella sp. related to T. seriatim-granulata Roem.
Schlœnbachia peruviana von Buch.
Lamna sp. ? A shark's tooth probably of this genus.
No. 13. Ostrea sp.
Gryphæa forniculata White.
Cyprimeria sp.
Fragments of other forms occurring in Nos. 11 and 15.
No. 15. Gryphæa forniculata White.
Exogyra texana Roemer.
Avicula belviderensis Cragin.
" leveretti Cragin ?
Lithophagus n. sp.
Trigonia emoryi Conrad.
Cardita belviderensis Cragin.
Cardium (Protocardia) texanum Con.
Cyprimeria sp.
Tellina ? sp.
Natica sp.
Turritella sp. related to T. seriatim-granulata Roem.
Anchura kiowana Cragin.
Sphenodiscus sp.
Lamna ? sp.
Reptilian vertebra.

From Blue Cut Mound, four miles southwest of Belvidere, Kan.

No. 5. Ostrea sp.
Avicula belviderensis Cragin.
Inoceramus sp.
Corbula crassicostata Cragin.
Sphenodiscus sp.
No. 6. Ostrea sp.
Gryphæa pitcheri Morton ?
Turritella sp. related to T. seriatim-granulata Roem.

No. 7. Enallaster sp.
Pecten sp.
Avicula.
Nucula catherina Cragin.
Anchura kiowana Cragin.
Sphenodiscus sp.

No. 8. Ostrea sp.
Gryphæa forniculata White.
Plicatula senescens Cragin.

No. 9. Ostrea sp.
Leda sp.
Corbula crassicostata Cragin.
Impressions of several other Pelecypods.

No. 10. Ostrea sp.

No. 11. Cardium mudgei Cragin.
Corbula sp.
Turritella sp. related to T. seriatim-granulata Roem.

No. 12. Ostrea sp.

No. 13. Ostrea sp.
Cytherea? sp.

No. 14. Ostrea sp.
Gryphæa forniculata White.

No. 15. Ostrea sp.
Gryphæa forniculata White.
Corbula crassicostata Cragin.

No. 18. Ostrea sp.

No. 19. Ostrea sp.
Gryphæa tucumcarii Marcou. Small and rather distorted specimens.

No. 21. Gryphæa tucumcarii Marcou.

No. 22. Gryphæa tucumcarii Marcou.
Cardium mudgei Cragin?
Turritella sp. related to T. seriatim-granulata Roem.
Anchura kiowana Cragin.

List of Fossils from hill four miles west of Sun City.

Cardium mudgei Cragin?
Cyprimeria sp.
Corbula sp.
Turritella sp. related to T. seriatim-granulata Roem.
Anchura kiowana Cragin.

Mr. Stanton reports the following genera and species from the Belvidere shales, at all the localities mentioned:

Enallaster sp.
Ostrea sp.
Gryphæa pitcheri Morton.
G. forniculata White.
Exogyra texana Roemer.
Plicatula senescens Cragin.
Pecten sp.
Avicula belviderensis Cragin.
Avicula leveretti Cragin, Texas.
Inoceramus comancheana Cragin.
Lithophagus sp.
Nucula catherina Cragin.
Nucula sp.
Leda sp.
Trigonia emoryii Conrad.
Cardita belviderensis Cragin.
Cardium bisolaris Cragin.
Cardium (Protocardia) texanum Conrad.
Cyprimeria sp.
Cytherea?
Tellina? sp.
Mactra antiqua Cragin.
Corbula crassicostata Cragin.
Roudaria? quadrans Cragin.
Dentalium sp.
Natica.
Turritella sp. related to T. seriatim-granulata Roemer.
Anchura kiowana Cragin.
Trochus texanus Roemer.
Schlœnbachia peruviana von Buch.
Sphenodiscus sp.

The foregoing studies of the flora and fauna by Professors Knowlton and Stanton, aside from my own opinions, disagree with Prof. Cragin's conclusions on the age and position of the Cheyenne sandstone and Belvidere shales, which he referred to the Neocomian in general and to the Trinity and Fredericksburg divisions of the Comanche series in Texas and Arkansas in particular. It is difficult to find a basis for Prof. Cragin's conclusions in the paleontology testimony he himself has presented, as will now be shown.

An analysis of the species at various times reported by Prof. Cragin, from the Belvidere shales, shows the following well-known species peculiar to the greater divisions of the Cretaceous in other regions of the United States.

Ripley, uppermost Cretaceous of Atlantic coastal region:

Neithea quinquacostata Sow.
Anomia tellinoides Meek.
A. argentaria Morton.
Gryphæa bryani Gabb.
Modiola burlingtonensis Whitfield.
Idonearca tippana Conrad.
I. vulgaris Conrad.
Liopistha protexta Conrad.

Eight species.

Montana division (western equivalent of Ripley of Atlantic coast):

Cyprina ovata M. & H.
Ostrea anomioides Meek.

Two species.

Colorado Group (middle division of Upper Cretaceous):

Ostrea diluviana? Lam. Austin Chalk.
Cyprimeria crassa Benton (probably Montana) New Mexico.
Plicatula arenaria.

Three species.

Dakota Group:

Cardium kansasense Meek, Salina, Kansas.

One species.

Washita division of the main area of the Comanche series:

Gryphæa forniculata White.
Gryphæa pitcheri Mort.
Exogyra flabellata i. e. texana.
Neithea occidentalis Conrad.
Nucula catherina Cragin.
Inoceramus comancheana Cragin.
Trigonia emoryii Conrad.
Cardium hillanum Sow. (i. e. texanum Conrad).
Corbula crassicostata Cragin.
Pholodomya sancti sabæ Roemer
Turritella marnochii White.
A. acutocarinatus Shum., i. e. peruvianus de Buch.

Twelve species.

Species common to Fredericksburg and Washita divisions:

A. peruvianus von Buch.

One species.

Fredericksburg or Middle division Comanche series:

Exogyra texana Roemer.	Trochus texanus Roemer.
	Two species.

Trinity or Basal division:

Homomya alta Roemer.	Ostrea franklini Coquand.
Cucullæa terminalis Conrad.	Three species.

He reports two species which have been found in the Washita of Tucumcari:

Pinna comancheana Cragin.	Cardita belviderensis Cragin.

Besides the above he gives the following species, so far reported to occur only in these beds. (Total 21 species.)

Astrocœnia nidiformis.	Cardium mudgei Cragin.
Nereis incognita Cragin.	Roudaria ? quadrans Cragin.
Plicatula senescens Cragin.	Tapes belviderensis Cragin.
Avicula belviderensis Cragin.	Pholadomya ? elegans ? Cragin.
Petersia medicinensis Cragin.	Mactra antiqua Cragin.
Remondia ferrissii Cragin.	Leptosolen otterensis Cragin.
Limopsis subimbricatus Cragin.	Neritoma marcouana Cragin.
Cucullæa terminalis, var. recedens Cragin.	Vanikora propinqua Cragin.
	Anchura kiowana Cragin.
Cardita belviderensis Cragin	Margarita marcouana Cragin.
Cardium (Nemocardium) bisolaris Cragin.	M. (Solariella) Newberryi Cragin.

From this list we can now strike out two species, *O. franklini* Coquand, which has been disproved by Stanton, and *Cucullæa terminalis* Conrad, abandoned by Cragin.

A similar analysis of the list of species given by Mr. Stanton results as follows:

He finds none of the eight Ripley species reported by Prof. Cragin, nor any of the forms reported from Montana, Colorado, Dakota, or Trinity divisions.

He finds fifteen forms previously identified in the Washita division of the North Texas region, as follows:

Gryphæa tucumcarii Marcou.	Inoceramus comancheana Cragin.
Gryphæa pitcheri Morton.	Trigonia emoryi, Conrad.
Exogyra forniculata White.	Nucula catherina Cragin.
Exogyra texana Roemer.	Corbula crassicostata Cragin.
Avicula leveretti Cragin ?	Trochus texana Roemer.
Cardium (Protocardia) texanum Conrad.	Schlœnbachia peruvianus von Buch.
Cyprimeria sp.	Sphenodiscus sp.
Turritella, related to T. seriatimgranulata Roemer.	Total fifteen.

Common to Washita and Fredericksburg:

Exogyra texana Roemer. Schlœnbachia peruvianus von Buch.

Fredericksburg division:

Trochus texanus Roemer.

Mr. Stanton also finds the following species described from Kansas by Cragin, viz.:

Cardium bisolaris Cragin.
Mactra antiqua Cragin.
Plicatula senescens Cragin.
Avicula belviderensis Cragin
Roudaria quadrans Cragin.
Nucula catherina Cragin.
Cardita belviderensis Cragin.
Corbula crassicostata Cragin.
Inoceramus comancheana Cragin.
Anchura kiowana Cragin.

Total ten.

Tabulating these results, they show:

	Reported by Cragin.	Reported by Stanton.
Uppermost Cretaceous { Ripley species, 8; Montana, 2 }	10	0
Colorado species	3	0
Dakota species	1	0
Washita species, { Texan, 11; Tucumcari, 2 }	13	15
Washita species, Belvidere species	21	10
Common to Washita and Fredericksburg	2	2
Fredericksburg species	1	1
Trinity species	1	0
Species common to other localities, 31		
Peculiar species 21		
Total	52	28

When Prof. Cragin first announced the occurrence of *Ostrea franklini* and the Trinity sands in Kansas—before giving the paleontologic details since published—the writer was inclined to accept his conclusions.* But as Prof. Cragin's paleontologic publications progressed, it became my opinion, even without having seen the region, that the Belvidere beds of Kansas represented the writer's upper or Washita division of the Lower Cretaceous section, and not entirely the Fredericksburg and Trinity as asserted by Cragin. This opinion was confirmed after seeing, later, Prof. Cragin's collections at Washburn College.

If distantly situated beds are to be correlated by the law of common species, it is impossible to see upon what ground Prof. Cragin referred these beds entirely to the Trinity and Fredericks-

* See Annual Report Arkansas Geological Survey, vol. ii, 1888, p. 115.

burg. According to the fauna as identified by him and as analyzed above, they could more logically have been referred to the uppermost Upper Cretaceous (the Montana division) than to the Fredericksburg, since the list contains more Ripley-Montana than Fredericksburg species. But the Washita species as enumerated by him far exceed those from all other divisions, and hence upon his own data the beds should have been chiefly referred to this division.

Concerning the alleged Ripley, Montana, Colorado and Dakota species mentioned by Prof. Cragin, it is strange that none of them were found in the collections studied by Mr. Stanton, and we cannot escape the conclusion that they were founded upon erroneous identifications.

Mr. Stanton's studies of the fossils of the Belvidere shales also demonstrate the opinion I have long entertained, that these fossils are largely of the age of the Washita division of my Texas section, and not solely the Fredericksburg and Trinity divisions, as maintained by Cragin. I am glad to have my own conclusions sustained by such an authority, and I fully agree with him that the Belvidere beds represent in general the Washita division and probably the attenuated Fredericksburg as seen in the North Texas section.

There are several points more strongly suggesting this affinity than Mr. Stanton has brought out. Mr. Stanton's diagnosis removes the alleged *O. franklini* from the list of Kansas species, while Prof. Cragin himself has retracted the other Trinity species (*Cucullæa terminalis* Conrad) which he once reported.* The facts eliminate the sole molluscan species upon which Prof. Cragin could correlate these formations with the Trinity division of Texas.

Mr. Stanton also finds in the Belvidere shales two additional species which Cragin himself has recently described from Texas, to wit: *Avicula leveretti*,† of the Washita of Denton county, Texas, and the peculiar *Inoceramus* to which I have called attention in previous writings, as being found only in the Preston beds,‡ and to which Prof. Cragin has recently given the name *I. comancheana*.§ Thus we have common to the Belvidere beds of Kansas and the Preston beds of the Washita division of Texas and Indian Territory the following peculiar species which occur in no other geologic horizon, and seem to intimately connect these beds at the two localities:

* American Geologist, vol. xiv, 1894, p. 3.

† Invertebrate Paleontology of the Texas Cretaceous, Austin, June, 1893, pp. 171–172.

‡ Bull. Geol. Soc. of America, vol. v, p. 332.

§ Colorado College Studies, 1894, p. 53.

Gryphæa forniculata White.
Avicula leveretti Cragin.
Inoceramus comancheana Cragin.

Of the fifteen recognized species common to both the Kansas and Texas regions all occur in the Washita division of Texas and eleven are found only in it. The Fredericksburg fossils reported by him with the exception of one little known fossil hitherto reported only from the Caprina limestone of the Fredericksburg (*Trochus texana* Roemer), are all of species which in Texas also occur in the Washita division. These species are as follows: *Exogyra texana* Roemer, *Sphenodiscus sp.* Cragin, *Schlœnbachia peruviana* von Buch, and *Trigonia emoryi* Conrad. In all the writer's years of labor and study of the region he has never seen *Trigonia emoryi* in the beds of the Fredericksburg division, and although so reported by the Texas Geological Survey, he does not believe it occurs there, while it is common, abundant and widely distributed in the beds of the Washita division.

The *Sphenodiscus* from the Belvidere beds may possibly be confused with *S. pedernalis* Roemer, of the Fredericksburg division. A large number of undescribed species belonging to this group of Ammonites occur in the Comanche Series from the Glen Rose through the Washita division. The writer has observed these differences for years and submitted the species to eminent authorities. It can only be said now, as Mr. Stanton has already said, that the Sphenodiscus of the Belvidere beds—a figure of which without description has been published by Cragin*—is not *S. pedernalis* of Roemer. On the other hand, some of the Belvidere specimens seem to resemble species occurring in the Denison beds of the Washita division.

This leaves only two undoubted species common to the Fredericksburg and Washita in the Belvidere beds. These are *Exogyra texana* Roemer, and *Schlœnbachia peruvianus* von Buch.

Exogyra texana Roemer is found to range upward into the Washita division in New Mexico, in Trans Pecos, Texas, and at El Paso, but the writer, in the course of his extensive observations, has never seen it in Central Texas above the Fredericksburg division. While this form usually has a well defined zone of abundance in the Walnut clays at the base of the Fredericksburg division, it really has a wide vertical range, occurring in the underlying Glen Rose and the upper beds of the Caprina limestone in the Austin region and associated with a Fort Worth fauna at Frontera, three miles west of El Paso.

* The Neocomian of Kansas, American Geologist, 1894, Plate I, fig. 4.

As has been previously shown by Roemer, this species greatly resembles *Exogyra matheroniana*, an allied species, which in Europe also has a wide vertical range and extends as high as the Senonian. It was largely owing to its abundant occurrence in Texas that Roemer made the cardinal mistake of considering the Lower Cretaceous beds to be Upper.

On the other hand, none of the many peculiarly characteristic Fredericksburg species of Texas occurs in the Kansas beds.

Concerning the twenty-three species which Prof. Cragin describes and which have as yet been reported only from the Belvidere shales, the writer believes that many of them are due to the fact that they represent the naturally denser population of the more northern shallower littorals; others will be found to occur in the rich unstudied littoral faunas of the Washita division in North Texas,* while some of them will be reduced to synonyms. They all belong to that group of littoral genera with a wide range and of little value for minute correlation.

The species called throughout this paper *Gryphæa forniculata* White is the same as the one from Comet Creek, Oklahoma, first figured by Prof. Marcou as *Gryphæa pitcheri* Morton,† and later called by him *Gryphæa Rœmeri*.‡ The nomenclature of the Gryphæata oysters of the Comanche series will be thoroughly revised in a separate paper which the writer has in print. Prof. Marcou's name *G. Rœmeri* probably has precedence over *G. forniculata* White, but it may be shown neither of these will stand.

This Gryphæa so abundant at Belvidere is likewise found in great numbers in the Kiamitia clays, not only about Denison and Fort Worth, but also along a persistent line of 300 miles from Goodland, Indian Territory, to south of the Brazos in Texas. Its hemera in Texas is exclusively confined to the Preston beds, and Prof. Marcou has always held that it is a Cretaceous form; it is the species upon which he established the existence of the alleged Neocomian in America.

An interesting fact in the Black Hills and Blue Cut sections is that the large Gryphæa which comes in near the top of the shales is identical with the form collected by Prof. Marcou and is the species called *Gryphæa tucumcarii* by him (later called *Gryphæa dilatata* var. *tucumcarii*).§

* Since penning these words Prof. Cragin himself has already verified this prophecy by publishing many species from the Denison beds which emphasize this assertion. See Fifth Annual Publication, Colorado College Studies, received April, 1895.

† Geology of North America, Plate IV, fig. 5, 5*a*, 6.

‡ Proc. Boston Soc. Natural History, 1861, p. 95.

§ Loc. cit., Pl. IV, fig. 1, 1*a*, 2.

Prof. Marcou insisted that the beds from which this species came were of Jurassic age, and upon its occurrence he maintained the existence of the Jurassic system in this region. It occurs at Belvidere, as on the original plains of the Kiamitia near Goodland, in Indian Territory, where it was last year collected by Mr. T. Wayland Vaughan of my division, and at Kent* in Trans Pecos, Texas, stratigraphically above and intimately associated with the species which he called *Gryphœa pitcheri.* Thus we have in Kansas and Indian Territory Prof. Marcou's alleged Jurassic species occurring stratigraphically above species he called Cretaceous, which facts forever remove any previous doubt, if any existed, in favor of his theory of the existence of the Jurassic formation in Texas, Indian Territory, New Mexican region.

A lithologic comparison of the Belvidere shales and those of the Washita division, North Texas section, is also of interest. While differing in detail, there is one broad generic resemblance. They are both in general shallower water deposits than the beds of the Fredericksburg division, the shales being blacker and containing beds of littoral sand.

Owing to the underlying Dakota flora of the Cheyenne sandstone there may be doubt in the minds of some whether to assign the Belvidere shale to the Dakota or to the Washita division, but it is difficult in view of the facts presented to see upon what possible ground they could have been referred to the Trinity division.

Prof. Knowlton's determination of the dicotyledonous Dakota flora in the top of the Cheyenne sandstone shows that from a paleontologic standpoint these sandstones have no resemblance to the flora of the Trinity division at Glen Rose, Texas, beds which contains a flora of typical Potomac non-dicotyledonous species.† The Cheyenne sandstones are of far later age than the Trinity, and occupy a stratigraphic position at the base of the Washita midway between the Trinity and the Dakota.

These facts being true, Prof. Cragin's assertion that the Dakota sandstone (No. IV of the general section) in Kansas rests directly on the Fredericksburg division without the intervention of the Washita division is also disproved.

Concerning the correlation of the Belvidere beds with the Neocomian, as done by Prof. Cragin, we can only repeat our opinion, founded upon facts previously given, that the Washita division is homotaxially nearer the equivalent of the Gault, and that the lower lying beds of the Trinity division are

* According to Mr. E. T. Dumble, American Geologist, November, 1893, pp. 310–312.

† See Proceedings U. S. National Museum, vol. xvi, pp. 261–282.

more nearly the nearer equivalents of the Neocomian in the United States.*

The Camp Supply Beds.—There can be little doubt but that the localities of the Cretaceous near Camp Supply reported by Prof. Cope,† and at Comet Creek, reported by Prof. Jules Marcou,‡ represent a portion of the same general sedimentation as the Belvidere beds which Prof. Cragin himself has reported in Northern Oklahoma.

From the beds near Camp Supply Prof. Brown, of the University of Kansas, reports eleven invertebrate species, as follows:

1. Gryphæa§ forniculata White.
2. Exogyra texana Roem.
3. Ostrea‖ subovata Shum.
4. Ostrea quadriplicata Shum. (variety).
5. Cucullæa terminalis Conrad.
6. Neithea occidentalis Conrad.
7. Plicatula incongrua Cragin.
8. Trigonia emoryii Conrad.
9. Trigonia sp.
10. Turritella seriatim granulata Roemer.
11. Schlœnbachia peruvianus von Buch.

Of the nine species named, the following have been reported from the Belvidere shales of Kansas:

1. Exogyra texana Roemer.
2. Gryphæa forniculata White.
3. Trigonia emoryii Conrad.
4. Cucullæa terminalis Conrad.
5. Turritella seriatim granulata Roemer.
6. Schlœnbachia peruvianus von Buch.

The following are characteristic species of the Washita division of Central Texas:

1. Gryphæa forniculata White.
2. Ostrea subovata Shum.¶
3. Ostrea quadriplicata Roemer.
4. Plicatula incongrua Conrad.
5. Trigonia emoryii Conrad.
6. Schlœnbachia peruvianus von Buch.

The following species are common to the Fredericksburg and Washita divisions of Texas:

Neithea occidentalis Conrad.
Turritella seriatim-granulata Roemer.
Schlœnbachia peruvianus von Buch.

* Age and Significance of the Trinity Division. Proc. Biological Society of Washington, vol. viii, pp. 17–20, 1893. Bull. Geol. Soc. of America, vol. v, pp. 336–37, 1894.

† Observations on the Geology of Adjacent Parts of Oklahoma and North West Texas, Proc. Nat. Sci. Acad. Phila., 1894, p. 63.

‡ Geology of North America, p. 17.

§ Originally published as *G. pitcheri* Morton. Prof. Brown informs me by letter that it is the form figured by Marcou, i. e. *G. forniculata* White.

‖ Originally published as *O. crenulimargo* Roemer by Prof. Brown. He informs me that he now regards it a variety of *Ostrea quadriplicata* Shum.

¶ See remarks on this species by Dr. Benj. F. Shumard, Trans. Academy of Science of St. Louis, vol. i, p. 587. He here states that its horizon is the Washita limestone and gives more light upon it than is contained in his original description of it in Marcy's Report on Red River.

The vertebrata from these beds strikingly resemble those described by Williston and Cragin from the Belvidere beds of Kansas with the exception of two species of Pycnodont fishes belonging to the genera Uranoplosus and Cœlodus, for which this is a new horizon.*

Concerning these vertebrates Prof. Cope† remarks:

"The three species of Pycnodont fishes were new to science, and they have a Lower Cretaceous facies. Plesiosaurus is represented by dorsal vertebræ only, but these are not of the Upper Cretaceous type. I have never found Lepidotid fish remains in the Upper Cretaceous of North America, while they are characteristically Lower Cretaceous and Jurassic in Europe. The only occurrence of Lepidotid fishes so far recognized in North America, is based on some teeth sent by Mr. Charles H. Sternberg in the Dakota sandstone of Kansas, and on the new species, *Macrepistius arenatus*, from the Trinity bed of Texas discovered by Prof. R. T. Hill. (See Journal of the Academy Natural Science, Philadelphia, vol. ix, Part 4). The crocodilion remains are undeterminable."

From the molluscan species it will be seen that these beds paleontologically more resemble the Washita division than the Fredericksburg. Furthermore, they show the same general association of molluscan species as do the Belvidere shales, and like them differ from the beds of the Central Texas region by containing vertebrates. That they are a southern extension of the Belvidere beds there can be no reasonable doubt.

The Comet Creek Bed.—Little is known concerning the isolated remnant of the Cretaceous formations at Comet Creek, in G county, Oklahoma, the only locality of the Comanche Cretaceous recognized as having been seen by Prof. Jules Marcou in his journey with the Pacific railway explorations.‡ According to this author this locality consists of a single stratum of "Gryphæate limestone" "five feet thick" containing one fossil species, the *G. pitcheri* of Marcou. This species has been found elsewhere only in the Washita division and is especially abundant in both the Belvidere shales of Kansas and the Preston beds of Texas. This is the fossil which Prof. Marcou figures so well as *Gryphœa pitcheri* § Morton, but for which he himself later suggested the more appropriate name of *G.*

* The species of the genus Mesodon from Texas described by Prof. Cope with these fishes, as coming from Texas, belong to the Trinity division.—See New and Little Known Paleozoic and Mesozoic Fishes, Journal Academy of Natural Science, vol. x, Philadelphia, 1894.

† Proc. Phila. Acad. of Nat. Science, loc. cit., 243.

‡ See Geology of North America, p. 17.

§ He says, Geology of North America, page 38: "The drawings are very exact and were done from nature by Humbert, the most skilful artist for fossils in Paris."

Rœmeri,* and which White later described as *G. forniculata*, as called throughout this paper.

Inasmuch as these beds lie in the Kansas province, i. e., the region north of the Ouachita system of mountains, and is completely cut off from the Texas region by them, it is reasonable to infer, until the localities can be visited, that the Comet Creek bed is a part of the same general formation as those near by at Camp Supply and Belvidere.

The Tucumcari Region.—The Tucumcari exposures, as we shall call the New Mexican localities of the Cretaceous, are the most isolated of all the Comanche deposits, and, as we have shown, there is no possibility of tracing by stratigraphic continuity their relations with the main Kansas and Texas areas. They are two hundred and fifty miles southwest and west of the Belvidere and Comet Creek localities; about two hundred miles northwest of the nearest Texas localities in the breaks of the Plains on the headwaters of the Brazos, and three hundred miles north of the Kent localities in Trans Pecos, Texas. If there was stratigraphic connection between these localities across the intervening areas, it was forever destroyed by the great pre-Plains erosion, or obscured by the succeeding Plains sedimentation.

Yet paleontology again comes to our aid to show that the small thickness of Comanche Cretaceous preserved in this isolated area was intimately connected with the other outlying areas. It is unfortunate that in the following remarks we have not the benefits of the publication of the results of the field season spent by Prof. Alpheus Hyatt in this region in the year 1889. The writer has seen his collections, however, and has no fear in saying that, when published, they will substantiate the general proposition maintained in this paper. That he and every other modern writer holds these beds to be of Cretaceous age, and not Jurassic, as maintained by Prof. Jules Marcou, is also fully substantiated. We shall not enter into this controversy here. Aside from Prof. Hyatt's unpublished collection, three collections have been made from this region.

1. By Prof. Jules Marcou, who collected two species as follows: *Gryphœa tucumcari* Marcou, later figured by him as *Gryphœa dilatata* var. *tucumcarii;* and *Ostrea Marshi* Marcou.

2. A collection made by the writer, April 30, 1891, and now in the collections of Johns Hopkins University, a list of which was published in Science of July 14, 1893.

3. A collection made by members of the Texas Geological Survey, in the summer of 1891, a list of which as identified by Mr. T. W. Stanton of the U. S. Geological Survey, was published on page 208 of the third annual report of that survey.

*Proceedings Boston Society of Natural History, 1861, p. 95.

In addition Prof. Cragin has recognized from the Tucumcari collections of the Texas Survey two species which he had collected from Belvidere, *Cardita belviderensis* Cragin and *Pinna comancheana* Cragin. Mr. Stanton has also identified *Roudaria* [*?*] *quadrans* Cragin in the Tucumcari collections made by Prof. Hyatt, and *Trigonia emoryi* Con., *Protocardia texanum* Con., *Cardita belviderensis* Cragin, *Tapes belviderensis* Cragin, and Cyprimeria sp. from the collection made by the writer.

Counting all these known fossils, we have from the Tucumcari beds the following list of species of invertebrates:

Turbinolia texana [?] Conrad.
Ostrea Marshi, as determined by Marcou.
Ostrea quadriplicata Shumard.
Gryphæa dilatata, var. tucumcarii Marcou.
Gryphæa pitcheri Morton.
Exogyra texana Roemer.
Plicatula, species undescribed.
Neithea occidentalis Conrad.
Trigonia emoryii Conrad.
Protocardia multistriata Con.
P. texanum Conrad.
Cytherea leonensis Conrad.
Pinna comancheana Cragin.
Cardita belviderensis Cragin.
Tapes belviderensis Cragin.
Roudaria [?] quadrans Cragin.
Cyprimeria sp.
Turritella seriatim granulata Roemer.
Turritella marnochii White, or seriatim granulata Roemer.
Ammonites leonensis Conrad.

These species all come from the impure shaly beds below the highest escarpment of brown sandstone, which we shall elsewhere discuss under the Dakota, and above the unfossiliferous white sands, occupying a vertical range of about 115 feet in thickness.

Of the twenty species enumerated thirteen are also represented in the Belvidere beds, as follows:

Gryphæa dilatata var. tucumcarii Marcou.
G. pitcheri Morton.
Exogyra texana Roemer.
Plicatula, species.
Trigonia emoryii Conrad.
Protocardia multistriata Conrad.
Tapes belviderensis Cragin.
Pinna comancheana Cragin.
Cardita belviderensis Cragin.
Roudaria ? quadrans Cragin.
Turritella seriatim-granulata Roemer.
Turritella marnochii White.

The analogy between these fossils and those characterizing the Washita division is so striking that it hardly seems necessary to make comparisons of the species enumerated. The following are peculiar to and characteristic of the Washita division:

Turbinolia texana Conrad.
O. quadriplicata Shumard.
G. dilatata var. tucumcarii Marcou.
G. pitcheri Morton (var. not given).
Plicatula sp.
Trigonia emoryii Conrad.
Pinna comancheana Cragin.
Cardita belviderensis Cragin.
Protocardia texanum Conrad.
Turritella marnochii White.
Ammonites leonensis Conrad.

Of the remaining six, one, *Cytherea leonensis* Conrad, is a form which is reported in the Mexican Boundary Report from near Leon Springs. The writer has never seen this species *in situ*. *Ostrea Marshii* is a form which Dr. B. F. Shumard calls *O. subovata*, and which he has identified from his "Washita limestone," which is practically synchronous with the whole of our Washita division. Of this species he says:*

"I have before me specimens of *O. subovata* from Fort Washita, several localities in Grayson and McLennan counties, and from Mt. Bonnell, near Austin, some of them in a beautiful state of preservation, and have compared them most carefully with Marcou's figure of *Ostrea Marshii*, in the Geology of the U. S., without being able to detect any difference whatever of specific value. . . . I have also compared my specimens of *O. subovata* with an authentic example of *O. Marshii* from Europe, and regard them as being specifically distinct, as much so as we usually find in closely allied species."

Protocardia multistriata Conrad is a species of *Protocardia* which may occur in both the Fredericksburg and Washita divisions. The writer has specimens from the Denison beds of the Washita division which are indistinguishable from it.

This leaves only three species, *Turritella seriatim-granulata* Roemer, *Exogyra texana* Roemer, and *Neithea occidentalis* Conrad, which may have a common range into both the Washita and Fredericksburg divisions.

The absence of the rich fauna of the Fredericksburg and Glen Rose which constitutes the great thickness of the Central Texas section is conspicuous.

It must be apparent that the fossils from the Comanche Cretaceous at Tucumcari are nearly related to the faunas of the Washita division of North Texas, and to the Trans Pecos and Belvidere regions, and they show certain transitional conditions between the variations seen in the faunas of these extreme localities, such as the occurrence of species so far as known hitherto found in only one of the regions, such as *Turbinolia texana*, of El Paso region, *O. quadriplicata* Shumard, of the Central Texas region, *Ammonites leonensis* Cragin, of the Central Texas and Trans Pecos region, and *Pinna comancheana* Cragin, *Roudaria? quadrans* Cragin, and *Cardita belviderensis* Cragin, of the Belvidere region.

The age of the arenaceous beds underlying the first fossiliferous horizon of Tucumcari is still problematic. In previous papers the writer has noted their lithologic resemblance to the basement arenaceous Trinity littoral of the Comanche series of Texas.

*Trans. Academy of Science, St. Louis, 1860, vol. i, No. 4, p. 587.

The white sands between the Red Beds and Washita fauna are lithologically somewhat different from the Cheyenne sandstones, but it is an interesting fact hitherto unpublished, that they contain dicotyledonous leaves of at least one species identical with those of the Cheyenne sandstone, the *Sterculea Snowii* of Lesquereux. This specimen was collected by the State Geological Survey, and erroneously described,* as Prof. F. H. Knowlton has shown,† as a new species under the name *Sterculea drakei* Cummins. It was also erroneously published,‡ as having come "From the upper sandstone of the Tucumcari beds four miles west of Tucumcari Mountain, New Mexico, above the bed of blue clay, 'bed F' of Marcou's section."§ Mr. N. F. Drake in a recent letter to Mr. J. A. Taff,‖ as announced by the latter before the Geological Society of Washington, April, 1895, stated that he collected this particular specimen, and that it came from the basal sandstone below the molluscan-bearing beds and not from the Dakota above it. It is the writer's opinion that when these basal beds are fully studied, they may be found to represent the initiatory sediments of the Comanche sea upon the Red Beds in this region, like the Trinity sand of Central Texas, the Antlers sands of Southern Indian Territory, and the Cheyenne sandstone of Kansas, all members of the great initiatory littoral formation, marking epochs in the migration of the sea which, during the Comanche epoch, transversed them diagonally northward across the Great Plains Region.

A comparison of the two sections at Tucumcari and Belvidere which the writer has personally studied, reveal some common interesting general features. Both localities show topographic similarity in that they are remnantal buttes in the margins of the Plains. The summits of both sections are the mortar-bed-like rocks of the Tertiary Plains formation resting, through unconformity by erosion, on a sandstone of supposed Dakota age. Beneath this alleged Dakota sandstone in each locality are clay shales with marine fossils of the Washita division; below these molluscan-bearing shales are sands containing the dicotyledonous *Sterculea Snowii* Lesquereux, while the base of each is the Red Beds.

The observable differences between the Belvidere and Tucumcari localities are as follows: *G. dilatata* occurs at the base of the Washita beds at Tucumcari, while at Belvidere it ranges near their summit. The Tucumcari fauna contains above the

* Annual Report, Texas, State Geol. Survey, 1891, p. 210.
† American Journal of Geology, vol. ii, No. 4, p. 372.
‡ Geol. Survey of Texas, Third Annual Report, 1891, p. 210.
§ Ibid, p. 209.
‖ We are indebted to Mr. J. A. Taff for permission to use this information.

G. dilatata zone, *Ammonites leonensis* Conrad and *O. quadriplicata* Shumard, characteristic middle and upper Washita species of the Central Texas region, which do not occur at Belvidere. In general association the species of the Tucumcari locality have greater resemblance to that of the uppermost beds of the Washita division of the Central Texas section, while the common forms of the Belvidere beds, such as *Schlœnbachia peruvianus* and *Gryphœa Rœmeri*, are more common to the Preston or basal beds of the Washita. More minute studies of the range of species in the Tucumcari beds is necessary before any positive conclusions on these subjects can be stated.

The seventy-five feet of alleged Dakota sandstone overlying the fossiliferous beds of Tucumcari will be more fully discussed in a future paper.

The outlying beds of the Washita division are also found far southward in the Trans Pecos region of Texas at Kent,* El Paso and as far west as Arivichi in Sonora, where its fauna was reported by Gabb. We cannot here continue the presentation of the minute data concerning them, but they, together with the data we have given concerning the beds in Kansas, Oklahoma and New Mexico, all demonstrate the generalization we have before presented,† that the beds of the Washita division far overlapped interiorward those of the Trinity division. This study has enabled us to classify and understand the significance of the outlying areas of the Cretaceous in Oklahoma, New Mexico, and Trans Pecos, Texas, and their paleontologic relations as shown in the appended table.

The geology of these outlying areas of the Cretaceous preserved in the scarps of the Plains adds greatly to our knowledge of the distribution, variation, paleontology, and history of the beds of the Comanche series and of the progressive oscillatory conquest of the Great Plains region by the sea in Cretaceous time. The Belvidere beds have revealed the following additions to our knowledge of Cretaceous paleontology: First, a lower stratigraphic occurrence of the dicotyledonous Dakota flora than known, whereby we may now say that dicotyledons make their first appearance before the beginning of the Washita sub-epoch, instead of in the Dakota as hitherto believed. Second, a similar downward range in the geologic scale of the Icthyan vertebrates of hitherto supposed Upper Cretaceous range. Third, intermingling of these plants and fishes with molluscan species and other vertebrates of the Washita division such as has not hitherto been found in the Comanche series.

* See sections by E. T. Dumble, Bull. Geol. Soc. America, vol. vi, pp. 376–388, and American Geologist, vol. xii, p. 309.

† Bull. Geol. Soc. of America, vol. v, p. 332–338.

These beds represent the modified attenuated northern extension of the Washita division and probably a portion of the Fredericksburg division of the Comanche series of Texas, which, as we have previously shown, far overlapped to the northward those of the Trinity division. The beds of the later division have not been found north of the 34th parallel and there is every reason to believe that their original sedimentation did not extend north of this line. Neither are the remarkable limestones and accompanying forms of the great Caprina limestone of southern Texas represented in the outlying areas.

Known Occurrence of Species of the Outlying Areas of the Comanche Series.

	Washita.					Fredericksburg.	Trinity.
	Kansas.	Oklahoma.	New Mexico.	Trans Pecos, Tx.	Central Texas.		
Turbinolia texana Conrad	--	--	×	×	--		
Terebratula wacoensis Roemer	--	--	--	×	×		
Ostrea subovata Shumard	?	×	×	×	×		
Ostrea quadriplicata Shumard	--	×	×	×	×		
Gryphæa forniculata White	×	×	×	×	×		
Gryphæa pitcheri Morton	×	×	×	×	×		
G. dilatata var. tucumcarii Marcou	×	×	×	×	--		
Exogyra texana Roemer	×	×	×	×	--	×	
Exogyra plexa Cragin	--	--	--	×	×		
Plicatula incongrua Conrad	--	×	×	×	--		
Plicatula belviderensis Cragin	×	×	×	×	--		
Lima wacoensis Roemer	--	--	--	×	×	×	
Neithea occidentalis Conrad	--	×	×	×	×	×	
Avicula belviderensis Cragin	×	--	--	--	--		
A. leveretti Cragin	×	--	--	--	×		
Pinna comancheana Cragin	×	--	×	--	?		
Inoceramus comancheana Cragin	×	--	--	--	×		
Nucula catherina Cragin	--	--	--	--	--		
Trigonia emoryii Conrad	×	?	×	×	×		
Cardita belviderensis Cragin	×	--	×	--	--		
Protocardia texanum Conrad	×	×	×	×	×		
P. multistriatum Conrad	--	--	×	×	×		
Cyprimeria species	×	--	×	×	×		
Cytherea leonensis? Conrad	--	--	×	×	--		
Cytherea sp	×	--	--	--	×		
Mactra antiqua Cragin	×	--	--	--	--		
Corbula crassicostata Cragin	×	--	--	--	×		
Tapes belviderensis Cragin	×	--	×	--	--		
Roudaria quadrans Cragin	×	--	×	--	--		
Turritella seriatim-granulata Roemer	×	×	×	×	×	×	
T. marnochii White	--	--	--	--	--		
Trochus texanus Roemer	?×	--	--	--	--	×	
Ammonites leonensis Conrad	--	--	×	×	×		
Schlœnbachia peruvianus von Buch	×	×	--	×	×	×	
Sphenodiscus sp	×	--	--	×	×	×	

Art. XXII.—*The Relations of the Diurnal Rise and Fall of the Wind in the United States;* by Frank Waldo.

I. *Relative Rapidity of Diurnal Rise and Fall of Wind.*

An inspection of the curves indicating the diurnal change in the wind velocities shows usually at a glance whether the rise of the wind to the mid-day maximum takes place more rapidly or more slowly than the subsequent fall of the wind.

For January over nearly the whole of the United States the rate of fall of the wind is more rapid than the rate of rise toward the mid-day maximum. Still in the western U. S. there is a central region extending from northern New Mexico to Montana and a region in the extreme southwest in southern California and southwestern Arizona where the rise is more rapid than the fall; and in a number of places irregularly distributed the rates of rise and fall are equal; while in the eastern part of the U. S., in the Ohio valley, there is a small section where the rise and fall are about equal, and around this there is a narrow region where the rise is more rapid than the fall.

For July the fall of the wind is in general more rapid than the rise: but in the western U. S. there are regions, in western Colorado and eastern Utah, in northern Texas, Oklahoma and southern Kansas, and on the central and southern Pacific coast, where the rise is more rapid than the fall; while also in the eastern U. S., in central Ohio and at some places on the Atlantic coast the rise is more rapid than the fall. The places where the rise and fall are equal are not so numerous in July as in January.

For the Year, to the east of the medial meridian of the U. S. (about the 100° longitude) the fall of the wind after the mid-day maximum is more rapid than the rise preceding it: but to the west of this line the rise of the wind proceeds at a more rapid rate than the fall. There are, however, some exceptions to this rule. Over a limited region in southern Oregon and northwestern Nevada, and again in southeastern Arizona and southwestern New Mexico, the fall of the wind is more rapid than its rise. Also on the central Mississippi River and around Lake Erie the rise of the wind is more rapid than its fall.

II. *Period of Mid-day Rise of Wind.*

The duration of the period when a *decided* continuous rise of the wind occurs towards the nearly mid-day maximum can be indicated in a general way for the various regions of the U. S.

For January immediately along the Mississippi River Valley there is a rise of wind during 6 hours. To the east of this there is a decrease to 4 hours at the north, along the Great Lakes, with a slight decrease to 5 hours at the center just east of the Alleghany Mountains, and in the extreme southeast of the U. S. But near the Atlantic coast there is an increase to 7 hours.

To the west of the Mississippi Valley there is a rather rapid decrease to 3 or 4 hours at the north. At the center there is an immediate increase to 7 hours on the 97th meridian, then a decrease to 3 hours at the 105th meridian in central Colorado, then a slight increase to 4 or 5 hours, then another decrease to 3h. in central Nevada, from which there is an increase to 7h. or more on the Pacific coast. At the south there is a decrease to 4h. in central Texas, then an increase to 7h. in southern New Mexico, then a decrease to 3h. in southern Arizona, and an increase to 5h. on the South Pacific coast. There seems to be about the same time of rise on the not exposed Pacific and Atlantic coasts north and south; and also on the eastern and western Gulf Coast.

For July, along the 92d meridian, which lies just a little to the west of the Mississippi River, the time of rise of wind is about 7 hours. To the west of this there is: at the north, an increase to 9h.; at the center at first little change and then a slight increase to 8h., which, on the Pacific slope, increases suddenly to 11h.; at the south, at first a rapid increase to 10h. and then a rapid decrease to 5h. in southern Arizona, and finally a return to 7h. on the southern Pacific coast.

To the east of the central 7 hour region, of longitude 92° passing through Duluth, there is: at the north an increase to 9h. on the Upper Lakes, a return to 7h. on the Lower Lakes, and an increase to 9h. on the Atlantic coast; at the center an increase to 8h. for most of the region and to 9h. on the coast, but with a relapse to 7h. just east of the Alleghany Mountains; at the south there is an increase to 9h. on the Atlantic coast, but along the Gulf of Mexico a decrease to 5h.

On the eastern Gulf coast the rise is for 5h. and at the western coast it is 10h. On the Atlantic coast for exposed stations there is a decrease from 10h. at the north to 5h. at the south of Florida; while for the stations where the land influence is more predominating there is an increase from 8h. at the north to 10h. at the south. On the Pacific coast there appears to be a decrease from about 10h. at the north to 7h. at the south for the better land exposures.

For the Year there is along about the 92d meridian, that is in the Mississippi River Valley, a continuous decided rise during 7 hours.

To the west of this there is a gradual decrease to about 5 hours at the north; very little change but probably a slight increase to 8h. near the coast at the center; a slight but rapid increase to 8h. to the south of the center, but in the extreme southwestern U. S. a decrease to 6h., and in central south Texas a local minimum of 4 hours.

To the east of the Mississippi River there is: at the north a slight increase to 8 hours in the Upper Lake region, with a decrease to 5 hours in the Lower Lake region and an increase again to 7h. or 8h. near the Atlantic coast; at the center the rise of wind continues for 6h. except near the Atlantic coast, where it increases to 7h.; at the south there is a rise during 7h. or 8h.

At the places of unusually high exposure for the anemometers on the land, and also for the water exposures, the time of rise of the wind seems to differ but little from that of the ordinary land exposures for the same region.

III. *Average Rate of Increase of Wind to the Maximum.*

The average of rise in miles per hour during the period of rapid rise, which extends in most cases from about sunrise tc the time of maximum wind, presents regional characteristics.

For January there is a central region crossing the U. S. about along the 100th meridian in which the rise is at the rate of 0·4 miles per hour. To the east of this the rate of rise is about 0·3 miles per hour: with a local increase to 0·4 m. p. h. in eastern North Carolina and Virginia, and to 0·5 m. p. h. on the western shores of Lakes Michigan and Huron. Also directly in the Mississippi River Valley there appears to be a regular decrease from about ·35 m. p. h. on the upper Mississippi to 0·1 or less on the lower Mississippi.

To the west of the 100th meridian there is a slight gradual decrease to 0·3 m. p. h. in the northwestern U. S.; but there is an increase to over 1·00 m. p. h. in the extreme southwestern U. S., and in fact a maximum of 1·6 m. p. h. is reached in Arizona. In most of the southwestern U. S. west of the 100th meridian and south of the 42° parallel the rate of increase of wind is over ·50 m. p. h.

For July the average rate of increase of wind is about 0·5 miles per hour along the 97th meridian. To the west of this medial region there is a decrease to 0·40 m. p. h., at the north inland, and to less than 0·3 m. p. h. on the coast: at the center and the south a slow increase to about 0·6 m. p. h., and then a very rapid increase to 1·1 m. p. h. or 1·2 m. p. h. as the extreme southwest and the western coast is approached. On the Pacific coast there is an increase from less than 0·3 m. p. h. at the extreme north to 1·2 m. p. h. and 1·1 m. p. h. at the center and south.

To the east of the central meridianal region of 0·5 m. p. h. there is probably little change on the average at the north, although there is some lack of uniformity in the data for various stations, the rate of increase varying from 0·4 to 0·6 m. p. h. At the center and south there is a slight decrease to 0·4 m. p. h. with a small sectional local increase to 0·6 m. p. h. in the central Ohio River Valley, and local decrease to 0·3 m. p. h. in the lower Mississippi Valley.

There is a local increase to 0·7 m. p. h. in southeastern Texas, and a decrease to 0·4 m. p. h. on the southeastern coasts of the United States.

For the Year along about the 95th meridian (slightly to the east of it at the north and a little to the west of it at the south), the rate of rise of the wind is 0·5 m. p. h. To the west of this at the north there is at first a small local increase to 0·6 m. p. h. and then a gradual decrease to 0·4 m. p. h.

At the center and south there is at first a slight, and then, at the extreme west, a very rapid increase to about 0·9 m. p. h. on the coast. At the south there is at first a slow and then a rapid increase to 1·1 m. p. h. or 1·2 m. p. h. with a further decrease to 1·0 on the coast.

To the east of the 95th meridian there is at the north a rapid decrease to about 0·35 m. p. h. which is preserved to the Atlantic; but there is some disagreement for individual stations. At the center there is an increase to 0·7 m. p. h. or 0·8 m. p. h. in the middle Ohio Valley and then a decrease to 0·3 for the exposed Atlantic coast stations. At the south there is a decrease to 0·3 m. p. h. on the lower Mississippi, and then an increase to ·45 m. p. h., which extends quite to the Atlantic coast.

Princeton, N. J.

ART. XXIII.—*Stratigraphy of the Kansas Coal Measures;* by CHARLES ROLLIN KEYES.

TWO papers* have been published recently which for several reasons should receive attention at this time. In the first place, both accounts are soon again to appear in another form. In the second place, both articles consider at some length questions regarding the deposition of the Coal Measures of the Interior basin that have been lately discussed rather fully in the description of the Carboniferous formations of Iowa and Missouri. The salient points of the discussion of the Iowa and Missouri regions have been so misinterpreted in their application to the Kansas field and the conclusions thus drawn are so misleading, that very erroneous inferences might be deduced concerning the original views expressed were not some of the discrepancies pointed out. In this connection it may not be out of place also to set forth some new information which has been obtained since the reports of the two states mentioned were issued, and to call attention to the observations recently made in Kansas which go to substantiate fully certain opinions previously urged† concerning the subdivisions of the Coal Measures of the Western Interior basin.

In considering the conditions of deposition of the Coal Measures very much more has been assumed for the views presented in the Iowa report than was there expressed. At first sight it would be difficult to understand how this could happen; but upon reference to the hypothesis advanced for the Kansas rocks it becomes clear. Great stress has been placed upon the present dips of the strata and diagrams are offered in explanation. But it appears that the importance of these dips has been overrated in its application to the hypothesis advanced and in its militating against the other view. The inclination of the strata at the present time is in reality of small import, for since the beds were first laid down many changes in dip have doubtless taken place and profound erosion has obscured much of the evidence that would be of value as supporting the hypothesis. There is one point of considerable consequence, however, which has been entirely overlooked. The observed dips of the beds in Kansas are apparent dips and do not necessarily represent the true direction of inclination. That they are westerly slants is because the cross-sections were made along streams which flow eastward. In dissenting from the generalizations made for the country east of the Missouri river, special

* E. Haworth: Kansas Univ. Quart., vol. iii, pp. 271–295; Lawrence, 1895.
† Iowa Geol. Sur., vol. ii, 1893; also Missouri Geol. Sur., vol. iv, 1894.

emphasis is placed on the fact that in passing from the east to the west in Kansas the observations made are not in accord with those of Missouri and Iowa. In going in that direction—west—they most assuredly would not. That would be about the same as if the sections in Iowa were constructed in a somewhat north and south direction or in a way that would be parallel to the ancient shore-line instead of at right angles to it.

In eastern Kansas the original seaward slant of the beds was evidently to the northwest and a little farther to the west it was perhaps more nearly northward. In the states of Iowa and Missouri the observations were made from very different points of vantage—from the east or north sides of the bay-like expansion. More specifically, in looking towards the sea, straight out from the shore, the direction in northern Iowa would be to the south or southwest; in southern Iowa and northern Missouri directly west; in southwestern Missouri northwest. The reason is this: the Western Interior coal basin occupied a broad shallow depression, and the Carboniferous waters consequently filled a wide semi-circular bay opening to the westward.

In the Iowa report it is not stated, as is set forth in the recent paper, that the coastal area was a region of greater subsidence than the oceanic. Nothing is said specifically regarding the relative rates of uprising or downsinking of the two districts; but it is stated that the oscillations affected very wide areas, and even, perhaps, approached in character continental elevation and depression. Of course considerable stress was placed upon the movements of the shore lines; for the reason that these are the present measures of the changes of the sea with reference to the land. The area being so broad and so shallow was particularly susceptible to all changes of relation between the land and water; and comparatively slight vertical movements would have produced great alterations in the extension of the sea.

Lately it has been conclusively shown that during the latter part of the Lower Carboniferous (Mississippian) the Interior basin was an area of uprising. The old shore must have extended from the present northwest corner of Iowa in a curved line through Des Moines, Kansas City and southwestward through Kansas into Oklahoma territory. It probably even extended farther to the west, but of this there is no evidence at present. At the time of greatest depression, or when the sea encroached most on the land, the border line was extended eastward to beyond the present position of the Mississippi river and from St. Louis extended southwestward over a considerable part of the area now forming the northwestern flank of the Ozark uplift. Even during the deposition of the

Coal Measures there is abundant evidence of many minor oscillations and special attention has been called* to a number of them. With the existence of such conditions as these the present dips lose much of their significance.

The important point is not so much the absolute dip but the slant of the strata with reference to the Coal Measure floor. When this is taken into consideration it doubtless will be found that the estimates usually placed upon the thickness of the Coal Measures are excessive, and that the common figures, which for Missouri have been 2000 feet and now for Kansas some 2800 feet, are doubtless very much too great. As evidence of this a diamond drill core taken out of a well at Kansas City showed a typical mica schist at a depth of 2400 feet, indicating that the entire Paleozoic had been passed through at about 2300 feet below the base of the Upper Coal Measures at that point.

It may be concluded from what has just been said, from the data presented in the two recent papers on the Kansas Coal Measures, and from what is known of the field relations of the Carboniferous formations in western Missouri and southeastern Kansas, that the four arguments in the article mentioned, which are set against the explanations offered for the deposition of the Coal Measures in the eastern and larger part of the basin, are not only invalid but the evidence itself upon which they rest disproves them. Viewed in the proper light, the Kansas rocks present identically the same stratigraphic features as do those of Missouri and Iowa.

Regarding the subdivisions† of the Coal Measures, it is of interest to learn that the same line of division has been independently adopted in Kansas which had been proposed a short time previously in Iowa and Missouri. Instead of a different classification for each state and a different dividing line for each locality, perhaps, the present selection now makes the subdivisions uniform for the whole Western Interior coal basin.

The objections raised‡ to the diagrams representing the stratigraphy of the Coal Measures in Iowa§ are not so serious, nor the ideas which are graphically represented such wide departures from the commonly accepted views, as the Kansas author has stated. In fact the attention is called to a certain class of phenomena which are, unfortunately, too frequently overlooked in stratigraphical work. The manifest object of the diagrammatic representation in the Iowa reports is to show that while

* Iowa Geol. Sur., vols. i and ii; also Bull. Geol. Soc. America, vol. ii, pp. 277–242, 1891.

† Haworth: Division of the Kansas Coal Measures, Kansas Univ. Quart., vol. iii, pp. 291–295; Lawrence, 1895.

‡ Kansas Univ. Quart., vol. iii, p. 291; Lawrence, 1895.

§ Iowa Geol. Sur., vol. i, pp. 117–118; Des Moines, 1893; also ibid., vol. ii, pp. 161–162; Des Moines, 1894.

the "Lower" and "Upper" Coal Measures do have a relation of one above the other and from a mining standpoint of an upper and a lower member, they do not hold positions indicating that as a whole the one is geologically older than the other, or that the lower was deposited before the upper. On the other hand, the facts show clearly that the terms lower and upper are misnomers in the sense that they are usually used, carrying with them as they do the idea of relative age. Moreover, along the great bedding planes marginal sediments were laid down at the same time as thalassic deposits were formed farther out from the shore. Therefore, as a line for the separation of the Coal Measures into two subdivisions, into a productive and a barren series, as a line which under existing conditions is of practical use in mining operations, one which also indicates the first marked physical and faunal changes in the sequence of strata in passing in a seaward direction from the ancient margins of the basin, the first great limestone met with was selected as the most reasonable, natural and convenient horizon. For this reason, it was stated* that in considering the Coal Measures as a whole, two tolerably distinct classes of sediments were readily recognized: (1) the marginal or coastal deposits, and (2) the beds laid down in the more open sea. These two categories are sharply contrasted lithologically, stratigraphically and faunally.

The first category is characterized by the rocks being predominantly argillaceous shales and sandstones, with practically no limestones. The individual beds usually are very limited in extent, and replace one another in rapid succession, both laterally and vertically. The sandstones often form great lenticular masses, sometimes deeply channeled on the upper surface, the excavations being filled with Coal Measure clays. These and many other phenomena attest a constantly shifting shore line and shallow waters. The fossils contained are nearly all brackish water forms, or shore species. Remains of pelagic organisms are not numerous.

On the other hand, the second class of deposits is made up largely of calcareous shales, with heavy beds of limestone. The layers are evenly bedded, and extend over very considerable distances. The faunas are chiefly composed of strictly open-sea forms.

With this idea of the Coal Measures of the Interior basin, the limits of the two formations in Iowa and the districts to the south assume somewhat different lines from those which have been commonly recognized.

The geological cross-sections recently made in central Iowa

* Missouri Geol. Sur., vol. iv, pp. 80–82; Jefferson City, 1894.

show clearly that the thick limestone of Winterset may be regarded as the base of the "Upper" Coal Measures. Coastal sediments carrying workable seams continue up to this line. Above it, open-sea deposits abruptly replace the former, and the coal veins are almost entirely wanting. This is admirably shown in the sections along Middle river in central Iowa, where Tilton* has gone into details on the subject. In one direction the course of the outcrop of the great limestone of Winterset is northwestward from the typical locality. It passes from Madison county through Guthrie and soon is lost beneath the Cretaceous. In the opposite direction it has been traced southward to the southern boundary of Iowa. In Missouri it appears to be continued by what is known as the Bethany limestone, which sweeps southward and then southwestward in a broad arc into Kansas. At Kansas City it seems to be represented by one of the principal beds exposed in the bluffs at that place. In Kansas Haworth† has just announced that he has traced what he calls the Erie or Triple limestone across the state in a southwesterly direction from Kansas City into Oklahoma territory; and that he has correlated it with the Bethany limestone of Missouri. With the recognition of these facts the base of the Upper Coal Measures has been traced over all of the Western Interior coal basin.

The appellation Bethany limestone for the basal formation of the Upper Coal Measures may be extended somewhat, so as to include more than No. 78 of the Broadhead section in Missouri and may be made to cover several of the limestone beds above the layer to which the term Bethany Falls was originally applied, for the reason that these layers are separated from the main bed only by thin, unimportant seams of shale. Thus it appears that the Winterset limestone of Iowa and the Erie limestone of Kansas are but extensions of the Bethany limestone of Missouri as now understood; and as the latter was the first to be recognized and to receive a specific geographical name, it has priority and must therefore supplant the other terms proposed.

* Iowa Geol. Sur., iii, pp. 135–146; Des Moines, 1895.
† Kansas Univ. Quart., vol. iii, pp. 293; Lawrence, 1895.

ART. XXIV.—*On the so-called Schneebergite*; by A. S. EAKLE and W. MUTHMAN.

IN the year 1880, A. Brezina* published a short announcement, "Ueber ein neues mineral, den Schneebergit," which was found on the Bockleitner Halde at Schneeberg in Tyrol. A qualitative analysis by H. Weidel gave as the principal constituents antimony and calcium, so Brezina supposed it might be a second modification of romeite or romeine, which according to Damour should have the formula $Sb_2O_3 . Sb_2O_5 . 3CaO$. Groth in his "Tabellarische Uebersicht der Mineralien" gives as the most probable formula for romeite $CaSb_2O_4$ and for schneebergite $Ca_2Sb_2O_7$, making this last identical with atopite.

A quantitative analysis of the schneebergite had not been made, so it appeared to us desirable to make one with a small amount of clean material. The mineralogical collection here contains a series of specimens of this rare mineral from Schneeberg, the greater part of which were collected at different times by von Elterlein during his study of the mineral deposits of that locality.

Most of the mineral appears as crystalline aggregates upon the ore, which latter consists of a mixture of magnetite, zincblende and chalcopyrite; the gangue mineral is massive quartz. The aggregates are partly kidney-shaped and consist of rounded crystal grains, with scarcely recognizable form. The color varies from honey-yellow to bright wine-yellow; the surface is often brown from a slight decomposition, the color being due to a thin coating of iron hydroxide. The perfectly fresh, undecomposed crystals are isotropic and occasionally show weak and abnormal double refraction, especially when they contain inclusions of fine particles of the ore.

On other ore-specimens the mineral appears as thin coatings or as a deposit; occasionally can well defined crystals be observed, all of which show the single form of the octahedron. The crystals are generally accompanied by calcite and breunerite, from which the mineral has evidently originated, as has been shown by v. Elterlein;† commonly the schneebergite surrounds the calcite, if it has not entirely replaced it. The paragenesis can be followed still better in sections under the microscope. It can be seen that the calcium-iron carbonate changes at first to a light yellow, double refracting mineral of indefinite composition, which by further change becomes granular and isotropic and finally passes into the pure schneebergite.

* Verhandl. d. k. k. geolog. Reichsanstalt, 1880, 313.

† Jahrbuch der k. k. geolog. Reichsanstalt, 1891, xli, 336; Zeitschr. für Kryst., xxiii, 283.

Some difficulty was experienced in isolating the material for an analysis and extreme care was necessary in order to get a perfectly pure product. The separated particles of ore fell easily by weak pressure with an agate spatula into single isotropic crystalline grains; a microscopical examination of this coarse powder showed an accompanying mixture of magnetite, zincblende, irregular fragments of milk-white quartz, calcite and almost opaque, unknown black particles of a mineral which was unattacked by acids, apparently some silicate; all of these impurities were present only in very small amounts and made at most 5 per cent of the total weight. The material was first digested with dilute hydrochloric acid and afterwards nitric acid was added and, after a short time, warmed in order to be sure of the decomposition of any sulphide present; the granular crystals of schneebergite are not attacked if the acid is sufficiently dilute. The well-washed and dried residue still contained quartz and the black particles, but these were removed mechanically and about 0·4 gr. of the mineral was obtained, which in respect to purity was all that could be desired.

The specific gravity was first carefully determined by means of a pycnometer; the amount of substance used was 0·4110 gr. and the specific gravity found was 3·838 (the average of three weighings from 3·823–3·848). Weidel found with 0·17 gr. the gravities 3·9, 4·1 and 4·3. As the amount of mineral was so small, a qualitative analysis was conducted in a quantitative way according to Weidel's results, who, as above stated, found antimony and calcium as the principal elements. The material was fused with potassium and sodium carbonates, with the addition of some nitric acid (in order to prevent the reduction of the antimony); the fused mass was dissolved in hydrochloric acid and there resulted a liquid, colored yellow by the iron present, which contained a substance having the exact appearance of silica. On the addition of hydrogen sulphide a deep brown precipitate was formed, which showed when examined, besides much sulphur from the oxidation of the hydrogen sulphide by the salts of iron, nothing but silica and some platinum, which last evidently came from the fusing-crucible, as fusions containing saltpeter will always attack platinum somewhat. Neither antimony, bismuth nor copper, which Weidel found, were present.

Further analysis of the filtrate gave only iron and calcium and the amounts were Fe_2O_3 32·33 per cent and CaO 32·58 per cent. An exact determination of the silica could not be made because it was partly used in the qualitative analysis of the precipitate. Professor Groth kindly placed at our disposal more of the material from the museum collection and about 0·2 gr. of this was prepared. To remove the impurities, the material was treated with stronger hydrochloric acid, which also slightly attacked the schneebergite with the separation of silica. An analysis of the carefully cleaned material gave SiO_2 35·45 per cent and Fe_2O_3 32·11 per cent. The formula for this composition exactly tallies with that of a lime-iron garnet, as the following analyses show:

	Found. I.	Found. II.	Calculated for $3CaO . Fe_2O_3 . 3SiO_2$.
SiO_2	----	35·45%	35·43
Fe_2O_3	32·33	32·11	31·50
CaO	32·58	----	33·07

It follows from this examination, with certainty, that the schneebergite in the collection here, of which there is a whole series coming from different sources, is nothing more than a very pure lime-iron garnet, topazolite. The ore specimens came from the same locality as those described by Brezina and analyzed by Weidel. In respect to the color, hardness, microscopic relations, crystal form and the iron and calcium content, our mineral exactly coincides with that described by Brezina, so we make the supposition that the schneebergite is a garnet of the above composition. Our mineral fused in the blast flame to a dark brown liquid, while Brezina gave his as infusible. Our supposition is supported also by the circumstance that Brezina described the material as insoluble in acids; calcium salt of an oxy-acid of antimony would naturally be easily dissolved in strong hydrochloric acid. Apparently, on account of the small amount of very impure material which Weidel had, a mistake was made in the qualitative analysis.

The occurrence is exceedingly interesting, as garnet is seldom found in simple octahedra, and, until the present, a completely non-aluminous topazolite, with the exception of that from the Mussa Alp, has not been observed. The iron precipitate was treated with pure freshly-prepared sodium hydroxide, but no trace of aluminum was found; also the mineral contained no magnesia.

Munich, Bavaria, May, 1895.

Art. XXV.—*Native Sulphur in Michigan;* by W. H. Sherzer.

During the past year interesting deposits of sulphur have been discovered in the Upper Helderberg limestone, of Monroe county, Michigan, of which, it is believed, no report has yet been made. Native sulphur has not been recognized as one of the minerals of this state, although as early as 1865 Prof. E. A. Strong collected from the gypsum beds of Grand Rapids a quart, or more, of platy particles, which he forwarded to Dr. Alexander Winchell, previously State Geologist.

The present locality is in the northern part of the county, upon the line of the Lake Shore and Michigan Southern R.R., one mile west of the village of Scofield. Here a quarry was opened some three years ago by the Michigan Stone & Supply Co., of Detroit, the rock being crushed and used mostly for macadamizing purposes. The bed-rock is overlain with from four to seven feet of soil and blue bowlder clay and its surface is scratched and grooved by glacial action. Channels and large "sink-holes" have been dissolved out by the water from the surface. The upper four feet of this bed is a grayish impure limestone, considerably "jointed," made up of fine, closely compacted layers, frequently contorted and banded with carbonaceous matter. It contains, in places, great numbers of small, obscurely defined fossils. This passes into a compact dolomitic limestone, from seven to eight feet in thickness, beneath which lies the so-called "sulphur-bed." This is a stratum of yellowish-brown impure limestone, varying in thickness from one to three feet and having but little dip. It contains brachiopods, corals and bryozoa and considerable carbonaceous material, here and there giving a strong oily odor. Wherever exposed to view it is seen to be cavernous in structure, the pockets varying in size from a fraction of an inch up to three feet. The larger ones are flattened and lie with their longer axes parallel to the plane of the bed, as though dissolved out by water flowing along the bed, rather than from above. Just beneath this "sulphur bed," and quite sharply separated from it, is a seam of bluish-gray, gritty, siliceous lime-rock, varying in thickness from one to three feet. This is curiously streaked with flexuous, but approximately vertical channels, lined with brownish, carbonaceous material, suggestive of the remains of fucoid stems. Under the magnifier the entire rock is seen to be finely porous and to consist of sand grains embedded in the calcareous paste. Passing downward, the rock becomes more of the nature of a sandstone and is said to become softer. The "sulphur bed" is thus seen to lie from sixteen to eighteen feet below the surface between a compact, dolomitic limestone and a calcareous sand rock. The pockets in the bed, above described, are lined with scalenohedrons of calcite, or tabular crystals of celestite, or both together. In some places the latter mineral becomes a chocolate brown. The sulphur generally occurs in bright lustrous masses towards the center of the cavity, intermatted frequently with the above minerals. Fragments as large as one's fist are readily removed. Some of the smaller cavities contain nothing but sulphur and one was found filled with selenite crystals. About an acre of this bed had been removed when the locality was visited and from this the superintendent estimated that one hundred barrels of pure sulphur had been obtained.

It becomes a matter of interest to speculate upon the source of the mineral, since sulphur is so commonly associated with volcanic phenomena. At Grand Rapids it has, without doubt, resulted from the decomposition of the calcium sulphate, but no deposits of gypsum are known in this part of the state. That it was brought to the place of deposition in some form by water, along with the celestite and calcite, admits of no doubt. Although the overlying limestone contains a few cavities, but few of them contain any of the sulphur, and these are situated very near the sulphur bed. The underlying rock is still more free from the mineral, so it seems that the water must have been introduced from the *side.* At one end a stream of water was found entering the quarry at the level of this bed, highly charged with hydrogen sulphide and depositing a considerable quantity of the white precipitate of sulphur over the rocks and weeds. Some distance from where the water enters, this precipitate begins to assume a slightly yellow tinge, and upon breaking open the larger masses a nucleus of crystalline sulphur may occasionally be detected. Similar masses were found in some of the cavities, the outer portion having a lightish-yellow, mealy appearance, while the interior is solidly crystalline. The well water of the entire region is said to be charged with this same gas and it seems highly probable that the sulphur has resulted from its decomposition. Not unfrequently masses of the sulphur are found, however, of which the outer surface is vesicular, as though corroded by some solvent. Still, not believing that the hydrogen sulphide has been or could be formed directly from the action of the water upon the native mineral, it remains to consider its source. In many instances this gas is formed from the decomposition of iron pyrite, or marcasite, in the rocks, the iron being converted into an oxide and the sulphur obtaining its hydrogen from the water. No trace of these minerals, however, was detected in any of the rocks, although it is possible that they may occur in sufficient quantities farther back. The presence of so much carbonaceous matter in the bed itself, as well as in the rock above and below, indicated by the color and odor, leads me to strongly suspect that the gas has resulted from the decay of organic remains, animal or vegetable, or both.

Ypsilanti, Mich., July 12th, 1895.

ART. XXVI.—*On the Double Salts of Cæsium Chloride with Chromium Trichloride and with Uranyl Chloride;* by H. L. WELLS and B. B. BOLTWOOD.

NEUMANN* has made an extensive investigation of the double salts formed with chromium trichloride and the chlorides of several other metals, not, however, including cæsium. He obtained a violet double salt in each case with ammonium, potassium, rubidium, beryllium and magnesium, corresponding to the general formula, $2M'Cl . CrCl_3 . H_2O$, while with lithium, sodium, calcium, strontium, barium, zinc and cadmium he was unable to prepare any double compounds. The double fluorides, $2NH_4F . CrF_3 . H_2O$, and $2KF . CrF_3 . H_2O$, which are analogous to Neumann's salts, have been mentioned by Wagner,† who also prepared the compounds $4NaF . 2CrF_3 . H_2O$ and $3NH_4F . CrF_3$. The existence of the latter salt has been confirmed by Petersen.‡

Since Neumann had not prepared any cæsium-chromium chloride, and because, from the well-known comparative insolubility of cæsium double salts, it seemed possible that a greater variety of compounds would be obtained with this than with other metals, we have undertaken an investigation in this direction. As the result of a systematic search, however, we have added only a variation in water of crystallization to Neumann's general formula.

Two salts have been obtained. One of these, $2CsCl . CrCl_3 . H_2O$, is violet in color, corresponding exactly to Neumann's compounds, while the other, $2CsCl . CrCl_3 . 4H_2O$, is green. The violet salt was prepared by saturating warm aqueous solutions containing various proportions of the two simple chlorides with gaseous hydrochloric acid. The green salt was obtained from cold solutions by the use of hydrochloric acid, and without its use by evaporation over sulphuric acid.

The salt $2CsCl . CrCl_3 . H_2O$ forms aggregates of very minute crystals of a magnificent red-violet color. It is stable in the air and does not lose its water at 160°. It is very slowly soluble in cold water, forming a green solution from which the green salt is deposited upon evaporation at ordinary temperatures. The four crops analyzed were prepared with amounts of cæsium chloride and chromic chloride varying from 15 g. of the first and 50 g. of the second to 50 g. of the first and 10 g. of the second. Gaseous hydrochloric acid caused a deposition of the salt from warm solutions. The products, after careful

* Liebig's Annalen, ccxliv, 329. † Berichte, xix, 896.
‡ J. pr. Ch., II, lx, 52.

drying with paper and over sulphuric acid, gave the following results upon analysis:

	A.	B.	C.	D.	Calculated for $2CsCl \cdot CrCl_3 \cdot H_2O$.
Cæsium	50·31	49·72	49·64	----	51·79
Chromium	10·44	10·53	10·68	10·70	10·15
Chlorine	34·65	34·77	34·37	----	34·56
Water	4·11	5·12	----	----	3·50
	99·51	100·14			100·00

The salt $2CsCl \cdot CrCl_3 \cdot 4H_2O$ is deposited from cold concentrated solutions in the form of green, apparently monoclinic crystals. It is somewhat deliquescent, very soluble in water and loses no water in the desiccator over sulphuric acid. At 110° it readily loses three molecules of water and is converted into the violet salt. Three crops analyzed were prepared as follows: Crop A, by evaporating a solution of 50 g. cæsium chloride and 25 g. of chromic chloride; Crop B, by dissolving the violet salt in water and evaporating over sulphuric acid; Crop C, by cooling a concentrated solution of 50 g. of each chloride with the aid of ice and saturating it with hydrochloric acid. The results were as follows:

	A.	B.	C.	Calculated for $2CsCl \cdot CrCl_3 \cdot 4H_2O$.
Cæsium	46·40	46·13	46·73	46·86
Chromium	9·80	9·53	10·79	9·19
Chlorine	31·30	31·14	----	31·27
Water	----	----	----	12·68

A determination was also made of the water lost at 110°:

	Found.	Calculated for $3H_2O$ in $2CsCl \cdot CrCl_3 \cdot 4H_2O$.
Water	9·90	9·51

The variation in color of the two salts that have just been described is interesting in connection with the violet and green modifications of chromic salts in general, which have furnished the ground for much investigation and discussion. In the case under consideration the transformation from one color to the other is accomplished by the addition or subtraction of water. It seems highly probable, however, that the change in water is accompanied by a fundamental change in the molecular structure, because the violet salt, containing the smaller amount of water, is very much more slowly soluble in water than the green salt, forming like the latter a green solution. We have found that the whole of the chlorine, in the cold green solutions of these cæsium salts, is not precipitated as silver chloride, thus showing that they agree in this respect with other green solutions of chromic chloride.

It is a curious circumstance that the green chromic sulphate has been considered* to contain less water than the violet modification, while with our cæsium salts exactly the reverse is true, the green salt containing the larger amount of water. It is also remarkable that, while violet chromic solutions are turned green by heat, our violet salt, nevertheless, is produced in hot solutions and the green salt in cold ones. The theory advanced by Krüger and maintained by van Cleeff† that the green color of chromic sulphate solutions is due to the formation of a basic salt and free acid or an acid salt, seems hardly applicable to the green cæsium salts, ince it crystallizes from solutions saturated with hydrochloric acid in which a basic salt would seem to be an impossibility. In view of these apparently conflicting facts, it seems necessary to draw the conclusion that the differences in color exhibited by chromic compounds and their solutions are due to more than one cause, probably to the formation of basic salts in certain cases, and also, in other instances, to a change in water of crystallization which is evidently accompanied by a molecular transformation.

Uranyl chloride and cæsium chloride.—A careful series of experiments with cæsium chloride and uranyl chloride has resulted in the discovery of but a single salt. This compound, $2CsCl . UO_2Cl_2$, corresponds, except that it contains no water, to the previously described salts, $2KCl . UO_2Cl_2 . 2H_2O$, $2KBr . UO_2Br_2 . 2H_2O$, $2NH_4Cl . UO_2Cl_2 . 2H_2O$ and $2NH_4Br . UO_2Br_2 . 2H_2O$, but some fluorides of other types have been described.

The compound under consideration forms apparently orthorhombic, yellow crystals which are usually small and blade-like in shape. The products used for analysis were made under the following conditions: Crop A, by making a concentrated aqueous solution of 10 g. of cæsium chloride and 50 g. of uranyl chloride, then running in gaseous hydrochloric acid until crystals began to form and cooling; Crop B, by the same method as above, using 50 g. of cæsium chloride and 10 g. of uranyl chloride; Crops C and D, by spontaneous evaporation of solutions containing 50 g. of cæsium chloride and 15 g. of uranyl chloride; and E, by the evaporation of a solution of 15 g. of cæsium chloride and 50 g. of uranyl chloride. The results were as follows:

	A.	B.	C.	D.	E.	Calculated for $2CsCl . UO_2Cl_2$.
Cs	39·43	39·63	40·07	....	....	39·15
UO_2	40·37	41·14	40·96	41·85	43·39	39·95
Cl	20·63	21·17	20·85	20·84	20·59	20·90

* Vide van Cleeff, J. pr. Ch., II, xxiii, 58.

† Loc. cit.

The cæsium chloride used in this investigation was from a liberal supply of cæsium and rubidium salts presented to this laboratory, for the encouragement of scientific research, by Herr E. Merck of Darmstadt, Germany, and we wish to express our sincere thanks to him for his generosity.

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

Art. XXVII.—*On two new Meteorites*; by E. E. Howell. With Plate IV.

1. *The Cherokee Meteorite.*

This meteorite was found in March, 1894, by Mr. S. B. May a few hundred yards from the Clarkson gold mine, two and one-half miles east of Cherokee Mills, and about five miles S.W. of Canton, Cherokee Co., Ga.

Mr. May was plowing new ground when he discovered the meteorite, only partially covered with soil. It was of a rough lense shape with one side flattened and weighed 15½ pounds. With the aid of an old axe the mass was finally separated, and the smaller part was carried away, mislaid, and apparently lost beyond recovery by a party who did not appreciate its value.

The larger portion, weighing 8½ pounds, was secured by Mr. S. W. McCallie, Assistant State Geologist of Georgia, and obtained by me in an exchange with the State Museum. This mass has evidently been materially reduced in size and weight by oxidation, leaving, however, a solid mass after the oxidized portions were removed.

The Widmanstätten figures are strongly marked and distinctive, the special feature being the large masses of plessite which are shown in Plate IV printed direct from an etched section.

The following is an analysis for which I am indebted to Mr. H. N. Stokes by the courtesy of Prof. Clarke, Chief Chemist of the U. S. Geological Survey; it shows nothing unusual in composition.

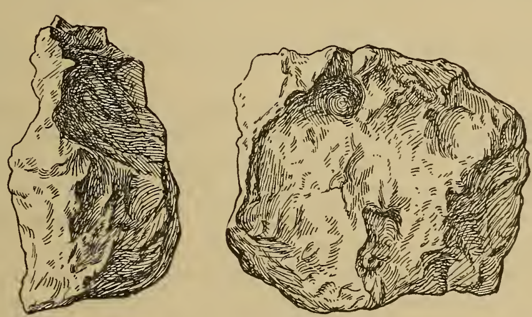
Fe	91·96
Ni	6·70
Co	0·50
Cu	0·03
Si	*tr.*
P	0·11
S	0·01
C	*tr.?*
	99·31

The only other meteorite to my knowledge found in that portion of the state is the "Losttown" found in 1868 and described by Shepard. This, however, was very different in appearance and composition, containing only 3·66 per cent of nickel, which alone would be sufficient to distinguish them.

2. *The El Capitan Meteorite.*

This handsome meteorite was found by a Mexican sheep herder, Julian Jesu, in July, 1893, on the northern slope of the El Capitan range of mountains in New Mexico. Three small pieces were broken from the thin edge, which show beautifully the octahedral structure of the iron. The smallest of these, weighing a few ounces, was sent to the National Museum, and the two larger, weighing respectively 1 lb. 12½ ozs. and 3 lbs. 14 ozs., together with the main mass, 55 lbs., came into my possession at different dates in 1894.

The weight of the iron when whole was about 61 lbs.; the general shape is shown in the accompanying cuts. It measured 10×9×5 inches thinning at one edge and had the usual irregular pitted surface.



My information in regard to the history of the meteorite, as well as the meteorite itself, was obtained from Mr. C. R. Biederman of Bonito, N. M. Mr. Biederman says that he, in company with many miners, was standing in front of a store in Bonito sometime in July, 1882, when "they saw a meteorite which looked like a fiery ball moving rapidly toward the north at an angle of 45° and vanish behind the Capitan range." Mr. Biederman thinks the meteorite found by the Mexican is the one they saw fall, and there is nothing in its appearance to disprove his claim. It is entirely free from oxidation and evidently fell at a comparatively recent date.

The Widmanstätten figures are developed very easily and clearly, as is usual with irons containing the percentage of nickel which this has, showing it to belong to the usual type of octahedral irons, with rather broad bands of kamacite somewhat like those in the Cooperstown meteorite.

I am indebted also to the courtesy of Prof. Clarke for the following analysis of this iron by Mr. H. N. Stokes of the U. S. Geological Survey:

Fe	90·51
Ni	8·40
Co	0·60
Cu	0·05
Si	*tr.*
P	0·24
S	*tr.*
	99·80

ART. XXVIII.—*The Reduction of the Acids of Selenium by Hydriodic Acid*; by F. A. GOOCH and W. G. REYNOLDS.

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

A METHOD for the iodometric determination of selenious acid has been recently announced by Muthmann and Schaefer* which is based upon the reduction of selenious acid by hydriodic acid and the direct titration of the iodine thus liberated. To determine the selenious acid it is only necessary to add it in solution to an acidulated solution of potassium iodide, when iodine and selenium are both set free in elementary form, the former being directly determinable by titration with sodium thiosulphate after addition of starch. The difficulty in the process is said to be the uncertainty as to the exact point in the titration at which the starch blue disappears from the liquid in which the finely divided and opalescent selenium is held in suspension. For this reason the process is recommended for use only when great accuracy is not essential.

Evidently if the reaction between the acidulated iodide and selenious acid is single and complete, the process should be capable of improvement by removing the selenium before the titration is attempted. This we have succeeded in doing without difficulty. We find the most convenient and rapid way to remove the finely divided selenium is to filter the liquid con-

* Berichte d. d. chem. Gesell., xxvi, 1008.

taining it by means of the vacuum pump upon a thick felt of asbestos in a perforated crucible or cone of large filtering surface. With a properly prepared filter of this description there is no difficulty in separating the selenium in a very few moments so completely that it is possible to determine the iodide remaining dissolved in the excess of potassium iodide with all the accuracy characteristic of this most exact of titration processes. We find, however, that when the difficulty of determining the end-reaction in the titration of the iodine by the thiosulphate is overcome, it becomes apparent that the reaction upon which Muthmann and Schaefer depend is not perfect. Either the reduction of the selenious acid to selenium is not complete, or else the iodine remains in combination to a slight extent with the selenium and so fails to appear in the filtrate. This is evident from the results of the experiments of Table I, in which the selenious acid and potassium iodide acidulated with hydrochloric acid were brought together, the liquid thrown upon the asbestos filter, the selenium washed until free from soluble iodine, and the filtrate containing the iodine treated as usual with sodium thiosulphate in presence of starch. The details of treatment are described sufficiently in the table. The selenium dioxide was prepared for the work from the so-called pure elementary selenium by dissolving it in strong nitric acid, evaporating off the excess of the last, treating the solution of the residue in water with barium hydroxide, filtering to remove selenic acid formed in the oxidation and traces of sulphuric acid possibly present as an impurity, recovering the selenium dioxide by evaporation, and purifying it by subliming and re-subliming it in a current of dry air until it was clean and white.

Table I.

SeO_2 taken. grm.	KI used. grm.	HCl used. (Sp. gr. 1·20) cm^3	Volume before filtering. cm^3	SeO_2 found. grm.	Error. grm.
0·0499	1	5	100	0·0479	0·0020 —
0·0499	1	5	100	0·0477	0·0022 —
0·2035	3	5	100	0·1896	0·0139 —

From these figures it is plain that iodine was not found in the filtrate in amount corresponding to the selenium dioxide present. In the following experiments of Table II. an excess of the thiosulphate was added before filtering off the selenium so that there should be every opportunity for the iodine and thiosulphate to interact before the removal of the selenium. In two experiments the proportion of hydrochloric acid was increased tenfold for the purpose of seeing whether the presence of a large amount of free acid influences the result.

TABLE II.

SeO_2 taken. grm.	KI used. grm.	HCl used. (Sp. gr. 1·20) cm^3	Volume before filtering. cm^3	SeO_2 found. grm.	Error. grm.
0·0499	1	5	100	0·0489	0·0010—
0·0499	1	3	100	0·0485	0·0014—
0·0499	1	50	100	0·0489	0·0010—
0·0499	1	50	100	0·0488	0·0011—
0·2006	3	5	100	0·1925	0·0081—
0·2030	3	5	100	0·1945	0·0085—

These results show improvement over those obtained when filtration is made before acting with the thiosulphate, but it is obvious that the presence of a large proportion of free hydrochloric acid is without effect upon the reaction, and that the iodine set free and measured is still deficient in proportion to the amount of selenium dioxide present. Plainly the reduction of the selenium dioxide is incomplete or else there is formed between the selenium and iodine a combination, such as was noticed by Hautefeuille* in the interaction of iodine upon hydrogen selenide. In either case it should be possible to push the reaction farther toward completion by submitting the mixture of selenious acid, potassium iodide, and hydrochloric acid to distillation. We have used for this purpose an apparatus employed and described in connection with previous similar work in this laboratory. The distillation flask is a Voit gas-washing flask, and this is sealed to the inlet tube of a Drexel wash-bottle used as a receiver, to the outlet tube of which is sealed a Will and Varrentrapp absorbtion apparatus to serve as a trap. The mixture to be distilled was introduced into the flask, a solution of 3 grm. of potassium iodide in 100 cm^3 of water was put into the receiver and trap and during the distillation a slow current of carbon dioxide was passed through the apparatus to keep the boiling regular. Naturally the acidified solution of the iodide in the flask retains with great tenacity traces of dissolved iodine, so that, in order to determine all the iodine liberated in the reaction, the residue in the flask as well as the distillate in the receiver and trap was titrated in the usual way with sodium thiosulphate. The details of treatment and the results are recorded in Table III.

* Compt. Rend., lxviii, 1554.

TABLE III.

SeO_2 taken. grm.	KI in flask. grm.	HCl in flask. (Sp. gr. 1·20) cm^3	Total volume boiled. cm^3	Time in minutes.	SeO_2 found. grm.	Error. grm.
0·0499	1	5	60	5	0·0497	0·0002 —
0·0499	1	5	60	5	0·0497	0·0002 —
0·0499	1	5	60	10	0·0496	0·0003 —
0·2000	3	5	60	10	0·1995	0·0005 —
0·2000	3	5	60	10	0·1991	0·0009 —
0·2023	3	5	60	10	0·2018	0·0005 —
0·5018	3	5	60	10	0·4635	0·0383 —

These results are all fairly good, though all a little deficient, for amounts of selenium dioxide up to 0·2 grm; but when the amount of the dioxide reaches 0·5 grm. the iodine found in the distillate and in solution in the residue falls far below the theory based upon the assumption that the products are selenium, iodine, and water. The selenium in the residue was left after the boiling in fine dense crystalline condition in the experiments with the smaller amounts, so that it did not interfere with the titration of the free iodine; but in the last experiment, in which approximately 0·5 gram. of the dioxide was treated, the selenium remained in pasty form adhering to the flask. Subsequent examination proved that the pasty selenium held iodine, which was liberated slowly to water and more rapidly to an aqueous solution of potassium iodide. The largest errors have been found (excepting that of the last experiment from the discussion) when the free iodine was filtered off from the reduced selenium; better results were obtained when the precipitated selenium was first treated with the thiosulphate before filtering; and in the distillation process the best approximations are made to true indications. It is obvious that as the proportion of selenium and iodine increase, the tendency to form a combination is more manifest. The error thus introduced in the determination of the selenium dioxide by the distillation process is allowable up to the limit of 0·2 grm.

Potassium iodide in hydrochloric acid acts much less readily upon selenic acid than upon selenious acid. When the hydrochloric acid is present in small proportions in the mixture of selenic acid and the iodide the reduction is very imperfect, but it tends to approach completion as the strength of hydrochloric acid is increased.

It is obvious, in the light of the previous experiments with selenious acid, that it is unreasonable to expect the full liberation of iodine in the action of selenic acid upon the iodine when the free iodine is not removed from the sphere of action as it is liberated. In the distillation process the case is otherwise, and there is no reason to anticipate that the determination of selenic acid should present greater difficulty than is encountered in treating selenious acid under similar circumstances. The experiments of Table IV, in which selenic acid (obtained by oxidizing known amounts of selenium dioxide by means of potassium permanganate in the manner described in a previous paper from this laboratory)* is treated according to the distillation method outlined above for the determination of selenious acid, show that this expectation is realized, and that the analytical results are fairly good.

Table IV.

SeO_3 taken. grm.	KI in flask. grm.	HCl in flask. (Sp. gr. 1·20) cm^3	Total volume boiled. cm^3	Time in minutes.	SeO_3 found. grm.	Error. grm.
0·0593	1	5	60	5	0·0593	0·0000
0·0593	1	5	60	5	0·0591	0·0002 –
0·0593	3	5	60	10	0·0596	0·0003 +
0·1779	3	5	60	10	0·1769	0·0010 –
0·1779	3	5	60	10	0·1780	0·0001 +
0·1779	3	5	60	10	0·1764	0·0015 –

In conclusion, it is plain that while the simple contact of solutions of selenious acid or selenic acid and potassium iodide acidified with hydrochloric acid does not determine the liberation of the full amount of iodine which would be expected if selenium, iodine and water were the sole products of action, it is possible to bring about such action with a close approximation to completeness, when the amounts of selenium present are not too large, by submitting such mixtures to distillation. We prefer, in applying the reaction to analytical purposes, to work with the apparatus and under the conditions described—treating, preferably, not more than 0·2 grm. of the selenium oxide, using from 1 grm. to 3 grm. of potassium iodide in the distilling-flask with 5 cm^3 of strong hydrochloric acid in a total volume of 60 cm^3 and continuing to boil for ten minutes.

*Gooch and Clemens, this Journal, l, 51.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Helium, a constituent of certain Minerals.*—In a paper by W. RAMSAY, J. NORMAN COLLIE and M. TRAVERS, read before the Chemical Society on June 20, the results are given of an extended series of experiments upon the gas yielded by cleveite and allied minerals, to which the name of helium was given by Ramsay in the first account of its discovery a few months since, as already noted in these pages. This name was based upon the fact that the spectrum of the gas in question is characterized by a yellow line, which is very nearly, if not quite, coincident (see remarks on p. 261) with the line D_3 in the solar spectrum (wave length 5875·982 Rowland). It will be remembered that some thirty years since Lockyer and Frankland gave the name helium to the hypothetical solar element corresponding to the absorption line D_3.

The authors recall the fact at the outset that Palmieri states that a yellow spectral line with wave length 587·5 was obtained by him from a soft substance occurring as a lava-like product ejected by Vesuvius. They also allude to the investigations of Hillebrand on the various kinds of uraninite and the gases occluded by them which he regarded as nitrogen, and show that they actually contain 10 p. c. by volume of this gas, enough to explain the confirmatory chemical experiments showing the presence of nitrogen as also the strong nitrogen spectrum—for the spectrum of helium is masked by a comparatively small amount of nitrogen. It is added that if Hillebrand had operated with cleveite he would in all probability have discovered helium.

A large number of minerals have now been tested, 2 to 5 grams of the coarsely powdered substance in each case being heated to redness in a small bulb of combustion-tubing, previously exhausted by a Töpler pump. The details as to manipulation and the analytic processes applied to remove gases evolved with the helium (hydrogen, etc.) cannot be described here. The following species yielded helium and in most cases hydrogen also: Yttrotantalite, samarskite, hjelmite, fergusonite, tantalite, pitchblende, polycrase, all containing uranium; also, monazite, xenotime, orangeite. Negative results were obtained from a number of other minerals, including columbite, perofskite, thorite, allanite, gadolinite and others.

After briefly considering the composition of the minerals named with a view to deciding as to what constituent is effective in retaining helium, the authors remark: "From these details, it may be concluded that the helium is retained by minerals consisting of salts of uranium, yttrium, and thorium. Whether its presence is conditioned by the uranium, the yttrium or the thorium, we are hardly yet in a position to decide. To judge by the Cornish ore [pitchblende], oxide of uranium alone is sufficient to retain it; but that its presence is not absolutely necessary is shown by its existence in monazite and xenotime. The high atomic weights of uranium and thorium and the low atomic weight of helium suggest some connection; and yet yttrium, which possesses a medium atomic weight, sometimes appears to favor the presence of the gas; for yttrium is present in yttrotantalite, which, however, contains uranium, and in cleveite, in which uranium is present in relatively large amount.

Of the minerals experimented upon, the only ones which may be taken as a source of helium are cleveite, the uraninite investigated by Hillebrand (Glastonbury, Conn.) and bröggerite. Samarskite and yttrotantalite might be added to these, but large quantities of these species would have to be worked up.

In order to fix the *density* of helium a number of separate determinations were made upon the gas liberated from bröggerite and cleveite. The final results are as follows:

Gas from bröggerite by heating	2·152
Gas from bröggerite with $HKSO_4$	2·187
Gas from cleveite	2·205
Mean density	2·181

The *ratio* of the two *specific heats* was also determined by the method depending upon the velocity of sound in the gas and the value obtained was:

1·652

This is very near the theoretical value 1·66. The purest sample of argon gave 1·659. It follows that helium has "the same claim to be considered a monatomic gas as mercury gas; or if it is a mixture, it must be a mixture of monatomic gases."

The *solubility* of helium was determined by the same method employed for argon and the result obtained is

1 vol. water absorbs 0·0073 volume helium.

This is the lowest solubility hitherto recorded. The authors, noting the fact that the solubility of a gas is in general related to the temperature at which it condenses to a liquid, remark that the low solubility of helium points to a very low boiling point, as low or perhaps lower than that of hydrogen. Experiments on the temperature of liquefaction are promised by Prof. Olszewski. It is added that helium is totally insoluble in absolute alcohol and benzene.

The following remarks upon the spectrum of helium, and finally the conclusions to which the work as thus far carried out have led, are here quoted in full:—

The Spectrum of Helium.—Mr. Crookes is making an exhaustive study of the spectrum of helium, and will shortly publish an account of his work. But, as some of the deductions to be drawn later depend on the lines observed, it is necessary here to add a few words. In general terms, the spectrum has already been described. The particular point to which attention is necessary here is that at least two of the lines in the spectrum of helium, seen with a wide dispersion prism, are coincident with two of the argon lines. These occur in the red, and comprise one of each of the two pairs of characteristic argon lines. This observation has been frequently repeated, using for the purpose spectroscopes of different dispersive power, and throwing into the field both spectra at the same time, with an exceedingly narrow slit; and we may say that if not absolutely identical, the lines are so near that it is not possible with the means at our disposal to recognise any difference in position. But the relative brilliancy is by no means the same. One of the argon lines, rather faint, is coincident with the prominent red of the helium spectrum, and one of the strong red argon lines is coincident with a faint red line in the helium spectrum.

Besides these two, there is a line in the orange-red, which though perhaps not identical, yet is very close. This line is faint in helium, but moderately strong in argon. It is much more easily visible with helium in the "negative glow" than in the capillary tube.

It may also be of interest to state that, according to Runge's observation, the brilliant yellow line of helium is undoubtedly a doublet. This was frequently observed by us with a grating of 14,000 lines to the inch in the spectrum of the third order. But it must also be noted that one of the lines is very faint; the other, more refrangible, is immensely brighter. The distance, judged by eye, appears to be about $\frac{1}{50}$th part of that between the lines D_1 and D_2 of sodium. Accurate information on this last point may be looked for from Mr. Crookes, Mr. Lockyer, and from many others who are interested in the probable occurrence of this element in the sun.*

General Conclusions.—It cannot be doubted that a close analogy exists between argon and helium. Both resist sparking with oxygen in presence of caustic soda; both are unattacked by red-hot magnesium; and if we draw the usual inference from the ratio between their specific heats at constant volume and at constant pressure, both are monatomic gases. These properties undoubtedly place them in the same chemical class, and differentiate them from all known elements.

Although opinion is divided on the precise significance of the ratio of specific heats, 1·66, it appears to be most probable that in all cases, as in that of mercury, this ratio points to the monatomicity of the molecule. If we assume this provisionally, it follows that the atomic weight of helium is identical with its molecular weight. The molecular weight is twice the density, for the molecular weights of gases are compared with the atomic weight of hydrogen, taken as unity; hence the atomic weight of

* Prof. Hale and Dr. Huggins have recently observed that the solar line D_3 is also a doublet. (W. R., July 20.)

helium on this assumption is $2{\cdot}13 \times 2 = 4{\cdot}26$. But again we assume, in making this calculation, that helium is a single element, and not a mixture of elements. Before discussing this question, it appears advisable to inquire whether there is any evidence which would corroborate the deduction that it is a monatomic element. This evidence must be sought for in the properties of argon, for those of helium have not as yet been sufficiently investigated.

We know from countless examples among compounds of hydrogen and carbon that increase in molecular weight is accompanied by rise of boiling point; and it may be stated as a proved fact that a polymeride has always a higher boiling point than the simpler molecule of which the polymeride is formed. Among the substances germain to this inquiry, ozone and oxygen may be cited; the complex molecule of ozone is shown by the higher temperature at which it boils. It might be concluded with certainty, therefore, that A_2, could it exist, should have a higher boiling point than A_1.

Next, it is generally the case that the boiling point of an element, provided it has not a complex molecule like that of sulphur and phosphorus, is lower, the lower its molecular weight. There are the well-known instances of chlorine, bromine, and iodine; but if it be objected that these all belong to the same group, we may cite the cases of hydrogen, $-243{\cdot}5°$; nitrogen, $-194{\cdot}4°$; and oxygen, $-182{\cdot}7°$; and we may add chlorine, $-102°$. If argon possessed the atomic weight 20 and the molecular weight 40, it is probable that its boiling point would lie above that of chlorine, instead of, as is actually the fact, at $-187°$—below that of oxygen. But, it may be objected, the boiling point is determined, not by the molecular weight, but by the density. It may be urged that the density of argon is 20, and that its molecules, like those of oxygen and nitrogen, are diatomic, in spite of the argument to the contrary from the ratio of specific heats. The answer to this objection is obvious; if this were so, its boiling point should lie above, and not below that of oxygen.

These considerations cannot, of course, be accepted as evidence, but merely as corroborative of the conclusion as regards the monatomicity of argon. If they apply to argon, they apply with equal force to helium; and if they are accepted, it follows that the atomic weight of helium is 4·26.

It is again necessary to consider the character of argon in attempting to answer the next question : Are argon and helium single elements or mixtures of elements? But before discussing it, let us consider another question: How does argon happen to occur in the air and helium only in minerals? Why is helium not present in air? A satisfactory answer to the question is, we think, contained in a paper by Dr. Johnstone Stoney (Chem. News, 1895, lxxi, 67). He there shows that were hydrogen to be present in air (and it might be present, in spite of the oxygen with which it could be mixed, for a small quantity would surely escape combination), it would, in virtue of the velocity of its own proper molecular motion, remove itself from our planet, and emigrate to a celestial body possessing sufficient gravitational attraction to hold it fast. Dr. Stoney suggests this explanation to account for the absence of an atmosphere and of water vapour on the moon, and for the presence of an atmosphere of hydrogen on the sun. It would also account for the absence of helium in our atmosphere, and for the presence of the chromospheric line D_3. Of course if an element can form compounds, or if it is absorbed by solids, as helium appears to be, it will, like hydrogen and helium, be found on the earth.

The inertness of these gases would favor their existence in the free state. And argon exists in the atmosphere, precisely because it forms no compounds. Similarly nitrogen is a constituent of air, because in the first place those elements with which it combines directly are comparatively rare, and also because such compounds are mostly decomposed by water; and the excess of nitrogen therefore occurs in the free state. Similarly, the occurrence of free oxygen is due to the fact that some remains over, after all or almost all the readily oxidized substances have already united with oxygen. If there exist gases similar to argon in inertness, they two may be looked for in air.

Now if argon possesses the atomic weight 40, there is no place for it in the periodic table of the elements. And up to now there is no exception to this orderly arrangement, if the doubtful case of tellurium be excluded. Rayleigh and Ramsay have shown that the high density of argon can hardly be accounted for by supposing that molecules of A_2 are mixed with molecules of A_1; and excluding as untenable the supposition that argon is a compound, the only remaining suggestion is that it is a mixture. No attempts have as yet been made to test the correctness of this idea; but experiments have already been started which, it is hoped, will throw light on this question.

The density of argon is too high; to fill its place in the periodic table, between chlorine and potassium, its density should be about 19 and its atomic weight 38. We might expect the presence of another element with a density of 41 and an atomic weight of 82, to follow bromine, as argon follows chlorine; and this element would probably also be a gas, since its density would be only a little higher than that of chlorine.

But here we meet with a difficulty. There are certain lines in the spectrum of helium coincident with lines in the argon spectrum. There can be only one explanation, excluding the extremely improbable hypothesis, which is not verified in any instance, that two elements may give spectra containing identical lines. That explanation is, of course, that each contains some common ingredient; and there appears to be a place for one with density 10 and atomic weight 20, to follow fluorine in the periodic table. The density of helium is, however, so low, that there does not appear room for any large quantity of a heavier gas; and to fit the periodic table, the density of argon should be diminished by removal of a heavier admixture, rather than increased by removal of a lighter one.

Such are the problems which now confront us. Until more experiments have thrown further light on the subject, we regard it as labor lost to discuss the relations of these curious elements to others which find their proper place in the periodic table.—*Nature*, July 25, Aug. 1.

2. *Argon and Helium in Meteoric Iron.*—Professor W. RAMSAY, extending his researches upon the new element argon, has proved that it exists with helium in meteoric iron. The meteorite investigated was that of Augusta county, Virginia, two ounces of which, heated to redness in a hard glass tube, yielded 45 c.c. of gas. This appeared to consist chiefly of hydrogen, but after it had been exploded with oxygen, and the carbon dioxide and excess of oxygen absorbed, a residue of half a cubic centimeter was obtained. Several vacuum tubes having been filled with this after being dried, spectroscopic examination proved it to be for the most part *argon*, the trace of nitrogen which first appeared rapidly disappearing. All the argon lines were observed and also, faintly, the yellow D_3 of helium. A comparison of the spectrum with that of the helium from cleveite showed the presence of the red, blue-green, blue and violet lines characteristic of it. From quantitative observations with a mixture of argon and helium it is concluded that the latter element makes up less than 10 p. c. of the gases obtained from the meteoric iron. *Nature*, lii, 224.

3. *The physical properties of Argon.*—LORD RAYLEIGH gives the following determination of the density of argon ($O_2 = 16$):

$$19{\cdot}940$$

This result was obtained with the gas prepared from atmospheric air with the aid of oxygen and alkali only, and employing large quantities (two liters at 0°). It agrees almost exactly with the determination of Professor Ramsay made upon a relatively small amount and with gas derived from magnesium. In spite of its greater density the refraction ($\mu - 1$) of argon is only 0·961 of that of air. Hence if for air under standard conditions, $\mu = 1{\cdot}0002923$, we have for argon

$$\mu = 1{\cdot}000281.$$

—*Nature*, lii, 293.

4. *The Fluorescence of Argon.*—M. BERTHELOT has carried on, in conjunction with M. Deslandres, a series of careful experiments on the fluorescence of argon which accompanies its combination with benzene under the influence of the silent discharge; this it appears is accomplished with the help of mercury in the form of a volatile compound. The effect at first is feeble and only to be observed in a dark room, but after some fifteen hours a brilliant emerald fluorescence is obtained, visible in broad daylight and indeed more intense than that given by any other known gas. The wave lengths of the lines given in the photographs are: 579, 577 and 546; 436, 405, 313, 312 (ultra-violet); also two violet lines besides, 420 and 416, scarcely visible, and

further 385 and 358. Most of these lines coincide very closely with the determination of Crookes of the lines of rarefied argon; 313, 312, however, are mercury lines. It is also noted that certain of the lines observed by Crookes coincide with those of mercury vapor and the same coincidence is noted in the lines visible in daylight under normal pressure in the fluorescence developed during the reaction of benzene on argon. These lines develop themselves only after several hours with the argon saturated with benzene and seem to be due to one of the condensed compounds from the benzene uniting itself with the argon and mercury.—*Comptes Rendus*, June 24; *Nature*, lii, 255.

5. *The Principles of Physics*, by Alfred P. Gage, Ph.D. 634 pp. Boston and London 1895 (Ginn & Company).—Those who are acquainted with the excellent features of Gage's *Elements of Physics* (1882) will expect to find the present volume, prepared to fill a somewhat different place, a desirable addition to our elementary text-books, and in this they will not be disappointed. It presents the principles of the subject from the didactic not from the experimental side, and it does so clearly and simply, with numerous fresh illustrations. The shortcomings of such a volume are those inevitably incident to the attempt to compress a subject of so vast extent into the limits of a small volume; the author has made, however, good use of the space which has been allowed him.

II. Geology and Mineralogy.

1. *The Protolenus fauna*; by G. F. Matthew. (Trans. N. Y. Acad. Sci., vol. xiv, pp. 101–153, Plates I–XI, March 17, 1895.) —This interesting early Cambrian fauna, some species of which have been described before,* has been increased to the number of seventy species, which were chiefly obtained from the section in Hanford Brook, St. John, New Brunswick, by Messrs. Gilbert Van Ingen and W. D. Mathews of the Geological Department of Columbia College and the author. The stratigraphical relations of the fauna may be described most concisely by reproducing the table of life zones of the St. John Group, the details of which are fully elaborated by the author in the Transactions of the Royal Society of Canada.

In descending order they are as follows:

St. John Group.	Division 3 Bretonian.	Band *d*	Fauna of *Tetragraptus quadribranchiatus.*	
		" *c*	" " *Dictyonema flabelliformis.*	
		" *b*	" " *Peltura scarabeoides.*	
		" *a*	" " *Parabolina spinulosa.*	
	Division 2 Johannian.	" *c*	" " *Lingulella radula.*	Place of the Olenus Fauna.
		" *b*	" " *L.* —— *Starri.*	
		" *a*	" " --------------	
	Division 1. Acadian.	" *d*	" " *Paradoxides Abenacus cf. Tessini.*	
		" c^2	" " *P.* —— *Etiminicus cf. rugulosus.*	
		" c^1	" " *P.* —— *lamellatus cf. œlandicus.*	
		" *b*	" " Protolenus (found in b^2 and b^3).	
		" *a*	No fauna known.	

* Trans. Roy. Soc. Can., vol. vii, sec. iv, p. 135; vol. xi, sec. iv, p. 85. Nat. Hist. Soc. N. Brunswick, Bull. 10, p. 34.

The mass of sediments which directly underlie this St. John Group, including the conglomerates called Etcheminian by the author, are now regarded by him to be actually Pre-Cambrian.

This fauna, therefore, appears to be the oldest of which we have any elaborate knowledge, although it should be noted that the Olenellus fauna has not been discovered in this section, and the fauna immediately succeeding the Protolenus fauna in the Hanford Brook section is the Paradoxides fauna.

The fauna is thoroughly primordial in character: there are two genera of Foraminifera (*Orbulina* and *Globigerina*). There are three genera of Spongida (*Monadites*, *Protospongia* and *Astrocladia?*). The Brachiopoda are represented by *Lingulella*, *Obolus*, *Trematobolus*, *Obolella*, *Linnarssonia*, *Acrotreta*, *Acrothele*, and a specimen referred to as an Orthid. Among the forms referred to *Obolus* are some which differ slightly from the typical genus and are described under the subgenus *Botsfordia.* The author has been able to make out several stages of development for *B. pulchra,* which he summarizes as follows: "This species, then, is marked by four stages of growth and development, of which the most prominent features are the following:—

(1.) *Embryonic.*—Formation of the embryonic shell.

(2.) *Larval or nœpionic.*—Lengthening of the hinge line and acquisition of mantle-margins.

(3.) *Adolescent or nealogic.*—Fixation of the hinge line, otherwise as the last, except that the radular ornament becomes irregular.

(4.) *Adult or ephebolic.*—Absence of radular ornamentation on the valve, and great expansion of the mantle-margin." The genus *Trematobolus* is remarkable as combining the unmistakable characteristics of the inarticulate order of Brachiopods, yet having a distinct articulation of the hinge line. The mollusca are represented by *Hyolithellus*, *Coleoides*, *Orthotheca*, *Hyolithes*, *Diplotheca*, a peculiar new genus, *Pelagiella*, which appears to have been a free swimmer and to belong to the Heteropoda, and *Volborthella.* In this group the Hyolithidæ are prominent, and all of the mollusca seem to have been of pelagic type. Nearly half of the species described are Arthropoda. Among the Ostracoda are *Hipponicharion*, *Beyrichona*, *Aparchites*, *Primitia*, *Schmidtella* and *Leperditia.* The new genus *Beyrichona* was originally described in the Transactions* of the Royal Society of Canada, and the author, upon study of better material, has modified the description by reversing the anterior and posterior portions of the shell. The two species referred to *Aristozoa* by Walcott, Mr. Matthew considers to be species of this genus. One supposed Phyllopoda (*Lepiditta*) is described. Of Trilobites, thirteen species are described, and referred to the genera *Protograulos*, *Ellipsocephalus*, *Micmacca*, *Avalonia*, *Protolenus* and *Bergeronia.*

As salient features separating this fauna from all others, the author mentions the following points: All the trilobites have

* Vol. iii, p. 65.

continuous eyelobes; the important family of the Ptychoparida is absent; the genera *Conocoryphe*, *Microdiscus* and *Olenellus* are absent. He further remarks: "This fauna is distinguished from that of *Olenellus* by two marked features. It is more *primitive* and also more *pelagic*. The way in which the trilobites are bound together by a single feature of a continuous eyelobe shows a unity of origin and a closer relationship than is found in the trilobites of any other fauna, and yet among these trilobites there are forms which in other respects are parallel to the types which developed in the later faunas. Thus in *Protolenus* we have the flat pleura, with the diagonal furrow of *Paradoxides*, but in subgen. *Bergeronia* the deeply-grooved, geniculated pleura of *Ptychoparia*, and at the same time the prominent glabella and deep dorsal furrows of *Solenopleura*. *Micmacca*, as has already been said, predicates *Zacanthoides* of a later fauna. Finally, *Protograulos*, in its almost obliterated glabella and flat cephalic shield, recalls *Agraulos* and *Holocephalina* of the Paradoxides fauna. It is a more *pelagic* fauna than that of *Olenellus*, for we notice the absence of many forms of the *Olenellus* fauna that were differentiated for shore-conditions. Trilobites with fixed outer checks, like *Olenellus* and *Microdiscus*, are absent; calcareous corals and sponges are rare, and no Lamellibranch is known. On the other hand, Foraminifera are quite common in some layers, and the Gasteropods are mostly such as were adapted for comparatively deep water."

Although the evidence is not conclusive that the fauna lived before the Olenellus fauna, it is without doubt a different fauna. The two faunas may have been contemporaneous, the author observes, the Protolenus fauna being adapted to deeper and quieter waters than the other. In this case "we would expect," he writes, "that at a locality where the two faunas occurred in succession in a series of deposits, the Olenellus fauna would be found beneath that of Protolenus," and he expresses the opinion that assises 4 and 5 (of the Hanford brook section) [this fauna occurring chiefly in assises 2 and 3] show no trilobite fauna and "this seems the more probable place for the Olenellus fauna, seeing that while this fauna has several genera of trilobites in common with the Paradoxides fauna, it has but two that are found in the Protolenus fauna." H. S. W.

2. *Pre-Cambrian organisms.*—L. CAYEUX has recently published* a preliminary note on the existence of numerous remains of Sponges in the pre-Cambrian schists of Brittany, thus adding to the known organisms of this early fauna.† The evidence is in the form of pyritized sponge spicules of which the original form

* "De l'existence de nombreux débris de Spongiaires dans le Précambrian de Bretagne," par L. Cayeux; Ann. Soc. Géol. du Nord., vol. xxiii, 1895, pp. 52–64, June, 1895.

† "Sur la présence de restes de Foraminifères dans les terrains précambriens de Bretagne. C. R. Ac. Sc., t. cxviii, pp. 1433–1435 et Ann. Soc. Géol. du Nord, vol. xxii, pp. 116–119. See also Bull. Soc. Géol., Fr., 3e Série, t. xxii, pp. 197–228, pl. xi (1894).

is preserved, and the author has determined species referable to each of the four orders of siliceous sponges, viz: Monactinellidæ, Tetractinellidæ, Lithistidæ and Hexactinelledæ.

The geological horizon from which the fossils came is the "phtanites de Lamballe" in the Phyllades de Saint-Lô of Barrois, near Lamballe, Brittany. The Radiolarians, previously described by the same author, were obtained from the same formation. The specimens in both cases were discovered by M. Ch. Barrois. The author infers, from the evidence of breaking and wearing of the spicules before they were pyritized, that there were strong marine currents in the waters when the deposits were found, and therefore that the depth was not great during the deposition of the phtanites. H. S. W.

3. *Grundzüge der Palæontologie* (*Palæozoölogie*) von Karl A. von Zittel, pp. i–viii and 1–971 and 2048 figures, 1895.—This is more than a condensation of the "Handbuch" which has taken such a well deserved first place among treatises on Paleontology. The great progress in systematic zoölogy since the "Handbuch" was begun in 1876, is expressed in a thorough revision of the classification, particularly of the Invertebrates. As these changes are of much importance to all who use the book, the chief of them are here noted.

Eight branches are recognized in the animal kingdom. The Vermes are given a separate place, and the Molluscoidea are separated from the Mollusca, as most zoölogists have done for the past twenty years. The Tunicates are not considered.

In the branch Protozoa, Monera are no longer recognized and the fossil forms are distributed in the two orders *Foraminifera* and *Radiolaria* of the class Rhizopoda.

The Coelenterata are separated into the three sub-branches *Porifera*, including the class Spongia, and *Cnidaria*, with the two classes Anthozoa and Hydrozoa, and *Ctenophora*; no fossil remains of the latter being reported. The four orders of Sponges which have a more or less siliceous framework are grouped together as *Silicispongiæ*.

The class Anthozoa is entirely rearranged: Haeckel's three sub-classes, *Tetracorallia*, *Hexacorallia* and *Octocorallia* are recognized. Madreporaria is subdivided into the three sub-orders of Edwards and Haime,—*Aporosa*, *Perforata* and, as an appendix, *Tabulata*, in which latter group are included the *Favositidæ* and associated forms, and the *Chætetidæ*, which in the "Handbuch" were distributed with the Bryozoa.

Haeckel's three sub-branches of the Echinodermata are adopted, viz: *Pelmatozoa* (Crinoidea, Cystoidea and Blastoidea), *Asterozoa* (Ophiuroidea and Asteroidea) and *Echinozoa* (Echinoidea and Holothurioidea).

Following the Wachsmuth and Springer classification, the Crinoids are distributed in the three orders *Larviformia*, *Camarata* and *Fistulata*. The Molluscoidea are recognized as a distinct branch. The subdivisions of the Bryozoa are left substantially as in the older work. In the Brachiopoda the only important change is in adopting the grouping of the Articulata suggested by Waagen, though with some change in the names, viz: *Aphaneropegmata*, *Helicopegmata*, *Ancistropegmata* (=Campylopegmata p. p. Waagen) and *Ancylopegmata* (=Ancylobranchia Gray, Campylopegmata p. p. Waagen).

The Mollusca are distributed in the five classes, *Lamellibranchiata*, *Scaphopoda*, *Amphineura* (adopted from Ihering), *Gastropoda* and *Cephalopoda*. Neumayr's natural separation of the *Anisomyaria* from the *Homomyaria* is recognized in the classification of the Lamellibranchiata; also his classification of the latter order into the sub-orders *Toxodonta*, *Pachyodonta*, *Heterodonta* and *Desmodonta*.

Fischer's division of the Nautiloidea and Ammonoidea respectively into Retrosiphonata and Siphonata is discarded. *Bathmoceras* is placed in the family Orthoceratidæ, and *Nothoceras* in the family Nautilidæ. The position of the siphon is made of prime importance in the Ammonoids, viz: A. the *Intrasiphonata*, with the single family Clymeniidæ, being separated from B. the *Extrasiphonata*, which includes the other families of the sub-order.

The three sub-orders *Belemnoidea*, *Sepiodea* and *Octopoda* are recognized in the Dibranchia.

The important modification of the breathing apparatus in the Arthropoda is made of sub-branch rank, thus separating the *Branchiata*, with the single class Crustacea, from the *Tracheata*, with the three classes Myriapoda, Arachnoidea and Insecta; the old divisions, *Entomostraca*, *Malacostraca* and *Merostomata* being retained as of sub-class rank.

As a result of the great differentiation discovered by Brongniart in the Carboniferous Insects of Commentry, Scudder's grouping of the Paleozoic Insects into Palæodictyoptera is discarded, and all the fossil Insects are distributed in the recognized existing orders, the *Aptera* being raised to ordinal rank.

Very few changes are made in the classification of the Vertebrates, the two volumes of the "Handbuch" on this branch having been more recently written. We, however, note the elevation of the *Leptocardii*, and the *Cyclostomi* to class rank, of which no fossil remains are reported, and the *Placodermi* to the rank of a sub-class, separating it from the Ganoids and placing it between the Selachii and the Dipnoi. Among the Mammals, the *Allotheria* of Marsh is reduced from ordinal to sub-ordinal rank, and the families of the Marsupialia are distributed in the three sub-orders *Allotheria*, *Diprotodontia* and *Polyprotodontia*. In the class Placentalia, Ameghino's *Litopterna* and Cope's *Ancylopoda*, the genera of which were previously considered in the sub-order Perissodactylia, are given the rank of distinct sub-orders in the order Ungulata.

The book is fully illustrated; each of the important groups is opened with a general description of structure and parts, and closed with a concise summary of the geological range of the families and genera.

The more important genera are concisely described, and a large number of less prominent genera are named in their proper places with their geological position. The German edition, which has already appeared, is to be followed soon, it is announced, by an edition in English. H. S. W.

4. *The occurrence of Tertiary clay on Long Island, N. Y.;* by ARTHUR M. EDWARDS, M.D., Newark, N. J. (Communicated.) I wish to record the finding of Tertiary clay at Rockaway, Long Island, N. Y. Tertiary rock or at least clay was expected to be found on the Atlantic shore of Long Island. It was searched for on Staten Island without results. The clay found was white, at Arrochar, and was identified as Cretaceous by the shells in it. But the Tertiary above that was looked for in vain, although it may be found there. But on Sunday, 11th of August, 1895, I visited Rockaway to study the geology. I saw the moraine of the glacial period strongly marked in three hills just beyond Brooklyn Hills station; on the top and overlying the glacial drift was a coating of glacial clay having fresh-water Bacillariaceæ (Diatomaceæ) in it, the same as I found in New Jersey. The hills ended here and the rest was flat until beyond Aqueduct station. No opening was made, but I think that Cretaceous clay is under the glacial drift. At Aqueduct station the salt water begins and the cars run out on tressel works to Rockaway, where is a sandy bar. At one place, where they have been digging a ditch and recovering the land from the sea, on the opposite side of Rockaway to the Atlantic Ocean, some of the soil has been dug up. On the top is the Bacillarian clay, the Champlain glacial clay. Below this is the white glacial clay containing fresh-water Bacillariaceæ, and below this is a dark, coarse clay which I took home and examined. It is Tertiary clay having marine Bacillariaceæ. But I should think it is Upper Miocene. Lower Miocene and Oligocene are as a rule lighter in color. But the shells in it are the same. I wish to record this finding now, as it is important.

Newark, N. J., August 8.

5. *On Composite Dikes in Arran.*—Professor JUDD has described in the Quarterly Journal of the Geological Society (vol. xlix, p. 536) a series of remarkable dikes in the Island of Arran, which are excellent examples of the "composite" type, already recognized elsewhere as in Canada and Norway, described by Lawson and Vogt respectively. Unlike these last, however, in which the differentiation has gone on within the dike itself, the Arran dikes belong to a different class, formed by the injection of different material into the same fissure. It should be mentioned that these dikes are part of the latest ejections of igneous material in the British Isles. One of the dikes, that of Cir Mhor, having a total breadth between the enclosing granite walls of twenty-four feet, shows two exterior brands of augite-andesite (55·8 p. c. SiO_2), four feet wide; within these is the dike proper consisting

of two bands of quartz-felsite (75·3 p. c. SiO_2), six feet wide, enclosing in the center a band four feet in width of pitchstone porphyry (72·4 SiO_2). Another dike, one of a series at Tormore, twelve feet in thickness and extending as a sheet for a long distance, consists of the following bands in order between walls of sandstone: augite-andesite, banded and spherulitic felsite (andesite), pitchstone, felsite (as before). Still another dike of the latter region shows a band of the pitchstone-porphyry cutting obliquely across both the bands of exterior augite-andesite and the quartz-felsite within it.

After giving a detailed account of the structure and composition, mineralogical and chemical, of these dikes, the author concludes with the following summary :

"Any suggestion concerning the possible *accidental* association of the augite-andesite and 'pitchstone' in the Cir Mhor dyke is at once negatived by the study of the remarkable plexus of dykes at Tormore. No one can doubt, after the study of this latter case, that there is a real and not merely an accidental connection between the ejection of materials of such very different composition and character: all the facts, indeed, point to the conclusion that the fissures were injected from the same subterranean reservoir, but that this reservoir contained two magmas of totally different chemical composition. In the same way, as is well known, a single volcanic vent may give rise at successive periods to two totally distinct kinds of lava.

"Nor can there be any difficulty in understanding how the same fissure, while still in connection with a reservoir of liquefied lava, may be reopened and re-injected at successive periods. The plane of weakness, along which the reopening of the dyke is effected, is sometimes, as in the Cir Mhor dyke, in its center; in other cases, as in the great north-and-south dyke of Tormore, and also in the most southerly of the transverse dykes of the same district, planes of weakness are found along one or both of the lateral walls of the dyke, and it is here that the re-injection is effected; in yet other cases, also illustrated at Tormore, the new fracture seems to be quite irregular in position and to traverse the old dyke-material in a sinuous line. In one instance we have evidence of three separate injections into the same fissure.

"In some cases the more acid rock (quartz-felsite and pitchstone) was the first ejected; but, quite as frequently, the basic material (augite-andesite) was the earliest to be intruded into the opening fissure. The relative ages of the two rocks in the dyke are shown, not only by the positions which they occupy, but by the circumstance that derived minerals from the older rock are found included in the younger one. That a very considerable interval of time must have elapsed between the two injections is shown by the fact that complete consolidation and crystallization of the materials of the one rock must have occurred before its invasion by the other rock : this is proved by the characters of the junctions and also by the derived crystals.

* * * * * *

"We may classify the explanations which have been suggested to account for the differentiation of lavas into two groups:—those which rely upon some process of selective crystallization, and those which premise some kind of separation taking place in a liquid magma prior to the commencement of crystallization and consolidation.

"Differentiation during crystallization has been referred to two distinct causes. Prof. Vogt, in order to account for the deposits so rich in magnetite occurring in Scandinavia and elsewhere, has put forward the theory that the remarkable magnetic properties of the iron-spinellid may account for its segregation, and that the mutual attraction of the magnetite-particles may lead to their accumulation at certain points in the still fluid magma. But this ingenious suggestion omits a very important consideration. It has been shown by Prof. Rücker, that both metallic iron and magnetite, when heated, rapidly lose their magnetic properties, and that at a dull red heat all phenomena both of attraction and polarity disappear alike in metallic iron and in magnetite. Such being the case, it seems impossible to conceive of such a degree of heating of a magma as would permit of internal movements, and yet would not at the same time destroy the attractive properties of the magnetite.

"The other suggested method by which differentiation may be brought about in a magma during the process of crystallization, is based on the fact that, as a general rule, the more basic minerals crystallize out of a molten mass before those of acid composition, and that, as a consequence of this, the matter left liquid continually tends to become more and more acid in composition. That in these masses of molten rock consisting of basic crystals diffused through an acid menstruum, a process of partial or complete liquation may occur, is shown by the phenomena which have been observed at Santorin, Krakatoa, Beinn Hiant, Garabal Hill, etc. This method of differentiation, while it affords a satisfactory mode of explanation of the first class of composite dykes—that so well described by Lawson and Vogt—is clearly inapplicable to the cases in Arran, where the porphyritic crystals and glassy basis in the two constituent rocks are so strikingly contrasted one with another.

"We are thus compelled to fall back upon the view that an actual separation takes place among the materials of a molten magma *before the work of crystallization has commenced;* and I may, in conclusion, pass in review the several suggestions that have been offered to account for such action in a mixed mass of molten silicates.

"Bunsen and many authors since his time have dwelt upon the fact that such molten masses of silicates are really solutions, and must obey all the laws which govern solvent action. Guthrie and Lagorio have especially insisted on this view of the subject.

"Many writers on the question have been impressed by the view that the two magmas into which a mass of molten silicates may be supposed to break up must vary greatly in density; and several of these writers have suggested, in more or less distinct terms, that this difference in specific gravity may be the efficient cause of their separation. But until recently it was difficult to realize the physical principles that would cause density-differences to come into play as factors of differentiation. The researches of Gouy and Chaperon, however, supply a possible explanation of the phenomenon. These authors have pointed out that, in accordance with well-recognized thermodynamical principles, there should be—in a very great volume of a solution, especially if near saturation—a tendency for concentration to take place in the lower parts of the mass. Such vast masses of molten silicates as must exist in the deeper parts of the earth's crust are precisely the kind of solutions in which we may expect to find the action of this law illustrated.

"There is still another physical principle which has been appealed to as affording an explanation of the differentiation which takes place in a liquefied mass of silicates. In the same year that Gouy and Chaperon demonstrated the causes that would lead to "the concentration of solutions by gravity," van't Hoff published his paper on 'The Role of Osmotic Pressure in the Analogy between Solutions and Gases.' He argued that solutions must follow the law of gaseous tension, and that if two parts of a solution be maintained at different temperatures, concentration must take place in the cooler part. It is interesting to note that, six years before van't Hoff published his general conclusions, Soret had conducted a series of experimental researches which showed that, when two portions of a solution are maintained at different temperatures, there is always a tendency to concentration in the colder part.

"If, as we may assume is generally the case, the lowest portions of the great liquid reservoirs within the earth's crust are at the highest temperature, then the principles established by Gouy and Chaperon and by van't Hoff respectively would operate in contrary directions and tend to neutralize each other. It is sufficient for our present purpose, however, to call attention to the fact that there are now well-recognized physical principles, in accordance with which differentiation must necessarily be set up in the heated solutions constituted by molten masses of mixed silicates, anterior to, and independently of, the liquation that may follow selective crystallization. That differentiation does take place before, as well as during, crystallization, the phenomena exhibited by the two classes of composite dykes afford interesting and striking proofs."

6. *A plumbiferous Tetrahedrite;* by G. Chr. Hoffmann (communicated).—The mineral here described was obtained from the Antelope claim, Kaslo-Slocan mining camp, West Kootanie district, British Columbia. Of the specimens examined—some consisted of the tetrahedrite, in question, associated with galena and small quantities of sphalerite and pyrite; others, of the perfectly pure mineral in a gangue of white opaque quartz. The latter furnished the material employed for the analysis.

It is massive, with an indistinct fibrous structure : color, iron-gray: streak, dark clove-brown: luster, metallic: acquires a beautifully irised tarnish—the colors being various shades of yellow, green, blue, and purple. Mr. R. A. A. Johnston found it to have a specific gravity (after correction for a little intermixed quartz), at 15·5° C., of 5·082. An analysis by him, upon carefully selected material, gave the results of I; and deducting the gangue (silica) and recalculating the remaining constituents for one hundred parts those given in II are obtained.

	S	Sb	As	Cu	Ag	Pb	Zn	Fe	Quartz
I	20 59	26·81	0·22	21·03	10·64	8·91	5·91	0·88	5·57 = 100·56
II	21·68	28·22	0·23	22·14	11·20	9·38	6·22	0·93 = 100	

7. *Minerals and how to study them: A book for beginners in Mineralogy ;* by Edward Salisbury Dana. 380 pp. New York, 1895 (John Wiley & Sons).—This is a small work on Mineralogy of very elementary character, the scope of which may be made sufficiently clear by the following quotation from the Preface :—" The author has occupied some hours, which could not be devoted to more serious labor, in preparing this little book, in the hope that it might serve to encourage those who have a desire to learn about minerals, and also to increase the number of those whose tastes may lead them in this direction. He shares with most teachers at the present time, the conviction that the cultivation of the powers of observation is a most essential element in the education of young people of both sexes; he believes further, that no subject is better fitted to accomplish this object and at the same time to excite active interest than that of Mineralogy. The attempt has been made to present the whole subject in a clear, simple and so far as possible, a readable form, without cheapening the science. As the understanding of the different parts of the subject requires some preliminary knowledge of physics and of chemistry, a little elementary matter in these departments has been introduced." . . .

8. *The Constitution of the Silicates;* by F. W. Clarke. Bulletin of the U. S. Geological Survey, No. 125, 109 pp., Washington, 1895.—This bulletin, recently issued, contains a detailed statement of the author's views upon the chemical constitution and structural formulæ of the silicates. Numerous articles by the author upon parts of this subject have from time to time appeared, many of them in this Journal; but all interested will be glad to find here a full presentation of the conclusions to which his study as well as his admirable experimental work have led. While he does not claim that the last word has been said upon this subject, this contribution to the most important and difficult part of mineral chemistry is of very high value and throughout both suggestive and helpful.

9. *Native Silica: a treatise upon a series of specimens of Quartz, Rock crystal, Chalcedony, Agates and Jaspers*, etc.; with a descriptive catalogue of the specimens forming the collection of the late Right Hon. the Earl of Derby, K. G., by Bryce Wright, F.R.G.S. 263 pp. 8vo. London, 1894 (Wyman & Sons).—This is a handsomely printed catalogue containing, besides the

mention of individual specimens, brief but interesting chapters upon the different kinds of precious stones included; we note one on the agate, another on the cutting, polishing and staining of agates at Oberstein, and others similar.

III. Miscellaneous Scientific Intelligence.

1. *Report of the Committee appointed by the Smithsonian Institution to Award the Hogdkins Fund Prizes.*—The Committee of Award for the Hodgkins prizes of the Smithsonian Institution has completed its examination of the two hundred and eighteen papers submitted in competition by contestants.

The committee is composed of the following members: Doctor S. P. Langley, chairman, *ex-officio*, Doctor G. Brown Goode, appointed by the Secretary of the Smithsonian Institution, Assistant Surgeon-General John S. Billings, by the President of the National Academy of Science, Professor M. W. Harrington, by the President of the American Association for the Advancement of Science. The Foreign Advisory Committee, as first constituted, was represented by Monsieur J. Janssen, Professor T. H. Huxley, and Professor von Helmholtz; and after the recent loss of the latter, Doctor W. von Bezold was added. After consultation with these eminent men, the committee decided as follows:

First prize, of ten thousand dollars, for a treatise embodying some new and important discoveries in regard to the nature or properties of atmospheric air, to Lord Rayleigh, of London, and Professor William Ramsay, of the University College, London, for the discovery of *argon*, a new element of the atmosphere.

The *second prize*, of two thousand dollars, is not awarded, owing to the failure of any contestant to comply strictly with the terms of the offer.

The *third prize*, of one thousand dollars, to Doctor Henry de Varigny, of Paris, for the best popular treatise upon atmospheric air, its properties and relationships. Doctor de Varigny's essay is entitled "L'Air et la Vie."

(Signed), S. P. Langley, G. Brown Goode, John S. Billings, M. W. Harrington. August 9, 1895.

Supplementary Report of the Committee appointed by the Smithsonian Institution to Award the Hodgkins Fund Prizes.—After having performed the function to which the committee was called, as announced by the circular of the secretary of the Smithsonian Institution, dated March 31, 1893, which function did not include the award of any medals, there remained several papers to which the committee had been unable to give any prize and to which they had felt desirous to give some honorable mention, and on their representing this to the Smithsonian Institution they have been commissioned to do so, and also to give certain medals of silver and bronze which had been subsequently placed at their disposition.

The committee has decided that honorable mention should be made of the papers, twenty-one in number, included in the following list, which also gives the full names, titles, and addresses of the authors, and the mottoes or pseudonyms which in four instances were employed. To three of the papers a silver medal is awarded and to six a bronze medal:

Honorable Mention with Silver Medal.

PROF. A. L. HERRERA and DOCTOR VERGARA LOPE, of the City of Mexico: "La Atmosfera de las altitudes y el bienstar del hombre."

MR. C. L. MADSDEN—"Geo"—Helsigör, near Copenhagen, Denmark: Thermographical Studies.

MR. F. A. R. RUSSELL, of London, Vice-President of the Royal Meteorological Society of Great Britain: "The Atmosphere in Relation to Human Life and Health."

Honorable Mention with Bronze Medal.

M. E. DEBURAUX-DEX and M. MAURICE DIBOS—"Spes"—of Rouen, France: "Etudes des courents aériens continentaux et de leur utilization par des ærostats long-courriers."

DOCTOR O. JESSE, of Berlin: "Die leuchtenden Nachtwolken."

DOCTOR A. LOEWY, of Berlin: "Untersuchungen über die Respiration und Cirkulation unter verdünnter und verdichteter Sauerstoffarmer und sauerstoffreicher Luft."

MR. ALEXANDER MCADIE—"Dalgetty"—of Washington: "The known properties of atmospheric air considered in their relationships to research in every department of natural science, and the importance of a study of the atmosphere considered in view of these relationships; the proper direction of future research in connection with the imperfections of atmospheric air and the conditions of that knowledge with other sciences."

MR. HIRAM S. MAXIM, of Kent, England: "Natural and Artificial Flight."

DOCTOR FRANZ OPPENHEIMER and DOCTOR CARL OPPENHEIMER—"E pur si muove"—of Berlin, Germany: "Ueber atmosphärische Luft, ihre Eigenschaften und ihren Zusammenhang mit dem menschlichen Leben."

Honorable Mention.

MR. E. C. C. DALY, of University College, London: "The decomposition of the two constituents of the atmosphere by means of the passage of the electric spark."

PROFESSOR F. H. BIGELOW, of Washington: "Solar and Terrestial Magnetism and their Relation to Meteorology."

DOCTOR J. B. COHEN, of Yorkshire College, Leeds, England: "The Air of Towns."

DOCTOR F. J. B. CORDEIRO, U. S. N., of Washington: "Hypsometry."

PROFESSOR EMILE DUCLAUX, of the French Institute, Paris, France: "Sur l'actinométrie atmosphérique et sur la constitution actinique de l'atmosphère."

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(Signed) S. P. Langley, G. Brown Goode, John S. Billings, M. W. Harrington. August 9, 1895.

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[THIRD SERIES.]

ART. XXIX.—*Recent Progress in Optics;** by W. LECONTE STEVENS.

Introductory.

THE reviewer who aspires to give an account of recent progress in any department of science is met at the outset by two causes for embarrassment: What beginning shall be selected for developments called recent? What developments shall be selected for discussion from the mass of investigations to which his attention has been called? So rapidly is the army of workers increasing, and so numerous are the journals in which their work is recorded, that the effort to keep up with even half of them is hopeless; or, to borrow a simile employed by the late Professor Huxley, "We are in the case of Tarpeia, who opened the gates of the Roman citadel to the Sabines, and was crushed under the weight of the reward bestowed upon her."

I have selected a single branch of physics, but one which can scarcely be treated rigorously as single. From the physical standpoint optics includes those phenomena which are presented by ether vibrations within such narrow limits of wave length as can affect the sense of sight. But these waves can scarcely be studied except in connection with those of shorter and of longer period. Whatever may be the instruments employed, the last one of the series through which information is carried to the brain is the eye. The physicist may fall into error by faulty use of his mathematics; but faulty use of the senses is a danger at least equally frequent. Physiological

* Address delivered by the Vice-President of Section B at the meeting of the American Association for the Advancement of Science, August 29.

optics has of late become transferred in large measure to the domain of the psychologist; but he in turn has adopted many of the instruments as well as the methods of the physicist. The two cannot afford to part company. If I feel particularly friendly to the psychologist, more so than can be accounted for by devotion to pure physics, it may be fair to plead the influence of old association. If I am known at all in the scientific world, the introduction was accomplished through the medium of physiological optics. But, with the limitations imposed, it is not possible even to do justice to all who have done good work in optics. If prominence is assigned to the work of Americans, it is not necessary to emphasize that this Association is made up of Americans; but, with full recognition of the greater spread of devotion to pure science in Europe, of the extreme utilitarian spirit that causes the value of nearly every piece of work in America to be measured in dollars, we are still able to present work that has challenged the admiration of Europe, that has brought European medals to American hands, that has been done with absolute disregard of monetary standards; work that has been recognized, even more in Europe than in America, as producing definite and important additions to the sum of human knowledge.

In drawing attention to some of this work it will be a pleasant duty to recognize also some that has been done beyond the Atlantic; to remember that science is cosmopolitan. The starting point is necessarily arbitrary, for an investigation may last many years and yet be incomplete. To note recent progress it may be important to recall what is no longer recent.

Light Waves as Standards of Length.

You are, therefore, invited to recall the subject of an address to which we listened in this section at the Cleveland meeting in 1888, when Michelson presented his "Plea for Light Waves." In this he described the interferential comparer, an instrument developed from the refractometer of Jamin and Mascart, and discussed various problems which seemed capable of solution by its use. In conjunction with Morley, he had already used it in an inquiry as to the relative motion of the earth and the luminiferous ether,* and these two physicists together worked out an elaborate series of preliminary experiments† with a view to the standardizing of a metric unit of length in terms of the wave length of sodium light. By use of a Rowland diffraction grating Bell had determined the sodium wave length with an error estimated to be not in excess of one part in two hundred thousand.‡ Could this degree of accuracy be

* This Journal, May, 1886, p. 377.
† Ibid., December, 1887, p. 427.
‡ Ibid., March, 1887, p. 167.

surpassed? If so, it must be not so much by increased care in measurement as by increase of delicacy in the means employed. The principle applied in the use of the interferential comparer is simple enough; the mode of application cannot be clearly indicated without a diagram, but probably all physicists have seen this diagram, for it was first brought out eight years ago.* By interference of beams of light, reflected and transmitted by a plate of plane-parallel optical glass, and then reflected back by two mirrors appropriately placed, fringes are caught in an observing telescope. One of the mirrors is movable in front of a micrometer screw, whose motion causes these fringes to move across the telescopic field. If the light be absolutely homogeneous, the determination consists in the measurement of the distance through which the movable mirror is pushed parallel to itself and the counting of the number of fringes which pass a given point in the field of view. According to the theory of interference, the difference of path between the distances from one face of the plate to the two mirrors should be small; beyond a certain limit interference phenomena vanish, and this limit is smaller in proportion as the light is more complex. In the case of approximately homogeneous light there are periodic variations of distinctness in the fringes. For example, assume sodium light, which in the spectroscope is manifested as a pair of yellow lines near together. In the refractometer there are two sets of interference fringes, one due to each of the two slightly different wave lengths. When the difference of path is very small, or nearly the same for both of these radiation systems, the fringes coincide. The wave length for one is about one-thousandth less than that for the other. If the difference of path is about five hundred waves, the maximum of brightness for one system falls on a minimum of brightness for the other, and the fringes become faint. They become again bright when the difference of path reaches a thousand wave lengths. The case is entirely similar to the familiar production of beats by a pair of slightly mistuned forks.

The method of interference thus furnishes through optical beats a means of detecting radiation differences too minute for resolution by ordinary spectroscopic methods. Spectrum lines are found to be double or multiple when all other means of resolving them fail; and the difficulty of attaining truly homogeneous light is far greater than was a few years ago supposed. By the new method it becomes possible to map out the relative intensities of the components of a multiple line, their distance apart, and even the variations of intensity within what

*Ibid., December, 1887, p. 427.

has for convenience been called a single component. Each of the two sodium lines is itself a double whose components are separated by an interval about one-hundredth of that between the long known main components; and an interval yet less than one-fifth of this has been detected between some of the components of the green line of mercury. Indeed Michelson deems it quite possible to detect a variation of wave length corresponding to as little as one ten-thousandth of the interval between the two main sodium lines.*

This new found complexity of radiation, previously thought to be approximately if not quite simple, proved to be a temporary barrier to the accomplishment of the plan of using a light wave as a standard of length. It necessitated careful study of all those chemical elements which give bright lines that had been supposed to be simple. The red line of cadmium has been found the simplest of all those yet examined. The vapor in a rarefied state is held in a vacuum tube through which the electric spark is passed, and under this condition the difference of path for the interfering beams in the refractometer may be a number of centimeters. A short intermediate standard, furnished with a mirror at each end, is now introduced into the comparer and moved by means of the micrometer screw. Its length is thus measured in terms of the cadmium wave length. A series of intermediate standards of which the second is double the first, the third double the second, etc., are thus compared, and finally in this way the value of the meter is reached.

The feasibility of this ingenious method having been made apparent, Michelson was honored with an invitation from the International Bureau of Weights and Measures to carry out the measurement at the observatory near Paris with the collaboration of the director, M. Benoît. After many months of labor, results of extraordinary accuracy were attained. For the red line of cadmium at an air temperature of 15° C. and pressure of 760^{mm}, two wholly independent determinations were made. From the first a meter was found equal to 1553162·7 wave lengths; from the second, 1553164·3 wave lengths,—giving a mean of 1553163·5, the deviation of each result from the mean being very nearly one part in two millions.† A determination by Benoît from the first series gave 1553163·6, which differs but one-tenth of a wave length from the mean of Michelson's measurements.

The direct comparison of the lengths of two meter bars, though not easy, is a simple operation in comparison with the

* Astronomy and Astrophysics, February, 1894, p. 100.

† Travaux et Mémoires du Bureau internationale des Poids et Mésures, vol. xi, p. 84, 1894.

indirect method just described, but does not surpass it in accuracy. Everyone knows that the meter is not an exact sub-multiple of the earth's circumference, and that the determination of its exact value from the seconds pendulum is full of difficulty. It may perhaps be said that the optical method is no more absolute than the pendulum method, for no human measurements can be free from error; that there is no possibility of the destruction of the original meter and all certified copies of it; and that there is no proof or probability that molecular changes are gradually producing modifications in standards of length. Even if we should grant that for all practical purposes the labor of determining the meter in terms of an unchanging optical standard has been unnecessary, the achievement is a signal scientific triumph that ranks with the brilliant work of Arago, Fresnel and Regnault. In preparation for it much new truth has been elicited, and light waves have been shown to carry possibilities of application that Fresnel never suspected.

The physicist is nearly powerless without the aid of those who possess the highest order of mechanical skill. The interferential comparer could never have been utilized for such work as Michelson has done with it had not Brashear made its optical parts with such an approach to perfection that no error so great as one-twentieth of a wave length could be found upon the reflecting surfaces.* In the conception, mechanical design, and execution, the entire work has been distinctively American.

The interferential refractometer has been used with much skill by Hallwachs† for comparing the variation of refractive index of dilute solutions with variation of concentration. The fact of solution brings about a change of molecular constitution, affecting both the electric conductivity and the refractive index; and the changes in optical density are measurable in terms of the number of interference fringes which cross the field of view for a given variation of dilution.

Luminescence.

While all work on the visible spectrum is confessedly optical, we can no longer make an arbitrary division point and declare that one part of the spectrum belongs to the domain of optics and the other not. Since the days of Brewster and the elder Becquerel fluorescent solutions have enabled us to bring within the domain of optics many wave lengths that were previously invisible. Stokes's explanation of this as a degradation of

* Travaux et Mémoires du Bureau internationale des Poids et Mésures, vol. xi, p. 5, 1895.

† Wiedemann's Annalen, xlvii, p. 380, and liii, p. 1.

energy, quite analogous to the radiation of heat from a surface on which sunlight is shining, has been generally accepted. But whether the phenomena of fluorescence and phosphorescence are in general physical or chemical has for the most part remained unknown or at least very uncertain. E. Wiedemann, who suggested the term luminescence to include all such phenomena, has within the present year* published in conjunction with Schmidt a part of the outcome of an extended investigation undertaken with a view of clearing up these uncertainties. He has shown that it is often possible to distinguish between cases in which the emission of light springs from physical processes and those in which it is due to chemical action, or at least invariably accompanied by this. We have here, as in photography, a transformation of radiant into chemical energy, to which is superadded the re-transformation of chemical into radiant energy of longer period, and this either at the same time or long after the action of the exciting rays. Indeed between this process and that of photography in colors, the analogy is quite striking. What has generally been called phosphorescence is well known to be the effect of oxidation in the case of phosphorus itself, and in that of decaying wood or other organic matter which under certain conditions shines in the dark. Wiedemann has shown that the shining of Balmain's luminous paint, and generally of the sulphides of the alkaline earths, is accompanied with chemical action. A long period of luminosity after the removal of the source renders highly probable the existence of what he now calls chemi-luminescence. A large number of substances, both inorganic and organic, have been examined both by direct action of light and by the action of kathode rays in a controllable vacuum tube through which sparks from a powerful electrical influence machine were passed. Careful examination with appropriate reagents before and after exposure was sufficient to determine whether any chemical change had been produced. Thus the neutral chlorides of sodium and potassium, after being rendered luminous by action of kathode rays, were thereby reduced to the condition of subchloride so as to give a distinctly alkaline reaction. Many substances, moreover, which manifest no luminescence at ordinary temperatures after exposure, or which do so for only a short time, become distinctly luminescent when warmed. This striking phenomenon is sufficient to warrant the use of a special name, thermo-luminescence Among such substances may be named the well-known sulphides of the alkaline earths, the haloid salts of the alkali metals, a series of salts of the zinc and alkaline earth groups, various compounds with aluminum,

* Wiedemann's Annalen, April, 1895, p. 604.

and various kinds of glass. Some of these after exposure give intense colors when heated, even after the lapse of days or weeks. That the vibratory motion corresponding to the absorption of luminous energy should maintain itself for so long a time as a mere physical process is highly improbable if not unparalleled. That it should become locked up, to be subsequently evoked by warming, certainly indicates the storing of chemical energy, just as the storage battery constitutes a chemical accumulator of electrical energy. Other indications that luminescence is as much a chemical as a physical phenomenon are found in the fact that the sudden solution of certain substances is accompanied by the manifestation of light, if they have been previously subjected to luminous radiation, but not otherwise; that alteration of color is brought about by such exposure; and that friction or crushing may cause momentary shining in such bodies as sugar. There is no conclusive direct evidence thus far that such luminescence as vanishes instantly upon the withdrawal of light is accompanied by chemical action. But Becquerel demonstrated long ago with his phosphoroscope that there is a measurable duration of luminous effect when to the unaided eye the disappearance seems instantaneous.* Wiedemann now shows that when this duration is considerable there is generally chemical change. Since duration is only a relative term, it seems highly probable that even cases of instantaneous luminescence, commonly called fluorescence, are accompanied with chemical action on a very minute scale, and that all luminescence is therefore jointly physical and chemical in character. We have thus color evoked by the direct action of light, which disturbs the atomic equilibrium that existed before exposure, and the manifestation of such color continues only until the cessation of the chemical action thus brought into play.

The influence of very low temperature upon luminescence and photographic action has been studied by Dewar.† The effect of light upon a photographic plate at the temperature of liquid air, $-180°$ C, is reduced to only a fifth of what it is at ordinary temperature; and at $-200°$ the reduction is still greater, while all other kinds of chemical action cease. In like manner, at $-80°$ calcium sulphide ceases to be luminescent; but, if illuminated at this low temperature and then warmed, it gives out light. At the temperature of liquid air many substances manifest luminescence which ordinarily seem almost incapable of it; such are gelatine, ivory, and even pure water. A crystal of ammonium platinocyanide, on the other hand, when immersed in liquid air and illuminated by the electric

* Becquerel, Comptes Rendus, xcvi, 121.
† Chemical News, lxx, p. 252, 1894.

light, shines faintly when this is withdrawn. If now the liquid air be poured off so that the crystal rises rapidly in temperature, it glows brightly.

Luminescence and Photography.

Photography, like luminescence, is a manifestation of the transformation of energy, most frequently of initial short wave length. The production of color by photography is nothing new. It was noticed by Seebeck nearly a century ago that silver chloride becomes tinted by exposure to ordinary light, with accompanying chemical change; that if then subjected a long time to red light it assumes a dull red hue, or a dull bluish hue if held in blue light. It is likewise possible by proper selection of luminescent salts to produce a selected series of tints during and after exposure to those rays which are most effective in photography. But such colors cannot be made fixed and permanent. The problem of securing on the photographic plate a faithful and lasting reproduction of the various tints of a spectrum thrown upon it, has baffled most of those who grappled with this subject. That it has been fully and quite satisfactorily solved cannot yet be affirmed, but the last few years have brought a much nearer approach to success than an equal number of decades previously. Viewed from the scientific standpoint, the goal has certainly been touched, even if commercial demands are still made in vain.

Stationary Light Waves.

Two quite different methods are to be considered in tracing the recent development of this interesting application of optical principles. The first is originally due to Becquerel,* but lately in the hands of Lippman it has been improved and brought much nearer to success than by its originator. It depends upon the production of stationary waves of light. Everyone is familiar with the formation of stationary waves upon an elastic stretched cord, and with the acoustic exhibition of stationary air waves in a closed tube by Kundt's method of light powders. That similar loops and nodes must be produced under proper conditions by interference of waves of light would appear obviously possible; and so long ago as 1868 Dr. Zenker† of Berlin explained the photographic reproduction of color, so far as it had then been accomplished, by reference to stationary light waves. But no definite proof of their production had been brought forward. A few years ago Hertz demonstrated objectively the electro-magnetic waves whose

* Edmond Becquerel, Ann. de Chimie et de Physique, III, xxii, p. 451, 1848.
† Zenker's Lehrbuch der Photochromie, Berlin, 1868.

existence had been foretold by Maxwell's genius; and with suitable apparatus stationary electric waves are now almost as readily made evident as are those of sound. Hertz's brilliant success stimulated his fellow countryman, Otto Wiener, to undertake the apparently hopeless task of producing and studying stationary light waves. Wiener's admirable work* excited great interest on the continent of Europe, but it has been singularly neglected in England and America. It is worth much more than a passing notice.

Assume a plane silvered mirror upon which a bundle of rays of monochromatic light falls normally so as to be reflected back upon its own path. The superposition of reflected and direct waves causes a system of stationary waves, but under ordinary conditions these are wholly imperceptible. The nodes are formed upon a series of planes obviously parallel to the reflecting plane at successive distances of a half wave length. If now we consider a plane oblique to the mirror, it will cut these successive nodal planes in parallel lines whose distance apart will be greater in proportion as the oblique plane approaches parallellism to the mirror. Although a half wave length of violet light is only $\frac{1}{5000}$th of a millimeter, it is easy to conceive of the cutting plane forming so small an angle with the mirror that the distance between the parallel nodal lines shall be a thousand times a half wave length. Such would be the case if the inclination of the cutting plane is reduced to a little less than four minutes of arc. The nodal lines would then be $\frac{1}{5}$th millimeter apart, and readily capable of resolution if their presence can be manifested at all. Imagine a very thin transparent photographic film to be stretched along the oblique cutting plane, and developed after exposure to violet light as nearly monochromatic as possible. Then the developed negative should present a succession of parallel clear and dark lines, corresponding to nodal and anti-nodal bands along the oblique plane, the photographic effect being annihilated along an optical nodal line.

The realization of a photographic film thin enough for such an experiment is quite conceivable when we remember that under the hammer gold is beaten into leaves so delicate that 8000 of them would be required to make a pile one millimeter thick. By electro-chemical deposit Outerbridge† has made films of gold whose thickness is only $\frac{1}{100000}$th of a millimeter, or $\frac{1}{60}$th of a wave length of sodium light. Wiener obtained a perfectly transparent silver chloride film of collodion, whose thickness was about $\frac{1}{30}$th of a wave length of sodium light. This was formed on a plate of glass and inclined at a very

* O. Wiener. Wiedemann's Annalen, xl, p. 203, 1890.
† Journal of the Franklin Institute, vol. ciii, p. 284, 1877.

small angle to a plane silvered mirror which served as reflector. From an electric arc lamp the light was sent through an appropriate slit and prism, so that a selected spectral band of violet fell normally on the prepared plate in the dark room. The developed negative presented the alternate bands, in perfectly regular order more than a half-millimeter apart. Various tests were applied to guard against error in interpretation, and the existence of such stationary waves was proved beyond all doubt.

These waves, moreover, when polarized light was employed, furnished the means of determining the direction of vibration with relation to the plane in which the light is most copiously reflected when incident at the polarizing angle, and thus of subjecting to experiment the question as to whether the plane of vibration is coincident with this plane of polarization or is perpendicular to it. The former of these views was held by Neumann and MacCullagh, the latter by Fresnel. Let a beam of polarized light fall upon the mirror at an angle of about 45°. If the vibrations in the incident beam are parallel to the mirror, and hence perpendicular to the plane of polarization, those of the reflected and incident beams will be parallel to each other and hence capable of interference. But if the vibrations of the incident beam are in a plane identical with that of incidence, and hence in the plane of polarization, the vibrations of incident and reflected beams are in mutually perpendicular planes and hence cannot interfere. Wiener obtained interference fringes when the light was polarized in the plane of incidence, while that polarized in the plane perpendicular to this gave no trace of interference. The theory of Fresnel was thus confirmed experimentally. Again, the familiar phenomena of Newton's rings show us that on changing media there is a change of phase of the incident light, else the central spot where the two surfaces come into optical contact would be white instead of black. But there has been difference of opinion as to whether this change of phase occurs at the upper surface of the air film, where the light passes from glass to less dense air or at the lower surface where it passes from air to more dense glass. In the latter event there should be a node at the reflecting surface. Replacing the silvered plane surface by a lens in contact with the photographic film, Wiener obtained circular fringes with no photographic action at the center, showing the nodal point to be at the point of contact, and thus again confirming the theory of Fresnel.

[To be continued.]

ART. XXX.—*The Quantitative Determination of Perchlorates;* by D. ALBERT KREIDER.

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

THE method usually employed for the quantitative determination of perchlorates, by igniting to the chloride and weighing the halogen as the silver salt, is indirect and subject to error, especially as my experience proved, where the free acid is to be determined and where, consequently, an alkali which is apt to contain chloride is used to form the salt for the ignition. To purify the salt for this method only adds to the complication, and therefore a more satisfactory process was sought. In a recent article* from this laboratory by Professor Gooch and myself, a method for the detection of alkaline perchlorates associated with chlorides, chlorates and nitrates was detailed, with mention of certain efforts towards a quantitative determination. As throwing light upon the peculiar properties of perchlorates, and as an introduction to the satisfactory method which I have finally developed, some of the results of these earlier efforts will here be given.

In studying the properties of perchloric acid in the form of its potassium salt, we found that when treated with potassium iodide in the presence of boiling phosphoric acid, no reduction of the perchlorate is effected; unless indeed, the boiling be continued till the temperature rises to 215° to 220° C, where the meta-phosphoric acid begins to form. But when the meta-phosphoric acid (made by heating the syrupy ortho-acid to 360° C) is directly applied in the presence of potassium iodide and kept at a temperature of about 200° C, iodine is copiously evolved. To test this reaction quantitatively a number of experiments were made in an apparatus consisting of a retort, into the tubulature of which a glass tube was carefully ground and prolonged so as to reach to the bottom of the bulb and serve for the passage of a current of carbon dioxide, used to expel the air and carry the iodine into the receiver. The neck of the retort was bent so as to reach to the bottom of an Erlenmeyer receiving vessel, containing a solution of potassium iodide, which was trapped by a side-necked test tube. After introducing the perchlorate with the iodide and meta-phosphoric acid, all air was expelled by carbon dioxide and heat applied. The iodine collected in the receiver was titrated with decinormal thiosulfate, from which the perchlorate was calculated.

Table I gives the results of several experiments performed in this way, which prove that even with a large excess of potas-

* This Journal, vol. xlviii, p. 38.

sium iodide the perchlorate is so slowly reduced that the hydriodic acid escapes before the reduction is completed. In order to delay the distillation of hydriodic acid until the perchlorate had been completely reduced, the potassium iodide of experiment (3) was introduced in a short tube sealed at one end, so that the meta-phosphoric acid could attack it only slowly, and the heat quickly raised to about 300° C, but evidently without advantage. In experiment (4) the iodide was introduced in the same way, but the heat was applied gradually and more moderately, with considerably improved results.

TABLE I.

	$KClO_4$ taken. grms.	$HOPO_2$ used. cm^3	KI used. grms.	$KClO_4$ found. grms.	Error. grms.
(1)	0·1000	15	5·	0·0741	0·0259—
(2)	0·1000	17	10·	0·0844	0·0156—
(3)	0·1000	15	5·	0·0364	0·0636—
(4)	0·1000	15	5·	0·0977	0·0023—

A complete reduction of the perchlorate evidently necessitated the means of introducing the iodide in sufficient quantity and at will.

For this purpose the tube serving for the introduction of carbon dioxide was enlarged so as to hold the iodide, which could then be added to the solution at any time by a manipulation of the rubber conducting-tube for carbon dioxide, which would draw the acid up to the iodide and, retreating, would carry back an easily regulated quantity of the latter.

TABLE II.

	$KClO_4$ taken. grms.	KI used. grms.	$KClO_4$ found. grms.	Error. grms.
(5)	0·1000	5·	0·0984	0·0016—
(6)	0·1000	3·	0·0924	0·0076—
(7)	0·0500	2·	0·0508	0·0008+
(8)	0·0500	2·	0·0479	0·0021—
(9)	0·1000	7·	0·0977	0·0023—
(10)	0·1000	3·	0·0925	0·0075—
(11)	0·1000	3·	0·0999	0·0001—
(12)	0·1000	2·	0·0994	0·0006—
(13)	0·1000	4·	0·0966	0·0034—

Table II gives a number of results obtained in this way. Experiments (10), (11) and (12) differed from the others only in the employment of a bulb pipette instead of the retort: one end being bent so as to reach to the receiver and the other cut off rather short with a tube ground into it, serving the same purpose of conducting carbon dioxide and holding potassium iodide; the greater inclination of the potassium iodide tube made possible by this change appearing to offer advantages for the more gradual and regular introduction of the iodide. The amount of meta-phosphoric acid used was in all cases 15 cm^3. In experiment (13) heat was applied by means of a bath kept at 230°.

While several of these determinations gave only admissible errors, the irregularity of the remainder and the uncertainty in striking just the proper conditions for good results, proved the method worthless at least in that shape.

The experiments of Table III record the results of adding the acid drop by drop to an intimate mixture of the powdered perchlorate and iodide kept hot.

TABLE III.

	$KClO_4$ taken. grms.	KI taken. grms.	$KClO_4$ found. grms.	Error. grms.
(14)	0·1000	4·	0·1036	0·0036+
(15)	0·0500	2·	0·0502	0·0002+
(16)	0·0500	3·	0·0515	0·0015+

The high results of this table doubtless point to the dissociation of hydriodic acid or to the partial reduction of the meta-phosphoric acid in the temperature, which would naturally rise higher where so small an amount of liquid was present. But when the meta-phosphoric acid was there in greater amount the distillation of the hydriodic acid before the complete reduction of the perchlorate could not be prevented.

An ordinary mixture having thus been found insufficient to hold the hydriodic acid to the reduction of perchlorates, a search for some compound in which the perchlorate could be fused with an excess of potassium iodide and the mixture thus obtained subjected to the action of meta-phosphoric acid resulted in the employment of zinc chloride. Anhydrous zinc chloride was found to fuse at about 200° C. The perchlorate and iodide could be added to this fusion and the whole melted, thoroughly diffused and cooled without any evolution of iodine. This mass, when treated with meta-phosphoric acid in the apparatus previously employed, melted gradually with a copious evolution of iodine. Table IV shows the quantitative action. The amount of zinc chloride used was roughly taken about equal to that of the iodide.

TABLE IV.

	$KClO_4$ taken. grms.	KI taken. grms.	$KClO_4$ found. grms.	Error. grms.
(17)	0·0500	5·	0·0552	0·0052+
(18)	0·0000	5·	0·0044	0·0044+
(19)	0·0000	4·	0·0057	0·0057+

In (19) a mixture of cadmium iodide and potassium iodide taken in the proportion of their molecular weights was substituted for the zinc chloride. The known salt corresponding to the formula $CdI_2 . 2KI + 2H_2O$ was not so convenient because of its high melting point —230° C; but when the two iodides are taken in the proportion of their molecular weights, the mixture fuses at about 200° C. Although this mass after fusion was more easily soluble than the zinc residue, the blank determination revealed a source of error equally disparaging.

Gaseous hydriodic acid passed into a mixture of the perchlorate and meta-phosphoric acid at a temperature between 200° and 300° C, was markedly less effective than the generation of the acid on the spot; and the distilling of the perchloric acid by meta-phosphoric acid into a receiver of potassium iodide yielded only a trifling amount of iodine, while the passage of hydriodic acid over the fusing perchlorate in a short combustion tube was precluded by the high melting point of the perchlorate endangering the dissociation of the halogen.

The invariably high results obtained by the use of metaphosphoric acid in all those experiments in which there was a reasonable assurance that the hydriodic acid was held till the perchlorate was completely broken up—experiments (13), (14), (15), (17), (18) and (19)—indicated either a dissociation of hydriodic acid or a partial reduction of the meta-phosphoric acid. Of the latter cause there were some grounds for suspicion, but as its determination led too far from the object of the investigation, the use of phosphoric acid was abandoned. So far as our experience extended there remained then nothing among the reagents of the wet methods which was sufficiently active and stable enough to warrant its application. Fusion alone seemed capable of extracting the oxygen from the perchlorate. A number of preliminary tests were therefore made on certain salts of the halogens, in the hope of finding one which would be acted upon by the oxygen of the perchlorate with the liberation of the halogen, which latter could be collected in a receiver of potassium iodide and titrated with thiosulfate.

The double chloride of aluminum and sodium, $Al_2Cl_6 . {}_2NaCl$, melts at about 200° C, and was in other respects desirable. When fused with potassium perchlorate, chlorine was copiously evolved. The action of air on the fusion also liberated chlorine; but blank determinations in an atmosphere of carbon dioxide proved that under these conditions not a trace of chlorine was evolved. The apparatus employed for a quantitative test of this reaction on perchlorates consisted of a small distilling flask of about 20 cm^3 capacity, into the tubulature of which was ground a piece of glass tubing reaching well into the bulb and serving for the passage of carbon dioxide. The side neck was sealed to one of two connected Will & Varrentrap absorption bulbs containing a solution of potassium iodide to receive the chlorine. After weighing the perchlorate into the flask and adding a sufficient amount of the powdered double chloride, all air was expelled by carbon dioxide and heat applied till the fused mass was raised considerably above the melting point and kept there for some time. Table V contains the results of a number of experiments performed in this way.

TABLE V.

	$KClO_4$ taken. grms.	$KClO_4$ found. grms.	Error. grms.
(20)	0·0500	0·0438	0·0062—
(21)	0·0500	0·0482	0·0018—
(22)	0·0500	0·0460	0·0040—
(23)	0·1193	0·1175	0·0018—
(24)	0·1039	0·1018	0·0021—
(25)	0·0500	0·0477	0·0023—
(26)	0·1003	0·0946	0·0057—

These results came so close to being quantitative that a little help in the form of free acid seemed all that would be necessary to complete the reaction. But the addition of meta-phosphoric acid to the cooled mass after the fusion in (22) gave no additional evolution of iodine. In (25) gaseous hydrochloric acid was passed in with the carbon dioxide in the hope of meeting the deficiency, but was evidently no improvement. One test in which meta-phosphoric acid was added to the fusion, resulted in such a violent evolution of hydrochloric acid that the whole contents of the flask was forced into the receivers.

The results obtained by substituting (*a*) cadmium iodide and (*b*) anhydrous zinc chloride for the double chloride of aluminum and sodium are recorded in Table VI. In (27) (28) and (29) cadmium iodide was used and the iodine obtained by treating the cooled mass with dilute sulfuric acid (1 : 6) and potassium iodide for the reduction of cadmium oxide in each case added to that of the receivers. In (30) and (31), zinc chloride was employed, but no additional iodine was obtained by treatment with sulfuric acid and potassium iodide.

TABLE VI.

	$KClO_4$ taken. grms.	$KClO_4$ found. grms.	Error. grms.
(27)	0·1000	0·0745	0·0255—
(28)	0·1000	0·0693	0·0307—
(29)	0·1000	0·0679	0·0321—
(30)	0·1000	0·0245	0·0755—
(31)	0·1653	0·1156	0·0497—

In (31) manganous chloride was mixed with the zinc chloride in the proportion of 2 : 1 in the hope of strengthening the reducing action. The black color of the fusion revealed the formation of manganese dioxide, the equivalent of which in iodine was obtained by dissolving the cooled mass in water, adding dilute sulfuric acid and a known amount of ammonium oxalate, titrating the residual oxalate with permanganate solution and calculating the difference into iodine which was added to that obtained by tritrating the contents of the receivers. This addition of manganous chloride to the fusion of the double chloride of aluminum and sodium was forestalled by the necessity of subsequent solution of the fused mass, which contained an impurity in the form of ferric chloride, which of course in the presence of hydriodic acid would be reduced with evolution of iodine.

It was evident from all these results, as well as those obtained by use of other salts not necessary here to record, that fusion with salts of the halogens would not suffice for the complete reduction of perchlorates, or at least would not quantitatively register the result in the halogen liberated. The well known reaction of the oxidation of chromic oxide by fusion with alkaline carbonates was also applied. A combustion tube was used for the fusion, sealed at one end and, after the insertion of chromic oxide with a mixture of sodium and potassium carbonate, restricted at the other end so as to admit a small tube by which carbon dioxide could be entered to expel all air. A blank determination gave no chromate. When 0·1 grm. potassium perchlorate was mixed with an excess of chromic oxide and alkaline carbonate and carefully fused from the top and kept in a state of fusion throughout its length in an atmosphere of carbon dioxide, the fusion subsequently dissolved in water and the chromic oxide removed by filtration, an amount of chromate was obtained on titration equivalent to only 0·0347 grms. of potassium perchlorate.

Powerful as were the various reducing agents employed for the decomposition of perchlorates, they were all successfully resisted, even at the highest permissible temperatures; and if anything is proved by the results of the experiments above recorded, it is that perchloric acid is, in combination, one of the most powerful and stable acids known. Certainly nothing short of high temperatures is capable of overcoming the remarkable affinity by which the oxygen of this acid is held by its salts. At about 400° C the potassium salt fuses with evolution of oxygen, and as a last resort an attempt was made to have the oxygen thus obtained act on hydriodic acid by intervention of nitric oxide. It was the application of this principle that led to the final method, which both as to manipulation and results leaves nothing to be desired.

The method is essentially the collection of the oxygen of the perchlorate; its subsequent passage into an atmosphere of nitric oxide over a strong solution of hydriodic acid, and the titration of the iodine thus liberated with decinormal arsenic in alkaline solution. The apparatus employed consisted of a piece of combustion tubing 10 or 12cm. in length, drawn out at one end to a narrow restriction of length sufficient to prevent the action of the heat on the rubber tubing connecting it with a receiver filled with caustic potash. The tube must of course be cleansed from all organic materials and cannot be safely employed for more than three fusions. A platinum boat (porcelain fusing to the glass) served for the introduction of the perchlorate to the combustion tube, and in order to bring about a gradual and quiet fusion the perchlorate was covered with a small amount of an equal mixture of dry and pure sodium and potassium carbonates. Carbon dioxide obtained from a Kipp generator, the acid and marble of which had been previously boiled to expel all traces of air, and to which a little cuprous chloride had been added to take up any oxygen which might be absorbed from the top, was passed through a solution of iodine in potassium iodide to remove a trace of reducing agent which it was found to contain, and then washed with potassium iodide solution before being used. The larger end of the combustion tube was closed with a perforated rubber stopper by which it was attached to the carbon dioxide apparatus. After all air had been expelled from the inclined tube by means of carbon dioxide, it was connected by a short glass capillary and vacuum tubing joints with the receiver, into which about 50 to 100 cm^3 of gas was allowed to flow before the combustion was started and thus when only a small but inevitable bubble remained insoluble in the caustic potash the complete removal of air was indicated. To prevent the caustic potash from drawing into the combustion tube, a little more carbon dioxide was entered, when the current was closed by a pinch cock on the side towards the generator and heat gradually applied—with perforated asbestos cards on either side to check its radiation to the rubber—and continued till the contents of the platinum boat was in a quiet state of fusion. By lowering one of the bulbs of the caustic potash receiver, the oxygen was evolved under slightly diminished pressure and thus the chances of loss decreased. Then the tube was again inclined and carefully annealed while a current of carbon dioxide carried all of the oxygen into the receiver, which was then closed and disconnected. As a receiver, two leveling bottles were found vastly superior to a burette; the glass stop-cocks of the latter giving continual trouble by the action of the caustic potash upon them. I found that gas could be removed from a leveling bottle without the loss of a particle. if a perforated rubber stopper containing a capillary tube, which reached just even with the narrower end, was by a slight twist forced tightly into the neck of the bottle. In this way a regular funnel shape was obtained and the oxygen could be withdrawn without the slightest bubble remaining. The other end of the capillary was fitted with a short piece of vacuum tubing and screw pinch-cock, which worked incomparably better than the glass stop-cocks. The larger capacity of the bottle was favorable for the volume of oxygen evolved and its shape offered superior facilities for the absorption of carbon dioxide.

For the action of the oxygen on hydriodic acid through the medium of nitric oxide, various devices were tested. Passing it directly into nitric oxide over a solution of hydriodic acid in a Hempel absorption bulb was found to yield low and irregular results, due doubtless to the formation of nitric acid wherever the nitrogen tri-oxide, or per-oxide as the case might be, met water in which the hydriodic acid had been exhausted; as, for instance, along the sides of the bulb. Shaking the bulb as the oxygen entered improved the action, but was not sufficient. It was evident that for a complete action, the hydriodic acid solution must be strong and on the spot where the higher oxide of nitrogen is formed; and to avoid excessive use of the iodide the volume of water must be kept at a minimum. Letting a solution of hydriodic acid saturated with nitric oxide flow slowly into the Hempel bulb in which the oxygen was contained over water, was so slow in its action that a quantitative test was not applied. The plan of mixing the two gases under a strong solution of hydriodic acid by means of two capillaries with adjoining openings, was more effective and rapid, but it was wasteful of nitric oxide, which for complete action would have to flow in continual excess, whereas only a small amount of nitric oxide would really be necessary for the reaction, since it could be used and reused for the transfer of free oxygen to the hydriodic acid. A simple piece of apparatus was then devised to meet all these conditions. It consisted of a 100 cm^3 bulb pipette, cut off short at either ends with stop-cocks sealed to both stubs. The delivery tube of one of the stop-cocks was cut off rather short after being tapered and restricted so as to hold a rubber connecter tightly, while the other delivery tube was left long enough to reach to the bottom of an Erlenmeyer beaker. It is a convenience to have these conducting tubes 3 or 4^{mm} in diameter rather than capillaries, since for the various connections all air may be expelled from them by displacement with water, which is easily accomplished by using a long nozzled wash bottle. By attaching the shorter end to an ordinary water pump the air was partially exhausted when the stop-cock was closed and the bulb disconnected and lowered into a solution of hydriodic acid of approximately known strength, obtained by acidifying potassium iodide with hydrochloric acid. When the desired amount of liquid had been drawn in, the stop-cock was closed and connection made with the carbon dioxide, by which all residual air was expelled. Then the bulb, held so as to prevent the escape of the liquid, was again exhausted by attachment to the pump. After about $10cm^3$ of nitric oxide were admitted, attachment was made to the receiver containing the oxygen, which was allowed to enter slowly under the diminished pressure within the bulb, and with continous shaking of the contents of the latter. The latter precaution is essential to the process, as otherwise there is imperfect distribution of the hydriodic acid and the danger of forming nitric acid. But when the solution of hydriodic acid is kept strong and the shaking continued while the oxygen enters and for a minute or two afterward, depending on the rapidity with which it was admitted, the oxygen may be allowed to enter quite rapidly without any fear of imperfect action. The oxygen being immediately utilized, the partial vacuum is effected only by the heat generated, which is scarcely noticeable. As a rule the bulb and contents were well cooled before the oxygen was admitted.

It is necessary of course to prevent the access of air into the bulb until the acid has been neutralized, to accomplish which, without loss of iodine, potassium carbonate must be used, at least for the end reaction. To remove the contents of the bulb for titration, the two delivery tubes were filled with water, after removing all sodium hydrate from the one through which the oxygen was entered; the shorter end connected to a supported funnel containing a saturated solution of bi-carbonate and the longer one inserted into an Erlenmeyer beaker containing a saturated solution of bicarbonate in amount sufficient—as previously determined—to neutralize all the acid taken. By opening that stop-cock the delivery tube of which reaches below the liquid in the beaker, the bi-carbonate is drawn in by the partial vacuum, with liberation of sufficient carbon dioxide to force all the liquid out. Owing to the consequent effervescence as the liquid gains its exit, the flow must be regulated by the stop-cock so as to avoid loss of iodine, which is prevented by inclining the beaker so that the bubbles strike against its side instead of being allowed to splatter out of the opening. To wash out the bulb, it is raised almost horizontally, so as to prevent the liquid from running through, and the upper stop-cock opened to admit the bicarbonate from the funnel. Both stop-cocks are then closed, the bulb disconnected and agitated, after which it may be washed with water and admission of air without any fear of liberating more iodine. An excess of decinormal arsenic is then run into the beaker and titrated back with iodine.

The many little precautions essential to note for the manipulation are in practice accomplished in a few moments. Seven determinations (not counting one which was all but completed, when an accident terminated it) from the weighing of the perchlorate to the titration, were completed in one day; and the results recorded in Table VII show with what reliability. In making the series of experiments recorded in Table VII, it was found expeditious to have a partial vacuum always accessible instead of waiting each time for the exhaustion. This was obtained by connecting a vacuum flask with a two-holed stopper to an ordinary water pump, and having the other perforation fitted with a glass stop-cock. The bulb was merely attached to the vacuum by a piece of rubber tubing; the stopcock opened and closed immediately, by which means a sufficient exhaustion was secured. To have the vacuum always in readiness a valve, described in a former article of mine,* was placed in the rubber leading to the pump, and when lubricated with glycerine would hold the vacuum perfectly. The nitric oxide employed was supplied by a Kipp generator, in which globules of copper were acted upon by nitric acid mixed with an equal volume of water. To purify the gas evolved from any possible trace of the higher oxides, it was first passed through an acidified solution of potassium iodide in Geissler absorption bulbs, the latter one of the three being alkaline. This method of generating nitric oxide in a Kipp generator (preferably charged with dilute acid and kept warm by immersion in hot water when large amounts of the gas are to be drawn at frequent intervals) was devised by Professor Gooch, by whom it has been employed for some time. It is automatic and eminently satisfactory. The hydriodic acid was obtained from a solution of potassium iodide containing one gram in ten cubic centimeters; thirty cubic centimeters being taken for each experiment, and acidified with the required amount of hydrochloric acid immediately before using, so as to prevent any liberation of iodine by the oxygen of the air. In those experiments in which more than this amount of potassium iodide was employed a correspondingly stronger solution of the latter was used, so that the volume of water was in all cases thirty cubic centimeters.

* This Journal, l, p. 132.

TABLE VII.

	$KClO_4$ taken. grms.	KI taken. grms.	HCl taken. cm^3	$KClO_4$ found. grms.	Error. grms.
(32)	0·1000	3·	3·	0·1003	0·0003+
(33)	0·1000	3·	3·	0·1006	0·0006+
(34)	0·1000	3·	3·	0·0998	0·0002−
(35)	0·1000	4·	4·	0·1003	0·0003+
(36)	0·1000	3·	3·	0·1003	0·0003+
(37)	0·1000	3·	4·	0·0999	0·0001−
(38)	0·1000	3·	3·	0·1003	0·0003+
(39)	0·1000	3·	4·	0·1001	0·0001+
(40)	0·1500	3·	4·	0·1493	0·0007−
(41)	0·2000	6·	6·	0·1999	0·0001−
(42)	0·2000	6·	6·	0·2009	0·0009+
(43)	0·0100	3·	3·	0·0099	0·0001−
(44)	0·0100	3·	3·	0·0100	0·0000
(45)	0·0000	3·	3·	0·0003	0·0003+

In experiments (40) and (43) during a momentary pause in the shaking of the bulb during the absorption, a black deposit of iodine began to form on the glass, and the result proves the importance of the precaution previously given, that the hydriodic acid should be kept hurling about the bulb until the action is completed. The blank determination (45) shows a constant error of the process which is about 0·0003+ and will be seen to correspond very closely to the average error of the determination. The cause is doubtless to be attributed to the trace of air which may remain in the bulb or be dissolved in the water. Since it can easily be determined and the correction made, it does not detract in any degree from the reliability of the determination.

To determine perchloric acid associated with other oxidizing agents it is only necessary to treat the mixture with the reagents which this investigation and the one referred to has shown to accomplish the reduction without affecting the perchlorate; subsequently evaporating to dryness and treating the residue according to the above process, viz., by heating in a current of carbon dioxide until decomposition is complete; collecting the oxygen over caustic potash; allowing it to enter a partial vacuum bulb containing a solution of potassium iodide, hydrochloric acid and nitric oxide under constant agitation; and determining by means of a standard solution of arsenic the amount of iodine set free. The method is proving applicable also to the determination of oxygen in air or wherever it may be obtained in the free state, unless diluted to such an extent with other gases that the vacuum would be filled by the diluent; even this contingency could be met by enlargement of the absorption bulb.

Many helpful suggestions are to be credited to Professor Gooch.

Art. XXXI.—*On an Occurrence of Copper in Western Idaho;* by R. L. Packard.

The Seven Devils is the name (of rough frontier origin) given to a range or group of mountains on the extreme western border of Idaho where that state is separated from Oregon by the Snake River on its northerly course to empty into the Columbia. The river runs through a deep gorge as it passes the mountains, the east side of which is formed by members of the Seven Devils group, while the western side or wall, which is very precipitous, is formed by a range on the Oregon side called the Eagle Mountains. The few sharply pointed, precipitous peaks which are the Seven Devils proper and have given their name to the whole group have an altitude of over seven thousand feet. They are of igneous origin and attracted the attention of prospectors many years ago, who found gold in the streams issuing from their domain and copper in the mountains adjoining them.

The only occurrence of copper of importance which has so far been exploited is found in the southern part of the range and is confined to the neighborhood of a body of whitish granitic rock of very considerable but not yet determined extent. The copper occurs as bornite and the principal mine of the locality is named the Peacock, from the nature of the ore. The igneous rock, which evidently has a genetic relation to the copper deposits, has the general appearance of a granite and has always been so called. It is grayish white in color, and in hand specimens does resemble a biotite granite without muscovite. It weathers into rounded blocks which are sometimes met with in isolated groups, and at one point on the wagon road leading up from the Snake River to the copper mines, and about a mile from the latter, the head of a small ravine is filled with bowlders of this rock several feet in diameter which give the appearance of having been purposely rolled into the place. Water runs down among these rocks at some distance out of sight.

The whitish rock, where exposed, and in the bowlders, is seen to contain areas of a darker color which vary in size from two or three inches to as many feet in diameter and impress one at first as being inclusions of some other rock.

This igneous rock, one would say, was evidently the cause, if not the source, of the copper deposits found on its contact and in veins in its substance, and it became a matter of curiosity to examine its mineralogical and chemical character. Specimens were, accordingly, procured from points about a mile and a half apart, one on the wagon road leading to the mines (at the White Monument hill), and the other at the Victoria mine on the northern limit of the mines where the mountain descends abruptly to form one side of Deep Creek cañon. The slightly darker appearance of the rock at the latter place indicates that its composition varies somewhat from point to point. It is also an assumption that the whole mass is continuous for the distance mentioned. Indeed a flow of basalt intervenes at one place, but the extent of the flow is undetermined.

The thin sections from these specimens show that the rock has the following structure and composition. The structure is that of granite. The stout, tabular, triclinic feldspars largely predominate. Many of them are turbid. Interstitial quartz is present. The ferromagnesian minerals are hypidiomorphic, green, pleochroic hornblende, and some brown biotite, also limited by the adjoining feldspars. Apatite crystals, zircons, and some isometric granules of ore were also observed. A section from one of the inclusions described above showed the same mineralogical composition as the lighter-colored rock but the structure shows cataclastic areas. Green hornblendes, with inclusions, and triclinic feldspars, appear in the midst of the comminuted crystals. The section also shows biotite, with inclusions, limited by the adjoining feldspars, and the ore particles are much more numerous than in the lighter-colored rock. Zonal structure of the feldspars was noticeable in both sections.

The rock, therefore, as shown by these sections, is a diorite. Its analysis gave:

Ignition	·90
SiO_2	53·98
Al_2O_3, Fe_2O_3	27·64
CaO	7·03
MgO	4·63
Na_2O	4·51
K_2O	1·75
	100·44

The analysis, although only partial, is sufficient to show the basic character of the rock; and the excess of soda over potash, together with the high percentage of lime, confirms the microscopical determination of the predominance of the soda-lime feldspars over orthoclase.

The specimen from the Victoria mine was taken within a foot or two of a copper vein (bornite), and the section, viewed without the analyzer, shows fissures stained bluish-green by copper solution. In the thin section brown biotite and quartz are much more abundant than in the specimens just described, but the predominating plagioclase feldspars and the fragments of green hornblende indicate the dioritic character of the rock. The biotite is seen undergoing bleaching and an alteration to a green mineral.

Diorite must also occur in the mountains north of the copper mines, for a specimen taken from a mass of rocky *débris* on the trail which passes through the Seven Devils, and perhaps eight miles from the mines, proved to be diorite when examined in thin section.

The diorite of the copper locality is bounded on its western side by a zone of a garnet-epidote rock and the bornite is found in this rock in kidneys and larger masses. At the Peacock mine the ore and garnet rock appeared to dip towards the diorite. West of the garnet rock appears an igneous rock the character of which is yet undetermined. Crystalline limestone accompanied with garnet rock crosses the diorite to the north-east at about a mile south of the Peacock mine. Mines are established at this contact also. The distance from end to end of the copper belt may be three miles or more in a direct line. The copper ore, except at the Victoria mine, is associated with the metamorphic- or metamorphosed-garnet rock, which is, in some places, more than a hundred feet thick, but at the Victoria mine the bornite occurs in a vein which is in the body of the diorite although near its contact with an eruptive rock and outside of the garnet belt.

Copper and iron (as sulphides forming bornite) are not the only metals due to the diorite. The bornite carries silver, sometimes up to twenty ounces per ton, and native gold is occasionally found in it. The gravel of the diorite is washed for gold, and a quartz vein carrying a little gold is "located" near the contact of diorite and basalt. A little galena has been noticed. It was at this place that the molybdate of lime, described as powellite,* was found four years ago.

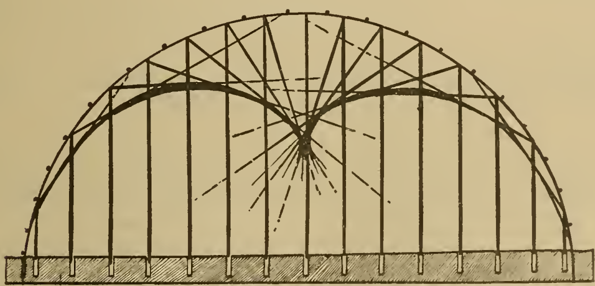
* This Journal, xli, 138, 1891.

Washington, D. C., June 19, 1895.

Art. XXXII.—*Demonstration of Caustics*; by Robert Williams Wood.

The caustic surfaces by reflection from concave mirrors can be shown geometrically to be the paths to which all the reflected rays are tangent. A simple way of demonstrating this experimentally is the following: A strip of thin steel about 16 inches long, by 1 in width, is polished on one side until it has a good mirror surface. An accurate optical surface is of course unnecessary. The curve, for example a semi-circle, whose caustic is to be shown is drawn on a piece of photographic printing paper, and pinned down onto a board with a dozen or more pins, stuck vertically through the line. The steel strip is bent into this arc, and pressed firmly against the row of pins, the ends being held in place by a couple of small nails. In front of the steel arc across the diameter is set up a strip of Bristol board with a number of vertical slits, about $\frac{1}{16}$ of an inch wide, and half an inch apart. On setting up the board in strong sun-light, in a plane pointing a little below the sun, the parallel rays passing through the slits trace their course on the paper, are reflected and trace their reflected paths also, which in the case of a semi-circular mirror will all be found to be tangent to an epicycloid. The complete curve can be traced by raising the grating for a moment or two. During the exposure it is best to bridge over the steel arc with a piece of card-board to exclude diffused daylight.

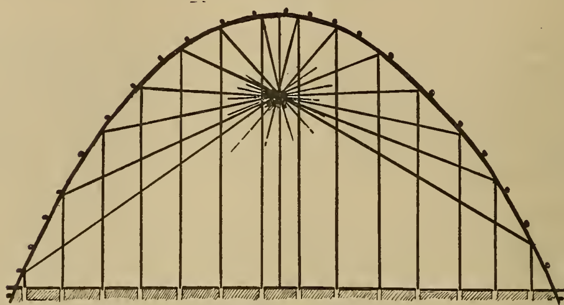
1.



Epicycloidal Caustic showing tangential rays.

The accompanying drawings (figs. 1 and 2) are copied directly from the photographic tracings, and are of course negatives, the black lines representing the paths traced by the luminous rays. It is not easy to get a parabolic surface that shall bring all the rays to a focus, each side of the curve being apt to have a focus of its own; but a little careful manipulation and changing the position of the pins a trifle, will usually bring them together. The card-board screen is shown (tipped over) in the drawing of the epicycloidal caustic.

2.



Reflection from a Parabolic Surface.

The axis of the reflecting surface must of course point directly at the sun, or rather a little below it. If the paper is fairly sensitive the exposure need not be over a minute or two, and the motion of the sun will give no trouble. If a longer exposure is necessary the mirror may be turned a trifle from time to time.

These phenomena are adapted to projection, by employing a nearly parallel beam thrown along the screen, either directly or by means of a mirror. The reflecting surface and the slits should be much larger than the ones used for photographic representation.

Berlin, Germany.

Art. XXXIII.—*The Spectrum of Helium**; by William Crookes, F.R.S.

In the Chemical News for March 29th last (vol. lxxi, p. 151) I published the results of measurements of the wave-lengths of the more prominent lines seen in the spectrum of the gas from clèveite, now identified with helium. The gas had been given to me by the discoverer, Professor Ramsay; and being from the first batch prepared, it contained other gases as impurities, such as nitrogen and aqueous vapor, both of which gave spectra interfering with the purity of the true helium spectrum. I have since, thanks to the kindness of Professors Ramsay and J. Norman Lockyer, had an opportunity of examining samples of helium from different minerals and of con-

* From an advanced proof sent by the author.

siderable purity as far as known contamination is concerned. These samples of gas were sealed in tubes of various kinds and exhausted to the most luminous point for spectrum observations. In most cases no internal electrodes were used, but the rarefied gas was illuminated solely by induction, metallic terminals being attached to the outside of the tube.* For photographic purposes, a quartz window was attached to the end of the tube, so that the spectrum of the gas could be taken "end on."

My examinations have chiefly been made on five samples of gas.

1. A sample from Professor Ramsay in March last. Prepared from clèveite.

2. A sample from Professor Ramsay in May last. Prepared from a specimen of uraninite sent to him by Dr. W. F. Hillebrand. Gas obtained by means of sulphuric acid; purified by sparking.

3. A sample from Professor Ramsay in June last. Prepared from bröggerite.

4. A sample from Professor Lockyer in July last. Prepared by a process of fractional distillation from a sample of bröggerite sent to him by Professor Brögger.

5. A sample of gas from Professor Ramsay "helium purissimum." This was obtained from mixed sources, and had been purified to the highest possible point.

In the following table the first four samples of gas will be called: 1. "clèveite, R."; 2. "uraninite, R."; 3. "bröggerite, R."; and 4. "bröggerite, L." Only the strongest of the lines, and those about which I have no doubt, are given. The wave-lengths are on Rowland's scale.

The photographs were taken on plates bent to the proper curvature for bringing the whole spectrum in accurate focus at the same time. The spectrum given by a spark between an alloy of equal atoms of mercury, cadmium, zinc, and tin, was photographed at the same time on the plate, partially overlapping the helium spectrum; suitable lines of these metals were used as standards. The measurements were taken by means of a special micrometer reading approximately to the $\frac{1}{100,000}$th inch, and with accuracy to the $\frac{1}{10,000}$th of an inch. The calculations were performed according to Sir George Stokes's formula, supplemented by an additional formula kindly supplied by Sir George Stokes, giving a correction to be applied to the approximate wave-lengths given by the first formula, and greatly increasing the accuracy of the results.

* Journal of the Institution of Electrical Engineers, Part 91, vol. xx, Inaugural Address by the President, William Crookes, F.R.S., Jan. 15th, 1891.

Wave-length.	Intensity.	
7065·5	5	A red line, seen in all the samples of gas, Young gives a chromospheric line at 7065·5.
6678·1	8	A red line, seen in all the samples of gas. Thalén gives a line at 6677 and Lockyer at 6678. Young gives a chromospheric line at 6678·3.
5876·0	30	The characteristic yellow line of helium, seen in all the samples of gas. Thalén makes it 5875·9, and Rowland 5875·98. Young gives a chromospheric line at 5876.
5062·15	3	
5047·1	5	A yellow-green line, only seen in "helium puriss." and in "bröggerite, R," and "L." Thalén gives the wave-length as 5048.
5015·9	7	A green line seen in all the samples of gas. Thalén gives the wave-length 5016. Young gives a chromospheric line at 5015·9.
4931·9	3	
4922·6	10	A green line, seen in all the samples of gas. Thalén gives the wave-length 4922. Young gives a chromospheric line at 4922·3.
4870·6	7	A green line, only seen in "uraninite, R." Young gives a chromospheric line at 4870·4.
4847·3	7	A green line, only seen in "uraninite, R." Young gives a chromospheric line at 4848·7.
4805·6	9	A green line, only seen in "uraninite, R." Young gives a chromospheric line at 4805·25.
4764·4	2	There is a hydrogen line at 4764·0.
4735·1	10	A very strong greenish blue line, only seen in "uraninite, R."
4713·4	9	A blue line, seen in all the samples of gas. Thalén's measurement is 4713·5. Young gives a chromospheric line at 4713·4
4658·5	8	A blue line, only seen in "uraninite, R."
4579·1	3	A faint blue line, seen in "uraninite, R." Lockyer gives a line at 4580, from certain minerals. I can see no traces of it in the gas from bröggerite. A hydrogen line occurs at 4580·1.
4559·4	2	Young gives a chromospheric line at 4558·9.
4544·1	5	
4520·9	3	A faint blue line, seen in "uraninite, R." Lockyer gives a line at 4522, seen in the gas from some minerals. Young gives a chromospheric line at 4522·9. It is absent in the gas from bröggerite.
4511·4	5	A blue line, seen in "uraninite, R," but not in the others. It is coincident with the strong head of a carbon band in the CO_2 and Cy spectrum.
4497·8	2	There is a hydrogen line at 4498·75.

Wave-length.	Intensity.	
4471·5	10	A very strong blue line, having a fainter line on each side, forming a close triplet. It is a prominent line in all the samples of gas examined. Young gives the wave-length 4471·8 for a line in the chromosphere, and Lockyer gives 4471 for a line in gas from bröggerite.
4435·7	9	Seen in "helium puriss."
4437·1	1	Young gives a chromospheric line at 4437·2.
4428·1	10	These two lines form a close pair. I can only see them in "uraninite, R." No trace of them can be seen in the gases from other sources. Young gives chromospheric lines at 4426·6 and 4425·6.
4424·0	10	
4399·0	10	A strong line, only seen in "uraninite, R." Absent in the gas from the other sources. Lockyer gives a line at 4398 in gas from certain minerals. Young gives a chromospheric line at 4398·9.
4386·3	6	Seen in all the samples of gas. Young gives a chromospheric line at 4385·4.
4378·8	8	These two lines form a pair seen in "uraninite, R," but entirely absent in the others.
4371·0	8	
4348·4	10	Seen in "uraninite, R." Lockyer finds a line at 4347 in the gas from certain minerals.
4333·9	10	Probably a very close double line. Seen in "uraninite, R" and "clèveite, R." Not seen in the other samples. Lockyer gives a line in the gas from certain minerals at 4338.
4298·7	6	Only seen in "uraninite, R." Young gives a chromospheric line at 4298·5.
4281·3	5	Only seen in "uraninite, R."
4271·0	5	Only seen in "uraninite, R." The strong head of a nitrogen band occurs close to the line.
4258·8	7	Seen in all the samples of gas.
4227·1	5	Only seen in "uraninite, R." Young gives a chromospheric line at 4226·89.
4198·6	9	These three lines form a prominent group in "uraninite, R," they are very faint in "clèveite, R," and in "bröggerite, L," but are not seen in "bröggerite, R."
4189·9	9	
4181·5	9	
4178·1	1	An extremely faint line. Lockyer gives a line at 4177, seen in the gas from certain minerals, and Young gives a chromospheric line at 4179·5.
4169·4	6	Seen in "helium puriss."
4157·6	8	A strong line in "uraninite, R," very faint in bröggerite, R," and "L," not seen in "clèveite, R."
4143·9	7	Strong in "clèveite, R," in "helium puriss.," and in "bröggerite, L." It is faint in "uraninite, R," and not seen in "bröggerite, R." Lockyer gives a line at 4145 in gas from certain minerals.

Wave-length.	Intensity.	
4121·3	7	Present in all the gases except "clèveite, R."
4044·3	9	Present in "uraninite, R," and "clèveite, R." Absent in the others.
4026·1 4024·15	10 6	These lines form a very close pair, seen in all the samples of gas, except "bröggerite, R." Lockyer find a line in bröggerite gas at 4026·5.
4012·9	7	Seen in all the samples of gas.
4009·2	7	Seen in "helium puriss."
3964·8	10	The center line of a dense triplet. Only seen in "clèveite, R," in "helium puriss.," and "bröggerite, L." Hale gives a chromospheric line at 3964.
3962·3	4	Seen in all the samples of gas.
3948·2	10	Very strong in "uraninite, R," very faint in "clèverite, R," and not seen in the others. Lockyer finds a line in gas from bröggerite at 3947. There is an eclipse line at the same wave-length.
3925·8	2	Seen in "helium puriss."
3917·0	2	Seen in "helium puriss."
3913·2	4	Only seen in "uraninite, R," and "helium puriss." Hale gives a chromospheric line at 3913·5.
3890·5 3888·5 3885·9	9 10 9	A very strong triplet, seen in all the samples of gas. Lockyer finds a line having a wave-length 3889 in gas from bröggerite. Hale gives a chromospheric line at 3888·73. There is a strong hydrogen line at 3889·15.
3874·6	6	Only seen in "uraninite, R."
3867·7	8	Seen in "helium puriss."
3819·4	10	Seen in all the samples of gas. Deslandres gives a chromospheric line at 3819·8.
3800·6	4	Seen in "helium puriss."
3732·5	5	Seen in "helium puriss." Hale gives a chromospheric line at 3733·3.
3705·4	6	Seen in all the samples of gas. Deslandres gives a chromospheric line at 3705·9.
3642·0	8	Only seen in "uraninite, R."
3633·3	8	Seen in "helium puriss."
3627·8	5	Only seen in "uraninite, R."
3613·7	9	Seen in "helium puriss."
3587·0	5	Seen in "helium puriss."
3447·8	8	Seen in "helium puriss."
3353·8	5	Seen in "helium puriss."
3247·5	2	Seen in "helium puriss."
3187·3	10	The center line of a close triplet. Very faint in "clèveite, R," and "uraninite, R," and strong in "helium puriss." and in "bröggerite, L." It is not seen in "bröggerite, R."

Wave-length.	Intensity.	
2944·9	8	A prominent line, only seen in "helium puriss." and in "bröggerite, L."
2536·5	8	Seen in "helium puriss." A mercury line occurs 2536·7?.
2479·1	4	Seen in "helium puriss."
2446·4	2	Seen in "helium puriss."
2419·8	2	Seen in "helium puriss."

Some of the more refrangible lines may possibly be due to the presence of a carbon compound with the helium. To photograph them a long exposure, extending over several hours, is necessary. The quartz window has to be cemented to the glass with an organic cement, and the long-continued action of the powerful induction current on the organic matter decomposes it, and fills the more refrangible end of the spectrum with lines and bands in which some of the flutings of hydrocarbon, cyanogen, and carbonic anhydride are to be distinguished.

There is a great difference in the relative intensities of the same lines in the gas from different minerals. Besides the case mentioned by Professor Kayser of the yellow and green lines 5876 and 5016, which vary in strength to such a degree as to render it highly probable that they represent two different elements, I have found many similar cases of lines which are relatively faint or absent in gas from one source and strong in that from another source.

Noticing only the strongest lines which I have called "intensity 10," "9," or "8," and taking no account of them when present in traces in other minerals, the following appear to be special to the gas from uraninite :

4735·1	4424·0	4371·0	4189·9	3948·2
4658·5	4399·0	4348·4	4181·5	3642·0
4428·1	4378·8	4198·6	4157·6	

The following strong lines are present in all the samples of gas :

7065·5	4922·6	4258·8	3885·5
6678·1	4713·4	4012·9	3885·9
5876·9	4471·5	3962·3	3819·4
5015·9	4386·3	3890·5	3705·4

The distribution assigned to some of the lines in the above tables is subject to correction. The intensities are deduced from an examination of photographs, taken with very varied exposures; some having been exposed long to bring out the fainter lines, and some a short time to give details of structure in the stronger lines. Unless all the photographs have been exposed for the same time, there is a liability of the relative intensities of lines in one picture not being the same as those in another picture. Judgment is needed in deciding whether a line is to have an intensity of 7 or 8 assigned to it; and as in the tables I have not included lines below intensity 8, it might happen that another series of photographs with independent measurements of intensities would in some degree alter the above arrangement.

In the following table I have given a list of lines which are probably identical with lines observed in the chromosphere and prominences:

Wave-length observed of helium.	Intensities.	Wave-lengths of chromospheric lines,* Rowland's scale.
7065·5	10	7065·5
6678·1	10	6678·3
5876·0	30	5876·0
5015·6	6	5015·9
4922·6	10	4922·3
4870·6	7	4870·4
4847·3	7	4848·7
4805·6	9	4805·25
4713·4	9	4713·4
4559·4	2	4558·9
4520·9	3	4522·9
4471·5	10	4471·8
4437·1	1	4437·2
4428·1	10	4426·6
4424·0	10	4425·6
4399·0	10	4398·9
4386·3	6	4385·4
4298·7	6	4298·5
4227·1	5	4226·89
4178·1	1	4179·5
3964·8	10	3964·0 H.†
3948·2	10	3945·2 H.
3913·2	4	3913·5 H.
3888·5	10	3888·73 H.
3819·4	10	3819·8 D.
3732·5	5	3733·3
3705·4	6	3705·9 D.

* A Treatise on Astronomical Spectroscopy, by Dr. J. Scheiner, translated by E. B. Frost, Boston, 1894.

† The wave-lengths to which the initials D. and H. are added are wave-lengths of lines photographically detected in the spectrum of the chromosphere by Deslandres (D) and Hale (H). Their photographs do not extend beyond wave-length 3630. Professor Lockyer (Roy. Soc. Proc., vol. lviii, p. 116, May, 1895) has already pointed out fourteen coincidences between the wave-lengths of lines in terrestrial helium and in those observed in the chromosphere, the eclipse lines, and stellar spectra.

ART. XXXIV.—*On the Igneous Rocks of the Sweet Grass Hills, Montana;* by W. H. WEED and L. V. PIRSSON.

IN northern Montana, the broad expanse of the great plains that lie east of the Rocky Mountain Cordillera is interrupted by a group of peaks, rising abruptly from the general level near the Canadian boundary line. These peaks, forming three isolated mountain masses, are known as the Sweet Grass Hills, or Three Buttes. Their sharp outlines and isolated position attract attention from every point of view, while recent discoveries of copper leads and ores of the precious metals, together with the excellence of the coal beds upon their flanks, have caused an influx of prospectors from the mining regions of the state.

The locality is now easily reached, as a tri-weekly stage runs from Shelby junction, where the Great Falls and Canada road crosses the Great Northern Railway, to the settlements on Birch Creek. The East and West Buttes are twenty miles apart, the Middle Butte lying to the south about midway between. The summits reach a height of 3,000 feet above the plains, and each butte is the center of a small mountain area whose verdure-clad slopes, copious springs and flowing streams are in strong and pleasing contrast to the desolate monotony of "Lonesome" prairie to the south. Through the kindness of Dr. G. M. Dawson, Assistant Director of the Canadian Geological Survey, who is the only geologist that has explored the Hills, the authors have been allowed to examine a number of specimens of the volcanic rocks constituting the central cores of these interesting mountain masses. The general geology of the Sweet Grass Hills has been described by Dr. Dawson,* from whose report the following notes have been taken.

The three buttes constituting the Sweet Grass Hills occur in the center of a broad and low anticlinal uplift that stretches for many miles parallel to the Rocky Mountain front, from which it is separated by a broad, shallow, synclinal basin. Each mountain mass consists of a core of igneous rock surrounded by Cretaceous beds uptilted at high angles, whose inclination gradually becomes less and less away from the eruptive rock, merging into the horizontal strata of the plains.

The igneous rocks forming the central masses of these mountains, though very dense and compact, are seldom seen in solid masses, since they break readily into irregular, angular fragments from a few inches to two feet across, forming debris

* Report Canadian Geol. Survey, 1882–4, C, pp. 16, 45. "Report upon country in vicinity of the Bow and Belly rivers, Northwest Territory."

piles that obscure all exposures. Dikes are occasionally found in the foot-hills or surrounding plains country, and appear to have a direction radiant from the higher peaks.

The East Butte, whose highest peak reaches an elevation of 6,200 feet above the sea, consists of four main points arranged in an irregular square. The conical northwestern peak is the most prominent; it is connected by a high ridge with the round-topped southwestern peak. The sedimentary rocks consist of yellowish and gray sandstones and black shales of Colorado Cretaceous, or Belly River (Montana?) age, the latter rocks being carved along the valleys into castellated shapes whose fluted surfaces, balcony ledges and intricate fret work, form most picturesque and attractive forms. These sedimentary rocks dip away from the Butte in all directions; the harder strata form more or less continuous ridges separated by depressions carved in the shales, and encircling the mountain. Near the igneous rocks the beds are much hardened and altered by contact metamorphism.

The dike rock described herein* occurs as a broken wall, traversing the horizontal sandstones and clays ten miles north of the summit of the East Butte. Its course is east and west.

The West Butte is the largest of the three, and rises to a height of 6,500 feet. It forms a mountainous area with numerous round-topped peaks and ridges separated by deep, precipitous valleys. The highest point is a large, blunt-topped summit with vertical rocky cliffs forming the eastern face. The sedimentary strata, dipping away from the peaks of igneous rock, show considerable contact metamorphism, and large areas of these altered rocks occur in the central portion of the mountain.

The structure here described corresponds closely with that observed in the mountain groups to the south of the Sweet Grass Hills. The Moccasin mountains, two isolated mountain masses, rising above the plains south of the Missouri, near the Judith mountains, consist of igneous cores whose rocks closely resemble those of this region, and are clearly laccolitic in character. Similar laccolites occur in the northeastern part of the Little Belt range, and the eruptive rocks of the outlying mountain groups, the Bear Paw, Little Rocky and Judith ranges, are also, in part at least, laccolitic. At most of the localities, however, the Paleozoic rocks are exposed, the intrusion having occurred in the shales forming the base of the Paleozoic series, whereas the Sweet Grass rocks are all of late Cretaceous age.

The igneous rocks here described are of similar types and correspond closely to those forming the laccolitic mountains just mentioned.

* See description by Dr. Dawson, loc. cit., p. 45.

Quartz Diorite Porphyrite.

This rock is represented by two specimens from West Butte. It is dense, of a dark gray color and thickly spotted with white feldspar phenocrysts. They are generally equidimensional and about 2^{mm} across, but in one specimen examples of twice this size occur. At times they are somewhat elongated and are then arranged in flowage planes showing fluid movements. Occasional small crystals of hornblende up to 4^{mm} in length can be seen. The rock weathers with a brownish crust.

Microscopically the following minerals are observed to be present: Apatite, hornblende, iron ore, plagioclase, orthoclase and quartz.

Plagioclase. As indicated in the hand specimens, this is very abundant as a phenocryst. The crystals are generally well formed and tabular on *b*(010). They are twinned according to the albite and Carlsbad laws. They are usually zonally built and the more basic inner portion shows a perceptible dispersion of the optic axes. They vary in composition from a basic labradorite to a medium acid oligoclase; thus a section in the zone *a*(100) on *c*(001) gave extinctions on either side of the albite twinning line of 26°, while the Carlsbad twin gave 12°, thus showing a basic labradorite approaching bytownite—a determination confirmed on other sections. In these sections the zonal growth is greatly marked and steadily becomes more acid towards the periphery. In another specimen the feldspars are more acid and even approach acid oligoclase.

The hornblende is pretty common in short, stout, ill-formed crystals and is nearly always changed to masses of opacite and chlorite and other decomposition products. It is the usual dark green variety. Twins at times on *a*(100).

The groundmass in which the above minerals lie is a very fine-grained, patchy or micro-poikilitic mixture of quartz and feldspar, the latter usually too much altered or kaolinized for identification but certainly composed in part of orthoclase. The quartz occurs also at times in irregular grains, which rise to the position of small phenocrysts. A greenish-yellowish mineral of the chlorite group occurs very often in cavities arranged in vermicular growths.

Quartz Syenite Porphyry.

This rock is represented by two specimens from East Butte. It is tough and compact, of a pale brown color which changes to a pale green gray on weathered surfaces. This groundmass is very thickly crowded with phenocrysts of feldspar which vary very greatly in size from examples 11^{mm} by 6^{mm} down to some only $0{\cdot}5^{mm}$ across. They have the common flesh color of orthoclase. There are also many little crystals of black augite smaller than the smallest feldspar phenocrysts.

The microscope shows the following minerals present: Zircon, iron ore, apatite, ægerine-augite, oligoclase, orthoclase, anorthoclase and quartz.

The zircon is rare and appears in very small stout columnar crystals. The iron ore is not abundant, but there is a moderate amount of it. The augite is in short, very thick little prisms about $0{\cdot}5^{mm}$ long. Prisms and pinacoids are present. It generally contains a pale green diopside core which rapidly passes into a bright green ægirite-augite mantle; often the diopside core is wanting and the crystal passes into deep green ægirite on the exterior, the optical properties suffering a corresponding change. Some examples are changed exteriorly to ferruginous products by alteration. The oligoclase appears in the form of idiomorphic phenocrysts of tabular form or somewhat columnar on the $\breve{a}$ axis about 1^{mm} long. Both the Carlsbad and albite twinnings are present. It is a rather common phenocryst. Much more abundant, however, are larger, ill-formed orthoclase crystals which present no unusual features. They commonly show the Carlsbad twin, but a Baveno twin was seen in one case. The anorthoclase is also quite abundant and is frequently intergrown with orthoclase. It contains successive rows or sets of short, excessively fine lamellæ of albite, twinned according to the albite law. It is sharply differentiated from the oligoclase both by the difference in double refraction and by its method of twinning. All three of these feldspars are apt to be collected together into grouped masses. They are slightly kaolinized.

The above phenocrysts lie scattered in a rather fine groundmass composed of allotriomorphic feldspar and quartz. The structure is micro-granitic and the amount of quartz is considerable. The feldspar is mostly alkali feldspar, unstriated, but a certain amount of oligoclase is present in the second generation. Small microlites of a mineral of strong refraction are present which may be of augite.

The systematic position of this rock type is rather peculiar; it is clearly of high silica, alumina and alkalies, and of these latter soda is very largely present. It contains considerable iron, while lime and especially magnesia play but an inconspicuous role. It is closely allied to the granite porphyries by the large amount of quartz in the groundmass, but it does not contain any quartz phenocrysts. On the other hand, the amount of plagioclase present, while not sufficient to throw the rock out of the alkali group, shows tendencies towards diorite porphyrite. Under these conditions it seems most closely allied to the syenitic group of rocks and the name of quartz syenite porphyry is given it.

Minette.

This is shown by a specimen from a dike north of East Butte. It is a dull, dark stone-gray color, filled with phenocrysts of biotite which have a maximum diameter of 5^{mm}. They are very common, and being arranged in an approximately parallel position, they give the rock a facility for cleavage in that plane. The lens shows a pale yellowish augite to be also present.

Under the microscope the following minerals are seen: Apatite, iron ore, biotite, augite, orthoclase and calcite.

The biotite is of a very pale leather-brown color and feebly pleochroic. It has a zonal structure, being invariably bordered by a narrow deep brown rim. The axial angle is extremely small and the axial plane is parallel to an edge of the hexagonal section; it is thus a meroxene. The large plates are greatly embayed and irregular and frequently composed of smaller individuals in parallel position. It thus corresponds precisely to the biotite characteristic of minettes as described by Rosenbusch.* Apatite is not very common. It presents nothing unusual. The iron ore is entirely in the second generation. The augite is in rather large, stout, ill-formed crystals, colorless and with here and there patches of alteration into carbonates. The groundmass in which the phenocrysts lie is composed of a mixture of very fine biotite leaves and shreds, small grains and rods of augite, grains of iron ore and laths of an untwinned feldspar which appears to be orthoclase. The orthoclase laths are at times arranged in rude spherulitic forms. Often among the augite prisms are some that are deep green and strongly pleochroic and extended in an optically negative direction. They must therefore be of ægirite. Between the feldspar laths there frequently appears small formless patches of a colorless isotropic substance that is believed to be glass.

The rock has a porphyritic structure and it is a very typical minette. It is also quite fresh, there being no alteration except in the augite. It contains some fragments of calcite that appear to be foreign to it, as if brought up from rocks below as an inclusion. In it the dark minerals play a preponderating role, the feldspars being present but in comparatively small amount in the groundmass. Its petrological affinities ally it with the syenite-porphyry of East Butte, with which it probably stands in geological relation. From this point of view it is interesting to note the occurrence of the ægirite both in the porphyry and in the minette.

Washington and New Haven, June, 1895.

* Mass. Gesteine, p. 310, 1887.

ART. XXXV.—*On the Distribution and the Secular Variation of Terrestrial Magnetism, No. III;** by L. A. BAUER, PH.D.

AS stated in the preceding number, the special object of this communication is to see whether we can refer the *secular variation* to the secular shift of the secondary magnetic dip poles revealed when considering the phenomena of the distribution of terrestrial magnetism.†

If this be the case, its importance cannot be overestimated. The investigation of the phenomenon which has been the source of such perplexity for several centuries—the so-called secular variation, whereby remarkable changes occur in the distribution of the earth's magnetism in the lapse of time—has then entered upon a new stage; for the prime reason that we can now refer the secular variation to shifting magnetic poles that are nearly on the equator and, hence, in a region easily accessible, and in which magnetic observations are continually being made, instead of to magnetic poles in the polar regions where observations are rarely made on account of the difficulty of access.

The magnetic charts published from time to time can represent the distribution in terrestrial magnetism in the equatorial regions fairly well, while that in the polar regions must be more or less guess-work. Hence, the difficulty of locating approximately the *secondary* magnetic dip poles is a minimum in comparison with the assignment of position of those we believe to be in the arctic and antarctic regions.

It behooves us then to look carefully into the matter forming the chief subject of our present inquiry. The problem to be solved I shall state as follows:

What is the secular motion of the secondary magnetic dip poles?

Before entering upon the discussion of this question it will be desirable to state that all the conclusions thus far have been obtained empirically. No theory has been advanced. My purpose hitherto has been to accumulate facts to serve ultimately as a foundation upon which to base a theory. A sufficient number of empirical laws and facts have now been derived to justify and to make desirable the undertaking of a theoretical attack, to be begun in the following number. The results to be given in the present paper are still free from theoretical assumptions. They are facts of pure observation.

* The main results of this paper were presented to the Washington Philosophical Society, May 25, 1895. Abstract in Science, June 21, 1895.

† This Journal, Art. XX, September, 1895.

It will be recalled that we found that the main distribution phenomena could be represented by two rectangular magnetic systems, a polar and an approximately equatorial, the former of about 5 or 6 times the strength of the latter. This conclusion was reached with the aid of the magnetic observations for 1885. Suppose we carry out the same investigation for other dates, shall we reach the same result?

Let us begin with the year 1780, since for this date we possess the earliest fairly reliable isoclinic chart. This chart gives us the approximate distribution of the magnetic dip for that date. It was constructed by Christopher Hansteen.* The first thing to be done is to construct the "isapoclinics" according to the method explained in No. II. For this purpose, I have scaled the dips for points 20° distant in longitude and in latitudes +60°, ±40°, ±20° and 0°. The data for latitude 60° S. could not be safely obtained and hence the "isapoclinics" are not extended beyond 40° S. For the regions of the two foci (secondary dip poles), I have made a few closer scalings.

Having obtained the data as based upon observation, the computed dip I_c is again derived with the aid of equation:

$$\tan I_c = 2 \tan \varphi,$$

φ being the geographical latitude. It will be remembered that this is the dip that would prevail at the place where the latitude is φ if the earth were uniformly magnetized about the geographical axis and *were at rest.* The departure of the actual (or observed) dip from this computed dip is:

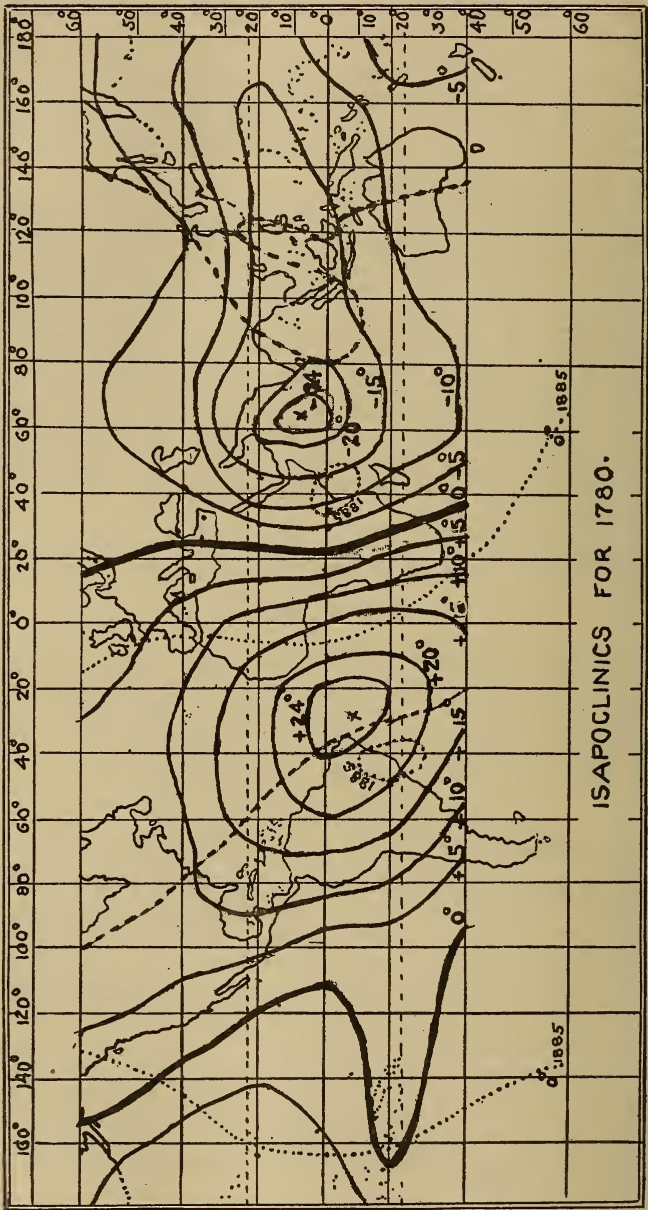
$$\triangle I = I_{obs'd} - I_{comp'd} = I_o - I_c.$$

These differences we form for all the scaled values, plot them on a map in their true geographical position, and finally draw lines through all the places having the same $\triangle I$, or departure, paying due regard to sign. The lines obtained thus I have termed lines of equal-departing dip or, briefly, isapoclinics. The result for 1780 is given on the diagram, page 316. For the sake of convenience in comparison the same curves for 1885 are reproduced from No. II.†

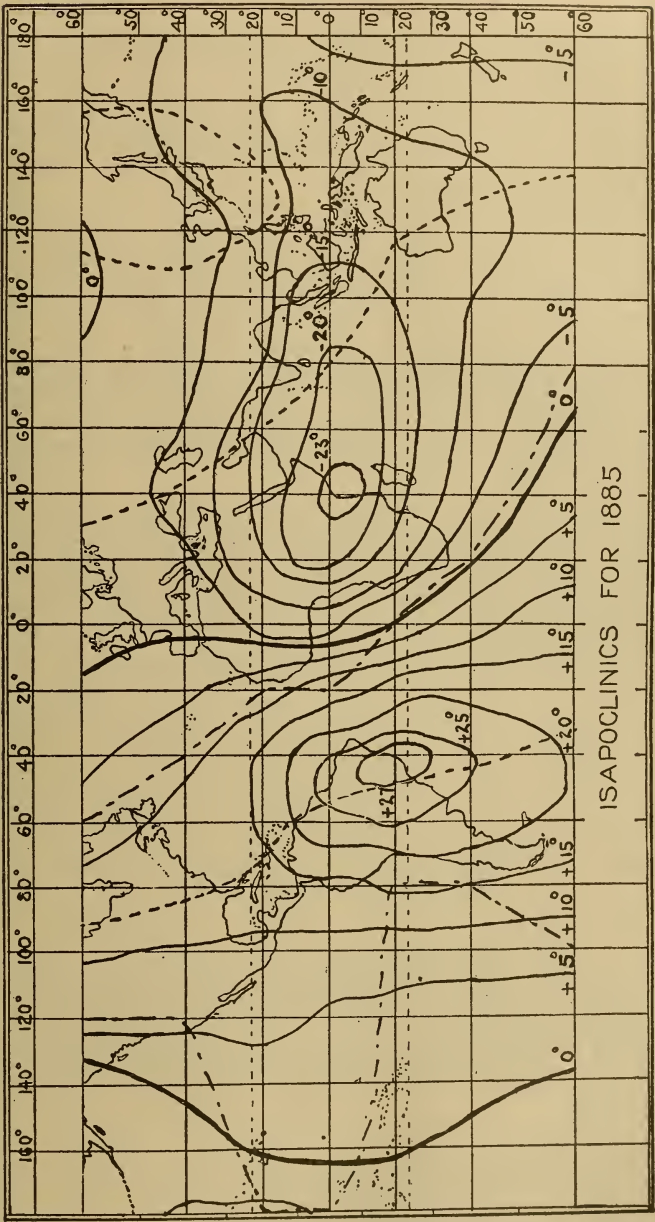
It will be seen that the main result is the same for both dates. The secondary polarization is again nearly equatorial. Hence, the final conclusion of No. II is borne out by this early date. We shall see later that this is also true for an intermediate year, 1829.

* The chart will be found in the Atlas to his "Untersuchungen über den Magnetismus der Erde, Christiania, 1819. A reduced copy is given in Neumayer's "Atlas des Erdmagnetismus," Gotha, 1891, plate No. 41.

† In the reproduction the isapoclinic + 25° has been slightly improved.



ISAPOCLINICS FOR 1780.


ISAPOCLINICS FOR 1885

The plus isapoclinics are again simpler in form than the minus ones, and from this fact one could argue that if we were to construct the "equiabspotentials," the foci of the plus equal-departing potentials would fall more closely together with that of the plus isapoclinics, than the one of the minus equiabspotentials with that of the minus isapoclinics.* In other words, in the Indian and Pacific Oceans another disturbing factor seems to come into play. I reached the same conclusion when investigating the secular motion of a free magnetic needle.† I found, namely, that the secular magnetic wave travels in the main westward, but in eastern Asia, in the Pacific Ocean and on the western coast of America we have evidences of a wave, seemingly of a smaller amplitude, that travels *eastward.* We are thus succeeding in gradually drawing the lines closer and closer around the disturbing factors of terrestrial magnetism. And this is very important since theory cannot determine the deflecting centers for us; observation must point them out to us.

The next thing to which I wish to draw attention is the question at the head of this paper—*what is the secular motion of the secondary magnetic poles?* By comparing both diagrams it will be seen that beyond a doubt *the whole secondary magnetic system has been moving along the equator westwardly from 1780 to 1885.*

To make this clearer the following figures‡ are given :

	Position in 1780.		1829.		1885.	
	Lat.	Long. fr. Gr.	Lat.	Long. fr. Gr.	Lat.	Long. fr. Gr.
Secondary magnetic north pole	10° S.	30° W.§	10° S.	40° W.	20° S.	45° W.
" " south "	10 N.	65 E.	0	50 E.	5 S.	40° E.
" " equator cuts the geographical "	0	21 E.	0	7 E.	0	9 W.
	0	252 ? E.	0	187 E.	0	191 E.

The assignment of the positions of the poles is liable to an uncertainty of about 5° in latitude and in longitude. It is especially interesting to include in the comparison the results for 1829 as they have been derived from Erman and Petersen's figures based upon the Gaussian potential theory of terrestrial magnetism.‖

* See footnote to No. II, p. 200.

† See "Beitraege zur Kenntniss des Wesens der Saecular-Variation des Erdmagnetismus," p. 35, first footnote and p. 44.

‡ The results here given are slight improvements upon the quantities already published.

§ In the "abstract" published in Science, June 21, 1895, p. 675, this was erroneously given as 50° W. instead of 30° W.

‖ Erman and Petersen: Grundlagen der Gaussischen Theorie und die Erscheinungen des Erdmagnetismus im Jahre, 1829. Berlin, 1874. Table of computed inclinations.

It will be observed that both poles have undoubtedly been moving westwardly during the interval from 1780 to 1885. It would appear, moreover, as though they are not moving along the equator but along a line inclined to it, from the northern to the southern side. How much reliance is to be put upon this latter result I cannot, at present, say.

	Average Annual Motion 1780–1885. In Latitude.	In Longitude.
Secondary Mag'c N. P.	$0^\circ 092$	$0^\circ 146$
" " S. P.	0·146	0·242
Mean	0·119	0·194

These figures would appear to indicate that the two poles are moving westwardly and southwardly at different rates. Whether this is really the case must be the subject of a more detailed examination. It is sufficient to know, at this stage of our inquiry, the general direction and the average rate of motion.

Since the intersections of the agonic lines*—the lines marking out the places where the magnetic declination is zero—with the equator fall so nearly together with the secondary magnetic poles, it may be interesting to see how the agonic lines have been moving along the equator for the last 3½ centuries. This opportunity is furnished by the table on the following page.

In the third and sixth columns are given the positions as obtained from charts giving the lines of equal magnetic declination. The fourth and seventh columns contain the computed quantities supposing the motion to have been linear. The formula, obtained by a least square adjustment of the observations properly weighted, is for the west agonic:

$$\lambda_w = +50^\circ{\cdot}6 + 0^\circ{\cdot}228\,(t - 1850)$$

for the east agonic,

$$\lambda_e = -83^\circ{\cdot}0 + 0^\circ{\cdot}139\,(t - 1850)$$

λ being the longitude and t the date to which λ refers.

By casting the eye over the differences between the observed and computed quantities, it will be noticed that the accord is satisfactory. Plotting the observed quantities, it will readily be seen that the motion for 350 years has been nearly linear for both agonics. A very slight curvature is noticeable in the secular motion of the west agonic. In the case of the east agonic, the errors of observation (or fluctuations) are so large as to mask any slight curvature that might be present.

We have before us a most interesting result. For 3½ centuries the lines of no declination have been moving apparently

* Shown on the diagrams by the broken lines.

uniformly along the equator in a westward direction! *If* the motion continues at the same rate around the equator, then the west agonic will accomplish a complete revolution in $\frac{360}{228}$ = 1580 years, the east agonic in $\frac{360}{139}$ = 2590 years! The average annual motion of the two agonics is 0°·194, and the average period of revolution (if the agonics revolve around the equator) about 2000 years.

Longitudes of Intersections of Agonic Lines with the Equator.

Date.	Authority.	West Agonic.			East Agonic.		
		Obs'd.	Comp.	O.–C.	Obs'd.	Comp.	O.–C.
		°	°	°	°	°	°
1540	W. van Bemmelen* -----	−23†††	−20·1	−3	−100	−126·1	−26
1580	" -----	−17	−11·0	−6	---	−120·5	--
1600	" -----	− 8	− 6·4	−2	−116	−117·8	+ 2
1610	C. Hansteen† -----------	−13	− 4·1	−9	−118	−116·4	− 2
1640	W. van Bemmelen* -----	− 2	+ 2·7	−5	−117	−112·2	− 5
1665	" -----	+ 9	+ 8·4	+1	−126	−108·7	−17
1680	" -----	+17·5	+11·8	+6	−112	−106·6	− 5
1700	E. Halley‡ -------------	+17·5	+16·4	+1	−118	−103·8	−14
1710	C. Hansteen† -----------	+22·5	+18·7	+4	−119	−102·5	−16
1720	" -----------	+26	+21·0	+5	---	−101·1	--
1730	" -----------	+28	+23·2	+5	− 93	− 99·7	+ 7
1744	" -----------	+31	+26·4	+5	−105‡‡‡	− 97·7	− 7
1756	" -----------	+31	+29·2	+2	− 97‡‡‡	− 96·1	− 1
1770	" -----------	+39	+32·4	+7	− 99‡‡‡	− 94·1	− 5
1780	" -----------	+39	+34·6	+4	−100‡‡‡	− 92·7	− 7
1787	" -----------	+40	+36·2	+4	−101‡‡‡	− 91·8	− 9
1800	" -----------	+43	+39·2	+4	−100	− 90·0	−10
1817	T. Yeates‖ -------------	+42	+43·1	−1	− 77	− 87·6	+11
1827	A. Erman§ -------------	+53	+45·4	+8	− 75	− 86·2	+11
1829	Erman & Petersen¶ ----	+50	+45·8	+4	− 74	− 85·9	+12
1833	P. Barlow** ------------	+43·5	+46·7	−3	− 75	− 85·4	+10
1840	E. Sabine†† -------------	+49	+48·3	+1	−105	− 84·4	−21
1850	C. A. Schott‡‡ ----------	+49·5	+50.6	−1	---	− 83·0	--
1858	British Admiralty‖‖ -----	+50·5	+52·4	−2	− 80	− 81·9	+ 2
1872	" " §§-----	+54	+55·6	−2	− 74·5	− 79·9	+ 5
1875	C. A. Schott‡‡ ----------	+52.5	+56·3	−4	---	− 79·5	--
1880	British Admiralty¶¶ ---	+55	+57·4	−2	− 79·5	− 78·8	− 1
1885	G. Neumayer*** --------	+54·2	+58·6	−4	− 80	− 78·1	− 2

* De Isogonen in de XVIde en XVIIde Eeuw, Utrecht, 1893; values are preliminary, according to the author.

† Untersuchungen über den Magnetismus der Erde, Christiania, 1819, Atlas.

‡ Halley's Equal Variation Chart in Greenwich Observations for 1869, or in "Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus," No. 4, Hellmann, Berlin, 1894.

‖ Thomas Yeates' Equal Variation Chart for 1817; made use of copy in British Museum.

§ Erman's isogonic chart in Berghaus' Physikalischer Atlas, 1st edition, 1845.

¶ "Grundlagen der Gaussichen Theorie," etc., Berlin, 1874.

** Barlow's isogonic chart in Phil. Trans., 1833.

†† Sabine's isogonic chart, 1840; used copy in "Treatise upon Terrestrial Magnetism," London, 1871.

‡‡ Bulletin No. 6, U. S. Coast and Geodetic Survey.

‖‖ Used reduced copy in Neumayer's Atlas des Erdmagnetismus, Gotha, 1891.

§§ Used reduced copies in Admiralty Manual for Deviations of the Compass, German edition, Vienna, 1873, and London edition, 1874.

¶¶ Isogonic chart in Report of Challenger Expedition, Vol. II. Combined the result from this chart with that from Neumayer's chart for 1880.

*** Neumayer's Atlas des Erdmagnetismus.

††† East longitude. minus; west longitude, plus.

‡‡‡ Mean of several intersections.

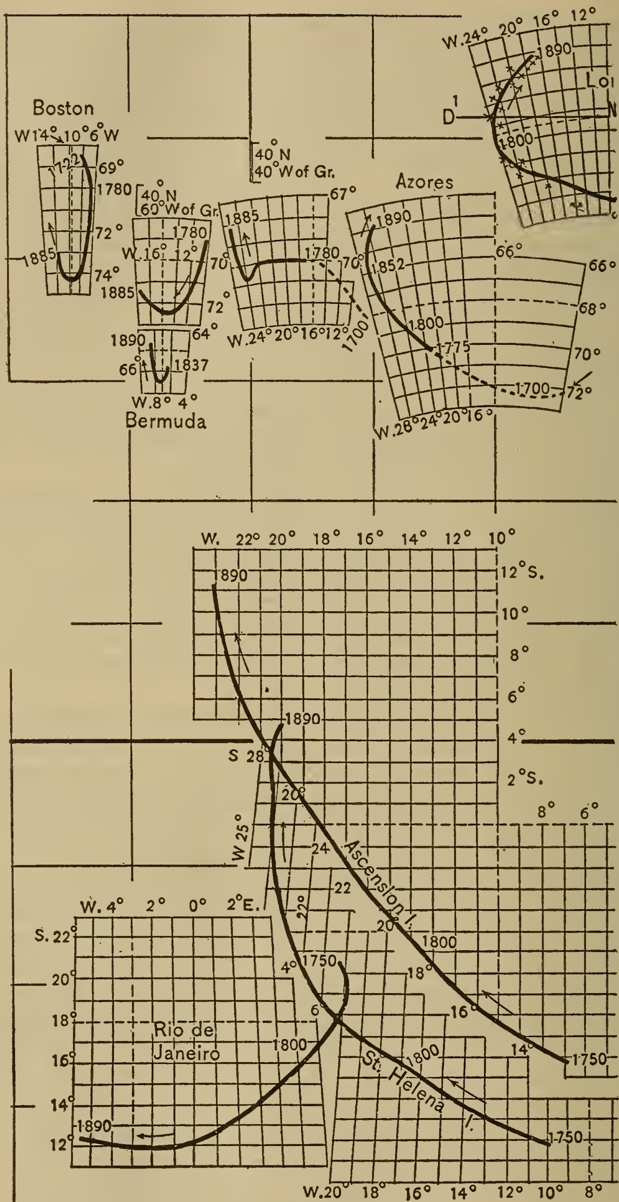
These results show how useless it is to endeavor to determine the secular variation period from the supposed motion of the agonic lines around the earth, as some eminent investigators have done. Not only will the result depend upon the particular agonic considered, but also upon the parallel of latitude along which the motion is supposed to take place. We are seemingly forced again to a conclusion which I have already formulated, viz., that we have no evidence as yet that the earth possesses a common secular variation period, it being questionable whether there really is a period at the close of which the same path will be traversed by a free magnetic needle. If the earth does possess a common period, then the curves at present being described at various stations are but branches or loops of the complete curve. If this period is as long as 2000 years, as above indicated, abundant opportunity is furnished for regarding the partial periods at the various stations as submultiples of the total period.

It should be noted that the period of 2000 years deduced from the average motion of the agonics is identical with that which we obtain if we suppose that the secondary magnetic system revolves around the equator at the average rate of the two secondary poles, viz: $\frac{360}{0\cdot194} = 1860$ years. That is, the average annual westwardly motion in longitude along the equator is about the same (nearly 0°·2) for the secondary magnetic poles and the agonics.

I am inclined to think that the differences in the annual rate of motion as exhibited by the two secondary poles and, likewise, by the two agonics is real—parts of the same magnetic system may move with different velocities, the rate of motion of the particular part being governed by the portion of the earth over which it is passing. We must then be careful not to suppose that because a certain phase has traversed a section of the earth in a certain time, its rate of motion will continue the same over another section. In this way there arises a warping, a distortion or overlapping of our magnetic system.

A number of illustrations could be given as to how we can read the broad facts of the secular variation from the positions and the motions of the secondary magnetic poles. I shall give only two, however, in the present number.

First. *Where should we expect the largest and the smallest secular change in declination during the interval 1780–1885?* The largest change in declination would be expected where the change in the horizontal component of the secondary system is a maximum, i. e., in the region traversed by that branch of the secondary magnetic equator corresponding to the shorter distance in longitude of the secondary poles, hence over the eastern Atlantic and adjacent countries.



The least change in declination would be encountered where the horizontal component of the secondary system would be least affected by the motion of the poles, i. e., in the region traversed by the other branch of the secondary magnetic equator, viz., the western Pacific Ocean.

Both deductions are amply borne out by observations and are prettily illustrated by a chart, as yet unpublished, to which I have made allusion several times, viz., the chart showing graphically the secular variation in declination for points on the earth distant 20° in latitude and in longitude.

As a second illustration of the importance of study of the secondary magnetic poles, I shall reproduce a few of the secular motion curves given in previous papers, and endeavor to explain a phenomenon which was a source of perplexity to me when I first observed it.

On the diagram* opposite we have given the curves that have been described in the course of time by a magnetic needle freely suspended. It will be noticed that while the direction of motion is clockwise throughout there is a marked difference between some of the curves, as for example, between those of Ascension and St. Helena Islands and that of Rio de Janeiro. It would appear as though the latter curve has swung itself around. The same thing is exhibited by the curve for station 40° N. and 60° W. and by the curves west thereof. West of this station, the curves for the interval drawn follow the American type; east, the European. It is evident that some important change in magnetic distribution must have occurred in the interval 1750–1890 in the region between the stations exhibiting the contrasted motions.

Upon looking into this matter I find that the secondary north end attracting pole during the stated interval moved between Ascension Island and Rio de Janeiro—away from Ascension Island and towards the latter station. Hence, it follows that the dip of the north end of the needle at Ascension Island decreased, or that of the south end *increased*, while on the other hand, the northerly dip at Rio de Janeiro increased or that of the southerly *decreased*. At Ascension Island and stations east (up to a certain line), the southerly dip increased; at Rio de Janeiro and west (up to a certain line), it decreased. This is precisely the state of affairs exhibited by the curves, as will be seen by inspection.

For the better understanding of the foregoing the following geographical positions are given:

	Latitude.	Longitude.
St. Helena Is.	15° 55′ S.	5° 44′ W.
Ascension Is.	7 56 S.	14 23 W.
Rio de Janeiro..........	22 55 S.	43 10 W.

From the table on p. 318 we find that the position of the secondary north pole was:

in 1780	10° S. 30° W.
in 1885	20 S. 45 W.

* Taken from the Physical Review, vol. iii, No. 13, Plate I.

In 1780 it was consequently west of St. Helena and Ascension Islands but east of Rio de Janeiro. In 1750 it was still west of the first two stations though now nearer them, as is apparent from the secular variation curves—the increasing southerly inclination still prevailing in 1750. In 1885 it appears to have been close to Rio de Janeiro, and we ought to expect about this date the maximum northerly or minimum southerly dip to occur. As a matter of fact, this turning point was reached in about 1882 (see curve).* The southerly dip is at present increasing, i. e., the secondary north end attracting pole will be found at the present time *west* of Rio de Janeiro.

Similar considerations will explain to us the change in magnetic declination at these three tropical stations.

Enough has been given to show how exceedingly helpful the secondary magnetic poles may be to us in the study of the phenomena of the distribution and of the secular variation of geomagnetism.

By watching the progressive westward motion of the secondary south end attracting pole, which was in 1885 in about 5° south latitude and 40° east longitude we may be able to predict the coming of the phase of minimum northerly inclination which is at the present time setting in in central Europe and marching westwardly.

It may be of interest and of value to give the dates at which the branch of the secondary magnetic equator corresponding to the shorter difference in longitude of the secondary poles passed through various stations along the line of westward march. The figures were obtained with the aid of the relation

$$\triangle I = 0 = I_{obs'd} - 2 \tan \varphi \text{ or } I_{obs'd} = I_{comp'd} = 2 \tan \varphi.$$

Station.	Latitude.	Longitude.	Date of Passage of Sec. Mag'c Eq.
	° ′	° ′	
Berlin	52 32 N.	13 23 E.	1820
Rome	41 53	12 26	1830
Basle	47 34	7 36	1839
Geneva	46 12	6 09	1845
Paris	48 50	2 20 E.	1858
London	51 30	0 07 W.	1862
Equator	0 0	21 E.	1780
"	0 0	7 E.	1829
"	0 0	2 E.	1840
"	0 0	9 W.	1885
Capetown	33 56	18 29 E.	1844
St. Helena Island	15 55 S.	5 44 W.	1890
Ascension "	7 56	14 23 W.	1905 (?)
Rio de Janeiro	22 55	43 10 W.	----

* Deduced by me in Beitraege zur Kenntniss des Wesens der Sac. Var'n, p. 36, before the presence of secondary poles had been recognized.

In conclusion a few words must be said with regard to the results obtained thus far. We have found that by resolving the observed magnetic field into two, one polar and symmetrical about the rotation axis, the other the residual field, that this latter is apparently directed approximately equatorially. It has been amply demonstrated, I believe, that this mode of resolution is a very convenient and promising one for the study of the complex phenomena of the distribution and the secular variation. This breaking up of the total field into two has thus far been wholly arbitrary, however. To assert the actual existence of the secondary equatorial field we must endeavor to deduce it theoretically in some manner. We must show that there is some cause for such a polarization. For example, suppose we have given the primary polar field, which in fact we know to exist, though in a more complex form, can we deduce from the motions of the earth a secondary equatorial polarization as the result of self-induction? If so, what conditions of the physical constitution of the earth must we presuppose in order to get such an unsymmetrical equatorial polarization as our residual field reveals? That is, why are the secondary magnetic dip poles but 90° different in longitude?* It is evident that the solution of this question is likely to throw some light upon the secrets hidden in the bowels of the earth. It will be interesting to see whether we shall reach the same result obtained by Prof. Bigelow in a totally different manner, viz., that the earth is a magnetic shell of the thickness of about 790 miles.†

Finally, can the secular variation be explained by the reflex action of the secondary field upon the primary? This is the nature of the questions that will serve as the subject of a systematic examination in subsequent numbers.

Chicago, Aug. 15, 1895.

* The two foci obtained by constructing "the isanomalous lines of geomagnetic potential" are according to Prof W. von Bezold about 180° apart in longitude. See foot-note page 200, of previous number.

† F. H. Bigelow: The Earth a Magnetic Shell, this Journal, Art. VIII, August, 1895.

ART. XXXVI.—*Studies in the Electro-magnetic Theory.—I. The law of electro-magnetic flux*;* by M. I. PUPIN, Ph.D., Columbia College, New York.

THE law of electro-magnetic flux is a short expression for the well-known quantitative relations between electromotive force and electric flux on the one hand and magnetomotive force and magnetic flux on the other. Ohm's law is a part of it.

These relations are statements of experimental facts which we know to hold true for constant and slowly varying forces. The object of this investigation is to show the exact position which this law occupies in Maxwell's electro-magnetic theory; to point out its limitations; to show that Maxwell's electro-magnetic theory of light demands a more general form of this law; and finally, to present a general form of this law of which both its ordinary form and also those forms which were assumed hypothetically in some of the recent developments of the electro-magnetic theory of light are special cases.

1. *The two fundamental laws of Maxwell's Electro-dynamics.*

A brief statement of Maxwell's electro-magnetic theory seems desirable in this discussion. For the sake of brevity none but its most essential features will be presented, and that in such a way as to emphasize as forcibly as possible the essential differences between this theory and the older electro-magnetic theories.

The essential features of the Maxwellian theory are reducible to two, which may be called its two characteristic features. These two characteristic features can be exhibited in a very simple manner by considering the gradual change in form and in meaning which the following two well known experimental laws, relating to magneto-electric and to electro-magnetic induction, undergo as we pass from the views of old electric theories to those of the Maxwellian theory. These laws I choose to state in the following form for reasons which will be evident presently:—

First law:—A varying magnetic field induces a field of electric force in all electric conductors within its region. The electromotive force around any simple circuit† of this induced

* Read in abstract before the Am. Assoc. Adv. Science at its Springfield meeting, Aug. 30, 1895.

† The expression *simple circuit* needs an explanation. Consider any point of the field. Pass a plane through it and in this plane draw an infinitely small area around the point under consideration. If the boundary of this elementary area be such that none of its points contain more than one branch of the boundary curve, then this boundary curve is a simple circuit around this point.

electric field is proportional to the rate of variation of the magnetic flux through any surface bounded by this circuit.

Second law:—An electric current induces a field of magnetic force . . . .
The magnetomotive force around any simple circuit of this induced magnetic field is proportional to the current passing through any surface bounded by this circuit.

For the sake of brevity the factors of proportionality are not explicitly mentioned. It is well to observe, however, that they are numerical and that by a suitable selection of electric units they could be made unity in each case.

There is evidently a considerable formal resemblance between these two experimental laws when they are stated in the form in which they have just been stated. This formal resemblance can be carried considerably further without departing from the views of pre-Maxwellian electric theories. All that is needed is a simple adjustment of the electric terminology of the pre-Maxwellian period. This is the step which is now in order. It leads along the shortest path from old theories to Maxwell's electro-magnetic theory.

Consider two electric conductors A and B, insulated from each other, one charged with a certain quantity of positive electricity and the other with an equal charge of negative electricity. Consider now a surface surrounding any one of these two conductors. The total electric flux through this surface is numerically equal to the total quantity of electricity enclosed by the surface. Hence it is also equal to the total *integral electric current* which would be obtained if the total positive charge were carried across this surface to the negatively charged conductor and thus the two conductors reduced to their neutral state. We can speak, therefore, of a total electric flux across a surface as of a *fictitious integral current* through this surface. We can speak of it also as of a *total electric displacement* in the sense that if the two conductors are neutral and a certain quantity of positive or negative electrification is transferred from one to the other and therefore displaced from one side of the bounding surface to the other we shall have a total electric flux across this surface numerically equal to the total electric displacement across the same surface. With this mental reservation, namely, that we are using certain terms in their figurative sense only, we can always employ the expressions "*total electric flux*," "*total integral current*," and "*total electric displacement*" as synonymous terms without departing from the views of pre-Maxwellian theories.

So far we have not restricted the fictitious total integral current or displacement to any particular paths. That shall be done now.

Let these paths be such that at any moment the total fictitious electric transference through any elementary area up to that moment is equal to the electric flux through that area at that moment. Then, as long as we remember that we are speaking of a *fictitious* "*integral current*" and a *fictitious* "*electric displacement*" through any elementary area in an electric field, we can employ these two terms as synonymous with "electric flux" through that area without departing from the views of the pre-Maxwellian period.

Again just as the electric current through any elementary area of a conductor is defined as the rate of variation of the integral current, so we can also speak of a current through the dielectric without deserting the views of old electro-magnetic theories provided that we take it as granted that this dielectric current is fictitious, since it is the rate of variation of a fictitious integral current. The expression "*dielectric or displacement current*" becomes, therefore, synonymous with rate of variation of the electric flux. Similarly we can substitute the expression *magnetic current* for the expression "*rate of variation of magnetic flux.*"

To distinguish the real, that is the electric conduction current, from the fictitious or displacement current, the expression "*conduction current*" must be used when the real and not the fictitious (displacement) current is meant.

This precaution is unnecessary in the case of the magnetic current, since there is no magnetic conduction current.

The laws of magneto-electric and of electro-magnetic induction can now be stated more symmetrically, as follows:—

First law:—A region of magnetic . . . . . currents induces a field of electric force *in all electric conductors within that region.* The electromotive force around any simple circuit in this induced electric field is proportional to the magnetic . . . . . . current passing through any area which is bounded by this circuit.

Second law:—A region of electric *conduction* currents induces a field of magnetic force . . . . The magnetomotive force around any simple circuit in this induced magnetic field is proportional to the electric *conduction* current passing through any area which is bounded by this circuit.

The formal resemblance between the two laws is very striking now. It would be perfect if we either omitted the words which are in italics or filled out suitably the dotted lacunæ.

The last alternative is not admissible, because we know nothing about magnetic conduction currents, nor about magnetic conductors. The first alternative does not strike one so unfavorably. There is really no evidence against the permissibility of omitting the words in italics from the statement of the first law. It is true that Faraday's experiments, by which he discovered that law, prove the existence of no other induced electromotive forces excepting those which Faraday detected in conductors. But these experiments neither affirm nor do they deny the presence of magneto-electric induction in dielectrics. On the other hand, Faraday's experiments on dielectric and diamagnetic substances and his speculative views of electro-magnetic phenomena urge us with an irresistible force to the belief that electromotive forces just like magnetomotive forces are induced around every circuit, no matter whether that circuit pass through a conductor or through a dielectric (including the most perfect of all dielectrics, that is a perfect vacuum), and that just as the magnetic displacement current is real in the sense that it produces inductive effects, so the electric displacement current is not a fiction, as one who is faithful to the views of older electric theories has to assume, but it is just as real as the electric conduction current in the sense that it is an actually existing process in the dielectric, which is just as capable of inducing magnetomotive forces as the conduction current. The mechanism of this process is, of course, just as unknown to us as the mechanism of that process which is called the electric conduction current. Maxwell was the first to feel the force of this tendency of Faraday's experiments and speculations and to yield to it, making thus a radical departure from the views of old electric theories. His statement of the two laws of induction omits, therefore, the words which are in italics in the last statement of these laws. Hence the following wording of these two laws is in accordance with Maxwell's views:—

First law:—*Every magnetic current induces a field of electric force. The electromotive force around any simple circuit in this induced electric field is proportional to the magnetic current passing through any area which is bounded by this circuit.*

Second law:—*Every electric current induces a field of magnetic force. The magnetomotive force around any simple circuit in this induced magnetic field is proportional to the electric current passing through any area which is bounded by this circuit.*

In this generalized form these two laws form the foundation of Maxwell's electro-magnetic theory.* This theory may, therefore, be described broadly as that theory which generalizes the two experimental laws of magneto-electric and of electro-magnetic induction by extending the region of magneto-electric induction and of the electric current from conductors to the dielectric.

* See O. Heaviside, Phil. Mag., February, 1888; H. Hertz, Wied. Ann., xxiii, p. 84, 1884; xl, p. 577, 1890.

So far an electro-magnetic field of invariable geometrical configuration has been considered. It should be observed now that the two laws suffice to describe completely the inductive effects in an electro-magnetic field of variable geometrical configuration also. A field of variable geometrical configuration means, of course, a field in which the various *sources of flux* (like electrically or magnetically charged bodies and conductors carrying electric currents) are in relative motion with respect to bodies which are under the inductive action of these sources. According to these laws the inductive effects in any circuit depend on the rate of variation of the flux through that circuit and on nothing else; they are, therefore, independent of the particular method by which that variation is produced; whether by varying the intensity of the field; or by motion of the various parts of the field; or by keeping everything constant and moving the circuit under consideration, it is immaterial. This is simply an extension of the experimental fact that the electromotive force induced in a conducting circuit follows the same law whether that electromotive force be induced by the motion of the circuit towards a magnet or by the motion of the magnet towards the circuit, or by keeping the two in fixed relative position and varying the strength of the magnet.

The fundamental quantities in this theory are electric current and electromotive force on the one hand and magnetic current and magnetomotive force on the other. Calling them the *fundamental vectors of the electro-magnetic field*, we can say that the *first characteristic feature of Maxwell's electro-magnetic theory consists in the perfectly symmetrical form of cross-connection between its fundamental vectors, one of these cross-connections stating the law of induced magnetomotive force and the other stating the law of induced electromotive force.*

A symbolical statement of these two laws shows this symmetry more clearly.

Let X, Y, Z be the components of the induced electromotive intensity at any point of the field.

Let α, β, γ be the components of the induced magnetomotive intensity at same point of the field.

Let $\left.\begin{matrix}\frac{df}{dt}, \frac{dg}{dt}, \frac{dh}{dt}, \\ \frac{da}{dt}, \frac{db}{dt}, \frac{dc}{dt},\end{matrix}\right\}$ be the components of the intensity of the electric and magnetic currents, respectively, at the same point.

If the electric vectors be measured in electrostatic and the magnetic vectors be measured in electro-magnetic units, then, V being the ratio between the two, we can state symbolically the two laws as follows:

$$\left.\begin{aligned}\frac{4\pi}{V}\frac{da}{dt} &= -\left(\frac{\delta Z}{\delta y}-\frac{\delta Y}{\delta z}\right)\\ \frac{4\pi}{V}\frac{db}{dt} &= -\left(\frac{\delta X}{\delta z}-\frac{\delta Z}{\delta x}\right)\\ \frac{4\pi}{V}\frac{dc}{dt} &= -\left(\frac{\delta Y}{\delta x}-\frac{\delta X}{\delta y}\right)\end{aligned}\right\}\text{ First law.}$$

$$\left.\begin{aligned}\frac{4\pi}{V}\frac{df}{dt} &= \frac{\delta\gamma}{\delta y}-\frac{\delta\beta}{\delta z}\\ \frac{4\pi}{V}\frac{dg}{dt} &= \frac{\delta\alpha}{\delta z}-\frac{\delta\gamma}{\delta x}\\ \frac{4\pi}{V}\frac{dh}{dt} &= \frac{\delta\beta}{\delta x}-\frac{\delta\alpha}{\delta y}\end{aligned}\right\}\text{ Second Law.}$$

An immediate consequence of these two laws is the following important relation :—

$$\frac{\delta}{\delta x}\left(\frac{da}{dt}\right)+\frac{\delta}{\delta y}\left(\frac{db}{dt}\right)+\frac{\delta}{\delta z}\left(\frac{dc}{dt}\right)=0$$

$$\frac{\delta}{\delta x}\left(\frac{df}{dt}\right)+\frac{\delta}{\delta y}\left(\frac{dg}{dt}\right)+\frac{\delta}{\delta z}\left(\frac{dh}{dt}\right)=0.$$

That is to say, the magnetic and the electric currents follow the laws of flow of an incompressible fluid. Hence they form closed paths. This is one of the essential differences between the Maxwellian theory and the older electro-magnetic theories. Numerous other essential differences can be deduced directly from the two laws by a proper interpretation of the physical meaning of the perfect formal similarity existing between them. One or two only of the several of these essential differences which were first pointed out clearly by Hertz,* should be mentioned here, in order to show their general character. The magnetic field induced by a loop of wire carrying an electric current (which we may call a varying electric solenoid) has the same form as the electric field induced by a varying magnetic solenoid which has the same geometrical configuration as the loop; hence just as two varying electric solenoids exert a magnetic force, so two varying magnetic solenoids exert an electric force upon each other.

An experimental proof of the existence of the electric field of force induced by a varying magnetic solenoid would constitute a *direct experimental evidence* in favor of the Maxwellian theory. It is evident, however, that extremely serious and apparently insurmountable technical difficulties would be encountered by every attempt to verify experimentally this relation and similar other reciprocal relations which, taken

* Wied. Ann. xxiii, p. 84, 1884.

together, constitute the physical meaning of the perfect similarity in form between the two fundamental laws of Maxwell's electro-magnetic theory.* Rowland's classical experiment which proved the existence of a magnetic field produced by a moving electrostatic charge, and Röntgen's detection of the magnetic effect of a varying dielectric polarization, may be considered as the only direct experimental evidences ever obtained.

2. *Second part of Maxwell's theory.*

A search for a source of indirect experimental evidences leads to the second and most interesting, but at the same time most difficult, part of Maxwell's electro-magnetic theory. *The principal feature of this part is the second characteristic feature of this theory. It is the importance of the function which is performed by the physical constants of the field, namely, by the specific inductive capacity, the magnetic permeability, and the resistivity.*

These constants Maxwell defines by the law of flux, which in the well known notation is expressed as follows:

$$\left.\begin{aligned} f &= \frac{K}{4\pi}X,\ g = \frac{K}{4\pi}Y,\ h = \frac{K}{4\pi}Z \\ a &= \frac{\mu}{4\pi}\alpha,\ b = \frac{\mu}{4\pi}\beta,\ c = \frac{\mu}{4\pi}\gamma \\ u &= \frac{X}{k},\ v = \frac{Y}{k},\ w = \frac{Z}{k} \end{aligned}\right\} \text{for isotropic media.}$$

$$\left.\begin{aligned} f &= \frac{K_1}{4\pi}X,\ g = \frac{K_2}{4\pi}Y,\ h = \frac{K_3}{4\pi}Z \\ &\cdots\cdots\cdots\cdots \\ u &= \frac{X}{k_1},\ v = \frac{Y}{k_2},\ w = \frac{Z}{k_3} \end{aligned}\right\} \text{for anisotropic media.}$$

It should be observed now that the first part of this law, referring to isotropic media, is a statement of experimental facts as long as we confine ourselves to constant and slowly-varying forces; it is an hypothesis† in every other case. The second part, referring to anisotropic media, was a pure hypothesis at the time when Maxwell first stated it. He justified it by pointing out the close connection between the optical and the electro-magnetic constants. Hence just as double refraction of light in a substance proves that the optical constants of the substance are different in different directions, so the double refraction of

* Lodge, Phil. Mag., June, 1889.

† See Goldhammer, Wied. Ann. xlvi, p. 99, 1892.

electro-magnetic waves in a substance can be accounted for by the electro-magnetic theory by assuming that the electro-magnetic constants of the substance are different in different directions. There seems to be no strong evidence against the assumption that Maxwell looked upon this form of the law of flux as merely a first approximation to truth.

We are ready now to describe the sources of indirect experimental evidences in favor of the hypotheses on which rest the two fundamental laws of Maxwell's electro-dynamics. It seems desirable, however, to make first the following slight digression. Combining the two fundamental laws with the law of flux and considering, for the sake of brevity, that the medium is isotropic and non-absorptive, we obtain:

$$\left.\begin{array}{l} \frac{K}{V}\frac{dX}{dt} = \frac{\delta\gamma}{\delta y} - \frac{\delta\beta}{\delta z} \\ \ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots \end{array}\right\}(A)$$

$$\left.\begin{array}{l} \frac{\mu}{V}\frac{\delta\alpha}{dt} = -\left(\frac{\delta Z}{\delta y} - \frac{\delta Y}{\delta z}\right) \\ \ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots \end{array}\right\}(B).$$

Equations (A) and (B) and similar equations for absorptive and anisotropic media are very often called the mathematical statement of the two fundamental laws of Maxwell's electro-dynamics. Such a presentation of the Maxwellian theory seems not only entirely unnecessary but also misleading. For the hypotheses by means of which Maxwell passed from the two experimental laws of magneto-electric and of electro-magnetic induction to the two fundamental laws of his electro-dynamics have very little if anything to do with what may or may not be the complete form of the law of flux as stated above, not even if we choose to accept Maxwell's mechanical models of the electro-magnetic field as correct representations of what is going on in such a field. In these models the constants K, μ, k, have a definite mechanical meaning, but this meaning does by no means lead to the conclusion that for all periodicities of the impressed forces equations (A) and (B) are equivalent to that mathematical statement of the two fundamental laws in which the current and the forces appear as fundamental vectors, and no reference whatever is made to the physical constants of the field. Equations (A) and (B) should, therefore, be treated as an adulteration of Maxwell's fundamental laws, the foreign element in this adulteration being that form of the law of flux which Maxwell employed. This adulteration may do, and as will be pointed out presently, actually does just as well, in many instances, as the real thing, but there are considerations, to be discussed presently, which seem to speak very forcibly against the equivalence between this adulteration and the real thing.

The main thread of the discussion can now be taken up again. Combining the two fundamental laws with the law of flux, the well known relations of which the following are types are easily obtained:

$$\frac{d^2X}{dt^2} + \frac{4\pi}{k_1K_1}\frac{dX}{dt} = \frac{V^2}{\mu K_1}\Delta^2 X$$

. . . .

. . . .

$$\frac{d^2\alpha}{dt^2} + \frac{4\pi}{k_1K_1}\frac{d\alpha}{dt} = \frac{V^2}{\mu K_1}\Delta^2 \alpha$$

. . . .

. . . .

For all non-absorptive isotropic insulators we shall have

$$\frac{d^2X}{dt^2} = \frac{V^2}{K}\Delta^2 X$$

. . . .

$$\frac{d^2\alpha}{dt^2} = \frac{V^2}{K}\Delta^2 \alpha$$

. . . .

These equations describe the source of indirect experimental evidences of the Maxwellian theory. They constitute the second part of this theory, and they show better than any words can the important function which the physical constants of the field perform in our modern views of electro-magnetic phenomena. It was reserved for Hertz and his followers to reveal by actual experiment the wealth of this source and to demonstrate beyond all reasonable doubt that long electro-magnetic waves are propagated in perfect accordance with the laws stated in these equations. These laws are, within certain limits which will be mentioned presently, a perfect analogy to the laws of propagation of luminous waves. Hence experimental results obtained from electro-magnetic phenomena involving the operation of forces whose period is not shorter than the shortest period of the Hertzian waves, give a decisive victory for the hypotheses which underlie the Maxwellian electro-magnetic theory.

But this theory is much broader. It states that, probably, light is an electro-magnetic phenomenon. It fails, however, to give a satisfactory account of some of the most striking optical phenomena, as, for instance, dispersion, absorption, rotation of the plane of polarization, etc. In other words, it fails to give a satisfactory general relation between optical and electro-magnetic constants without resorting to additional hypotheses.

This failure is not confined to the electro-magnetic theory; all optical theories labor under the same difficulty. There is, however, one distinct and important advantage which the electro-magnetic theory has over other optical theories. It is the definiteness of its premises. For whereas the dynamical theories of light must start with the material attributes, density and elasticity, of an unknown substance, the ether, which possibly may not resemble ordinary matter and whose material attributes, if it has them at all, seem to be entirely outside of the possibility of direct experimental test, the electro-magnetic theory endows the same substance with no other attributes excepting those contained in Maxwell's first and second law of electro-dynamics and the law of flux, and it proves the actual existence of these attributes by direct experiment covering a large region of electro-magnetic phenomena, the region of the Hertzian waves. It is, therefore, perfectly sure of its ground in one extensive region of ether manifestations.

The limitations of the Maxwellian hypotheses are also very clear from the character of the experiments which guided the formation of these hypotheses. These experiments were performed with constant or very slowly-varying forces, hence the obvious probability that Maxwell's hypotheses need a modification in the case of electro-magnetic phenomena involving the operation of rapidly-varying forces; in other words, Maxwell's electro-magnetic theory must be extended so as to include the periodicity of its fundamental vectors before it can become a satisfactory optical theory.

The first and the second law of Maxwell's electro-dynamics in the form stated above contain no mention of the physical constants of the field. If our experience with optical phenomena can be relied upon to guide us in our attempt to extend the electro-magnetic theory, then we should naturally infer that the element of periodicity can enter into Maxwell's electro-magnetic theory through the physical constants, only, of the field, and therefore through the law of flux and not through the two fundamental laws, which, in my opinion, do not contain these constants explicitly. It is, therefore, the law of flux which in all probability must be extended so as to include the periodicity of the impressed forces, if Maxwell's electro-magnetic theory is to become a theory of light. A careful analysis of the several satisfactory electro-magnetic theories of dispersion and absorption and of the magnetic rotation of the plane of polarization supports this conclusion. I refer in particular to the following investigations and reserve a more detailed discussion of this matter for a future occasion:

Von Helmholtz, Wied. Ann. xlviii, pp. 389 and 723, 1893. Goldhammer, Wied. Ann. xlvii, pp. 93 and 265; xlvi, p. 71, 1892. Drude, Wied. Ann. xlvi, p. 353, 1892; xlviii, p. 122 and p. 356; xlix, p. 960, 1893. Ebert, Wied. Ann. xlviii, p. 1, 1893; li, p. 268, 1894.

3. *Extension of the law of flux.*

The question arises now, can we without resorting to any hypotheses not already contained in Maxwell's electro-magnetic theory find a more general and satisfactory form for the law of flux? This question can be answered in the affirmative, provided that by a law of flux we mean a quantitative relation between the electric force and the electric flux on the one hand and the magnetic force and magnetic flux on the other.

Consider two large conductors insulated from each other by a perfect non-conductor. Let one of them be connected to one pole of a galvanic cell and the other to the other pole. We know that as soon as these conductors are connected in the manner described an integral transient current takes place whose value depends on the capacity of the conductors. The work of the cell appears half as heat in the conducting parts and half as potential energy in the dielectric. If Q be the integral current and E the electromotive force of the cell, then

$$EQ = \text{total work of the cell.}$$
$$\tfrac{1}{2}EQ = \text{potential energy stored in the dielectric.}$$

Let X, Y, Z be the components of the intensity of the electromotive reaction at any point of the dielectric and at any moment during the flow of the integral current.

Let $\frac{df}{dt}, \frac{dg}{dt}, \frac{dh}{dt}$ be the components of the intensity of the electric displacement current at the same point and time, then

$$\int_0^t dt \int \left(X\frac{df}{dt} + Y\frac{dg}{dt} + Z\frac{dh}{dt} \right) d\tau = \tfrac{1}{2}EQ$$

where $d\tau$ is an elementary volume of the dielectric. The integration extends over the whole dielectric field and over the interval of time from the start to the completion of the integral current. It is evidently immaterial how X . . . . and f . . . . vary during the flow of the integral current; the final resultant potential energy in the dielectric is, according to experiment, always the same and equal to $\frac{1}{2}$EQ. According to their physical character X . . . f . . . are, of course, finite, continuous, and singly-valued functions of the time; we can apply, therefore, to the indicated integration all the rules of calculus which are applicable to such functions. Integrating by parts we obtain

$$\int(X_1f_1+Y_1g_1+Z_1h_1)d\tau-\int_0^t dt\int\left[f\frac{dX}{dt}+g\frac{dY}{dt}+h\frac{dZ}{dt}\right]d\tau=\tfrac{1}{2}EQ$$

where the suffix 1 denotes that the value at the moment of cessation of the integral current is to be taken.

Now it can be easily shown that the first integral equals EQ. Hence

$$\int_0^t dt\int\left\{\left(X\frac{df}{dt}-f\frac{dX}{dt}\right)+\left(Y\frac{dg}{dt}-g\frac{dY}{dt}\right)+\left(Z\frac{dh}{dt}-h\frac{dZ}{dt}\right)\right\}d\tau=0$$

Every functional relation between $X \ldots f \ldots$ which will satisfy this equation will be a permissible form of the law of flux.

For instance,

$$f=\frac{K}{4\pi}X,\ g=\frac{K}{4\pi}Y,\ h=\frac{K}{4\pi}Z$$

is one set of relations which will satisfy this equation.

Here is another set

$$f=\frac{1}{4\pi}(K_{11}X+K_{12}Y+K_{13}Z)$$

$$g=\frac{1}{4\pi}(K_{21}X+K_{22}Y+K_{23}Z)$$

$$h=\frac{1}{4\pi}(K_{31}X+K_{32}Y+K_{33}Z)$$

where $K_{12}=K_{21},\ K_{13}=K_{31},\ K_{23}=K_{32}$

By a suitable selection of coördinate axes this set can be written

$$f=\frac{K_1}{4\pi}X$$

$$g=\frac{K_2}{4\pi}Y$$

$$h=\frac{K_3}{4\pi}Z$$

A third set of relations is obtainable by supposing f, g, h to vary harmonically, since in this case

$$\frac{d^{2n}f}{dt^{2n}}=(-1)^n p^{2n}f,\ \text{etc.}$$

where $p = 2\pi\times$ frequency, we obtain

$$f=\left\{\frac{4\pi}{\frac{4\pi}{K_1}-p^2A}\right\}X$$

$$g=\left\{\frac{4\pi}{\frac{4\pi}{K_2}-p^2B}\right\}Y$$

$$h=\left\{\frac{4\pi}{\frac{4\pi}{K_3}-p^2C}\right\}Z$$

as another possible set of relations.

Here

$$A=a_1-a_2p^2+a_4p^4- \ldots .$$
$$B=b_1-b_2p^2+b_4p^4- \ldots .$$
$$C=c_1-c_2p^2+c_4p^4- \ldots .$$

In this permissible form of the law of flux the constant which corresponds to specific inductive capacity is a function of the periodicity. A large variety of other relations can easily be found all of which will satisfy the integral equation.

If the dielectric is absorptive then the value of the integral does not vanish but equals the heat developed in the dielectric. Hence in general

$$\text{(C)}\int_0^t dt\int\left\{\left(X\frac{df}{dt}-f\frac{dX}{dt}\right)+\left(Y\frac{dg}{dt}-g\frac{dY}{dt}\right)+\left(Z\frac{dh}{dt}-h\frac{dZ}{dt}\right)\right\}d\tau \geqq 0$$

contains all the possible forms of the law of flux relating to the electrical force and the electric flux, which are consistent with Maxwell's hypotheses and with the quadratic form of electropotential energy.

A similar relation between the magnetic force and the magnetic flux can be obtained. Consider a loop of wire in which a galvanic cell sets up a current. From the moment of closing the circuit up to the time when the current becomes constant magnetic energy is stored up in the medium. The final amount of magnetic energy will be in the well known notation

$$W=\tfrac{1}{2}LC^2$$

Let α, β, γ be the components of the intensity of the magnetomotive reaction at any point of the field and at any moment during the flow of the magnetic integral current.

Let $\frac{da}{dt}$, $\frac{db}{dt}$, $\frac{dc}{dt}$ be the components of the intensity of the magnetic current at the same point and the same moment, then

$$\int^t dt\int\left(\alpha\frac{da}{dt}+\beta\frac{db}{dt}+\gamma\frac{dc}{dt}\right)d\tau=\tfrac{1}{2}LC^2$$

Integrating by parts we obtain

$$\int(\alpha_1 a_1+\beta_1 b_1+\gamma_1 c_1)d\tau-\int_0^t dt\int\left(a\frac{d\alpha}{dt}+b\frac{d\beta}{dt}+c\frac{d\gamma}{dt}\right)d\tau=\tfrac{1}{2}\mathrm{LC}^2$$

The first integral refers to the state of the field when the electric current has become constant and therefore the magnetic integral current has ceased to flow. The value of this integral can be easily shown to be LC^2 and we have, therefore,

$$\int_0^t dt\int\left\{\left(\alpha\frac{da}{dt}-a\frac{d\alpha}{dt}\right)+\left(\beta\frac{db}{dt}-b\frac{d\beta}{dt}\right)+\left(\gamma\frac{dc}{dt}-c\frac{d\gamma}{dt}\right)\right\}d\tau=0$$

The same relations can be deduced from this integral as from (C). If the dielectric of the field is absorptive then the last integral equals the heat developed in the field. We can put, therefore

$$\text{(D)}\quad \int_0^t dt\int\left\{\left(\alpha\frac{da}{dt}-a\frac{d\alpha}{dt}\right)+\left(\qquad\right)+\left(\qquad\right)\right\}d\tau\geqq 0$$

as the most general relation between the magnetic force and the magnetic flux.

Equations (C) and (D) are the consequence of the following premises:—First, the hypotheses by means of which we pass from the two experimental laws of electro-magnetic and magneto-electric induction to Maxwell's two fundamental laws are correct. Second, it is an experimental fact that the electric energy of the field is proportional to the square of the integral electric and the magnetic energy is proportional to the square of the integral magnetic current which has passed across the field. Third, the principle of conservation of energy is applicable to the processes just described.

Since these equations (C) and (D) contain as a special case not only that form of the law of flux which Maxwell employed in the second part of his electro-magnetic theory, but also a large variety of other forms of that law, in which the physical constants which determine the propagation of an electro-magnetic disturbance appear as functions of the periodicity of the impressed forces, and since forms of the law of flux of the same type as these latter forms were assumed hypothetically in most of the recent developments of the electro-magnetic theory of light because they lead to a tolerably satisfactory explanation of the phenomena of dispersion, absorption, rotation of the plane of polarization,—it follows that we can accept these two equations as the most general expression for the law of electro-magnetic flux.

Summary.

The main points of this essay can be summed up as follows:

Maxwell's electro-magnetic theory consists of two *distinct* parts. The essential elements of the first part are the law of induced electromotive force and the law of induced magneto-motive force. These two fundamental laws are an extension of the two experimental laws of magneto-electric and of electro-magnetic induction, which extension consists in adding to what is already contained in these experimental laws the hypotheses that the magnetic and the electric flux in dielectrics are not a mere mathematical fiction, as the older electro-magnetic theories supposed, but an actually existing state in the dielectric whose rate of variation through any imaginary surface in the dielectric is proportional to the reacting electro-motive, respectively magneto-motive force, induced around the circuit of the boundary line of this surface. The value of the reacting force is independent of the nature of the substance through which the circuit passes. Hence the physical constants of the electro-magnetic field (that is specific inductive capacity, etc.) do not appear in the first part of Maxwell's electro-magnetic theory.

The second part of this theory takes account of these constants by adding to the two fundamental laws just mentioned the ordinary form of law of flux. The first two laws are a cross-connection between the varying flux of one type and the reacting force of the other type; the law of flux, on the other hand, is a direct connection between the force and the flux of its own type. Combining the two fundamental laws with the law of flux, we obtain the fundamental differential equations of the second part of Maxwell's electro-magnetic theory. These equations are a mathematical statement of the laws of propagation of an electro-magnetic disturbance through various media, exhibiting the remarkable fact that, on the one hand, the velocity of propagation of an electro-magnetic disturbance is approximately and the wave-form of propagation is exactly the same as in the case of light; on the other hand, however, the velocity of propagation of an electro magnetic wave through a non-absorptive dielectric is independent of its periodicity, a fact which does not hold true in the case of light.* Hence although both parts of the Maxwellian theory agree well with experimental facts which were brought to light by the labors of Hertz and of other physicists who extended the Hertzian methods of investigation, yet this theory falls short of being a satisfactory theory of light, because it represents the propagation of electro-magnetic waves as inde-

* An apparent exception to this is the propagation of light through the most perfect of all dielectrics, namely, the ether in a perfect vacuum The velocity of propagation of light through this dielectric is, within the narrow limits of the visible spectrum, independent of the wave length. The question, however, whether all wave-lengths travel through pure ether with the same velocity has not yet been answered definitely. The statement, therefore, that the velocity of Hertzian waves in ether is the same as that of light is somewhat indefinite.

pendent of the periodicity of these waves, and therefore fails to account for some of the most important optical phenomena like dispersion, absorption, etc. These phenomena we know to be due to the dependence of the optical constants of a substance on the periodicity of waves; hence, if Maxwell's electro-magnetic theory is to become a satisfactory theory of light, it must be extended so as to represent the electro-magnetic constants of a substance as functions of the periodicity of the impressed electro-magnetic forces. This extension of the Maxwellian theory will affect, therefore, the law of flux only, and not the first part of this theory, since this part does not and should not contain any reference whatever to the nature of the medium of which the electro-magnetic field is composed.

This opinion is confirmed by the recent developments of the electro-magnetic theory of light, since in these the law of flux and not the two fundamental laws of Maxwell's theory appear in a modified form. Besides, it is obvious that Maxwell's form of the law of flux holds true for constant and slowly varying forces only. In every other case its application is only tentative. The second part of the Maxwellian theory should, therefore, be considered as a tentative and therefore approximate description of the laws of propagation of electro-magnetic disturbances. A more accurate description of these laws must proceed from a more general form of the law of flux, a form which will hold true for forces of all periodicities. That such a form of the law of flux actually exists is rendered highly probable by considering the most general relation between the electric and magnetic forces and their fluxes which will satisfy Maxwell's fundamental hypotheses, and also the observed fact that the electric, respectively magnetic, energy of the medium through which an integral electric, respectively magnetic, current *has passed* is a quadratic function of that integral current. This general relation is expressed by the forms (C) and (D) deduced above.

Maxwell's provisional form of the law of flux is a special case of this general relation. This general relation suggests also that many other forms of the law of flux are permissible in which those physical constants which determine the propagation of an electro-magnetic disturbance appear as functions of the periodicity of the disturbance. But these constants are not specific inductive capacity, magnetic permeabilities and resistivity of the medium.

It still remains to be shown that according to Maxwell's electro-magnetic theory a law of flux containing explicitly the periodicity of the impressed forces is not only admissible but also necessary. When that is shown, then this theory will have fulfilled one of the most essential conditions which every satisfactory theory of light must fulfill.

Effingham Park, West Islip, L. I., Aug. 20, 1895.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Conversion of the black to the red mercuric sulphide.*—In a series of careful experiments W. Spring has obtained the following values for the specific gravity and specific volume of the black mercuric sulphide precipitated, and for the red sulphide both precipitated and sublimed.

Black, precipitated.

	18°·3	23·6	35·2	56·5	77·5
Sp. grav....	7·6242	7·6047	7·5686	7·5500	7·5578
Sp. vol.....	131·160	131·496	132·124	132·452	132·313

Red, precipitated.

	21°·6	23·5	34·6	56·5	77·7
Sp. grav....	8·1289	8·1246	8·1016	8·0851	8·0871
Sp. vol.....	123·018	123·082	123·432	123·684	123·653

Red, sublimed.

	15°·8	18·0	34·6	56·6	77·5
Sp. grav....	8·1587	8·1464	8·1199	8·0906	8·0979
Sp. vol.....	122·569	122·754	123·154	123·600	123·488

The above values, treated graphically, prove that the volume varies with the temperature with both the sulphides. The expansion increases rapidly with the temperature then grows less and less, finally diminishing so as to give a maximum at about 56°. It is hence concluded that the cause of the difference in color is to be found in the constitution of the molecule and not in their orientation, that is in the crystallization. On comparing the specific gravity with the molecular weight (232), calculation shows further that the molecule of cinnabar must contain the group HgS fifteen times if the black sulphide contains it fourteen times. The following are determinations of the specific heat at different temperatures of the two sulphides, both precipitated :

	Black.	Red.	Ratio.
25° to 30°......	0·08348	0·07487	1·115
35° to 40°......	0·09668	0·08707	1·110
45° to 50°......	0·11015	0·09335	1·118
55° to 60°......	0·11034	0·09852	1·120
65° to 70°......	0·12065	0·10737	1·123
75° to 80°......	0·14328	0·12702	1·128

The above values of the specific heat correspond at different temperatures to those of the volumes as given above. On comparing the volumes of the black and red sulphides at the same temperature the values 0·888 and 0·932 are obtained. From these the pressure can be calculated at which the one variety should be converted into the other. The value deduced is 34,000 atmospheres, on the supposition that the compressibility does not vary, and this not being strictly true, the required pressure in fact would be still greater or beyond the limit of experiment. The author, however, has found it possible to prepare a form of black sulphide differing less from the red in density. By subliming mercuric sulphide under ordinary conditions the red crystallized variety is formed, but if the vapors are diluted with a sufficient volume of inert gas (as CO_2, or N), a black powder is obtained containing black opaque crystals quite distinct from cinnabar and also distinct from the black variety obtained by precipitation. This variety was found to have a specific gravity of 8·0395 and a specific volume of 124·385 at 17°. For this a pressure of about 2,500 atmospheres, which it is easy to obtain, suffices to convert it into the red sulphide; the black sulphide being changed throughout its mass to the red vermilion. Finally the author finds that while the red sulphide if heated at 250° begins to turn black but assumes its red color on cooling, and while this is true up to 320°, if heated *above* 320°, it remains black permanently; this is then a critical temperature above which the red variety ceases to exist.—*Bull. Acad. Roy. Belgique*, III, xxviii, 238–257.

2. *The color, density and surface tension of hydrogen peroxide.*—Recalling the observations of Bunsen that pure water has a bluish color in a layer 2 meters in thickness and in one greater than 7·5 meters a bluish green, W. Spring states that his observations show that the color does not change with the thickness of the layer, the shade only varies. He ascribes the green tints to a yellow fluorescence produced by the play of the white light upon minute solid particles in suspension. He also notes the observations of Olzewski that liquid oxygen shows a blue color in a thickness of 30^{mm}. Further, he remarks that ozone as a gas has also a blue color in a layer of 1 meter in thickness (Hautefeuille and Chapuis), while in the liquid form it is blue and almost opaque in a layer of 2^{mm} (Olzewski). The author has now shown that hydrogen peroxide, like oxygen, ozone and water, also has a *blue color*, though hitherto it has been stated to be a colorless liquid. With great care he has prepared a considerable amount of the pure material, viz: 212 grams representing some 140^{cc} at 13°. Of this the specific gravity was found by means of a pycnometer to be 1·4996 at 1°·5, and the value of the surface tension, compared with that of water, was determined to be 0·456. The color was observed in a tube 1 meter in length; this placed vertically showed, after the bubbles of gas had disappeared, a distinct *blue* color somewhat tinged with green; the green however is regarded as non essential. A quantitative determination of the color showed that the tint, while similar to that of water, was deeper, the relation between the two being 1 : 1·83; this was obtained by comparisons of each with layers of copper chloride of such thickness as to give the same tint. From

this fact it is argued that in hydrogen peroxide the oxygen has lost less of its properties than in water, and this, in the author's opinion, confirms the view that the constitution is expressed as a feebly united compound of the group O_2 with H_2 rather than as a union of two hydroxyl groups, HO–OH. The blue color of the sky the author regards as explained primarily by the color belonging to the oxygen, ozone, water and hydrogen peroxide present in it; it is not due, however, to transmission simply but to reflection from the earth and refraction, as a mirage of diffused light, through extensive layers of the atmosphere. The author promises to discuss this latter subject more fully later.—*Bull. Acad. Roy. Belgique*, III, xxix, 363–384.

3. *Indirect Electrolysis of a liquid.*—E. ANDREOLI has recently described a modified method for the electrical decomposition of a liquid which he calls indirect or secondary electrolysis. He employs a bath divided by plates of porous porcelain into three compartments; the end ones he fills with some conducting liquid, while the middle one contains the liquid to be decomposed; the anode and cathode are immersed in the first and last compartments, respectively. If the arrangement is simply as thus far described the passage of the electrical current results only in the decomposition of the first mentioned liquid:—thus, if it is water containing salt, chlorine is liberated at the anode and sodium hydrate formed at the cathode while the other liquid, *e. g.* gold cyanide, is unaffected. If, however, a metallic plate, or better, several plates are immersed in the liquid of the central compartment, but not connected with either pole, this liquid is now decomposed and in the case given gold is deposited on the metallic surface. Thus a lead plate opposite the diaphragm near the negative pole becomes peroxydized, while the other side is coated with gold. Metallic plates placed vertically or horizontally in the layer of liquid near the positive compartment are coated with gold. If the liquid in the end compartments is gold cyanide, no change is found in it if tested after a considerable time, while the same liquid in the central compartment has been decomposed even to the point of exhaustion. This method has also been employed to transform bisulphite of sodium into the hyposulphite; this liquid is placed in the center with two metallic plates on the positive and negative sides respectively, while any convenient conducting liquid fills the ends. The latter liquid is unaffected by the passage of the current, while the other is decomposed with the liberation of gas and a piece of linen immersed in the bath is rapidly bleached.—*Le Génie civil*, xxvii, June 29, 1895.

4. *On the Constituents of Cleveite gas.*—A paper upon this subject by C. RUNGE and F. PASCHEN is printed in the September number of the *Philosophical Magazine* (p. 297) translated from the Proceedings of the Berlin Academy (July 11).

II. Geology and Mineralogy.

1. *Glacial lakes in the Genesee valley.*—The following is an abstract of a paper on "The Glacial Genesee Lakes," read by H. L. Fairchild at the summer meeting of the Geological Society, prepared by the author. This paper covered the lacustrine history of the Genesee hydrographic area, and incidentally the whole of its Pleistocene geology. The present hydrography of the Genesee basin was shown by a handsome map. Upon this map the low points in the boundary of the basin, or the passes into other drainage systems were indicated, with their altitudes. From the head waters of the Genesee in northwestern Pennsylvania to Lake Ontario the river has a fall of two thousand feet in about one hundred and fifty miles, of which fall six hundred feet are covered by the cataracts at Portage and at Rochester. It was claimed that during the northward retreat of the ice across western New York the ice acted as a moving dam, and the ponded waters in the basin escaped by different outlets at successively lower levels. The three principal earlier outlets were into the Alleghany-Ohio drainage; the important later outlet into the Canisteo-Chemung. Counting the primary episode of local lakes in the head-water valleys, and the present Ontario phase, the author enumerated ten distinct stages in the lacustrine history of the Genesee, or nine stages of local glacial waters. The eighth stage was that of Lake Warren; the ninth that of Lake Iroquois.

The numerous evidences of water-levels throughout the basin had been studied and measured without at the first attempting to correlate them with the several outlets, but a final comparison of the height of the terraces with the height of the water-scoured cols showed a remarkable and convincing relation. It was proved that with the uncovering of each successively lower outlet the terraces, deltas and other evidences of water-levels dropped to a corresponding height, a relation entirely inconsistent with the theory of marine submergence.

Several local morainic lakes were named of which the draining streams had fallen upon rock and been compelled to make rock gorges. Two of these rock-cuts occur in the main stream, at Portageville and at Mt. Morris.

During the ice-retreat there were several local contemporary lakes in the deep side valleys before those valleys were opened into the main valley, and these local lakes had their own outlets over the divide. There were also tributary lakes, where in a few cases north-sloping valleys, outside the divide, poured their glacial waters over the divide into the Genesee basin. These and other interesting features cannot be properly located and described without the map.

It was stated that all the valleys were of preglacial origin, and that there had apparently been little reversal of drainage. The only conspicuous post-glacial work is seen in the few rock-cuttings, and in the excavation of drift from the old valleys.

2. *Supplementary Notes on the Metamorphic Series of the Shasta Region of California.* Abstract of paper read before Section E of the American Association for the Advancement of Science; by JAMES PERRIN SMITH, Stanford University, California.—The Triassic limestones of the Shasta region show the remnants of an old system of anticlines and synclines, in places very perfect. Anticlinal noses and synclinal spoons are rare phenomena in massive limestones, but here they are unusually perfect. Many fossils were collected in the, probably, Lower Permian argillites at the top of the Carboniferous limestone, among them *Fusulina* aff. *longissima*, and many brachiopoda that resemble Permian forms.

Particular attention was paid to the Upper Trias, and many species were added to the known fauna ot this horizon, most of them being identical with or closely related to Alpine species. But the association of faunas was found to be new, and different from that known in other parts of the world. In the Alps and the Himalayas the *Trachyceras* fauna occurs below the zone of *Tropites subbullatus;* in the Shasta region the two faunas occur in the same beds, and even in the same hand-specimen. This is thought to indicate that either the *Trachyceras* fauna survived here longer than elsewhere, or else the *Tropites subbullatus* fauna appeared earlier in the Shasta region. The latter is thought to be the more probable, although both may be true, since the *Trachycerata* are indigenous to the Mediterranean region, while the *Tropitidæ* probably originated in the Pacific region.

The probable occurrence of the Juvavic horizon of the Trias was discussed, probably the only known occurrence of this horizon and fauna outside of the Tyrolean Alps.

3. *Ornithichnites and jaw bone from the Newark sandstone of New Jersey;* by ARTHUR M. EDWARDS, M. D. (Communicated.)—For several years I have carefully watched the quarries where the Newark (Jura-Triassic) sandstone was taken out at Newark, Arlington and at Belleville. Until now, however, I have not found large fossils except patches of the stems of ferns and Bacillariaceæ (Diatomaceæ) at Arlington. To-day at the Belleville quarry, just north of the city of Belleville, I was gratified to see some traces of larger fossils revealed in the lower levels of the quarry. These were Ornithichnites; a track of what is evidently Brontozoum with two of the joints well marked. A third is not so well marked. There are two nails of the foot evident. It is in a red shale which formed from fine-grained mud. Near by is a piece of fern, and scattered through the whitened sandstone are chrysocolla, cuprite and malachite. Last month I secured a jaw bone in excellent preservation with the teeth gone. It looks like *Dromatherium sylvestre* of Emmons. There are also slabs with markings on them which I cannot identify.

Newark, N. J., Sept. 11, 1895.

4. *Missouri Geological Survey—Lead and Zinc Deposits*, by Arthur Winslow, assisted by James D. Robertson, vols. vi and vii, pp. i–xxi, 1–763, plates i–xli, figures 1–268. Jefferson City, Mo., 1894.—The importance of the lead and zinc industry in Missouri is full justification for the preparation of this exhaustive treatise on lead and zinc deposits, by the geological survey of that state. The construction of the report follows the general lines of the admirable manganese report of Dr. Penrose, published by the Arkansas survey. The first part (pp. 1–507) is a summary account of the history, compounds, modes of occurrence and distribution of lead and zinc throughout the world, the final chapter of which, on the industries and statistics of lead and zinc, was written by Mr. Robertson. Although this part is chiefly a compilation, with its accompanying bibliography and frequent reference to sources, it will be of much value to the student as well as to the investor. The remainder of the report is devoted to an account of the history of mining in Missouri, the physiography and geology of the mines, and a detailed description of the several ore deposits and mines distributed throughout the state.

The investigations, which led to the writing of the report, were begun in 1889 in coöperation with the United States geological survey, whose representative, Dr. W. P. Jenney, collected a large body of facts illustrating the subject. Mr. Robertson of the state survey coöperated with Dr. Jenney in these investigations and was a co-worker with Mr. Winslow in the preparation of this final report.

Although communicated to the board of managers by Mr. Keyes, the report was planned and executed entirely by the late State Geologist, Mr. Winslow, who is to be congratulated upon the production of a work which brings together, in such orderly and satisfactory form, the knowledge up to date regarding the distribution and mode of occurrence of these mineral products.

The author's theory of the origin of the metalliferous minerals in the ore bodies is, briefly, that they were introduced into the cavities where they have been mined, "in solution," and that the source of these solutions was "original diffusion through the country rocks, and subsequent concentration through surface decomposition of the latter, supplemented by percolating waters."

H. S. W.

5. *Geological Survey of Canada.*—The Annual Report for 1892–93 has appeared. It contains, besides the usual summary reports of work done in the years 1892 and in 1893, two strictly geological reports, viz: "Preliminary Report on the Geology of a portion of Central Ontario," by Frank D. Adams, and "Prelim. Report on Geological investigation in Southwestern Nova Scotia," by L. W. Bailey. There are also "Chemical contributions" by G. Ch. Hoffmann and his assistants, and "Mineral Statistics and Mines" for 1892 by E. D. Ingall and his assistants. (Geol. Surv. Canada, A. R. Selwyn Direct., Ann. Rept. (new series), vol. vi, Repts. A (1892), A (1893), J, Q, R, S, 660 pages, Ottawa, 1895.)

6. *The Geological Society of America.*—The Geological Society held its seventh summer meeting in Springfield, Mass., August 27th and 28th, N. S. Shaler presiding. The following is a list of the papers presented :

GEO. M. DAWSON and R. G. MCCONNELL : Glacial deposits of Southwestern Alberta, in the vicinity of the Rocky Mountains.

C. H. HITCHCOCK: The Champlain glacial epoch.

WARREN UPHAM: Drumlins and marginal moraines of ice-sheets.

H. L. FAIRCHILD : The glacial Genesee Lakes.

B. K. EMERSON: The geology of old Hampshire county in Massachusetts.

N. H. DARTON: Notes on relations of lower members of coastal plain series in South Carolina. Resume of general stratigraphic relations in the Atlantic coastal plain from New Jersey to South Carolina.

ARTHUR HOLLICK: Creteceous plants from Martha's Vineyard. Results obtained from an examination of the material collected by David White in 1889.

R. T. JACKSON and T. A. JAGGAR: Arrangement and development of plates in the Melonitidæ.

GEORGE P. MERRILL : On asbestos and asbestiform minerals.

WILLIAM H. HOBBS: Pre-Cambrian volcanoes in Southern Wisconsin.

A. CAPEN GILL : A geological sketch of the Sierra Tlayacac, in the State of Morelos, Mex.

C. H. GORDON : Syenite-gneiss (Leopard Rock) from the Apatite region of Ottawa county, Canada.

J. F. KEMP : The titaniferous iron ores of the Adirondacks.

J. C. BRANNER : The decomposition of rocks in Brazil.

W. M. DAVIS: The bearing of physiography on Uniformitarianism.

C. R. VAN HISE: Analysis of folds.

N. S. SHALER: On the effects of the expulsion of gases from the interior of the earth.

7. *La Géologie Comparée, par Stanislas Meunier*, pp. 1–296, figures 1–35, Paris, 1895 (Bibl. Scientifique Internationale).—M. STANISLAS MEUNIER of the Natural History Museum of Paris, author of numerous papers on meteorites, has brought together in an attractive form, with typical French vivacity, a large body of facts illustrating the geological relations of the other planets of the solar system to the earth. The work is illustrated by 35 figures in the text, showing the forms of surface configuration of the planets and of structure of meteorites like those known on the earth. The author describes a number of remarkable similitudes between celestial and terrestrial objects, which are certainly interesting, though the reader may hesitate to adopt the author's conclusions.

8. *Die Eruptivgesteine des Kristianiagebietes: I Die Gesteine der Grorudit-Tinguait Serie ;* by W. C. BRÖGGER (Videnskab. Skrift 1 math. natur. Klasse, 1894, No. 4. Kristiania, 8°, pp. 206, 4 plates, etc.)—In his great work on the syenite-pegmatite dikes of southern Norway, Professor Brögger promised that this should soon be followed by a monograph on the eruptive rocks of the same district. The appearance of this volume has been eagerly awaited by all workers in this field of science. In his preface to the present work, the author states that he has been unable to carry out this plan and he now proposes to cover the same ground by a series of monographs on special subjects of which this, treating of a closely-related series of rock types, is the first.

It is to be followed by one dealing with the well known "rhombic porphyries."

The rocks now under discussion occur in dikes and are fine-grained and porphyritic. They consist essentially of alkali-feldspars and ægirite; where the silica percentage is high, quartz is also developed (grorudite); with falling silica it disappears (sölvsbergite) and below 60 per cent nephelite comes in as an important constituent (tinguaite). A fourth member of the series would be a rock with silica below 50 per cent and with nephelite preponderating over feldspar. This type the author recognizes in a rock described by Kemp* from Beemersville, N. J. and proposes for it the name of *sussexite.* This name, however, is clearly objectionable, if indeed it be not entirely ruled out by the fact that it has been applied since 1868 to a well-defined mineral species occurring at Franklin Furnace, N. J.

These rock types are described as to their occurrence in the field and mapped. Their petrology is discussed in detail and is accompanied by many analyses, plates, drawings and tables of mineral contents. Incidentally the author takes occasion to discuss and classify the alkali-iron hornblendes, introducing a new member to which the name of *kataforite* is given. His classification is as follows:

Barkevikite	angle $\mathfrak{c} \wedge c$ small 12°–14°	TiO_2 rich	ruling *brown* absorption colors	pleochroism $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}$
Kataforite	angle $\mathfrak{c} \wedge c$ large 30°–60°	TiO_2 poor	ruling red absorptions	$\mathfrak{b}>\mathfrak{c}>\mathfrak{a}$
Arfvedsonite *Riebeckite?*	angle $\mathfrak{c} \wedge c$ very large 75–86	TiO_2 free	ruling greenish blue colors	$\mathfrak{a}>\mathfrak{b}>\mathfrak{c}$.

A large portion of the book is devoted to theoretical petrology, and it is this that will be read with the greatest interest. Many new and important questions are brought up and discussed and much light is thrown upon old ones. In the brief limits of this notice it is impossible to do more than merely mention this fact, but it may be safely said that the importance of the present work in its bearing on general petrology can hardly be overestimated. L. V. P.

9. *Directions for collecting rock specimens.*—A useful series of papers, giving specific directions for collecting specimens in the field and preparing them for safe shipment, has been prepared by the Smithsonian Institution. Sufficient illustrations are given to guide the untrained in the preparation of tools and in methods of manipulation. The articles are entitled as follows: "Directions for collecting rocks and for the preparation of thin sections," by George P. Merrill, 15 pp.; "Directions for collecting and preparing fossils," by Charles Schuchert, 31 pp.; "Directions for collecting specimens and information illustrating the aboriginal uses of plants," by Frederick V. Coville, 8 pp., and "Directions for collecting minerals," by Wirt Tassin, 6 pp. (Bull. U. S. Nat. Mus., No. 39, Washington, 1895.)

* Trans. N. Y. Acad. Sci., vol. ii, p. 60, 1892.

10. *A preliminary Report on the Marbles of Georgia;* by S. W. McCallie. Bulletin No. 1, Geol. Survey of Georgia, W. S. Yeates, State Geologist.—This bulletin presents an account of the marbles of Georgia and the general condition of this industry at the present time. It is interesting to note that this State, in which the production for 1893 was valued at $261,666, stands second in the country in its production of marble. Vermont comes first with an output for the same year valued at $1,621,000 and New York third with one of $206,926; while for Tennessee and Maryland the corresponding values were $150,000 and $130,000 respectively.

11. *On some Swedish minerals;* by Hj. Sjögren.—A recent number of the *Bulletin of the Geological Institution of the University of Upsala* (vol. ii, part I, No. 3) contains an important article by Sjögren on some Swedish minerals (pp. 39 to 108). The subject of the chemical composition of the minerals of the Humite-Chondrodite group is reviewed with new analyses by Mauzelius on carefully selected material. The formulas derived are as follows:

Chondrodite	$Mg_3[Mg(F.OH)]_2(SiO_4)_2$
Humite..................	$Mg_5[Mg(F.OH)]_2(SiO_4)_3$
Clinohumite............	$Mg_7[Mg(F.OH)]_2(SiO_4)_4$

These formulas agree perfectly with those deduced independently and a little earlier by Penfield and Howe (this Journal, xlvii, 188, March, 1894).

In continuance of the same subject a description is given of Prolectite, a new mineral of the above group. This, owing to lack of material, has been only partly investigated thus far. It crystallizes in the orthorhombic system and its relations to the other species is as follows:

	Ratio of vertical axes.
Prolectite....................	3
Chondrodite	5
Humite.........................	7
Clinohumite.................	9

With the three long known species the ratio above given is also—as first shown by Penfield and Howe—that of the magnesium atoms present (see formulas above). This fact led the authors named to suggest the probable discovery of another member of the group with the formula $Mg[Mg(F.OH)]_2SiO_4$, and although prolectite has not yet been analyzed it is urged by Sjögren that its composition will probably be found to conform to this. The name (from προλεγειν to *foretell*) alludes to the fact that its existence was thus predicted.

A description is also given of Retzian, a new arsenate from the Mossgrufva, Nordmark. It occurs in small orthorhombic crystals imbedded in a mixture of dolomite and braunite. They have a chestnut-brown or chocolate-brown color; hardness about

4; specific gravity 4·15. In form it is closely related to flinkite, but its chemical composition is not entirely settled, the following partial analysis by Mauzelius having been made on a very minute quantity (0·08 gr.):

As_2O_5	MnO	FeO	PbO	CaO	MgO	SiO_2	H_2O	X	
24·4	30·2	1·7	0·2	19·2	2·7	0·5	8·4	14·6	=101·9

X including insoluble 4·3 and not identified 10·3.

Another point of interest is the description of URBANITE (see this Journal, July, p. 76), which is shown to belong to the pyroxene group. An analysis by Mauzelius gave:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	ign.
G.=3·52	51·61	0·74	27·24	0·54	1·73	4·90	2·75	10·59	0·36	0·90
										=101·36

Descriptions are also given of a soda-richterite, a soda-berzeliite, of the partially known mineral caryinite, of crystallized safflorite, of magnetite in cubic crystals, etc.

12. *Ueber gewundene Bergkrystalle*; von G. TSCHERMAK. Vienna, 1894 (Denkschriften der K. Akad. Wissenschaften, vol. lxi).—The remarkable crystals of quartz, not uncommon in Switzerland but known also from other localities, having curved faces and more or less twisted axial systems, have been minutely studied by Tschermak. He, while confirming the early observations of Weiss as to the regularity of these growths, has gone further and offered an explanation for them. This is based on the assumption of the simultaneous existence of three different methods of twinning. The first, which the majority of the specimens show, is the common law characteristic of many quartz crystals in which a plane of the hexagonal prism is the twinning plane. In the second law, the twinning plane is inclined to the vertical axis in the direction of the fundamental rhombohedron and very nearly perpendicular to it; in the third, the twinning plane is a face of a twelve-sided prism varying but little in position (only 1′ 40″) from that of the second prism. Several types of forms are shown to exist which are explained according as to whether two or three of these methods of twinnings coexist, and also determined by the method of their combination. The second and third twinning planes mentioned are properly vicinal planes, and hence the corresponding twins may be called *vicinal twins*. At the same time the suggestion is made that these vicinal twinning planes become fundamental planes with simple indices if it is assumed that the crystallization of quartz is not hexagonal-trapezohedral (tetartohedral), but triclinic-hemihedral. The plates accompanying the text give beautiful representations of some of the remarkable forms described, in which not only the deep smoky-brown color, but even the luster of the surface are faithfully reproduced.

III. Miscellaneous Scientific Intelligence.

1. *American Association for the Advancement of Science.*—The forty-fourth meeting of the American Association was held at Springfield, Mass., from August 28 to Sept. 4. The President of the meeting was Prof. Edward W. Morley of Cleveland. In the absence of the retiring President, Dr. D. G. Brinton, his address on the Aims of Anthropology was read by the General Secretary. Addresses were also delivered before the several sections, by their respective Vice-Presidents. The attendance at the meeting was not large, under four hundred, but the papers presented were numerous, as shown in the list given below, and the general success of the meeting was regarded as satisfactory; this was largely due to the excellent arrangements made by the local committee.

The next meeting was appointed for August, 1896, at Buffalo, N. Y., and Professor E. D. Cope was chosen President. The Vice-Presidents elected for the several sections are as follows: *Section A*, Wm. E. Story of Worcester, Mass.; *Section B*, Carl Leo Mees of Terre Haute, Ind.; *Section C*, W. A. Noyes of Terre Haute, Ind.; *Section D*, F. O. Marvin of Lawrence, Kansas; *Section E*, B. K. Emerson of Amherst, Mass.; *Section F*, Theodore N. Gill of Washington; *Section G*, N. L. Britton of New York City; *Section H*, Alice C. Fletcher of Washington; *Section I*, W. R. Lazenby of Columbus, O.

The following is a list of the papers accepted for reading before the several sections.

Section A. *Mathematics and Astronomy.*

J. B. Shaw: Development of some useful quaternion expressions, with applications to geometry of three and four dimensions.

C. L. Doolittle: The constant of aberration.

S. C. Chandler: On the constant of nutation.

A. N. Skinner: Progress of the zone work at the Naval Observatory, Washington, D. C.

L. A. Bauer: On the distribution and the secular variation of terrestrial magnetism.

M. A. Veeder: Sunspots and magnetic storms.

Edwin B. Frost: The spectrum of β Lyræ.

Artemas Martin: Notes on square numbers whose sum is either a square or the sum of other squares.

Albert S. Flint: Some results for stellar parallax from meridian transit observations at the Washburn Observatory.

Mary Proctor: Making astronomy popular.

Edgar Frisby: A convenient formula for computing times of moon rising. On a slide scale for computing precession.

Samuel W. Balch: Chronology and ancient eclipses.

H. M. Parkhurst: Period of R Comæ.

Section B. *Physics.*

M. I. Pupin: Flow of alternating current in an electrical cable. The most general relation between electric and magnetic force and their displacements.

J. H. Pillsbury: The significance of color terms. On standard colors. The analysis of floral colors.

Frank P. Whitman: On the comparison in brightness of differently colored lights and the "flicker" photometer.

E. R. von Nardroff: A new apparatus for studying color phenomena.

F. S. Muckey and William Hallock: Voice production, with photographs of the vocal cords in action. Voice analysis, with photographic record.

W. LeConte Stevens: Note on the limits of range of the human voice.

J. F. Mohler and W. J. Humphreys: Observations on the relations of certain properties of line spectra to the physical conditions under which they are produced.

F. E. Ives: The reproduction of colors by photography.

William Hallock: Electrolytic reproduction of resonators. A photographic method of comparing the pitch of tuning forks. Illustration of gems, seals, etc. Color definitions for the Standard dictionary.

Wm. A. Rogers: An examination of the statement of Maxwell that all heat is of the same kind. A new determination of the relative lengths of the yard and meter. The effect of age upon the molecular structure of bronze, glass and steel.

E. W. Morley and Wm. A. Rogers: Expansion of Jessop's steel, measured by interferential method.

John D. Parker: California electrical storms.

L. A. Bauer: A new formulation of the second law of thermodynamics.

Frederick Bedell: The method of reciprocal points in the graphical treatment of alternating currents.

H. D. Carhart: An experimental investigation of the rotatory field.

C. D. Child: Phenomena with electric waves analogous to those of light with a diffraction grating.

Willis L. Moore: Relations of the Weather Bureau to the science and industry of the country.

Frank H. Bigelow: Solar magnetic radiation and weather forecasts.

Cleveland Abbe: Clouds and their nomenclature.

Alfred J. Henry: Cloud photography.

Section C. *Chemistry.*

W. P. Mason: Foreign laboratory notes.

Ellen H. Richards and J. W. Ellms: The coloring matter of natural waters; its source, composition and quantitative measurement.

H. N. Stokes: Helium and argon.

F. P. Venable: Recent views on the periodic system.

C. H. Herty: Double salts and allied compounds.

E. W. Morley: On the volumetric composition of water.

W. A. Noyes: Camphoric acid. Journal reviews.

Alex. Smith: Constitution of the 1 : 4 dikestones.

P. C. Freer: The constitution of tetrinic acid. The teaching of organic preparations: the time, scope, methods and previous preparations. On the sulphides of arsenic formed in analytical work.

A. B. Prescott: Periodides. Periodides of pyridine. A few pyridine alkyl normal iodides. Some inquiries respecting inherent limitations in the accuracy of analytical work in general.

R. F. Flinterman and A. B. Prescott: Dipyridine trimethylene dibromide.

C. L. Jackson: Some new color reactions. A second modification of picrylmalonic ester. Instruction in general chemistry.

C. B. Dudley: Remarks on international standards of analysis of steel.

A. A. Blair and J. E. Whitfield: Ammonium phospho-molybdate and the reducing action of zinc in the reductor.

E. D. Campbell: Provisional schedule of admissible limits of accuracy in certain metallurgical analyses.

F. P. Dewey: Accuracy in metallurgical analysis.

T. H. Norton: On the use of thioacetic acid as a laboratory reagent. The phosphorus contained in phospho-cereal. Discussion on important phases of didactic chemistry. Laboratory construction and equipment.

R. B. Warder: The major premise in physical chemistry.

A. A. Noyes: Contributions to the knowledge of the laws of the velocity of polymolecular reactions.

H. C. Bolton: Bibliography as a feature of the chemical curriculum.

J. L. Howe: Relative order of theory and description in the teaching of general chemistry.

P. T. Austen: Chemistry as a liberal education.

H. W. Wiley: Quantitative exercises in general chemistry. Record of progress in agricultural chemistry.

E. E. Smith: Remarks on a specific form of cell metabolism.

E. A. de Schweinitz: Products of parthogenic bacteria.

W. O. Atwater: Some points connected with the chemistry and physics of metabolism. Chemistry of foods and nutrition.

Milton Whitney: Recent progress in physical analysis of soils.

Section D. *Mechanical Science and Engineering.*

H. N. Ogden: The economics of engineering public works.

De Volson Wood: Mathematical theory of the windmill.

J. J. Flather: Experiments on the flow of steam, and comparison of the results with Napier's formula.

Mansfield Merriman: On partially continuous drawbridge trusses, with a method of deducing formulas for the reactions.

H. S. Jacoby: On the design of fish-plate timber joints.

Wm. S. Rogers: The perfect screw problem; illustrated by a combined ruling engine and comparator in automatic operation.

Section E. *Geology and Geography.*

C. R. Van Hise: The relations of primary and secondary structures in rocks.

B. K. Emerson: The Archæan and Cambrian rocks of the Green Mountain range in Southern Massachusetts.

C. H. Hitchcock: Gotham's cave; or fractured rocks in Northern Vermont.

Arthur Hollick: Recent discovery of the occurrence of marine Cretaceous strata on Long Island.

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Section H. *Anthropology.*

F. H. Cushing: The dynasty of the arrow.
Stewart Culin: The origin of playing cards. The origin of money in China. Mustache sticks of the Ainus.
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*This paper and those immediately following were read before the Botanical Club.

Alice C. Fletcher: The sacred pole of the Omaha tribe. Indian songs and music.

W. W. Tooker: The mystery of the name Pamunkey. The Algonquian appellatives of the Siouan tribes of Virginia.

Washington Matthews: A vigil of the gods.

W. Z. Ripley: A study in anthropo-geography as a branch of sociological investigation.

Stansbury Hager: A melange of Micmac notes.

J. W. B. Hewitt: Grammatic form and the verb concept in Iroquoian speech. The cosmogonic gods of the Iroquois.

Arthur MacDonald: Anthropometrical, psycho-neural and hypnotic measurements.

J. D. Wright: The education of blind-deaf mutes.

L. O. Talbot: A study in child life.

Franz Boas: The Indians of Southern California.

Alex. F. Chamberlain: Word formation in the Kootenay language. Kootenay Indian personal names.

R. G. Haliburton: The year of the Pleiades of prehistoric star-lore. The influence of prehistoric pigmy races on early calendars and cults, with notes on dwarf survivals.

W. M. Beauchamp: An Iroquois condolence. Old Mohawk words.

J. McKeen Cattell: Mental measurements in anthropology.

F. W. Putnam and C. C. Willoughby: Some symbolic carvings from the ancient mounds of Ohio.

F. G. Wright: Account of the discovery of a chipped chert implement in undisturbed glacial gravel near Steubenville, Ohio.

George Leith: Notes on the bushmen of Transvaal.

Stephen D. Peet: Village life among the cliff dwellers. The Palæolithic cult, its characteristic variations and tokens. The different races described by early discoverers and explorers.

Harlan I. Smith: An Ojibwa transformation tale.

F. H. Cushing: The spider goddess and the demon snare.

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J. W. Sylvester: A system of co-metallism.

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W. R. Lazenby: Manual training in horticulture for our country schools.

J. L. Cowles: Equality of opportunity; how can we secure it?

W. L. O'Neill: On suicide.

E. L. Corthell: Growth of great cities.

Mary J. Eastman: A cottage settlement in Spain.

2. *Iowa Academy of Sciences.*—The exceptional privilege is enjoyed by the Iowa Academy of Science of having its Proceedings published by the State. Volume ii of the Proceedings for 1894 has appeared, making a volume of 225 pages, containing a number of valuable papers on geology and other branches of science. Several papers on glacial and preglacial geology, on stratigraphical problems, on paleontology—one on "Synopsis of American Paleozoic Echinoids" by C. R. Keyes, and others are of importance to those interested in the geology of the Mississippi Valley.

Obituary.

Professor C. V. Riley, the able and well known Entomologist of the Agricultural Department, died suddenly at Washington, D. C., on the fourteenth of September.

SPLENDID GAP MINE MILLERITES.

We purchased during September the largest and finest collection of Millerite specimens ever brought together at the Gap Mine. These specimens have been accumulating for a long time, the majority of them having been taken out nearly twenty years ago. The mine has been closed for about two years and is now permanently abandoned. The greater portion of the collection consists of plates of Millerite, both large and small, and ⅛ to ⅝ inch thick, made up of closely aggregated capillary crystals, whose terminations give the upper surface a velvety appearance; prices 10c to $5.00. There is also an excellent lot of specimens with the capillary Millerite coating Pyrrhotite, at 10c. to $2.50, and a goodly number of splendid radiated and botryoidal specimens at $1.50 to $5.00. Pure Millerite for blowpipe work, $2.00 per lb.

A TRIP TO NORTH CAROLINA.

Mr. English visited during September a number of important N. C. localities and secured many choice specimens, among them:

AUERLITE, the rare silico-phosphate of thorium, in good crystals from both the old and a new locality.

MUSCOVITE in remarkably sharp, and perfect, modified, loose crystals; a splendid large lot; 5c. to 25c. Also good groups of sharp crystals on the matrix, 10c. to 50c. The best collections will be improved by a series of these cheap yet fine crystals.

RUTILE crystals from Hiddenite, small but highly modified.

BERYLS. A few very highly modified little crystals from Hiddenite.

QUARTZ. A few loose crystals with an interesting trapezohedral development, from a new locality in Cleveland Co. A fine lot of the rare Quartzes of Alexander and Lincoln Counties. One specially fine, large crystal with bubble in it, $10.00. Mitchell Co. finds will be announced next month.

SIPYLITE, the very rare erbium mineral from Va., a new lot just received.

FROM MISSOURI. A shipment has just arrived from the famous Joplin Zinc region and brings us a fine lot of specimens. Iridescent tetrahedrons of Chalcopyrite attractively sprinkled over groups of pearl-colored, curved crystals of Dolomite. Splendid bright yellow, modified scalenohedrons of Calcite. Beautiful brilliant groups of Sphalerite, occasionally iridescent. Fibrous and radiated Sphalerite—the mineral which commonly passes as "Wurtzite," and a few crystalized specimens of the real Wurtzite.

FROM ICELAND. A grand lot of about 25 specimens of Heulandite, Stilbite and Epistilbite due Oct. 1st. The Iceland Zeolites are probably the finest in the world, and as we understand no more are obtainable, the present may be the last opportunity of securing them.

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The Mineral and Book business of Dr. A. E. Foote will be carried on as heretofore, under the management of Warren M. Foote.

AUGUSTA M. FOOTE,
WARREN M. FOOTE,
Executors for A. E. Foote, deceased.

1226 N. Forty-first Street,
Philadelphia, Pa.
October 22d, 1895.

Chas. D. Walcott.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. XXXVII.—*On the Wave Length of the D_3 Helium Line*; by A. DeForest Palmer, Jr.

Owing to the recent increased interest in the wave length of the helium lines due to the discovery of terrestrial helium, I have been led to calculate some observations on the D_3 chromosphere line carried out by myself at the Physical Laboratory of the Johns Hopkins University during February and March, 1893.

The measurements were made on the large fixed telescope spectrometer, used by Dr. Louis Bell* in his determination of the absolute wave length of the D solar lines, with a plane speculum metal grating having about fourteen thousand lines to the inch and five inches of grating space. The telescopes of this instrument are $16{\cdot}4^{cm}$ clear aperture and about 2·5 meters focal length; and with the grating used I obtained good dispersion and excellent definition in the first spectrum to the right of the normal to the grating. All the observations were made in this spectrum on account of its superior definition.

An image of the sun about 1^{cm} in diameter was formed on the slit of the instrument by aid of a large Foucault heliostat, and an achromatic lens of about four inches aperture. Appliances were provided for moving the image laterally across the slit, and, by means of a total reflecting prism, for turning it about the direction of the beam as an axis to bring any desired point of the limb over the slit.

* This Journal, vol. xxxv, p. 265.

The D_3 line appeared only when the sun's image was tangent to the slit and then as a bright but very short line in the center of the field of view vertically considered. Its definition and intensity were found to vary greatly from day to day, and for different points on the sun's limb. In general, when a solar prominence lay across the slit the line was very broad and intense, but the definition of its edges was poor, thus rendering it impossible to set the cross hairs on it with accuracy. The best combination of intensity and definition was obtained by avoiding prominences and working only on very clear days.

The observations were made by the ordinary micrometric method, the D_3 line being compared with the best solar standard lines in the field of view. The wave lengths of these standard lines, as taken from Prof. Rowland's "Table of Standard Wave Lengths,"* were

Fe	5916·475	Fe	5862·580
Fe	5914·384	Fe	5859·810
Fe	5905·895	Ba	5853·903
Na. D_1	5896·154	Average value	5887·028

Seventeen series of measurements were made, in each of which equal numbers of observations were taken on diametrically opposite points of the sun's limb in order to eliminate the effect of rotation.

The wave length of D_3 was calculated from each of these series by Prof. Rowland's method of interpolation, on the assumption that, for the space used, the spectrum was essentially normal. The average of the seventeen values thus found gives

$$5875·939 \pm ·006$$

for the wave length of the D_3 line, the probable error being calculated from the deviations of the several values from the mean in the usual manner.

To test the accuracy of the observations and method of calculation, the wave length of the mean line was computed from the observations and found to be 5887·027, a value which differs only by ·001 from the average of the wave lengths of the standard lines used, 5887·028.

I am indebted to Prof. H. A. Rowland and Dr. J. S. Ames for permission to use apparatus and for suggestions, and to Mr. W. S. Day for aid in making the observations.

Wilson Physical Laboratory, Brown University, Oct. 17, 1895.

* Astr. and Astro.-Phys., vol. xii, p. 321, and Phil. Mag., V, vol. xxxvi, p. 49.

ART. XXXVIII.—*Some additional Notes on Argon and Helium;* by EDWIN A. HILL.

AN English scientist in a recent letter, referring to the point made in my article on argon,* as to the inconsistency of regarding a free or nascent monatomic atom as devoid of chemical affinity, asks the very pertinent question whether I have considered the case of mercury vapor, which at 800° is monatomic and yet has practically no chemical affinity. I had indeed given this case some consideration, but lack of space kept me from referring to it in my previous article.

Lord Rayleigh and Prof. Ramsay, in their original memoir, use the following language: "In conclusion, it need excite no astonishment that argon is so indifferent to reagents. For mercury, although monatomic, forms compounds which are by no means stable at a high temperature in the gaseous state, and attempts to produce compounds of argon may be likened to attempts to cause combination between mercury gas at 800° and other elements." The assumption evidently being, that at all ordinary temperatures, argon is heated to a point above that at which chemical affinity is strongly manifested.

Of course argon may yet prove to be either a mixture or a compound of elements, but assuming it to be a single element, the important question still remains unsettled as to the number of atoms comprising its molecule.

The ratio of the two specific heats, as derived from experiments on the velocity of sound in argon, has been shown to be about 1·65, approximating closely to 1·67, the value which, according to the theory of Clausius, proves the gas to have no energy of rotation. The conclusion, that therefore the gas is monatomic, depends on at least three things:

1st. On the correctness of the assumption that a gas, with *little* or no rotational energy, cannot be di- or *n*-atomic, but must be monatomic. In my article on argon (l. c.) I have endeavored to show, that the amount of rotational energy acquired by gaseous molecules will depend on the relation between the repulsive forces acting during the encounter, and the attractive forces aggregating the atoms into a molecule; and that even if the rotational energy be but slight, di- or *n*-atomicity may be possible, and monatomicity does not therefore necessarily follow.

2d. The conclusion also depends upon the correctness of the deduction of Clausius, that a ratio of the two specific heats of 1·67 proves the gas to have no rotational energy. This is

* This Journal, May, 1895, p. 413.

questioned by C. E. Basevi (Nature, July 4, 1895, p. 221), who endeavors to show that the equation $\beta = \frac{2}{3} \frac{1}{\gamma - 1}$ of Clausius should be written $\beta = 3k(\gamma - 1)$, where $\beta =$ the number of atoms in the gaseous molecule. This latter equation he shows gives 2 for the value of β in argon, leading to the conclusion that argon is diatomic; the mathematical proof being given in full.

3d. The conclusion also depends upon the correctness of the method for calculating the ratio of the two specific heats. This ratio, it will be remembered, was obtained indirectly from the velocity of sound in argon gas, as determined by the "Kundt" dust figures. Dr. G. Johnstone Stoney,* in a paper read before the Royal Society, May 20, 1895, doubts the correctness of the method employed in this determination, and advances proof in support of the position that the ratio 1·65, thus determined, is not the true ratio of specific heats; and if so it is of course not yet shown that argon gas has no rotational energy, and the argument for its monatomicity fails.

4th. Moreover Prof. B. Brauner remarks:† "It has been shown most ably by Mendeleèff, that the argument derived from the relation of specific heats = 1·66 is not absolutely conclusive in favor of the monatomicity of the gases in question (argon and helium).‡ Practically the same point was made independently by myself in my previous article (l. c., pp. 409–410) and also foot note quoting Mendeleèff, whose remarks came to my notice after that article was in press.

Now all of these points may be well taken, or some may be sustained and others not, *but if any one of them is sustained the argument for monatomicity fails.* The fact is that monatomicity seems to most careful thinkers utterly inconsistent with the classification of Mendeleèff, as well as all the various modifications of it which have appeared from time to time. There seems to be a deep-seated feeling that something remains to be explained; that the general principles upon which Newlands, De Chancourtois, Mendeleèff, Meyer, and the host of others have based their classifications, are in the main correct; and that argon fails to find its place in these classifications because some of our preconceived notions of the molecule need to be modified; and hence the foregoing attempts. At any rate, such are the views which impelled me to publish my own article on argon and the periodic law.

* Nature, July 18, 1895, p. 286, and Proc. Roy. Soc., vol. lviii, p. 177. Nature gives an abstract only.

† Chemical News, June 7, 1895, p. 271.

‡ See Proc. Russian Chem. and Phys. Soc., March 2 (14), 1895; Nature, vol. li, p. 543, and Chemical News, July 12, 1895, p. 14.

Now the pertinency of the question about argon and mercury vapor is this. Every fact which seems to be against the theory of monatomicity increases the probability that some one or more of these various explanations of the apparent inconsistency between the specific heat ratio and the conclusions drawn from the Periodic Law, may be correct. These explanations have not all the certainty of geometrical demonstrations, and if the verdict on them is, for instance, "*very probable but not fully proven*," then every additional argument strengthens the probability.

Of course, by far the strongest argument against monatomicity is the Periodic Law, but what we are looking for, I take it, is additional evidence.

I have already remarked (l. c., p. 412–413) that the nascent or monatomic state of the element is, par excellence, that in which chemical affinity has its maximum development, and that all our chemical experience leads us to associate chemical affinity with the free and uncombined atom. Why then, if argon be monatomic, that is free and uncombined, has it no chemical affinity at ordinary temperatures?

Because (it is replied), at those temperatures it is already heated above the point at which chemical combination is possible, and as when we cool mercury vapor from 800° down towards the point at which it assumes the liquid state, it begins to exhibit chemical affinity, so were argon likewise cooled down towards the point at which it begins to liquefy (−189·6°), it also would probably exhibit chemical affinity. Now even were this true, the monatomicity of argon would not thereby be directly proven; we should merely have removed one great and almost insuperable objection against the monatomic theory. But on the other hand, if it be not true, then it would be very difficult, if not impossible, to still hold the monatomic theory. Unfortunately, thus far no experiments have been published showing whether or not argon, near the low temperature at which it becomes liquid, exhibits chemical affinity.* Were this shown to be so, the case for monatomicity would be thus far strengthened, in that a great objection to the theory would have been removed; but our present knowledge of the properties of argon does not lead us to expect the display of any such affinities, for the only approach to an argon compound thus far made has been effected by apparently increasing

* The suggestion that argon compounds will only be formed at low temperatures, which follows directly from the assumption as to argon being too hot to combine, was made in the Educational Times, April 1, 1895, p. 479, and by Mr. C. J. Reed, Chem. News, May 3, 1895, p. 213.

instead of decreasing the energy of the gas (combination with benzene).*

There are, however, some experiments which seem to point against the monatomic theory. Thus Lord Rayleigh remarks as follows :† "It has turned out that the gas possesses the same value of $\frac{PV}{T}$ as hydrogen, and that the value of this expression is not altered between $-90°$ and $+250°$ . . . . Argon therefore shows no signs of association on cooling nor of dissociation on heating." The inference is that like change of temperature would have no greater effect on its chemical affinity than on its state of molecular aggregation.

In the absence, however, of direct experiment to determine the point, we may pursue an indirect method. If we can, from the known properties of argon, determine the class of bodies to which it belongs and with which its greatest analogies are found, then whatever we can predicate of these bodies as a class, we can within reasonable limits predicate of argon also. If they, as a class, are at ordinary temperatures far below instead of above the point at which chemical affinity is overpowered by heat, then probably argon is likewise below rather than above that point; and if below, then the theory of its monatomicity has before it the very difficult task, of explaining away the lack of chemical affinity in the free atom of argon.‡

Of course if the molecule is di- or *n*-atomic, its chemical inertness, like that of N^2, is readily explained by the strength of the force aggregating the atoms in the molecule, which force opposes chemical affinity, since the force of affinity must first disintegrate the molecule before combination with other atoms can take place, that is, must first overcome the force of molecular aggregation.

In general we may say of molecules, that starting with the minimum of heat in a solid and inactive state, as they acquire heat energy they become successively liquid, gaseous, and are

* And I may add Berthelot's combination with carbon disulphide, and more recently, Prof. Ramsay's combination with incandescent carbon, Chem. News, Aug. 2, 1895, p. 51; in all which cases a large quantity of electrical energy is needed to bring about the combination.

† Nature, June 6, 1895, p 127.

‡ It may occur to some that should argon prove a mixture of gases, the argument fails, and as the evidence favors the mixture theory, the argument has but little weight. The conclusion, however, is incorrect. If argon is a mixture, its components are gases which resemble each other in chemical and physical properties so closely, that up to the present time no method of separating them has been discovered. Hence any inference as to the properties of this mixture, which we call argon, must apply with equal correctness to all constituents present in quantity. But if argon is a mixture, the apparent conflict with the periodic law may be explained by the presence of two gases, of different densities, but similar chemical and physical properties.

finally dissociated into atoms. The force of molecular aggregation is a maximum when heat energy is a minimum. With increase of temperature the force of aggregation between like atoms (as I and I for example) is finally weakened, so that in the liquid or gaseous state the affinity of unlike atoms for each other becomes the stronger force. At still higher temperatures, even these forces are overcome by the repulsive action of heat. We may say that heat overpowers the forces of aggregation (like with like) first, and those of chemical affinity (like with unlike) later and with more difficulty. Now mercury at 800° has reached this latter stage, and it is claimed that argon at ordinary temperatures is in the same condition.

The analogies of argon are evidently with such elements as H, N, O, F, and Cl, that is to say with the metalloids of low atomic weight and specific gravity, gaseous at ordinary temperatures, somewhat soluble in water, with very low melting and boiling points, and very difficult to reduce to the liquid and solid state; rather than with the metals, among which mercury must be grouped, characterized by high atomic weights and specific gravities, liquid or solid at ordinary temperatures, insoluble in water, with much higher melting and boiling points, and easily reduced to the liquid and solid state.

In endeavoring to draw conclusions as to the argon molecule, it would therefore seem less forced to reason from what we know of the former, the metalloids, which it closely resembles, rather than the latter class of bodies, the metals, with which it has but few analogies. We are thus led to regard argon as a body in which the atoms in the molecule (if di- or *n*-atomic) are very firmly bound together, like nitrogen for example, and in fact from whatever side we approach the question we are struck with certain marked analogies existing between these two elements. The inert character of nitrogen and its disinclination for direct combination with other substances, has always been regarded as proving the strength of the force aggregating its atoms into a molecule, rather than showing that the substance is monatomic, and at a temperature so high that it is above or near the point at which combination is no longer possible; and why not also in the case of its analogue, argon?

Of the five gaseous elements to which argon is most closely analogous, H, N, O, F, Cl, all are at all ordinary temperatures far below the point at which combinations with other elements are impossible, and why should it be thought that argon is in any way different from them and above instead of below that temperature?

Let us consider the following table:

	Metalloids						Metals	
	H	N	O	F	A	Cl	Na	Hg
	1	14	16	19	20	35·5	23	200
	gas	gas	gas	gas	gas	gas	solid	liquid
	colorless	colorless	colorless	greenish	colorless	greenish yellow	white	white
	electro neg.	electro neg.	electro neg.	electro neg.	?	electro neg.	electro pos.	electro po
Sp. Gr.	?	·90	1·37	1·265	1·5	1·33	·98	13·6
M. P.		—214°		below	—189·6	—102°	95·5°	—38·5
B. P.	—243°	—194°	—182·7°	—·95°	—187·	—33·6°	red heat	+357·25
At Vol		15·5	14·	15·5 ?	13·3	25·6	23·5	14·1

Evidently argon has the characteristics of a metalloid rather than of a metal.

Now of these bodies, F, Cl, and O at ordinary temperatures exhibit the strongest tendencies known for combination with other substances, and H and N, in the nascent state, are almost equally endowed with chemical energy, but this energy is masked so to speak, gradationally, by the force holding the atoms together in the molecule which acts against and in opposition to the force tending to cause chemical combination. This opposing force of aggregation, comparatively weak in F, is stronger in Cl and O, still stronger in H, very much stronger in N, and why not also, let us say, even stronger yet in argon; thus accounting for its chemical inertness.

Indeed, is there any good ground, reasoning from the known properties of these elements (if it be an element), for believing argon to be in such a different physical condition from the rest of them, as is implied in the assumption that it is too hot to combine with other elements?

The discoverers in their memoir have remarked, that "the chemical behavior of nitrogen is such as to suggest that its dissociated atoms would possess a high degree of activity, and that even though they might be formed in the first instance their life would probably be short." Could not this language with great propriety be applied to its analogue, argon, also?

The theory, upon which argon at ordinary temperatures is considered to be in the same physical condition as mercury at 800°, is probably somewhat as follows: Starting with the elements in the solid state at the absolute zero of temperature, and devoid of energy or tendency towards chemical combination with other bodies, as temperature increases they finally become liquid and then gaseous. The increasing affinity toward other bodies increases with liquefaction, and still more so when the elements are vaporized; finally the heat becomes sufficient to dissociate the molecules into free atoms, in which state the tendency towards chemical combination is at its maximum, because the opposing force of molecular aggregation is reduced to zero. From this point on, an increase in temperature decreases the affinity towards other substances, until finally we arrive at a temperature above which the repulsive force of heat (if such an expression be permissible), renders all combination impossible; which is the physical condition in which argon, at ordinary temperatures, is by this theory assumed to be.

Chemical affinity, then (the tendency for instance of the molecules H^2 and Cl^2 to form 2HCl), is not a simple force, but rather the resultant of at least three other *atomic*, not molecular, forces, viz: the attraction between the atoms H and Cl, which is opposed by the attractions between H and H and Cl and Cl. In general

$$F = f - \frac{c+h}{2}$$

where F = the chemical affinity of chlorine for hydrogen
f = the attraction between the atoms H and Cl
c = " " " Cl " Cl
h = " " " H " H

The theory assumes f, c and h to decrease with a rise, and increase with a fall in temperature, but f more slowly than c and h. When $f = \frac{c+h}{2}$, $F = 0$. If temperature be reduced f increases more slowly than $\frac{c+h}{2}$, hence the forces of molecular aggregation c and h are stronger the lower the temperature, while F, the affinity for other molecules, has a negative value.

Per contra, if temperature be increased, f decreases more slowly than $\frac{c+h}{2}$, and when $\frac{c}{2} + \frac{h}{2} = 0$, f will have a positive value, and F will have its maximum value, that is $F = f$; the case corresponding to the point where heat has dissociated the molecules into nascent atoms. Or rather the maximum value of F will occur somewhere between the dissociation temperatures of Cl and H. When both molecules are dissociated, since $\frac{c}{2} + \frac{h}{2} = 0$, increase of temperature reduces F and where $F = 0$, which case, for mercury vapor, is reached at 800°, we reach the upper limit of chemical combination; that is, the kinetic energy of the molecule is too great to allow of its combining with other molecules.

The following might at first seem an objection to this theory, viz: that considering the molecule HCl, if temperature is reduced f, the force binding the atoms H and Cl into a molecule finally becomes less than $\frac{h+c}{2}$ hence reduction of temperature ought to produce decomposition of HCl, whereas nothing of the sort occurs.

The answer is this, before HCl can be dissociated into H and Cl so that H^2 and Cl^2 can be formed, we must first overcome the force of attraction between the molecules of HCl, which, as temperature is reduced, increases until sufficient to unite the molecules into solid HCl. Hence although $\frac{h+c}{2}$ does become greater than f with reduction of temperature, the tendency towards dissociation is more than overcome by the increased force of aggregation between the HCl molecules.

Strictly this molecular force should be taken into account above, but I have omitted it to simplify the discussion. Compare here the following language of Dr. Möller: "Scientists have proved that chemical action entirely ceases even before so low a temperature (−273°) is reached . . . The form of motion which we call affinity between different molecules seems at that temperature to be wholly extinct, but the other form of motion, the affinity between homogeneous molecules and between the atoms of which they are formed, does not appear to be much impaired by the lowest temperature we can produce."*

In general then we may roughly outline the gamut of changes produced by increments of heat energy as follows:

1st. Absolute zero, no energy, maximum of force of aggregation, minimum of force of affinity, solid state.

2d. Liquid state, first marked indications of the force of affinity (though weakly displayed by some solids under great pressures or certain electrical conditions), reduced force of aggregation.

3d. Gaseous state, force of affinity stronger, of aggregation weaker.

4th. Temperature where dissociation begins.

5th. Temperature where dissociation is complete, and the force of aggregation completely overcome as between like atoms. Maximum of chemical affinity in fourth or fifth stage.

6th. Temperature at which the dissociated atom has no affinity for any other atoms, like or unlike.

Let us now consider the following table of melting and boiling points.

Substance.	Melting Point.	Difference.		Boiling Point.
H^2 = Hydrogen			Metalloids. Average difference, 34·8	−243
N^2 = Nitrogen	−214°	19·6°		−194·4
CO = Carbonic oxide	−207·	17 0		−190·
A^n = Argon	−189·6	2·6		−187
O^2 = Oxygen				−182
CH^4 = Methane	−185·8	21·8		−164
NO = Nitric oxide	−167·	13·4		−153·6
Cl^2 = Chlorine	−102·	68·4		− 33·6
Br^2 = Bromine	− 7·2	66 2		+ 59·
I^2 = Iodine	+114	70·		+184
Hg = Mercury	−38·5	395·5	Metals. Average diff., 511·3	+357
Cd = Cadmium	+320	450·0		+750
Zn = Zinc	420°	530		abt. 950°
Mg = Magnesium	abt. 600	large		at very high temperature
Li = Lithium	180°	670		abt. 750
Na = Sodium	95·5	large		at red heat
K = Potassium	60	"		above red heat

* F. P. Möller in Cod Liver Oil and Chemistry, p. 452.

Many of the metals are volatile if at all at such high temperatures that they have not been accurately measured, but generally the difference between the melting and boiling points is very great for metals. Apparently the rule is that the metalloids have a small while the metals have a large difference between their melting and boiling points, that is, that those elements (metals) whose chemical affinity is overcome by a small degree of heat energy, have large differences between their boiling and melting points, but that those (metalloids) whose affinity is only masked by a large degree of heat energy, have small differences between these points.

Thus compare Hg and Cd and the other metals above with H, N, O, Cl, Br and I.

Now if mercury at 800° is devoid of affinity, then the difference between its melting point and boiling point (395°) is about the same as between its boiling point and its upper limit of chemical combination (443°). But in the case of the metalloids, the difference between the melting and boiling points is small 66° to 70° for the halogens, from 17° to 20° for nitrogen, methane and carbonic oxide, and 13·4° for nitric oxide; while in these cases the difference is very large between the boiling points and the upper limits of combination, (by which I mean the temperatures at which chemical affinity is no longer manifest,) and the disproportion between these differences tends to become greater as the element approximates more and more closely to the characters of the ideal metalloid. Thus iodine begins to dissociate at 700° and at 1500° the process is complete, so that the upper limit of combination must be above 1500°, and instead of a ratio of differences like that in mercury of 395° to 443° we should have instead the ratio of 70° to 1416°+. *Inequality of differences characterizes the metalloids, equality the metals.* Now if argon is a metalloid (and is it not one if an element?), ought it not also to have this inequality of differences, and to have its upper limit of combination at a very high rather than low temperature? But if this limit be very high, argon can not at ordinary temperatures be like mercury at 800°, that is too hot to combine with other elements.

Again, if, as is the case, the melting and boiling points of argon are very close to each other, ought we not to expect that its melting point and upper limit should be separated by an interval correspondingly great?

In Br and Cl the characteristics become less metallic than with I, and approach more nearly to those of the ideal metalloid; and we find that while the difference between the melting and boiling points is but little changed, the differences between the boiling points and the upper limits are very greatly increased. The same is equally true of N, O and H. Why not also of argon? The characteristics of argon are preëminently non-metallic, the difference (2·6°) between its melting and boiling points is small, as it should be, and not large as in the case of metallic mercury (395·5°); hence the inference that like other metalloids its upper limit of combination is far removed from its boiling point, much farther so than in the case of mercury, that is, far above 800°. But we are asked to believe that it is even below the ordinary temperature of the laboratory. Everything, however, seems to me to point to the contrary conclusion, that argon, like hydrogen, nitrogen, oxygen, chlorine, bromine and the other non-metallic elements of its class, has a very high upper limit of combination, and not a low one like the metals; and hence that at ordinary temperatures it is no more above that limit than are oxygen and nitrogen, but that its chemical inertness is fully explained by assuming that the force binding together the atoms within the molecule is strong as in the case of nitrogen (and to a less degree in hydrogen), and that the contrary view is not justified by known facts.

And this brings us back to our starting point. If the inert character of argon is not due to heat, then how can it be monatomic and also devoid of affinity?

To quote from my previous article—"which is the more unique, a diatomic gas without rotational energy, or a free atom devoid of chemical affinity?" The presumption is at once strongly raised that it is not a monatomic gas but diatomic and chemically inert because the two atoms of the molecule are very strongly bound together, in fact too strongly for any ordinary chemical affinity to overcome the bond, and that perhaps after all there is some hitherto unsuspected weak link in the chain of reasoning supposed to prove its monatomicity, or, as was stated in the editorial in Nature (Feb. 7, 1895): "Till further evidence is forthcoming, a heavy strain is thrown on the link of the chain of argument which connects the ratio of the specific heats with the monatomicity of the gas." I have already pointed out that the conclusion as to monatomicity depends on the correctness of various assumptions which have already been called in question, viz: 1st, that when the rotational energy is small the gas must necessarily be monatomic; 2d, that the ratio of the two specific heats of 1·67 proves absence of rotational energy, and hence monatomicity, and 3d, that the method used for determining this ratio can give correct results. If any one of these propositions fails, monatomicity can hardly be sustained; and any evidence against monatomicity, like that we have been considering, even though not conclusive of itself, yet when construed with these three propositions, already called in question, and with due consideration of the requirements of the periodic law, makes out a pretty strong case, to say the least; and yet even here the future may give us new facts and require us to modify our conclusions; and there is hardly one of the many who have written upon this question that feels like laying down the law dogmatically at the present time, certainly not myself.

Since the publication of my previous paper, a notable discovery, that of helium, has been made by Prof. Ramsay, and the new gas has turned out to be a body very closely analogous to argon. As noted by the discoverer, both bodies resist sparking with O in presence of caustic alkali, both are unaltered by red hot magnesium. In each case the velocity of sound in the gas indicates approximately the value 1·66 as the ratio of the two specific heats, and although opinion is divided, says Prof. Ramsay and his colleagues, on the precise significance of this ratio, it appears to be most probable that in all cases, as in that of mercury, it points to the monatomicity of the molecule.

In general, they say,* an increase in molecular weight is accompanied by a rise in the boiling point, whether in the case of compounds or of elements; and they argue that if argon possessed the atomic weight 20 and molecular weight 40 it is probable its boiling point would lie above that of chlorine instead of being $-187°$ and below that of oxygen, as is actually the case. And this they consider points towards a molecular formula A^1 rather than A^2 and so corroborates the monatomic theory.

It would seem to me, however, as if this conclusion did not follow so plainly as assumed. I have thrown the data upon which the argument is based into tabular form:

Molecule	H^2	N^2	O^2	A^n	O^3	Cl^2	Br^2	I^2
Molecular weight,	2	28	32	40	48	71	158	254
Boiling point,	−243°·5	−194·4°	−182·7°	−187·0	−106°	−33·6°	+59°	+184°
Melting point,	?	−214°	?	−189·6	?	−102°	−7·2°	+114

Now whatever its atomic weight, the molecular weight of argon gas is 40, and if we argue anything at all from molecular weights we shall, I think, be led to place argon in the above table ($A^n = 40$) between $O^2 = 32$ and $O^3 = 48$, into which place its melting and boiling points (respectively $-189·6°$ and $-187·°$) cause it to fit fairly well. True its boiling point is a little lower, about 4°, than oxygen, while apparently it should be higher. Perhaps later determinations of these points may clear up the anomaly, which is hardly greater than the limits of possible error (in certain directions), or perhaps oxygen, as indicated by the researches of Baly,† may turn out to be a compound and

* Journal Chem. Society, July, 1895.
† Chemical News, April 5, 1895, p. 169.

not a single element, as has been so long supposed; or argon may be a mixture. At any rate, if boiling point is to be raised by an increase in molecular weight I see no reason for expecting $A^2 = 40$ to have a higher boiling point than $Cl^2 = 71$; as the molecular weight is lower so also should be the boiling point, and to my mind the facts either prove nothing or else favor rather than oppose the diatomic theory. If the boiling point depends upon molecular rather than atomic weight, can the boiling point give us any help in determining the atomic weight and the number of atoms in the molecule?

Some additional light seems to be thrown upon the subject by the recently determined refraction equivalent of argon. Mr. R. M. Deeley,* in his paper on this subject, after showing "that the refraction equivalents of the elements vary periodically with much regularity," remarks as follows:

"If argon, like calcium, has an atomic weight of 40, we should expect its refraction equivalent to be also about 10. On the other hand, if its atomic weight be 20, and if it (argon) falls between fluorine and sodium, the refraction equivalent might be 3 or even smaller than that of fluorine (1·6), for between carbon (5 or 6) and aluminum (7·7) the refraction equivalents decrease rapidly until fluorine is reached. They then increase with increasing atomic weight, and more than regain their original value at aluminum. The refraction equivalent is calculated from $P \times \frac{\mu - 1}{d}$" (P = atomic weight, d = density, water taken as unity.)

Now Lord Rayleigh† has recently shown that for argon $\mu = 1·000281$. This value is certainly remarkable, and proves argon to be as anomalous in its action upon the waves of light as in its behavior as to specific heats. In spite of its greater density (about 1·38, air = 1·) its refraction is only ·961 that of air; whereas, refraction usually increases with the density of the refracting medium instead of decreasing.

If $A^1 = 40$ the refraction equivalent by the above formula becomes about 6·3 instead of 10, the value which Mr. Deeley says would be required, were it monatomic with an atomic weight of 40; but if $A^2 = 40$ whence $A = 20$ (the diatomic theory) the corresponding value of the refraction equivalent 3·14 is entirely consistent with the position of argon in Mendelèeff's classification in Group VIII between fluorine = 1·6 and sodium = 4·3, 3·14 being very nearly a mean between these values; and as Mr. Deeley remarks (l. c.) "the equivalents decrease rapidly until fluorine is reached, and then increase with increasing atomic weight."

* See Chem. News, Feb. 8, 1895, p. 75.
† Nature, July 25, page 293.

The refraction equivalent of nitrogen as given by Mr. Deeley is 4·1 and on the theory (which has many who seem to favor it) that argon is an allotropic form of nitrogen with formula N^3, the corresponding value of the equivalent would be about 2·2 as against 4·1 required, so that this theory does not seem to be sustained. Assuming that the ratio 1·65 has been correctly determined, notwithstanding the criticism of Dr. Stoney, then the anomalous value of the rotational energy (disregarding the questions raised by Col. Basevi) seems to be associated in argon with an equally anomalous value of its refraction equivalent, and the question at once arises whether there is any connection between them.

Nature (July 18, 1895, p. 278), in discussing Mr. C. J. Reed's classification of the elements, makes a somewhat plausible suggestion worthy of consideration should the theory of monatomicity be sustained. "It is remarkable," says the editor, "that if helium has the atomic weight 4 it falls naturally in this group" (viz: $\frac{He}{4}$ 16 $\frac{?}{20}$ 16 $\frac{A}{36}$ 20 $\frac{Fe}{56}$ 28 $\frac{2}{84}$ 20 $\frac{Ro}{104}$ 28 $\frac{?}{132}$, all of which elements, if existent, can be classed as belonging in Family VIII), "and that its atomic weight deduced from the observed density, is somewhat greater than this number. If this difference should be due to the presence of some small quantity of element 84, then the spectroscopic evidence leading to the conclusion that argon and helium contain a common constituent would be explained." This theory assumes the monatomicity of both gases but places A = 36 between Cl = 35·5 and K = 39, which position is in no way inconsistent with the periodic law.

Thus density of helium = 2·13 and ×2 = 4·26 instead of 4.
" " argon = 19·9 and ×2 = 39·8 " 36.

The excessive densities being due to presence of the heavier element 84.*

I also have worked for some years on a classification of the elements, but like many others who have worked along similar lines I have been withheld from publication owing to the uncertainty surrounding the atomic weight determinations, the evidences that there were yet many undiscovered elements unknown to science, and the feeling that in such work, where the tendency to stray away into mere numerical speculation was very great, and where error was so likely to occur from the use of unreliable and imperfect data, the time was not yet fully ripe, and that the case was one where it was best to make haste very slowly.

* That helium is a mixture of several gases is now pretty well settled, and there is some evidence that argon is a mixture also, but not as conclusive.

We seem now, however, to be approaching an era of greater light, and I fully believe that the next few years will be productive of great advances in chemical and physical knowledge. I cannot now go into the subject of classification, but I will in conclusion refer to a closely related subject. In my previous article it will be remembered I called attention to a very regular alternation of intervals of 3 and 1 in the natural series of the elements, and in the table at page 416 of the May number of this Journal will be found a number of terms of the series so formed, not corresponding to known elements, which may possibly represent elements as yet unknown. It is remarkable that so many of those who have been giving their attention to the intricate subject of chemical classification have, by entirely different processes of reasoning, arrived independently at the common conclusion; that there are still a number of undiscovered elements, particularly in what may be termed the eighth or transitional family of Mendeleèff; and furthermore that they have so closely agreed on the atomic weights of the same. Of the various classifications thus far cited in connection with the discoveries of argon and helium, perhaps the most mature are those of Mr. C. J. Reed and M. Lecoq de Boisbaudran. When several investigators, working thus independently, and from data which though at times overlapping so to speak, yet are in the main different, or at any rate lead to different theories and systems of classification; when I say, in such cases, practically the same conclusions are arrived at, these results should naturally command a respectful consideration; and that is precisely what seems to have happened in the present case.

I can bring this out most clearly, I think, in tabular form, comparing some of the terms of the series referred to with the elements predicted by other classifications, etc.

1	2	3	4	5	6	7	8	9
Edwin A. Hill.	Lecoq. de Boisbaudran and B. Brauner.	C. J. Reed.	Dr. J. H. Gladstone.	Lt. Col. Sedgewick.	R. M. Deeley.	Prof. J. Emerson Reynolds.	Prof. Ramsay and colleagues.	Julius Thomsen.
? = 3	2·9							
helium ? = 4	3·9	4		5	5		4·26	4
argon = 20	20·0945	20	20	20	20	20		20
? = 36	36·40 ± ·08	36		37	36	36 to 39	A=40 ?	36
? = 67		68		62				
? = 83	84·01 ± ·20	84		82	83		82	84
? = 116		116				*Note A*		
? = 131	132·71 ± ·15	132		129–130				132

Authorities.

1. Argon, Prouts' Hypothesis and the Periodic Law, this Journal, May, 1895, p. 416.
2. Chemical News, March 8, 1895, p. 116, and June 7, 1895, p. 271, and Jour. Chem. Soc, July, 1895, cccxcii, p. 550.
3. Ibid., May 3, 1895, p. 213; Journal of the Franklin Institute, July, 1895, p. 68, and Nature, July 18, 1895, p. 278.
4. Nature, Feb. 21, 1895, p. 389.
5. Chemical News, March 22, 1895, p. 139.
6. Ibid., May 17, 1895, p. 244.
7. Nature, March 21, 1895, p. 486.
8. Journal Chemical Society, July, 1895, p. 707.
9. Zeit. Anorg. Chemie, viii, 283–8, and Chemisches Central-Blatt, Band II, 1895, p. 429.

Note A. Prof. Reynolds, while indicating the existence of members of Family VIII of higher weight than 36–39, does not assign their atomic weights in the article quoted. Atomic weights are given in the body of the table and the agreement, it will be seen, is very striking. It will be noted that three of the values in Mr. Reed's classification (68, 84, and 132) are just one unit greater than the corresponding values in my own series (67, 83 and 131).

The coincidences are certainly very striking.

New Haven, Ct., Aug. 10, 1895.

Addendum, October 7th, 1895.

The publication of the foregoing article having been delayed until the November issue renders necessary some additional remarks.

Prof. Ramsay (Chem. News, Aug. 2, 1895, p. 51) has produced a compound of carbon and argon by the action of an incandescent carbon arc in an atmosphere of argon. Four hours' action increased the volume one-fifth. Mr. Crookes (Chem. News, Aug. 30, 1895, p. 99) examined the product spectroscopically, finding residual argon, and also a compound with a spectrum very analogous to that of cyanogen and other carbon compounds. This, however, he says, is not evidence favoring the N^3 theory, since most volatile carbon compounds have similar spectra.

In view of the many analogies between argon and nitrogen, this new compound may have the formula CA, and be analogous to cyanogen, which can be formed in a very similar manner; i. e., by passing induction sparks between carbon poles in an atmosphere of nitrogen. This new compound furnishes a strong argument against the theory that argon at ordinary temperatures is like mercury at 800°, too hot to combine (hence its inertness). All the argon compounds thus far formed, as those of Berthelot with benzene and carbon disulphide, and the apparent absorption of argon by the magnesium and platinum poles, have been produced by heating and not cooling argon, and by increasing, not decreasing, its store of energy.

Lord Rayleigh, in his lecture before the Royal Institution (Nature, lii, 159–164) refers to the tendency of ozone O^3 to go slowly back to O^2, the normal type. But Bedson and Shaw (Chem. News, July 26, 1895, p. 48) have shown that the nitrogen contained in the natural crystals of rock salt contains the same proportion of argon as does atmospheric nitrogen, so that in a period of perhaps thousands of years there has been no tendency for argon to become N^2, hence the inference that argon is not N^3. Schild has pointed out (Chem. News, May 31, 1894, p. 259) that if argon is N^3, then any argon compound, when decomposed, should yield nitrogen, the normal, instead of argon, the allotropic form. Now Berthelot has shown (Chem. News, July 5, 1895, p. 1) that the analysis of the resinous compound of argon and carbon disulphide yields argon, not nitrogen, which makes strongly against the N^3 theory.

In line with this are the experiments of Peratoner and Oddo, mentioned by Meldola (Pres. Address, Nature Sept. 12, 1893, p. 483). They recently obtained nitrogen, not argon, from the electrolysis of hydrazoic acid and its salts, and they conclude that an allotropic form of nitrogen is impossible.

Is argon a mixture?

Evidence grows stronger that it is; as to helium there is not much doubt, and if anything can be argued from the analogies between argon and helium, argon is a mixture likewise.

Says Prof. Ramsay (Nature, July 25, 1895, p. 333): At least two helium lines are coincident with one each of two pairs of characteristic argon lines, but not with equal brilliancy, a faint argon line being identical with a prominent red helium line, and a strong red argon line with a faint red helium line; and besides these two there is a line in the orange red, faint in helium, but moderately strong in argon, which is very close if not identical.

Kayser's recent measurements of the argon lines (Chem. News, Aug. 30, p. 99), though measured to one more decimal place, do not agree with those of Crookes. They may not be to the same scale, but Mr. Crookes found 26 lines common to both the red and the blue argon spectra, whereas Kayser states they have no lines in common so far as he can see. This seems to favor the view that the red and blue argon spectra denote different constituents in the gas.

Helium proves much more insoluble in water than argon (1 vol. of water dissolves only ·0073 of helium). It has been found by Kayser associated with argon in the gases of certain mineral springs in Germany, and has also been by him detected in the atmosphere. (Chem News, Aug. 23, 1895, p. 89.) Also by Ch. Bouchard, associated with argon and some other unknown gas in the gases of certain mineral springs in the Pyrenees mountains (Nature, Sept. 12, 1895, p, 487). The question raised as to the presence in cleveite gas of helium, the element giving the solar line D^3, has now been fully settled, the line being double both in solar and terrestrial helium. A good account of this question and its solution will be found in the Observatory for Aug. 1895, p. 295.

The work of Runge and Paschen upon the spectrum of cleveite gas subdivides the lines into two series, each of which in all probability stands for a different gas or class of gases. They also note certain rythmical relations between the wave lengths and those of hydrogen lines, and note a marked similarity in type between the helium lines and those of the spectra of the alkali metals. (Philosophical Magazine, Sept. 1895, p. 297.)

We come finally to the work of Mr. Crookes on the helium spectrum published in the last issue of the Journal, which may be summarized as follows, the grouping being my own:

Helium Lines Observed by Wm. Crookes, F.R.S., etc.

Groups.	No. of Lines.	Intensities.			Occurrence in				
		Maximum.	Minimum.	Average.	Uraninite R.	Cleveite R.	Bröggerite R.	Bröggerite L.	Helium Puris.
A	16	30	4	9·2	strong	strong	strong	strong	strong
B	2	10	6	8	strong	strong		strong	strong
C	1	7	7	7	faint	strong		strong	strong
D	1	10	10	10	very faint	very faint		strong	strong
E	1	7	7	7	strong		strong	strong	strong
F	1	10	10	10		strong	strong		strong
G	1	5	5	5			strong	strong	strong
H	3	9	9	9	prominent	very faint		very faint	
h	1	8	8	8	prominent		very faint	very faint	
I	2	10	9	9·5	strong	strong			
J	1	8	8	8				strong	strong
K	1	4	4	4	strong				strong
L	1	10	10	10	very strong	very faint			
M	21	10	3	7·08	strong				
N	18	9	2	5·33					strong
Total	71				11	8	5	9	10

Blank spaces indicate the absence of lines and the table does not include a number of lines for which Crookes in his table gives no data, as for instance 4931·9 intensity 3, 4544·1 int. 5, etc. The term strong above means that each line is equally strong in the minerals named; thus in Group B, one of the lines has intensity 8 and the other intensity 10, in all samples of the gas except bröggerite R.

The natural inference is that each of the groups A to N represents one or more distinct gases, except that *h* may after all be identical with H. The line D^3 occurs in Group A. Helium purissimum is apparently one of the most complex, and bröggerite R one of the most simple of the five gases. By construing the work of other observers, as Runge and Paschen, with that of Crookes, these groups may be still further subdivided. Apparently the gases given off by minerals of the uraninite type, which are loosely spoken of as helium while they contain helium, are very complex mixtures of gases of the argon and helium types containing anywhere from 4 or 5 to 11 or more distinct constituents.

ART. XXXIX.—*Recent Progress in Optics*;* by W. LECONTE STEVENS. Part II.

Color Photography.

The conditions being now specified under which stationary light waves are produced, let us imagine common instead of monochromatic light, to be transmitted normally through a transparent sensitive film. Then a variety of stationary interference planes are produced. This is the underlying principle of the process employed by Lippmann in Paris, who in 1892† succeeded in obtaining a photograph of the solar spectrum in natural colors. Upon a surface backed with a reflecting mirror of mercury is a silver bromide albumen film, which has been treated with one or more aniline dyes to render it equally sensitive to waves of long and short period. After exposure and development the natural colors are manifested with brilliancy. Apart from the fundamental principle already expressed, it can scarcely be said that the rationale of the process has yet been very fully and clearly explained. Lippmann recognizes the stationary wave systems, with maxima and minima of brightness in the film and corresponding maxima and minima of silver deposit. If the incident light is homogeneous, a series of equidistant parallel planes of equal photographic efficiency are produced in the film. If the plate after development is illuminated with white light, then to every point within the film there comes from below a certain amount of reflected energy which is a continuous periodic function of its distance from the reflecting surface. The total reflected light of any color becomes then represented by the integral of this periodic function for the entire thickness of the layer. The solution of this integral brings the result that the intensity of the reflected light decreases with increasing thickness of the layer, approaching zero as a limit, so long as this light is of different wave length from the homogeneous light employed for illumination of the plate. Only light of the same wave length, or of an entire multiple of this, maintains a finite value. A similar consideration applies to each of the hues composing the white light. By such mathematical considerations Lippmann‡ reaches the conclusion that the light reflected from the plate must have exactly the same relations of wave length as that with which the plate was illuminated.

* Address delivered by the Vice-President of Section B at the meeting of the American Association for the Advancement of Science, August 29.

† Comptes Rendus, cxiv, p. 961, and cxv, p. 575.

‡ Journal de Physique, 1894, p. 97.

For the Lippmann photographs, which at first required a very long exposure and could even then be satisfactorily viewed at only a single definite angle, it is now claimed that an exposure of only a few seconds is needed, and that the colors are visible at all angles of incidence so long as the plate is moist.* But like the daguerreotypes of fifty years ago they are incapable of multiplication, and great as is the scientific interest connected with them, it seems scarcely probable that they can long continue to hold an important place practically. The problem of ascertaining definitely the cause of the return of a color the same as that which falls upon a given surface may seem to be solved mathematically, but the mastery of the physical conditions required to produce a single colored negative, from which may be had any desired number of positives with varied hues accurately reproduced, is still in the future. From the very nature of stationary light waves it does not appear probable that the Becquerel method as improved by Lippmann will give the means of multiplying copies of a single picture. Wiener has lately published an elaborate research upon this subject,† in which he recognizes the necessity for the employment not of interference colors but rather of what he calls body colors (körperfarben) due to chemical modification of the reflecting surface. M. Carey Lea‡ in 1887 obtained a rose-colored form of silver "photochloride" which "in the violet of the spectrum assumed a pure violet color, in the blue it acquired a slate blue, in green and yellow a bleaching influence was shown, in the red it remained unchanged." But in the absence of any means of fixing these colors a promising prospect brings disappointment.

While it is abundantly possible that colored illumination upon suitable color-receptive materials can give rise to similar body colors, we are still far from having these materials under control. There seems at present to be greater promise in another and quite different application of optical principles. The suggestion appears to have first been made by Maxwell§ in 1861, that photography in colors would be possible if sensitizing substances were discovered, each sensitive to only a single primary color. Three negatives might be obtained, one in each color; and three complementary positives from these, when superposed and carefully adjusted, would present a combination that includes all the colors of nature. In 1873 H. W. Vogel in Berlin discovered that silver bromide, by treatment with certain aniline dyes, notably eosene and cyanine

* Journal de Physique, 1894, p. 84.
† O. Wiener, Wiedemann's Annalen, June 1895, pp. 225–281.
‡ This Journal, May 1887, p. 349.
§ Royal Institution Lecture, May 17, 1861.

blue, can be made sensitive to waves of much longer period than those hitherto effective in photography. In 1885 he proposed to sensitize plates for each of a number of successive regions in the spectrum, and to make as many complementary pigment prints as negatives, which should then be superimposed. This somewhat complicated plan proved difficult in practice. In 1888 F. E. Ives* of Philadelphia, adopting the more simple Helmholtz-Maxwell modification of Young's theory of color, applied it to the preparation of suitable compound color screens which were carefully adjusted to secure correspondence with Maxwell's intensity curves for the primary colors. The result was a good reproduction of the solar spectrum. But to reproduce the compound hues of nature it is necessary specially to recognize the fact that although the spectrum is made up of an infinite number of successive hues, the three color sensations in the eye are most powerfully excited by combinations rather than simple spectral hues. Thus, according to Maxwell's curves the sensation of red is excited more strongly by the orange rays than by the brightest red rays, but the green sensation is excited at the same time. This fact has to be applied in the preparation of the negatives, while images or prints from these must be made with colors that represent only the primary color sensations. Properly selected color screens must therefore be used for transmission of light to plates sensitized with suitable aniline dyes; and the adjustment of ratios with this end in view is not easy. But it has been successfully accomplished. From three negatives thus made, each in its proper tint, positives are secured; and these are projected, each through its appropriate color screen, to the same area upon a white screen. The addition of lights thus sent from the triple lantern gives the original tints with great fidelity.

Mr. Ives has devised a special form of camera by which the three elementary negatives are taken simultaneously, and also an instrument, the photochromoscope, in which a system of mirrors and lenses brings to the eye a combination similar to that projected with the triple lantern. A double instrument of this kind forms the most perfect type of stereoscope, bringing out with great vividness from the prepared stereographs the combined effect of color, form, and binocular perspective. It is only within the past year that these improvements have been perfected. By further application of the same principles, Mr. Ives has produced permanent colored prints on glass, which do not require to be examined with the aid of any instrument. Each of three negatives is made with a colored screen which transmits tints complementary to those which it

* Journal of the Franklin Institute, January, 1889

is desired to reproduce. The three gelatine films are soaked in aniline dyes of suitable tints, and superimposed between plates of glass. When viewed as a transparency such a print gives a faithful reproduction of the natural colors.

The problem of color reproduction is thus solved, not indeed so simply, but more effectively, than by the method of interference of light, or by those body color methods that have thus far been applied. To the imaginative enthusiasts who are fond of repeating the once novel information that "electricity is still in its infancy," it may be a source of equal delight to believe that photography in colors, a yet more delicate infant, is soon to take the place of that photography in light and shade with which most of us have had to content ourselves thus far. But so long as an instrument is needed to help in viewing chromograms, the popular appreciation of these will be limited. We may take a lesson from the history of the stereoscope. Yet it is gratifying to recognize the great impetus that this beautiful art has received within the last few years. We may quite reasonably expect that the best is yet to come, and that it will have an important place among the future applications of optical science.

The Infra-Red Spectrum.

Among the splendid optical discoveries of this century probably the most prominent are photography and spectrum analysis, each belonging jointly to optics and chemistry. Photography was at first supposed to be concerned only with the most refrangible rays of the spectrum, but Abney and Rowland have photographed considerably below the visible red. Beyond the range thus attained qualitative knowledge was secured by Herschel, Becquerel, Draper, Melloni, Müller, Tyndall, Lamansky and Mouton. But our quantitative knowledge of this region began with the invention and use of the bolometer by Langley,* whose solar energy curve has been familiar to all physicists during the last dozen years. During this interval the bolometer has been used with signal success by Ångström, Rubens, Snow, and Paschen, who have made improvements not only in the instrument itself but in the delicacy of its necessary accompaniment, the galvanometer. The work of Snow† particularly, on the infra-red spectra of the voltaic arc and of the alkalies, and that done by him in conjunction with Rubens‡ on refraction through rock salt, sylvite, and fluorite, exhibited the capacities of the bolometer

* Langley, Selective Absorption of Solar Energy, this Journal, March, 1883, p. 169.
† Physical Review, vol. i, pp. 28 and 95.
‡ Astronomy and Astrophysics, March 1893, p. 231.

even better, perhaps, than Langley's previous work on the sun. But more recently with the collaboration of several able assistants, and more particularly the great ingenuity and mechanical skill of Wadsworth, the sensitiveness of Langley's galvanometer has been so exalted, and the bolometer connected in such manner with photographic apparatus, as to make it an automatically controlled system, by which an hour's work now brings results superior in both quantity and quality to what formerly required many weeks or even months.* Not only is an entire solar energy curve now easily obtained in a single day, but even a succession of them. It becomes thus possible by comparison to eliminate the effect of temporary disturbing conditions, and to combine results in such a way as to represent the infra-red cold bands almost as accurately as the absorption lines of the visible spectrum are indicated by use of the diffraction grating. It will undoubtedly become possible to determine in large measure to what extent these bands are due to atmospheric absorption and which of them are produced by absorption outside of the earth's atmosphere.

With the diffraction grating, supplemented by the radio-micrometer, Percival Lewis† has recently investigated the infra-red spectra of sodium, lithium, thallium, strontium, calcium and silver, attaining results which accord well with the best previously obtained by those who had employed the bolometer, and which demonstrate the exceeding delicacy of the radio-micrometer as an instrument of research.

The Visible Spectrum.

To follow out all the applications of the spectroscope that have resulted in recent additions to our knowledge would carry us far beyond the scope of a single paper. It is possible only to make brief mention of a few.

For a number of years Rowland‡ has been investigating the spectra of all the chemical elements, photographing them in connection with the normal solar spectrum, and reducing them to his table of standards, which is now accepted everywhere. The work is of such magnitude that years more must elapse before its completion. It now includes all wave lengths from 3722 to 7200, and of these the list already published extends as far as wave length 5150; or, from ultra violet nearly to the middle of the green.

Through the spectroscope chiefly has been established during the present year the discovery of the new atmospheric element,

* Langley "On Recent Researches in the Infra-red Spectrum," Report of Oxford meeting of British Association, 1894.

† Astrophysical Journal, June, 1895, p. 1, and Aug., 1895, p. 106.

‡ Ibid., Jan. to Aug., 1895.

argon, by Lord Rayleigh and Professor Ramsay;* its remarkable property of green fluorescence when the electric spark is passed through it in presence of benzene, by Berthelot and Deslandres;† and its association in meteoric iron and various minerals with helium, now proved to be a terrestrial as well as solar element, by Ramsay,‡ Crookes, Lockyer, and others.

With the diffraction spectroscope Rydberg,§ and Kayser and Runge‖ have discovered interesting relations among the spectral lines of a large number of terrestrial elements, arranging them into series whose distribution manifests chemical relationship quite analogous to that indicated in Mendeléeff's periodic law.

By photographing the spectrum of Saturn's rings and noting the relative displacement of the different parts of a spectral line, Keeler¶ has obtained a beautiful direct proof of the meteoric constitution of these rings, a confirmation of the hypothesis put forth by Maxwell in 1859, that the outer portion of the rings must revolve more slowly than the inner portion, and yet not satisfy the conditions of fluidity. His work has been repeated and confirmed by Campbell** at the Lick Observatory.

The spectro-heliograph devised by Hale†† has enabled him to photograph, on any bright day, not only the solar photosphere and spots but also the chromosphere and protuberances. He has made some remarkable attempts with this instrument to photograph the corona without an eclipse, unsuccessful thus far but not without promise of future success.

Polarized Light.

In the domain of polarized light, there have been several noteworthy recent researches. Nichols and Snow‡‡ have shown that calcite, though readily transparent for the brighter rays of the spectrum, rapidly diminishes in power of transmission for waves of short period, so that for the extreme violet this power is scarcely half so great as for the yellow. The transmissive power of this crystal for the infra-red rays, between the wave length limits of 1 micron and 5·5 microns, has been investigated with the bolometer by Merritt,§§ who reaches the

* Proc. Royal Society, Jan. 31, 1895.
† Comptes Rendus, June 24, 1895.
‡ Nature, April 4, May 16, July 4 and July 25, 1895.
§ Wiedemann's Annalen, 1893–1894.
‖ Ibid., 1888–1895.
¶ Astrophysical Journal, May, 1895, p. 416.
** Ibid., August, 1895, p. 127.
†† Astronomy and Astrophysics, March, 1893, p. 256.
‡‡ Philosophical Magazine, V, xxxiii, p. 379.
§§ Physical Review, May–June, 1895, p. 424.

interesting result that the transmission curve for the ordinary ray is wholly independent of that for the extraordinary, the absorption being in general much greater for the former. Several sharp absorption bands are found for each ray. For radiation whose wave length exceeds 3·2 microns the absorption of the ordinary ray is almost complete, so that calcite behaves for such radiation just as tourmaline does for the rays of the visible spectrum. The independence of the two transmission curves is found to exist also for quartz and tourmaline, these curves for the latter crossing each other twice in the infra-red region.

The application of polarized light to the investigation of internal stress in transparent media was made more than forty years ago by Wertheim,* who demonstrated that the retardation of the ray is proportional to the load. An extended series of such experiments has been lately made in this country by Marston,† who, besides confirming Wertheim's conclusion, shows that, "for small strains at least, the colors seen in a strained glass body, when polarized light is passed through it in a direction parallel to one of the axes of strain, are measured by the algebraic difference of the intensities of those two principal strains whose directions are perpendicular to the direction of the polarized light."

A new substance with double rotatory power, like quartz, has been discovered by Wyrouboff,‡ the neutral anhydrous tartrate of rubidium, which is unique in one respect. The rotatory power of the substance in the crystalline state becomes reversed in solution. This wholly new phenomenon introduces some perplexity in connection with certain molecular theories that have been formulated to account for double rotatory power.

Crehore§ has ingeniously applied Faraday's principle of electro-magnetic rotation of the plane of polarization in carbon disulphide to the photographing of alternate current curves. Every variation in the magnetic field causes variation in the amount of light transmitted through a pair of crossed Nicol prisms. The combination becomes a chronograph with an index as free from inertia as the beam reflected from a galvanometer mirror. The same instrument has been applied to measurement of the velocity of projectiles,‖ with results of exceeding interest to the student of gunnery.

* Comptes Rendus, xxxii, p. 289, 1851.
† Physical Review, September–October, 1893, p. 127.
‡ Journal de Physique, III, iii, p. 452, 1894.
§ Transactions of the American Institute of Electrical Engineers, October, 1894, p. 591.
‖ Journal of the U. S. Artillery, vol. iv, No. 3, p. 409, July 1895.

Physiological Optics.

The temptation to dilate upon recent progress in physiological optics has to be resisted. The revision of Helmholtz's great book on this subject was interrupted by the death of the distinguished author, but the last part is now approaching completion under the care of his pupil, Arthur König, who in conjunction with Diederici has done much important work in this domain. The selection of hues for the three primary color-sensations has been slightly modified. Young selected the two extremes of the spectrum, red and violet, together with green, which is about midway between them. The hues now accepted by Helmholtz and those who follow his lead, including the great majority of physicists, are a highly saturated carmine red, an equally saturated ultramarine blue, and a yellowish green, corresponding somewhat to that of vegetation. The red and blue agree with those previously determined by Hering, but the rivalry between the two schools on the subject of color-sensation continues, and perhaps will last through a period commensurate with the difficulty of devising crucial experiments.

Independent theories of color-sensation have been brought out by Mrs. Franklin* in America and by Ebbinghaus† in Germany. The former particularly is worthy of much more extended notice than can here be given. It may perhaps be quite properly called a chemical theory of vision. Light is always bringing about chemical changes in external objects, and the eye is the one organ whose exercise requires the action of light, while such chemical action is implied in the performance of most of the bodily functions, such as the assimilation of food and the oxidation of the blood. The bleaching action of light upon the visual purple, which is continually formed on the retina, has been known ever since the discovery of this in 1877 by Kühne, who secured evanescent retinal photographs in the eyes of rabbits. Mrs. Franklin considers that light-sensation is the outcome of photo-chemical dissociation of two kinds of retinal molecules that she denominates gray molecules and color molecules, of which the latter arise from the gray molecules by differentiation in such a way that the atoms of the outer layer group themselves differently in three directions, and the corresponding action of light of proper wave length gives rise to the three fundamental color-sensations. She develops the theory with much skill, applying it particularly to the phenomena of retinal fatigue and color-blindness. To the objection that

* Christine Ladd Franklin, "Eine neue Theorie der Lichtempfindungen," Zeitschrift für Psychologie und Physiologie der Sinnesorgane, 1892.

† H. Ebbinghaus, "Theorie des Farbensehens," l. c., 1893.

there is no direct proof of the existence of the assumed gray and color molecules, it may be answered that Helmholtz himself fully recognized the uncertainty of the assumption that three different sets of nerves respond to the three fundamental color-sensations, and he admitted that these may be only different activities in the same retinal cone. The supposition of three adjacent cones, responding respectively to the three fundamental sensations, is made only for the sake of greater convenience in discussion.

Indeed there is still much for us to learn regarding the nature of color-sensation. Among the yet unexplained phenomena are those of simultaneous color-contrast. The fact that a small brightly-colored area on a gray background appears surrounded by its complementary tint is familiar enough. For its explanation it has been common to assume that there is unconscious motion of the observer's eyes, incipient retinal fatigue, an error of judgment, or fluctuation of judgment. This has been tested by A. M. Mayer,* who ingeniously devised methods for showing these contrast phenomena on surfaces large enough to match the colors with those of rotating color disks, and thus to arrive at quantitative statements of their hues. When viewed through a small opening in a revolving disk the subjective contrast color was unmistakably perceptible when the duration of passage of the opening was less than $\frac{1}{1000}$th of a second. The same effect was obtained in a dark room with instantaneous illumination of the colored surface by the spark of an electric influence machine. The duration of illumination is thus almost infinitesimal, certainly not more than $\frac{1}{10000000}$ of a second. The hypothesis of fluctuation of judgment is thus shown to be wholly untenable. I have performed most of these experiments, either with Prof. Mayer or separately, and my testimony can therefore be united with his. The case is quite analogous to that of the perception of binocular relief which was once explained as the product of a judgment, but was found to be always possible with instantaneous illumination. Prof. Mayer has devised a disk photometer based on color-contrast, with which the error of a single reading was found much less than with the Bunsen photometer.

The rotating color disk has been applied by O. N. Rood† to the determination of luminosity independently of color by taking advantage of the flickering appearance on a rotating disk upon which two parts have different reflecting powers. An extreme case of this is that of a white sector upon a black disk. At a certain critical speed the retinal shock due to

* This Journal, July, 1893. † Ibid., September, 1893.

momentary impression by white light becomes analyzed into the subjective impression of spectral colors, the duration of the retinal sensation varying with the wave length of the incident light. The law of this variation has been studied by Plateau,* Nichols† and more recently with much precision by Ferry,‡ who showed that retinal persistence varies inversely as the logarithm of the luminosity. For a given source of light separated into its spectral components, the yellow is the brightest. For this hue accordingly the retinal impression is shortest and for violet it is longest.

Under appropriate conditions the after-effect on the retina has a certain pulsatory character, as first noted by C. A. Young§ in 1872, and carefully studied within the last few years by Charpentier‖ in France and Shelford Bidwell¶ in England. A disk with properly arranged black and white sectors, if brightly illuminated and looked at while revolving at a moderate rate, becomes apparently colored, just as a momentary glance at the sun causes the perception of a succession of subjective spectral hues which may last a number of seconds. The phenomenon in relation to the disk was known as early as 1838** and explained by Rood†† in 1860. The re-discovery of what has been long forgotten arouses all the interest of novelty. The "artificial spectrum top" devised by Benham‡‡ last autumn excited interest on two continents, and was promptly copyrighted by a prominent firm of opticians§§ in England. It would perhaps be equally enterprising to copyright the solar spectrum.

The limits of a single address forbid my touching upon the large and practically important subject of color-blindness. Indeed in both physical and physiological optics much has been omitted that is abundantly worthy of attention. In behalf of my hearers it may be wise to take heed, once more, of the fate of Tarpeia, who was overwhelmed with the abundance of her reward.

* Dissertation sur quelques propriétés des impressions produits par la lumière sur l'organe de la vue, Liège, 1829.

† This Journal, October, 1884.

‡ Ibid., Sept., 1892.

§ Philosophical Magazine, vol. xliii, p. 343, 1872.

‖ "Oscillations rétiniennes." Comptes Rendus, vol. cxiii, p. 147, 1891.

¶ On the Recurrent Images following Visual Impressions, Proc. Royal Society, March 27, 1894.

** Fechner, Poggendorff's Annalen, 1838.

†† This Journal, September, 1860.

‡‡ Nature, Nov. 29, 1894, p. 113.

§§ Ibid., March 14, 1895, p. 463.

ART. XL.—*Effect of the Mutual Replacement of Manganese and Iron on the Optical Properties of Lithiophilite and Triphylite;* by S. L. PENFIELD and J. H. PRATT.

THE numerous complete analyses of lithiophilite and triphylite which have been made by Penfield* and Wells† have shown in a striking way the transition from essentially $LiMnPO_4$ to the isomorphous $LiFePO_4$. The pure end products are not known, the lithiophilite richest in manganese being that from Branchville, Conn., with MnO=40·9 per cent and FeO=4·0 per cent, and the triphylite richest in iron that from Rabenstein and Bodenmais, Bavaria, with FeO=36·2 per cent and MnO=9·0 per cent.

Our knowledge of the optical properties of these minerals is confined to the results obtained by E. S. Dana‡ on the lithiophilite from Branchville, who found that the plane of the optical axes was 001, the acute bisectrix at right angles to 010, the divergence of the optical axes large, 2Ha (n for the oil being 1·47) =74° 45′ for red and 79° 30′ for blue, the dispersion therefore strong $\rho < v$. The character of the double refraction was found to be positive.

The present investigation has been made upon different varieties of lithiophilite and triphylite and was undertaken in order to determine the variations in the optical properties due to the mutual replacement of manganese and iron. The material was selected from specimens in the Brush collection and from the following localities: Branchville, Conn., three varieties of lithiophilite showing a considerable range in composition; Grafton, N. H., a variety about midway in composition between lithiophilite and triphylite; and Rabenstein near Zwiesel, Bavaria, the nearest approach to theoretically pure triphylite. None of the material showed crystal faces, and the sections and prisms that were prepared were orientated by the cleavages, of which there are two, one fairly good parallel to 001, the other less distinct parallel to 010. The material was not always well adapted for optical work, and it was often quite difficult to obtain sections that were sufficiently transparent. This was due, however, not to any decomposition of the mineral but to numerous crackled and opaque portions of the mass, caused perhaps by crushing. Liquid inclusions were abundant in the material from Branchville.

The cleavage was in no case so perfect that a fragment of suitable orientation for optical purposes could be broken out, and in order to prepare sections and surfaces parallel to a given

* This Journal, xiii, p. 425, 1877; xvii, p. 226, 1879, and xxvi, p. 176, 1883.
† Ib., xvi, p. 119, 1878. ‡ Ib., xvi, p. 119, 1878.

cleavage the following plan was adopted: A fragment showing the desired cleavage was fastened to a glass plate and while the cement was still soft the mineral was shifted in position by means of two small wedges running at right angles to one another until the reflection of a distant object, as a window bar, from the glass plate and the cleavage coincided, when the preparation was turned in different positions, thus showing that the cleavage was parallel to the glass. Then at the sides of the fragment glass plates of equal thickness were cemented, so as to form a large wearing surface, and the mineral ground away until even with the glass. The surface was next polished and a plate or prism prepared as occasion demanded.

The chemical composition of this group of minerals having been fully established by the complete analyses already referred to, the ferrous iron determinations were the only ones required for the present investigation, and these were made by dissolving the minerals in sulphuric acid and titration with potassium permanganate. The composition of the pure end products is as follows:

$$\text{Lithiophilite}\begin{cases}P_2O_5 = 45{\cdot}3\\ MnO = 45{\cdot}1\\ Li_2O = \ \ 9{\cdot}6\end{cases}\qquad \text{Triphylite}\begin{cases}P_2O_5 = 45{\cdot}0\\ FeO = 45{\cdot}5\\ Li_2O = \ \ 9{\cdot}5\end{cases}$$

Therefore if the amount of FeO is known, the percentage of MnO may be told within 1 per cent by deducting the percentage of FeO from the mean percentage of the bivalent oxides, 45·3.

The results of the investigation are given in the following table:

As seen from the table, the optical characters undergo a very considerable change due to the interchange of manganese and iron, and one that is perhaps greater than might be expected considering how nearly alike the two elements are in atomic weights. With an increase in iron there is an increase in the indices of refraction, and also the divergence of the optical axes changes rapidly. The material from Grafton happened to be of such a composition that it illustrates this latter variation in a very striking manner. In this special case the mineral is practically uniaxial for yellow light, although there was a slight variation in the character of the material, for when the section that was prepared was moved about in the polariscope there were some parts where the interference cross opened up to a very slight extent. At that particular part, however, where the measurements were made the material was uniaxial. Owing to the strong dispersion characteristic of the group, the plane of the optical axes for green was 001, as in the previous cases, while for red it was at right angles to the latter, or 100. The interference figure, therefore, as seen in the polariscope with white light, was similar to that of brookite, where the extreme colors of the spectrum, red and blue, are dispersed in planes at right angles to one another.

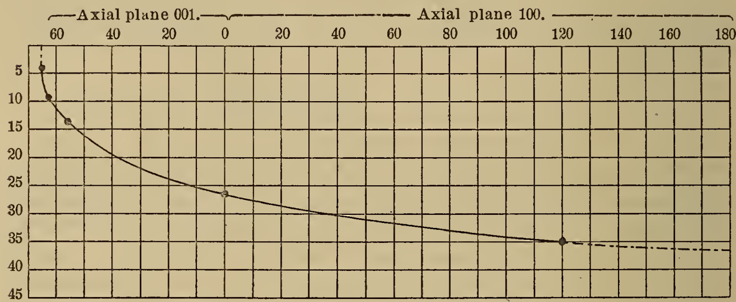
Locality, color, and per cent of FeO.	Indices of refraction and optical orientation. *gr.*=Tl. *y*=Na. *r*=Li.	α	β	γ	2Ha over axis *b* in *a*-monobromnaphthalene.	2V over axis *b*.	Plane of the optic axes, character of the dispersion and of the double refraction.
Branchville.	*gr.*	----	1·682	----	67° 9′	66° 25′	001
Salmon.	*y.*	----	1·675	----	66 5	65 13	$\rho<v$
FeO=4·24%	*r.*	----	1·672	----	65 4	63 23	Positive.
		𝔞=*a*	𝔟=*c*	𝔠=*b*			
Branchville.	*gr.*	----	1·682	----	64° 55′	64° 16′	001
Light clove-brown.	*y.*	1·676	1·679	1·687	63 34	62 54	$\rho<v$
FeO=9·42%	*r.*	----	1·674	----	62 10	61 1	Positive.
Branchville.	*gr.*	----	1·687	----	59° 56′	59° 20′	001
Light clove-brown	*y.*	----	1·682	----	56 59	56 4	$\rho<v$
with bluish cast.	*r.*	----	1·678	----	54 32	53 24	Positive.
FeO=13·63%							
					2E over axis *b*		
Grafton, N. H.	*gr.*	1·691	1·692	1·698	37° 28′	21° 53′	001
		𝔞=*a*	𝔟=*c*	𝔠=*b*			Positive.
Light blue or bluish-gray.	*y.*	1·688	1·688	1·692	0°	0°	Uniaxial. Positive.
FeO=26·58%	*r.*	1·683	1·684	1·691	25° 28′	15° 3′	100
		𝔞=*c*	𝔟=*a*	𝔠=*b*			Positive.
Rabenstein.		----	1·707	----		About 120°	100
Light gray with		----	1·702	----		or 60° over	$\rho<v$
greenish cast.		----	1·697	----		*c* or 𝔞	Negative.
FeO=35·05%		𝔞=*c*	𝔟=*a*	𝔠=*b*			

The material from Rabenstein was unfortunately poorly adapted for optical work. Numerous sections were cut parallel to the best cleavage, 001, but none was sufficiently transparent to admit of an accurate measurement of the divergence of the optical axes by means of the ordinary axial angle apparatus. By examination with convergent light under the microscope it was seen that the sections were at right angles to the acute bisectrix, and that the plane of the optical axes was 100. By using the most transparent section and the little apparatus devised by Klein,* for examination with polarized light in a liquid whose index of refraction is about like that of the mineral, it was found that the divergence of the optical axes 2Va was about 60° with dispersion $\rho<v$; hence 2V over the crystallographic axis *b*, as given in the previous cases, would be

* Sitz. Ber. Akad. Berlin, xxiv, p. 435, 1891; also Groth's phys. Kryst., 3d edition, p. 750.

120°. By means of a large prism the mean indices of refraction were determined with a fair degree of accuracy.

Although the results are somewhat meager, the authors are perhaps warranted in plotting some of them into a curve, using the percentages of FeO as ordinates and the divergence of the optical axes, 2V, measured in degrees over the axis *b*, as abscissas. This has been done for yellow light only, and it would indicate an interesting relation, for with an increase of FeO over 35 per cent 2V would probably become 180°, that is the material would be again uniaxial, but negative with *c* as the optical axis, and with a still greater increase in FeO the optical axes would have to open up into the pinacoid 010. The plane of the optical axes therefore for the lithiophilite end of the series is 001, for intermediate varieties somewhat nearer triphylite it is 100, and nearer the triphylite end we may expect it to be 010.



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

Art. XLI.—*On the Ammonium-Cuprous Double Halogen Salts;* by H. L. Wells and E. B. Hurlburt.

The existence of ammonium-cuprous double halides has long been known, but since no complete investigation of these compounds had been made, a careful study of them has been undertaken.

Mitscherlich* prepared the potassium salt, $4KCl . Cu_2Cl_2$, and mentioned the corresponding ammonium salt. This salt, $4NH_4Cl . Cu_2Cl_2$, has been obtained in the present investigation.

Deherain† described three double chlorides, $4NH_4Cl . Cu_2Cl_2 . H_2O$, $2NH_4Cl . Cu_2Cl_2$ and $NH_4Cl . Cu_2Cl_2$. The first of these salts, if the molecule of water is omitted, corresponds to the compound mentioned by Mitscherlich which we have

* Ann. Chim. Phys., lxxiii, 384. † Comptes Rendus, lv, 808.

obtained, and we are convinced that Deherain's formula for it is wrong. The second salt, $2NH_4Cl.Cu_2Cl_2$, has not been obtained by us, but since it corresponds in type to a bromide and an iodide which are easily prepared, its existence seems possible. The third salt of Deherain, $NH_4Cl.Cu_2Cl_2$, probably does not exist, for we have failed to obtain it, as has Ritthausen also. Ritthausen,* while not being able to prepare $NH_4Cl.Cu_2Cl_2$, obtained the compound $4NH_4Cl.3Cu_2Cl_2$, and we have confirmed this result. The compositions required for the two formulæ do not differ widely, so that it is probable that Deherain analyzed the salt $4NH_4Cl.3Cu_2Cl_2$ and gave it an incorrect formula.

As far as we know, no double bromides have been previously described. Saglier† has described an ammonium-cuprous iodide, to which the formula $2NH_4I.Cu_2I_2.H_2O$ is given. The single double iodide which we have obtained corresponds to Saglier's description and to his formula, except that we have found it to be undoubtedly anhydrous.

In the present investigation a great number of experiments have been made, with gradually varying proportions of the constituent salts in each case, in order to obtain as many compounds as possible.

The Chlorides, $4NH_4Cl.Cu_2Cl_2$ *and* $4NH_4Cl.3Cu_2Cl_2$.—These compounds were prepared by making hot hydrochloric acid solutions of mixtures of the simple salts, usually in the presence of copper wire, and cooling to crystallization. The first salt mentioned above is very readily oxidized by exposure to air, hence it has been found advisable in making it to use a flask and to protect the solution from air by means of a stream of carbonic acid.

The compound $4NH_4Cl.Cu_2Cl_2$ requires the presence of a comparatively large amount of ammonium chloride for its formation and crystallizes in colorless prisms which rapidly change in color through brown to green upon exposure to the air. Crystals 20^{mm} in length and 5^{mm} in thickness were observed.

The following analyses of two separate crops were made:

			Calculated for $4NH_4Cl.Cu_2Cl_2$.
Ammonium	17·91	18·12	17·48
Copper	29·69	29·28	30·79
Chlorine	50·66	50·37	51·73
	98·26	97·77	100·00

* J. pr. Ch., lix, 369.

† Comptes Rendus, civ, 1440.

It was necessary to dry the samples for analysis very rapidly on account of their instability, and some water was unavoidably left in them, causing the low summations. The amount of water corresponding to one molecule (Deherain's formula) is 4·19 per cent.

The other chloride, $4NH_4Cl . 3Cu_2Cl_2$, is produced when the simple salts are mixed in the required proportion in hydrochloric acid solution, and also under considerable variations from these proportions. It forms brilliant, colorless dodecahedrons which are moderately stable in the air at ordinary temperatures, but gradually turn green on exposure.

The following analyses of three separate crops were made:

	I.	II.	III.	Calculated for $4NH_4Cl . 3Cu_2Cl_2$.
Ammonium	9·39	9·73	9·73	8·92
Copper	47·19	46·73	46·79	47·15
Chlorine	42·81	43·11	43·13	43·93
	99·39	99·57	99·65	100·00

The calculated amounts of ammonium, copper and chlorine for Deherain's formula, $NH_4Cl . Cu_2Cl_2$, are 7·15, 50·50 and 42·35 respectively, and it does not seem possible that this formula represents the true composition of the salt, because the samples analyzed were well crystallized and evidently very pure.

The Bromides, $4NH_4Br . Cu_2Br_2$ and $2NH_4Br . Cu_2Br_2 . H_2O$.—By the use of ammonium bromide, cuprous bromide, hydrobromic acid and copper wire, these compounds were produced similarly to the chlorides, but since these salts oxidize much less readily than the chlorides, no protection by means of carbon dioxide was necessary in any case.

The first salt, $4NH_4Br . Cu_2Br_2$, is formed in the presence of an excess of ammonium bromide and resembles the corresponding chloride in form, occurring in long, colorless prisms which turn green after long exposure to the air. Analyses of two separate crops gave:

	I.	II.	Calculated for $4NH_4Br . Cu_2Br_2$.
Ammonium	10·24	10·24	10·61
Copper	18·81	18·47	18·68
Bromine	70·93	70·60	70·71
	99·98	99·31	100·00

The other bromide, $2NH_4Br . Cu_2Br_2 . H_2O$, is formed in the presence of a relatively greater amount of cuprous bromide. It forms brilliant, colorless rhombohedrons, sometimes 15^{mm}

long and 9^{mm} wide, and it is more stable in the air than the first bromide. Analyses of two separate crops gave:

	I.	II.	Calculated for $2NH_4Br . Cu_2Br_2 . H_2O$.
Ammonium	6·88	6·90	7·19
Copper	25·61	25·20	25·32
Bromine	63·76	64·08	63·90
Water (difference)..	3·75	3·82	3·59

The Iodide, $2NH_4I . Cu_2I_2$.—Only one double iodide could be obtained by the use of ammonium iodide and cuprous iodide in widely varying proportions in hydroiodic acid solutions. This circumstance agrees with the observation made upon several other series of double salts studied in this laboratory, that the number of double salts possible decreases from the chlorides to the iodides. Two separate crops gave the following results upon analysis:

	I.	II.	Calculated for $2NH_4I . Cu_2I_2$.
Ammonium	5·84	5·95	5·36
Copper	18·75	....	18 90
Iodine	75·07	75·55	75·74
	99·66		100·00

Summary.—The double salts obtained in the present investigation are as follows:

2 : 1 Type.	1 : 1 Type.	2 : 3 Type.
$4NH_4Cl . Cu_2Cl_2$	....	$4NH_4Cl . 3Cu_2Cl_2$
$4NH_4Br . Cu_2Br_2$	$2NH_4Br . Cu_2Br_2 . H_2O$	....
....	$2NH_4I . Cu_2I_2$	....

The two bromides are apparently new compounds, while a formula without water has been given to Saglier's iodide. The compound, $NH_4Cl . Cu_2Cl_2$, of Deherain probably does not exist.

It was hoped that ammonium-cuprous salts of other types, corresponding to the cæsium-cuprous salts described by one of us* would be found, but such has not been the case, and there is no correspondence between the two series. The view advanced in the article just mentioned, that the formula $4NH_4Cl . 3Cu_2Cl_2$ might be considered somewhat doubtful on account of its complexity and because its variation from the 1:2 type is slight, seems to have been unfounded.

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

*This Journal, xlvii, 96.

Art. XLII.—*On some Phonolitic Rocks from Montana;* by L. V. Pirsson.

Of the two rock types described in the following note the first was collected from a drift bowlder on the Missouri River near Fort Claggett by Mr. W. H. Weed of the U. S. Geological Survey, the second also from a drift bowlder in the ballast material of the Great Northern Railway, at Havre by the author. The occurrence of these two closely related types, the one on the north and the other on the south of the Bear Paw Mountain, certainly renders it probable that they have been derived from this little known mountain group and greatly heightens our interest concerning it.

While in the present stage of petrological knowledge the description of rocks devoid of their geological mode of occurrence and genetic relationships is of little use or interest, in the present case the types are so unusual and present so many features of petrological and mineralogical interest that it has been thought best to give a brief account of them. Moreover, the rocks have so strongly marked a habit that it has been thought well to call attention to them, since when their place of occurrence becomes known, they cannot fail to be of great service in tracing the movement of the drift in the region in which they are found. They add one more to the hitherto small number of occurrences of phonolite in this country.

Pseudo-leucite sodalite tinguaite.

Megascopically, the rock is of a very dark stone color with a strong greenish tinge. It is aphanitic, tough, dense and compact. On weathered surfaces it is a clear, rather dark green. Through this material, which forms the tinguaitic ground-mass, are scattered large white crystals which attain a diameter of $1\frac{1}{2}^{cm}$, are sometimes not above a quarter of this in size but usually average about 1^{cm} in diameter, and are so thickly scattered that commonly they are scarcely separated from each other by more than their own diameters. They are white to pale gray in color and have a greasy, waxy luster. In outline they are nearly spherical but generally show more or less crystal boundaries and most commonly approach octagons, in some cases showing the figure quite perfectly. They present in fact the different sections which may be obtained by passing planes through the icositetrahedron. They appear precisely like leucites but are in fact pseudomorphs after that mineral, as will be shown later.

Thickly scattered everywhere between these large pseudo-leucites are small white or pinkish-colored crystals which run from 1 to 2^{mm} in diameter, also spherical in form but which occasionally show sections characteristic of the dodecahedron. These are sodalites.

These two minerals, together with a rare occasional feldspar, tabular in form and 2 or 3^{mm} long, form the only phenocrysts. The rock is so thickly spotted with them that as a result of the contrast of their white color with that of the dark ground-mass it has a strongly mottled appearance that is extremely characteristic.

On weathered surfaces the pseudo-leucites assume a pale brown color and show a zonal weathering, in that they exhibit an outer shell about 1^{mm} in thickness, which is succeeded by a thin shell of more spongy material. On fresh surfaces this outer zone may also be seen by a slightly different color and luster from the rest of the crystal.

The sodalites on weathered surfaces turn brown and disappear easily, leaving pits in their former places.

When the rock is powdered and treated with acid it gelatinizes so readily and strongly as to show a very large proportion of high alkali silicates present. The solution in nitric acid yields an abundant precipitate with silver nitrate, indicating a large amount of sodalite in the rock.

Microscopic.—In thin section the microscope discloses the following minerals as present: Titanite, ægirite-augite, ægirite, sodalite, orthoclase, nephelite, fluorite, calcite and several unknown minerals; the pseudo-leucite is a mixture of orthoclase and nephelite.

Pseudo-leucite.—Under the microscope these are seen to be made up in general of an allotriomorphic mosaic of orthoclase and nephelite. In some cases the outer edge of the section is composed of orthoclase crystals with their longer axes perpendicular to the crystal faces of the original leucite. They form in fact the outer shell previously mentioned. Such an arrangement is similar to that of pseudo-leucites from Brazil and Magnet Cove, as noted by Graeff* and J. Francis Williams.† Inside of this shell, which is rarely perfect, the usual granitoid mixture occurs. At times the orthoclase laths in the center of the pseudo-leucite are grouped around some common point, forming a sphero-crystal, and a number of these may occur in the same pseudo-leucite. Again at other times the orthoclase contains small streaks and patches of nephelite in such a way as to give rise to a distinct micro-pegmatitic structure.

* Jahrb. f. Min., 1887, vol. ii, p. 257.
† Arkansas Geol. Surv., Ann. Rep., 1890, p. 268.

The orthoclase and nephelite composing the pseudomorph are fresh and clear, save a slight incipient kaolinization of the feldspar. Besides these minerals there are a few small included crystals of ægirite and some small crystals of minerals to be noted later.

Portions of these pseudomorphs were obtained and carefully freed from any of the surrounding matrix, powdered and treated with dilute nitric acid. After filtering, the solution gelatinized readily on evaporating and gave a strong reaction for soda, while only a doubtful trace of potash was present. This proves that occasional small patches of isotropic substance are either sodalite or analcite and not any original unchanged leucite substance.

Pseudo-leucites of the character described above were first found in Brazil by Derby. Graeff* believed them to be inclusions of eleolite-syenite, but Hussak† showed that they were in all probability to be referred to original leucites, a conclusion which was confirmed by the studies of precisely similar occurrences in tinguaite from Magnet Cove by J. Francis Williams.‡

Titanite.—This occurs rather rarely in small crystals about $\cdot 5^{mm}$. It has the usual characters.

Ægirite-augite.—Phenocrysts of augite are very rare. A few of a green variety with deep green ægirite borders have been noted 1 to 2^{mm} long.

Sodalite.—The crystals are very fresh and do not show any signs of alteration or zeolitization; a little infiltrated calcite in cracks is now and then seen.

They are filled with interpositions of extremely minute crystallites which are perhaps ægirite. They usually show by the arrangement of these a zonal structure. They are quite idiomorphic, and in the few cases where they touch orthoclase, they project into it with crystal boundaries. The small ægirites of the ground-mass usually surround them in such a way as to form green wreathes.

Orthoclase.—The large orthoclase phenocrysts are very rare; they are quite fresh save for incipient kaolinization.

The ground-mass in which these phenocrysts lie is made up of a felt of alkali feldspars in small lath-like forms and ægirite needles. The structure is pronouncedly trachytic but has a strong fluidal tendency, especially around the large phenocrysts, about which the streams of microlites bend and twist. Between the feldspar microlites are small formless patches of nephelite which only very occasionally show a crystal outline.

Fluorite.—This is found scattered through the rock in

* Jahrb. f. Min., 1887, vol. ii, p. 257.
† Ibid., 1890, vol. i, p. 167.
‡ Arkansas Geol. Surv. Ann. Rep., 1890, vol. ii. p. 267.

masses and stringers which are occasionally clearly visible to the naked eye. It occurs very commonly at times in the center of the large pseudo-leucite crystals or in vein-like masses filling cracks from the outer boundary. It has the usual unequal distribution of its violet pigment. The occurrence of the mineral renders it probable that its origin is due to pneumatolytic processes.

In the center of the pseudo-leucites there frequently occur small crystals of an unknown mineral. Its habit is that of a rather stout prism which rarely exceeds $\cdot 5^{mm}$ in length and is usually much smaller. It is bounded by well defined crystal planes. Examined with a lens in the hand-specimen, they are seen to be of a brown color with a resinous luster. It has a good cleavage parallel to one of the long prism planes. Placed on this cleavage face under the microscope the following optical properties appear. The extinction is parallel to the prism edge and a positive bisectrix emerges in the center of the field, the plane of the optic axes being parallel to the long prism edge. There is a not very strong pleochroism parallel to the prism edge = $\mathfrak{a}$ = brown, at right angles = $\mathfrak{b}$, a yellow. It was at first thought that the mineral might be astrophyllite, and three small crystals, all that could be obtained, were tested for MnO and TiO_2, for the former in a sodium carbonate bead, which was then dissolved in a minute quantity of H_2SO_4 and tested for TiO_2 with hydrogen peroxide. No reaction was obtained in either case, though a nearly equal quantity of astrophyllite from Brevig treated in the same way gave excellent reactions for both. The small solution of the mineral was then tested for iron, which was present. The mineral is not astrophyllite, both on chemical and optical grounds.

If we assume that the prism edge represents the vertical axis and the cleavage face is *a*(100), then the above facts and those learned by a study of the sections may be summarized as follows:

Orthorhombic, the pinacoids *a*(100) and *b*(010) present with long tapering pyramids or domes. Cleavage parallel to *a*(100). Axial plane parallel to *b*(010). And $\mathfrak{a} = c$, $\mathfrak{b} = b$, $\mathfrak{c} = a$. Color brown, luster resinous, pleochroism not marked, $\mathfrak{a}$ brown, $\mathfrak{b}$ yellow, $\mathfrak{c}$ between. Scarcely perceptible in thin section. Refraction high, at least 1·6. Double refraction high, at least ·04. Does not contain MnO ; contains not more than a trace of TiO_2; iron is present.

These properties distinguish the mineral from astrophyllite, låvenite, rinkite, mosandrite and cossyrite, which might be expected to occur in a rock of this nature. It is to be hoped that better and more abundant material may be discovered when the locality of this rock is found and its exact nature determined.

Besides this mineral, there is another present in the rock, which occurs in grains and in one case in a hexagon-shaped section, nearly always enclosed in sodalite and associated with fluorite. The double refraction is extremely low and in places the mineral appears isotropic. It appears much like apatite, but the hexagonal section shows the strongest double refraction seen (which cannot be over ·006) and does not extinguish parallel to an edge. The mineral is colorless. It is thought to be eudialyte, but it must be admitted that the determination is very doubtful.

Since the geological position of this rock is unknown, no analysis of it has been made. It would not differ materially from those already made of almost precisely similar rocks from other localities, and it could not be used in solving the general petrologic problems of the region.

Quartz tinguaite porphyry.

Megascopically, the rock shows a dense green ground-mass very similar to the type previously described, in which are very thickly scattered phenocrysts of feldspar. The feldspars are strongly tabular and somewhat columnar in habit and range from 1 to $1\frac{1}{2}^{cm}$ across the flat face (b 010) and from 3 to 5^{mm} in thickness. They show by a pronounced parallel arrangement an excellent flow-structure in the rock. It seems probable that the specimen is from a dike with the feldspars arranged parallel to its walls, as this is the most common way in which rocks of this type occur.

Microscopically, the following minerals are found present: Amphibole, ægirite-augite, ægirite, albite, orthoclase and quartz.

The *amphibole*, which occurs in short, rather stout prisms, is rather rare. The prisms are from ·5 to $·2^{mm}$ in length. It has a low double refraction and rather large extinction angle and is quite pale in color. Pleochroism not marked. $\mathfrak{c}$, light brownish green, $\mathfrak{b}$ very pale brown, $\mathfrak{a}$ medium leather brown, absorption $\mathfrak{a} > \mathfrak{c} > \mathfrak{b}$. Apt to be altered.

Ægirite-augite.—As usual, also often altered to ferruginous products. Enclosed in the feldspar phenocrysts, it shows its previous formation.

Orthoclase.—From their optical properties, as shown on cleavage fragments, the large phenocrysts are to be referred to this mineral. They contain inclusions of slender lath-like feldspars which from their twinning, etc., are believed to be of albite-oligoclase; they also contain enormous quantities of minute microlites of a mineral of rather high refraction occurring in grains and short prisms. This is thought to be augite.

The ground-mass in which the above phenocrysts lie appears much like that of the preceding rock, it is a compact felt of small laths of orthoclase (probably with more or less anorthoclase) and slender needles of ægirite often arranged in beautiful flow structures. Scattered through this are small irregular patches of quartz. This rock, on treatment with acid, does not show a trace of gelatinization, thus confirming the absence of nephelite. The quartz, of course, was optically proved.

Use of the term "tinguaite."—As is well known, Rosenbusch* first gave this term to phonolitic rocks from Brazil previously described by Graeff.† According to the idea expressed by him, they filled a definite position in his system of "dike" rocks.

Later, however, Derby,‡ from whom the original types had been received, states that they occur in effusive masses as well as in dike forms. On this account some writers have rejected the term. It seems to us, however, that as a name by which to designate those fine-grained porphyritic rocks which contain large amounts of ægirite in the ground mass, if used without regard to their geological mode of occurrence, the name is a very useful one for field and petrographic purposes and deserves to be retained. As a sequence of the abundance of ægirite needles in the ground-mass, such rocks have a distinct megascopic habit and color that it is very useful to recognize.§

* Mass. Gest., p. 628, 1887.

† Jahrb. für Min., 1887, vol. ii, p. 257.

‡ Quart. Jour. Geol. Soc., vol. xlvii, p. 254, 1891.

§ While the above article was passing through the press the author received Prof. W. C. Brögger's important and interesting work "Die Gesteine der Grorudit-Tinguait Serie," a previous sending having been lost in the ill-fated Elbe. The quartz tinguaite described above corresponds very closely with the "Grorudite" of Brögger, differing chiefly in the presence of the large feldspar phenocrysts. Brögger recognizes the difficulty of differentiating the phonolites occurring in flows from those in dikes and proposes to divide the group into those rich in lime (carrying hauyn and nosean) and those poor in lime (0·5–2·0 per cent) but rich in ægirite and nephelite, and thereby having the characteristic green color. The term tinguaite is to be reserved for the latter. This is essentially the same idea as that proposed above though in a somewhat more limited sense.

In adverting to Derby's article Brögger states that Derby does not say that the Brazilian tinguaites occur in effusive flows. This is true, but it is nevertheless precisely the idea that the writer, along with others, understands that he wishes to convey. It is to be hoped that Prof. Derby himself will see fit to clear up this matter, about which so much misapprehension seems to exist.

Mineralogical-Petrographical Laboratory,
Sheffield Scientific School of Yale University, New Haven, July, 1895.

Art. XLIII.—*The Reduction of Selenic Acid by Hydrochloric Acid;* by F. A. Gooch and P. S. Evans, Jr.

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

It has long been known that selenic acid is reducible by hydrochloric acid with evolution of chlorine, but the reaction was regarded as more or less uncertain until Petterson showed* that conditions of action may be secured under which the reduction proceeds so regularly that the chlorine evolved may be estimated iodometrically and taken as the measure of the selenic acid originally present, or of the selenious acid produced. According to this method of determination, it is only necessary to boil a solution of selenic acid in hydrochloric acid of moderate concentration, and if the solution is not too dilute the reduction is obtained in a few moments. Petterson did not, however, fix with exactness the limits of dilution within which a successful determination of the selenic acid may be expected. The object of this paper is to record the results which we have obtained in studying more closely the conditions necessary to an accurate and rapid reduction. We have used in our experiments solutions of selenic acid prepared by oxidizing pure, white, resublimed selenium dioxide according to the method laid down in a previous paper from this laboratory† for the quantitative determination of that substance. A portion of the crystalline oxide, approximately two grams, was carefully weighed, dissolved in 120 cm^3 of water containing one-twelfth of its volume of sulphuric acid, and treated with a strong solution of potassium permanganate until the color characteristic of a distinct excess of that reagent prevailed distinctly over that of the brown oxide of manganese thrown down in the oxidation. The liquid was warmed to about 50° C., bleached by oxalic acid, and the excess of this reagent was destroyed by more permanganate. On account of the tendency of manganous salts, when present in considerable amount in warm solutions containing but little free acid, to react upon any considerable excess of permanganate with the deposition of higher oxides of manganese, it is generally necessary to repeat the bleaching and oxidizing process two or three times before the final color of a slight excess of the permanganate remains in clear solution and indicates the completion of the oxidation of the selenium. Finally, the liquid was filtered, diluted carefully to the volume of one liter, and used as a standard solution.

* Zeitschr. Anal. Chem., xii, 287.
† Gooch and Clemons: this Journal, l, 51.

To determine in a general way the point of dilution at which mixtures of selenic and hydrochloric acids yield chlorine, we submitted various mixtures to distillation in a retort arranged with an inverted condenser (so that the aqueous distillate might be constantly returned to the retort) which was joined to an absorbtion apparatus charged with a solution of potassium iodide. A current of carbon dioxide was passed through the apparatus during the distillation, to carry forward whatever chlorine might be evolved in the process. The iodine liberated in the absorbtion apparatus was determined by titration with standard sodium thiosulphate. The results of these experiments are given in the accompanying table.

SeO_3 present. grm.	Total volume. cm^3	Per cent of HCl, sp. gr. 1·20, by volume.	Time in minutes.	Chlorine in terms of the theoretical total.
0·1144	100	5	5	None
"	"	10	"	None
"	"	15	"	About 1%
"	"	20	"	" 7%
"	"	25	"	" 30%
"	"	30	"	" 70%

It is plain that so long as the volume of the hydrochloric acid, sp. gr. 1·20, does not amount to more than ten per cent of the entire liquid no chlorine whatever is evolved, and that only when the percentage of this acid rises as high as thirty does the chlorine evolved during boiling for five minutes approach the theoretical yield. In the ordinary process of distillation, in which the inverted condenser is not used, the liquid must gradually concentrate and the acid become stronger, so that under such conditions the yield of chlorine in a definite period of time must generally be greater than that obtained in the corresponding experiments of the table. Obviously it is advantageous, in attempting the practical reduction of selenic acid, to begin the distillation with acid of strength sufficient to insure the evolution of chlorine in quantity at the outset, and we have found it best to start with a mixture one-third of which is the strongest aqueous hydrochloric acid, sp. gr. 1·20. With solutions so constituted the reduction goes on rapidly. We have found, however, that care must be taken not to prolong the boiling after the solution reaches a concentration corresponding to hydrochloric acid of half-strength; for under such conditions—attained in our experiments either by boiling down mixtures of selenious acid and hydrochloric acid, or by making mixtures of selenious acid containing hydrochloric acid of half-strength—we have found that selenium appears visibly in the distillate, while iodine is set free from the iodide in the receiver. Good results may be expected when the mixture, containing one-third of its volume of the strongest aqueous hydrochloric acid at the beginning, is boiled until all chlorine is expelled, care being taken that the volume of the liquid shall not become less than two-thirds of the original volume.

These are conditions which are easily kept; and we have found that from solutions having a total volume of 75 cm^3 and containing 25 cm^3 of the strongest aqueous hydrochloric acid (sp. gr. 1·20), the entire amount of chlorine corresponding to the reduction of 0·2 grm. of selenic acid to selenious acid is liberated in ten minutes. The details of these experiments are given in the accompanying table.

Se = 79·1, 0 = 16.

SeO_3 taken. grm.	Total volume at the outset.	HCl, sp. gr. 1·20, present.	Time in minutes.	SeO_3 found. grm.	Error.
0·0572	75 cm^3	25 cm^3	10	0·0568	0·0004 —
0·0572	"	"	"	0·0569	0·0003 —
0·1144	"	"	"	0·1143	0·0001 —
0·1144	"	"	"	0·1137	0·0007 —
0·1144	"	"	"	0·1147	0·0003 +
0·2288	"	"	"	0·2233	0·0005 —
0·2288	"	"	"	0·2279	0·0009 —

Art. XLIV.—*The Reduction of Selenic Acid by Potassium Bromide in Acid Solution;* by F. A. Gooch and W. S. Scoville.

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

It has been shown in previous papers from this laboratory that potassium bromide may be used with good effect in presence of acid and under well-defined conditions as a reducer of arsenic and telluric acids. This paper gives the results of similar experiments made to test the interaction between the bromide and selenic acid.

In our experiments we have used selenic acid carefully prepared by oxidizing pure, white, re-sublimed selenium dioxide by means of potassium permanganate in the manner described in the preceding paper. When intermixed with sulphuric acid and potassium bromide, selenic acid liberates bromine in proportion to the excess of acid, the bromide, and the elevation of the temperature. When such a solution is boiled the bromine is evolved and may be collected in potassium iodide contained in any appropriate receiver, and the iodine thus set free may be determined by standard sodium thiosulphate and taken as the measure of the bromine distilled. We have found an apparatus previously used in this laboratory in similar work (made by sealing the exit tube of a Voit wash-bottle, used as a retort, to the inlet tube of a Drexel wash-bottle used as a receiver, with a set of Will and Varrentropp absorption bulbs sealed to the outlet tube of the receiver, to serve as a trap) extremely convenient in the distillation process, and a current of carbon dioxide passed slowly through the apparatus aids greatly in carrying the bromine to the receiver and in promoting quiet boiling. We find that the applicability of the reaction to quantitative purposes turns upon the adjustment of the proportions of the reagents used. The following table contains the results obtained by varying the relative amounts of acid and bromide and the time of boiling. The selenium trioxide recorded as found is calculated upon the assumption that selenious acid is the product of the reduction according to the equation,

$$H_2SeO_4 + 2HBr = H_2SeO_3 + H_2O + Br_2$$
$$Se = 79{\cdot}1,\ O = 16$$

	SeO_3 taken as H_2SeO_4. grm.	H_2SO_4 of half-strength. cm³.	KBr taken. grm.	Initial volume. cm³.	Final volume. cm³.	SeO_3 found. grm.	Error. grm.
(1)	0·1145	5	1	60	25	0·1140	0·0005 –
					15	0·1193	0·0048 +
(2)	0·1145	5	5	60	30	0·1134	0·0011 –
					23	0·1184	0·0043 +
(3)	0·1145	10	1	60	27	0·1134	0·0011 –
					23	0·1141	0·0004 –
(4)	0·1145	20	1	60	35	0·1152	0·0007 +
(5)	0·1145	20	1	60	35	0·1144	0·0001 +
(6)	0·1145	20	5	60	45	0·1172	0·0027 +

From these results it is apparent that the amount of iodine set free in the receiver is dependent upon the proportion of the bromide, the strength of the acid, and the degree of concentration during the distillation. When the proportions of sulphuric acid, potassium bromide, and selenic acid are favorable, the bromine liberated is removed rapidly to the distillate, leaving the residue perfectly colorless, but as the distillation is continued the liquid residue again takes on color and more iodine is set free by the action of the distillate upon a clear solution of potassium iodide, while selenium is plainly visible in the receiver. When the amount of potassium bromide is large its effect is to retain bromine in the liquid so obstinately that no period of colorlessness intervenes before the second stage of color arrives; when its amount is small while that of the sulphuric acid is also small, the reduction of the selenic acid and the evolution of the bromine progress slowly; and when the amount of bromide is small while that of the acid is comparatively large, the interval of colorlessness is prolonged. The proportions which we found best in handling 0·25 grm. of selenic acid, or less, are an initial volume of 60 cm^3 containing 20 cm^3 of sulphuric acid of half-strength with 1 grm. of potassium bromide. Under these conditions we find, as in experiments (4) and (5) of the previous table, that the reduction is almost theoretically exact when the distillation is continued until the re-coloration of the boiling liquid is distinctly recognizable; and this point corresponds in practice very closely to a concentration of volume to 35 cm^3. In the following table are gathered the results of further experiments in which these conditions of action were preserved:

SeO_3 taken as H_2SeO_4. grm.	H_2SO_4 of half-strength. cm^3.	KBr taken. grm.	Initial volume. cm^3.	Final volume. cm^3.	SeO_3 calculated. grm.	Error. grm.
0·0590	20	1	60	35	0·0588	0·0002 —
0·0590	20	1	60	35	0·0591	0·0001 +
0·0614	20	1	60	35	0·0616	0·0002 +
0·0614	20	1	60	35	0·0607	0·0007 —
0·1180	20	1	60	35	0·1177	0·0003 —
0·1180	20	1	60	35	0·1180	0·0000
0·1534	20	1	60	35	0·1527	0·0007 —
0·2349	20	1	60	35	0·2350	0·0001 +

It is plain from these results that, if the conditions of action which we have indicated are observed, the reduction proceeds with regularity sufficient to warrant the use of the reaction as an analytical process.

Art. XLV.—*The Reptilia of the Baptanodon Beds;* by O. C. Marsh.

The Baptanodon beds form a distinct horizon in the Jurassic of the Rocky mountain region, their position being just above the red Triassic sandstones, on which they rest unconformably, and immediately below the Atlantosaurus beds. They consist entirely of marine strata of shales, limestones, and sandstone, and contain a peculiar invertebrate fauna in which *Belemnites densus*, M. and H., is a characteristic fossil.

The writer first recognized this horizon and determined its Jurassic age, in 1868, near Lake Como, in Wyoming, where the strata are well developed, and their geological position is clearly defined in the characteristic section at Como Bluff. In 1870, the writer again found the same horizon in the Green river valley, in Utah, on the eastern flank of the Uinta mountains. Here, also, he discovered the first vertebrate remains detected in the horizon, the most characteristic of which pertained to a small crocodile. The humerus was only five inches in length. The shaft is slender, and the distal end one and one-fourth inches in width. This animal may be referred to the genus *Diplosaurus*, found in the Atlantosaurus beds above, and the species be known as *Diplosaurus nanus*.

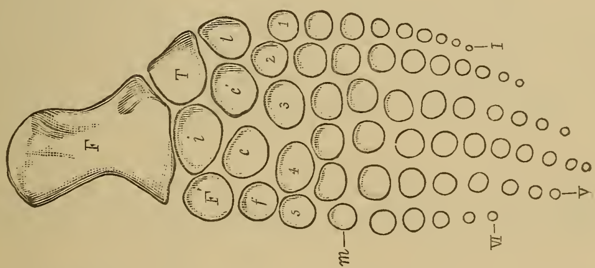


Figure 1.—Left hind paddle of *Baptanodon discus*, Marsh. One-eighth natural size.

Several years later, the writer carried on extensive explorations in this horizon in the Como region of Wyoming, and here was found the skeleton of the large saurian which has since given the name to the horizon. This new reptile, nearly allied to *Ichthyosaurus*, but without teeth, was first called *Sauranodon natans* by the writer,* but, as the generic name proved to be preoccupied, it was replaced by *Baptanodon*, and at the same time the paddle of a second species was figured (vol. xix, p. 491), and this is also shown in figure 1 above. A vertebra of the type species is represented in figure 2.

Subsequent researches brought to light a number of other specimens in the same region, and still others were obtained from more distant localities in the same horizon.

* This Journal, vol. xvii, p. 86, January, 1879.

A single vertebra, apparently of this genus, was obtained by the writer, in 1873, in eastern Oregon, and with it a *Trigonia*, both found in the Blue mountains. The locality was not visited by the writer, and he has no conclusive evidence that the horizon, apparently Jurassic, is the same as that in the Como region where the type of *Baptanodon* was found.

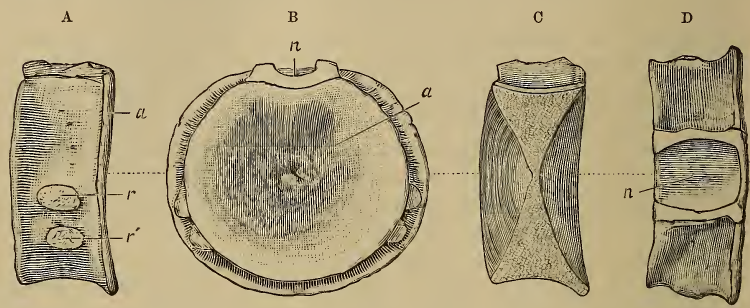


FIGURE 2.—Cervical vertebra of *Baptanodon natans*, Marsh. One-third natural size. *A*, side view; *B*, front view; *C*, section; *D*, top view; *a*, anterior articular face; *n*, neural canal; *r*, *r′*, faces for rib.

In 1885, a new outcrop of the Baptanodon beds was found in the Freeze Out mountains in Wyoming, and here several skeletons of *Baptanodon* were obtained, all in concretions of limestone, as in the original locality. One concretion from this new locality enclosed the skeleton of a small Plesiosaur of much interest, being the first Jurassic form observed in this country. This specimen was named by the writer *Parasaurus striatus*, the specific term denoting a characteristic feature of the vertebræ, which are all strongly grooved, as indicated in the one shown in figure 3, below.* This generic name also proved to be preoccupied, and was replaced by *Pantosaurus*,† the name of the species now being *Pantosaurus striatus*.

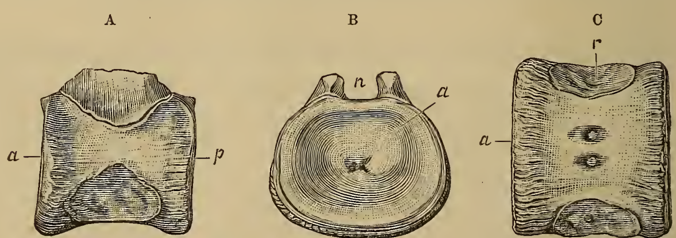


FIGURE 3.—Posterior cervical vertebra of *Pantosaurus striatus*, Marsh. One-half natural size. *A*, side view; *B*, front view; *C*, bottom view; *a*, anterior face; *n*, neural canal; *p*, posterior face; *r*, face for rib.

The skull in this genus was provided with teeth. The neck was long and slender. The vertebræ preserved resemble most nearly in form and size those of *Plesiosaurus plicatus*, Phillips.

Yale University Museum, October 16, 1895.

* This Journal, vol. xlii, p. 338, 1891. † Report Geological Congress, 1891, p. 159.

ART. XLVI.—*Restoration of Some European Dinosaurs, with Suggestions as to their Place among the* REPTILIA ;* by O. C. MARSH. (With Plates V–VIII.)

FOR several years, I have been engaged in investigating the Dinosaurs of North America, where these extinct reptiles were very abundant during the whole of Mesozoic time. The results of my study have been published from time to time, and I have already had the honor of presenting some of these to the British Association. In carrying out this investigation so as to include the whole group of Dinosaurs, wherever found, and bringing all under one system of classification, it has been necessary for me to study the remains discovered in Europe, and I have made several visits to this country for that purpose.

In comparing the forms known from the two continents, certain important differences as well as some marked resemblances between the two have been observed, and placed on record. In concluding my investigations of the North American forms, I have fortunately been able to make restorations of the skeletons of quite a number of very complete type specimens, and this has proved a most instructive means of comparing those from different horizons, and of different groups, among the known *Dinosauria* of America.

The success of this plan rendered it very desirable to extend it, if possible, to the best-known forms of European Dinosaurs. This I have been enabled to do in a few instances, and the main object of the present paper is to lay these latest results before you.

In approaching the subject of European Dinosaurs, and especially those of England, where the study of the group first began, I am well aware that I am on delicate ground, since many and various opinions have been expressed in regard to the nature of the remains here discovered, and particularly as to the form and appearance during life of the animals they represent. I may, perhaps, be permitted, in this connection, to say, what has often occurred to me, that the Dinosaurs seem to have been rather unfortunate, and to have suffered much from both their enemies and their friends. Many of them were destroyed and dismembered long ago by their natural enemies, but, more recently, their friends have done them further injustice in putting together their scattered remains, and restoring them to supposed life-like forms.

* Abstract of Paper read before Section C, British Association for the Advancement of Science, Ipswich, September 14, 1895.

You are all doubtless familiar with the story told by your witty countryman, George Lewes, in his life of Gœthe, of an international attempt to reconstruct the camel. To complete this task, the Englishman, it is said, travelled to distant lands, studied the animal in its native wilds, and then prepared his report; the Frenchman went to the museum in Paris, examined stuffed specimens and skeletons, and wrote his account; while the German remained in his study at home, meditated on the subject, and finally evolved his idea of the camel from his inner consciousness. Similar methods, but not on the same international lines, have been followed in the case of the Dinosaurs, and if some of those that have been restored could speak, whatever they might say about the prehistoric enemies that destroyed them, they would surely ask to be saved from their latter-day friends.

Seriously, I think justice has not been done to this remarkable group of reptiles in rehabilitating them for the benefit of the rising generation in science, and some of the attempts, I fear, have been so firmly implanted in text-book literature, that, like the oft-repeated myth of the "coral insect," the errors will pass down to the next century before being eradicated. The German method has sometimes been used by Anglo-Saxons, and with a success quite equal to that in the case of the camel. To take one instance familiar to you all, let me mention *Megalosaurus*, the first Dinosaur described, and also *Iguanodon*, an herbivorous colleague, on which it doubtless preyed. The first restoration of these two reptiles made them, as they were supposed to be in life, quadrupedal, or four-footed animals of forbidding aspect, and as such they have since haunted the visions of several generations, young and old, by night and by day. I have just made a pilgrimage to Sydenham to see with my own eyes these famous restorations, and, so far as I can judge, there is nothing like unto them in the heavens, or on the earth, or in the waters under the earth. We now know from good evidence that both *Megalosaurus* and *Iguanodon* were bipedal, and to represent them as creeping, except in their extreme youth, would be almost as incongruous as to do this by the genus *Homo*.

Lest it be supposed that I consider the Dinosaurs alone to have suffered from the attempts of their friends to restore them to life, I might recall to your remembrance the well-known figure in the text-books, of *Dinotherium*, reclining peacefully, with its feet and limbs concealed, for the simple reason that no one knew anything about them; or that other picture of the *Labyrinthodon* without a tail, deliberately making foot-prints upon the sands of time, while no such form has yet been discovered. I might refer to still more frightful examples of the dangers encountered by over-zealous historians of ancient life, but those given will suffice.

Restorations of European Dinosaurs.

The restorations of Dinosaurs I have now to present to this section are four in number, and represent some of the best-known European forms, types of the genera *Compsognathus*, *Scelidosaurus*, *Hypsilophodon*, and *Iguanodon*. These outline restorations have been prepared by me mainly for comparison with the corresponding American forms, but in part to insure, so far as the present opportunity will allow, a more comprehensive review of the whole group. The specimens restored are all of great interest in themselves, and of special importance when compared with their nearest American allies.

Compsognathus. (Plate V.)

The first restoration, that of *Compsognathus longipes*, Wagner, 1861, shown natural size in the diagram (Plate V), is believed to represent fairly well the general form and natural position, when alive, of this diminutive carnivorous Dinosaur, that lived during the Jurassic period. The basis for this restoration is (1) a careful study of the type specimen itself, made by me in Munich, in 1881; (2) an accurate cast of this specimen, sent to me by Prof. von Zittel; and (3) a careful drawing of the original made by Krapf, in 1887. The original description and figure of Wagner (Bavarian Academy of Sciences, 1861) and those of later authors have also been used for some of the details. No restoration of the skeleton of this unique Dinosaur has hitherto been attempted.*

Compsognathus has been studied by so many anatomists of repute since its discovery, that any attempt to restore the skeleton to a natural position will be scrutinized from various points of view. My interest in this unique specimen led me long ago to examine it with care, and I have since made a minute study of it, as related elsewhere, not merely to ascertain all I could about its anatomy, but also to learn, if possible, what its relations were to another diminutive form, *Hallopus*, from a lower horizon in America, which has been asserted to be a near ally. Both are carnivorous Dinosaurs, probably, but certainly on quite different lines of descent.

The only previous attempt to restore this remarkable Dinosaur was by Huxley, when in America, in 1876. He made a rapid sketch from the Wagner figure, and I had this enlarged for his New York lecture. This sketch, reproduced on the diagram before you (figure 1), represents the animal sitting down, a position which such Dinosaurs occasionally assumed, as shown by the footprints in the Connecticut Valley, which Huxley examined in place at several localities with great interest.

* The remains of the embryo within the skeleton of *Compsognathus*, first detected by me in 1881, while examining the type specimen, is not represented in the present restoration. This unique fossil affords the only known evidence that Dinosaurs were viviparous.

The great majority of Dinosaurian footprints preserved were evidently made during ordinary locomotion, although some series show evidence of more rapid movement. All those referred to carnivorous Dinosaurs are bipedal, and this is true of the footprints of many herbivorous forms.

FIGURE 1.—Sketch of *Compsognathus longipes*, Wagner. One-seventh natural size. (After Huxley.)

In the present restoration of *Compsognathus* (Plate V), I have tried to represent the animal as walking, in a characteristic position true to life.

Scelidosaurus. (Plate VI.)

The second of these restorations is that of *Scelidosaurus Harrisonii*, of Owen, shown natural size in the diagram. This reptile was an herbivorous Dinosaur of moderate size, related to *Stegosaurus*, and was its predecessor from a lower geological horizon in England. This restoration is essentially based upon the original description and figures of Owen (Palæontographical Society, 1861). These have been supplemented by my own notes and sketches, made during examinations of the type specimen, now in the British Museum.

Scelidosaurus is a near relative, as it were, of one of our American forms, *Stegosaurus*, now represented by so many specimens that we know the skull, skeleton, and dermal armor, with much certainty. The English form known as *Omosaurus* is still more nearly allied to *Stegosaurus*, perhaps identical.

A restoration of the skeleton of *Scelidosaurus*, by Dr. Henry Woodward, will be found in the British Museum Guide to Geology and Palæontology, 1890, p. 19. The missing parts are restored from *Iguanodon*, and the animal is represented as bipedal, as in that genus.

In the present outline restoration of *Scelidosaurus*, I have endeavored merely to place on record my idea of the form and position of the skeleton, when the animal was alive, based on the remains I have myself examined. In case of doubt, as, for example, in regard to the front of the skull, which is wanting in the type specimen, I have used a dotted outline, based on the nearest allied form. Of the dermal armor, only the row of plates best known is indicated. The position chosen in this figure (Plate VI) is one that would be assumed by the animal in walking on all four feet, and this I believe to have been its natural mode of progression.

Hypsilophodon. (Plate VII.)

The third of these restorations, that of *Hypsilophodon Foxii*, Huxley, 1870, given in outline, natural size, in the diagram, has been made with much care, partly from the type specimen, and in part from other material mostly now in the British Museum. The figures and description by the late Dr. Hulke* were of special value, although my own conclusions as to the natural position of the animal when alive do not coincide with those of my honored friend, who did so much to make this genus of Dinosaurs, and others, known to Science. The restoration by Dr. Hulke is shown in another diagram.

In the case of *Hypsilophodon*, a number of specimens are available instead of only one. This makes the problem of restoration in itself a simpler matter than in *Scelidosaurus*. Moreover, we have in America a closely allied form, *Laosaurus*, of which several species are known. A study of the genus *Laosaurus*, and the restoration of one species given on the plate before you, will clear up several points long in doubt.

Huxley and Hulke both shed much light on this interesting genus, *Hypsilophodon*, indeed, on many of the *Dinosauria*. The mystery of the Dinosaurian pelvis, which baffled Cuvier, Mantell, and Owen, was mainly solved by them, the ilium and ischium by Huxley, and the pubis by Hulke. The more perfect American specimens have demonstrated the correctness of nearly all their conclusions.

Iguanodon. (Plate VIII.)

The fourth restoration here given, that of *Iguanodon Bernissartensis*, Boulenger, 1881, one-fifth natural size, has been made in outline for comparison with American forms. It is based mainly on photographs of the well-known Belgian specimens, the originals of which I have studied with considerable care during several visits to Brussels. The descriptions and figures of Dollo† have also been used in the preparation of this restoration. A few changes only have been introduced in the accompanying plate, based mainly upon a study of the original specimens.

* Philosophical Transactions, 1882. † Bulletin Royal Museum of Belgium, 1882–'88.

Besides the four genera here represented, no other European Dinosaurs at present known are sufficiently well preserved to admit of accurate restorations of the skeleton. This is true, moreover, of the Dinosaurian remains from other parts of the world outside of North America.

To present a comprehensive view of the Dinosaurs, so far as now known, I have prepared the plate here shown, which gives restorations of the twelve best-known types, as I have thus far been able to reconstruct them.* Of these twelve forms, eight are from America: *Anchisaurus*, a small carnivorous type from the Trias; *Brontosaurus*, *Camptosaurus*, *Laosaurus*, and *Stegosaurus*, all herbivorous, and the carnivorous *Ceratosaurus*, from the Jurassic; with *Claosaurus* and *Triceratops*, herbivores from the Cretaceous. These American forms, with the four from Europe already shown to you, complete the series represented on this chart. They form an instructive group of the remarkable Reptiles known as *Dinosauria*.

The geological positions of *Compsognathus* and of *Scelidosaurus* are fully determined, but that of *Hypsilophodon* and *Iguanodon* is not so clear. The latter are found in the so-called Wealden, but just what the Wealden is I have not been able to determine from the authorities I have consulted. The Cretaceous age of these deposits appears to be taken for granted here, but the evidence as it now stands seems to me to point rather to the upper Jurassic as their true position. If I should find the vertebrate fossils now known from your Wealden in the Rocky Mountains, where I have collected many corresponding forms, I should certainly call them Jurassic, and have good reason for so doing. Moreover, after visiting typical Wealden localities here and on the continent, I can still see no reason for doing otherwise so far as the vertebrate fossils are concerned, and in such fresh-water deposits their evidence should be conclusive. I have already called attention to this question of the age of the Wealden, and do so again, as I believe it worthy of a careful reconsideration by English geologists.

EXPLANATION OF PLATES.

PLATE V.—Outline restoration of the skeleton of *Compsognathus longipes*, Wagner. One fourth natural size. Jurassic, Bavaria.

PLATE VI.—Outline restoration of the skeleton of *Scelidosaurus Harrisonii*, Owen. One-eighteenth natural size. Jurassic, England.

PLATE VII.—Outline restoration of the skeleton of *Hypsilophodon Foxii*, Huxley. One-eighth natural size. Wealden, England.

PLATE VIII.—Outline restoration of the skeleton of *Iguanodon Bernissartensis*, Boulenger. One-fortieth natural size. Wealden, Belgium.

* A copy of this plate will appear in the next number of this Journal.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The refractivity and viscosity of Argon and Helium.*—At the recent meeting of the British Association, Lord Rayleigh read a paper on the refractivity and viscosity of these gases. He described how, by means of an electric arc, kept up for several weeks in a mixture of oxygen and atmospheric nitrogen, he finally obtained more than a litre of argon at atmospheric pressure. This proved to have the same density as the specimen obtained by the magnesium method. The refractive index was measured by the interference method of Fizeau, the two beams being separated by slits in front of the lens nearest the eyepiece. The latter was constructed of cylindrical lenses. To avoid the use of cross-wires, the tubes containing the gases under comparison were arranged so as not to occupy the whole field of view, some light passing parallel to and outside them; two sets of fringes were thus obtained, which could be brought to coincidence by varying the pressure of either gas. Adjustments were made for several pressures, one of the tubes always containing air. The values of the refractivity ($\mu-1$) were, for argon 0·961, and for helium 0·146, that of air being taken as unity. The viscosity of each gas was measured by its rate of flow through a capillary tube, the results being (air $=1$) argon 1·21, helium 0·96. Lord Rayleigh mentioned that a sample of nitrogen collected from a Bath spring, where it bubbles out along with the water, gave the D_3 line of helium. Dr. Gladstone showed that the results of these experiments assign to argon the atomic weight 20, its specific refractive energy being intermediate between those of fluorine and sodium, but not between those of potassium and calcium.—*Nature*, lii, 533.

2. *On the compound nature of the gas from Cleveite.*—In the paper on the constituents of the gas from cleveite, alluded to in the last number, C. Runge and F. Paschen show that it must be regarded as made up of two and only two constituents. One of these, to which the bright yellow double line belongs, it is proposed to call helium,—this has the stronger spectrum; the other constituent as yet remains unnamed. After stating this conclusion and the theoretical grounds upon which it is based, the authors go on to say:

We have confirmed this rather hypothetical conclusion by the following experiment. The connection leading from our supply of cleveite gas to the vacuum tube contained a side branch parting from it and joining it again. There were stopcocks on either side of the side branch, and a third one in the side branch. In the main tube between the ends of the side branch a plug of asbestos was tightly inserted. To prepare the vacuum tube only the tap leading to the supply was closed, the whole space up to this tap being carefully evacuated. Now the side branch was closed, and the tap leading to the supply was opened. Then we observed that the light of the electric discharge in the vacuum tube was at first greenish, and after a while grew yellow. By cutting off the current of gas after a sufficiently short time, we succeeded in making a vacuum tube which remained greenish. On examining it in a small spectroscope with which we could overlook the whole spectrum, we found that the intensities of the lines had changed. The yellow line was scarcely as bright as the green line 5016, and the red line 7065 had apparently decreased relatively to 7282 and 6678, although it was still stronger than 7282. The two lines that had decreased in intensity belong to the second set of series, while the others are members of the first set. The other visual lines of the second set could not very well be examined because they are more in the violet part.

This observation confirms our spectroscopic result. The gas in cleveite may be taken to be a mixture of two gases of different density, of which the lighter one is more rapidly transmitted through the plug of asbestos. There is, however, the objection to be raised, that in the green tube the pressure is less, and that the difference of intensities is due to the pressure being different. This must be further inquired into.

We were not satisfied with the visual observation of the change of intensities in our green tube, but thought it desirable to test the conclusion by the bolometric measurement of the two lines that we have discovered in the ultra-red part of the spectrum. If we were right, the ultra-red line of smaller wave-length, which belongs to the second set of series, ought to have decreased in intensity relatively to the other ultra-red line. This we found to be so indeed. In the yellow tubes the intensity of the smaller wave-length was to that of the other on an average as 3 to 1, while in the green tubes it was as 1·8 to 1. This confirmation we consider the more valuable as it does not depend on any estimation which may be biassed by the personal opinion of the observer, but is based on an objective numerical determination.

Another confirmation may be gathered from the spectrum of the sun's limb and that of several stars. Let us confine our attention to the six strongest lines in the visible part of the spectrum :

7066, 6678, 5876, 5016, 4922, 4472.

The first, third, and sixth belong to the second set of series; the second, fourth and fifth to the first set. These six lines have all been observed in the spectrum of the sun's limb, as Norman Lockyer and Deslandres have pointed out. Now, according to their appearance in the spectrum of the sun's limb, they may be classed in two groups, one group being always present, the other group being sometimes present. C. A. Young long ago called attention to the difference in the frequency of appearance of the chromospheric lines. He has given them frequency numbers, roughly estimating the percentage of frequency with which the lines were seen during the six weeks of observation at Sherman in the summer of 1872. According to Young, 7066, 5876, 4472 have the frequency number 100, while 6678, 5016, 4922 have the numbers 25, 30, 30, showing that one of the two constituents was always present, while the other was only seen about once in every four cases.

The lines of both constituents have been observed in the spectra of a considerable number of stars β, δ, ε, ζ, γ, Orionis, α Virginis, β Persei, β Tauri, η Ursæ majoris, β Lyræ. In the spectrum of β Lyræ, thirteen lines have been identified with certainty. But the most interesting case in point is the spectrum of Nova Aurigæ, that wonderful star whose sudden appearance was announced to astronomers in 1892 by an anonymous postcard. In the spectrum of Nova Aurigæ the two lines 5016 and 4922 were very strong, while 4472 was weak and 5876 has only been seen by Dr. Huggins, we believe only on one occasion, and appears to have been very weak. Now 5016 and 4922 belong to the lighter constituent, and are together with 6678 the strongest lines in the visible part of the spectrum; while 5876 and 4472 are the strongest lines of the other constituent in the visible part of the spectrum. In Nova Aurigæ, therefore, the lighter constituent gave a much brighter spectrum than helium proper. But there may here be raised an objection, which indeed we do not know how to refute. Why has the line 6678 not been observed? It is a pity that the red part of the spectrum cannot be more easily photographed. Nova Aurigæ has now become very weak, and besides the spectrum is quite altered, so that we shall never know whether the red line 6678 was really absent or has only escaped notice.

From the fact that the second set of series is on the whole situated more to the refrangible part of the spectrum, one may, independently of the diffusion experiment, conclude that the element corresponding to the second set is the heavier of the two. In the spectra of chemically related elements like Li, Na, K, Rb, Cs, or Mg, Ca, Sr, or Zn, Cd, Hg, the series shift to the less refrangible side with increasing atomic weight. But it appears that in the spectra of elements following each other in the order of their atomic weights in a row of the periodic system like

Na, Mg, Al;
K, Ca;
Cu, Zn;
Rb, Sr;
Ag, Cd, In;

the series shift the opposite way, so that the spectrum of the element of greater atomic weight is as a whole situated further to the more refrangible side. Now in our case the density of the gas has been determined by Langlet (published by Cleve) and by Ramsay to be about double the density of hydrogen. Assuming the atomic weights of the two constituents to be between that of lithium and that of hydrogen, they would both belong to the same row of the periodic system, and therefore the more refrangible set of series would correspond to the greater atomic weight.

For convenience of reference all the observed lines are given in the following table, the wave-lengths being abridged to tenth-metres.

Lighter Constituent.

Principal series.		First subordinate series.		Second-subordinate series.
20400	....	6678	....	7282
5016	....	4922	....	5048
3965	....	4388	....	4438
3614	....	4144	....	4169
3448	....	4009	....	4024
3355	....	3927	....	3936
3297	....	3872	....	3878
3258	....	3834	....	3838
3231	....	3806	....	3808
3213	....	3785	....	

Heavier Constituent (Helium proper).

		Double lines.		Double lines.
11220	....	5876	....	7066
3889	....	4472	....	4713
3188	....	4026	....	4121
2945	....	3820	....	3868
2829	....	3705	....	3733
2764	....	3634	....	3652
2723	....	3587	....	3599
2696	....	3555	....	3563
2677	....	3531	....	3537
		3513	....	3517
		3499	....	3503
		3488	....	3491
		3479	....	3482
		3472		
		3466		
		3461		

—*Nature*, lii, 521.

3. *On the specific refraction of Argon.*—Dr. Gladstone read a paper before the British Association on specific refraction and the periodic law, with special reference to argon and other elements. In former years he had shown that the specific refractive energies of the elements in general were, to a certain extent, a periodic function of their atomic weights. With regard to argon, the specific refractive energy of argon gas as reckoned by Lord Rayleigh's data is 0·159. At the suggestion of Deeley, the bearing of

this result on the atomic weight of argon was considered. If the atomic weight be 19·94, the molecular refraction will be 3·15. This figure is almost identical with that belonging to oxygen and nitrogen gas, and differs considerably from that of calcium, which has a molecular refraction of 10·0 and a specific refractive energy of 0·248. These facts tend to suggest an atomic weight of 20 for argon, and to place it in the vicinity of the alkali metals.—*Nature*, lii, 537.

4. *Color Photography.*—Zenker, Lehrbuch der Photochromie, Berlin, 1868, explained the phenomena of the colors produced in sensitized media by the hypothesis of the working of stationary light waves. Objections, however, to this hypothesis were raised by Schultz-Sellack (Pogg. Ann., cxliii, p. 449, 1871). Lippmann (Comptes Rendus, cxii, 1891), however, showed the possibility of employing stationary waves in color photography, and his results apparently sustained the conclusions of Zenker. Schultz-Sellack, in support of his position, showed that powdered substances had served for the reproduction of color. For instance Seebeck used paper moistened with a gray preparation of chloride of silver. This use of powder has no connection with transparent layers formed by Becquerel on good reflecting surfaces, such as silver plates which have been covered with a chloride of silver by electrolysis. The recent researches, however, of Carey Lea throw doubt upon the hypothesis of Zenker, for he shows that the colors of chloride of silver can be formed in the dark by purely chemical processes. H. Krone also, in his treatise on the representation of natural colors by photographie (Verlag der deutschen Photographenzeitung, p. 43, 1894) asserts that the Poitevin method, which consists in bathing paper in different solutions, rests upon purely chemical grounds and is radically different from that of Lippmann's. Krone maintains that our present incomplete knowledge of the production of color in photography rests upon Zenker's theory. OTTO WIENER undertakes in an exhaustive article to settle the question: "Were the colors obtained by the early workers in this subject due to interference of waves of light or to absorption?" His experiments show that Becquerel's results depend upon interference, that in the images obtained by Seebeck and Poitevin no color change enters. They are obtained from the color of the particles, and Zenker's hypothesis does not apply to them. The color of the particles, body color, *körperfarbe*, also enters into Becquerel's results. Wiener addresses himself to the question why certain color stuffs give back the color of the illumination, and finds the explanation that the color stuff does not absorb the light of its own color but reflects it, while the other colors are absorbed by the stuff and broken up. It is therefore possible that colored illumination in suitable stuffs can awaken similar colors in color particles. He calls such material color-susceptible, *farbenempfängliche*. This possibility and the knowledge of its conditions leads to the foundation of a new art of color photography, which can be termed body color photography,

and the hope appears to be well-founded that the results obtained by this art will exceed those previously obtained. The giving back of the color can be termed color adaptation, *farbenanpassung*, since it consists in letting free the color material, which best resists the breaking-up influence of the illuminating color. The author concludes with some references to observations on the color of animals, by Darwin, Poulton, Roux and others, which illustrate the influence of color particles, according to his theory.—*Ann. der Physik und Chemie*, No. 6, 1895, pp. 226–281.
J. T.

5. *The Electric Aureole: and Stratifications in the Electric arc and in discharges in rarified gases.*—Many observers have noticed the peculiar forked flame discharges produced in the discharge from electrodes of the secondary circuit of a suitable transformer. Spottiswode was the first to excite a Ruhmkorf coil by an alternating dynamo, and thus to lead the way to a study of the relation between this forked flame-like discharge and the ordinary voltaic arc. LEHMANN has made an exhaustive study of this phenomena, both in the air and in various vessels containing rarified air and gases. He shows that the exchanges of heat between the walls of the vessels and the layers of rarified air must be considered in studying the phenomena of stratification. His paper contains many illustrations of the aureoles formed and of the isothermal surfaces about and between the electrodes, and a discussion of the influence of partial discharges on the phenomenon of stratification. His investigation has a bearing upon certain phases of the aurora borealis.— *Ann. der Physik und Chemie*, No. 6, 1895, pp. 361–388. J. T.

6. *Magnetism of Asbestos.*—Faraday placed asbestos in the list of weak magnetic bodies, but recent observers have discovered that certain varieties of this mineral are strongly magnetic. Swinton, in the Electrical Review, 34, No. 880, Oct. 5, 1894, has called attention to this property of asbestos, and BLEEKRODE shows that a gray variety exhibits strong magnetism even in comparatively weak magnetic fields. He points out that this substance should not be used as an insulating material in magnetic instruments.—*Ann. der Physik und Chemie*, No. 6, 1895, p. 398. J. T.

7. *Electric refraction of Liquids.*—P. DRUDE, using a modification of Blondlot's apparatus for exciting powerful electric oscillations, has obtained for electric waves in water a refractive index of 9 and a specific inductive capacity equal to 81.—*Ann. der Physik und Chemie*, No. 8, 1895, p. 633–655. J. T.

8. *Double refraction of electric waves in ice.*—V. BIERNACKI uses one of Lodge's coherers in connection with parabolic mirrors of small size, 45^{cm} in height, aperture 30^{cm} and focal length 3^{cm}. The introduction of a thick slab of ice between the two crossed mirrors with its axis 45° to both the focal lines exhibits the double refraction of the ice.—*Ann. der Physik und Chemie*, No. 8, 1895, p. 599–603. J. T.

9. *Double Refraction of Electric Waves.*—PETER LEBEDEW has succeeded in reducing the size of Hertz's apparatus for exhibiting the reflection-polarization and refraction of electric waves, so that he could work with waves only a fraction of a centimeter in length ($\lambda=0{\cdot}6^{cm}$) and with prisms scarcely more than a centimeter in height. The arrangement of the mirrors and the prisms is the same as that of the observing telescopes and prism in the case of the optical spectrometer. A prism of sulphur $1{\cdot}8^{cm}$ high, $1{\cdot}3^{cm}$ broad with a refracting angle of 25° was used. The values of the indices of refraction obtained were $N_1=2{\cdot}2$ $N_2=2{\cdot}0$ for the two directions in which Boltzman had measured the dielectric constants of sulphur. The square roots of the dielectric constants are, 2·18 and 1·95, and Maxwell's law therefore holds within the limits of error of observation. Instead of a spark micrometer, Lebedew employed a thermal junction of iron and constantan. His paper contains illustrations and descriptions of his apparatus.—*Ann. der Physik und Chemie*, No. 9, 1895, pp. 1–17. J. T.

II. GEOLOGY AND MINERALOGY.

1. *On the Temperature Variation of the Thermal Conductivity of Rocks;* by LORD KELVIN and J. R. ERSKINE MURRAY.

(1.) The experiments described in this communication were undertaken for the purpose of finding temperature variation of thermal conductivity of some of the more important rocks of the earth's crust.

(2.) The method which we adopted was to measure, by aid of thermoelectric junctions, the temperatures at different points of a flux line in a solid, kept unequally heated by sources (positive and negative) applied to its surface, and maintained uniform for a sufficiently long time to cause the temperature to be as nearly constant at every point as we could arrange for. The shapes of the solid and the thermal sources were arranged to cause the flux lines to be, as nearly as possible, parallel straight lines; so that, according to Fourier's elementary theory and definition of thermal conductivity, we should have

$$\frac{k(\mathrm{M, B})}{k(\mathrm{T, M})}=\frac{[v(\mathrm{M})-v(\mathrm{T})]\div \mathrm{MT}}{[v(\mathrm{B})-v(\mathrm{M})]\div \mathrm{BM}},$$

where T, M, B denote three points in a stream line (respectively next to the top, at the middle, and next to the bottom in the slabs and columns which we used); v(T), v(M), v(B) denote the steady temperatures at these points; and k(T, M), k(M, B), the mean conductivities between T and M, and between M and B respectively.

(3.) The rock experimented on in each case consisted of two equal and similar rectangular pieces, pressed with similar faces together. In one of these faces three straight parallel groves are cut, just deep enough to allow the thermoelectric wires and junctions to be embedded in them, and no wider than to admit the wires and junctions. Thus, when the two pieces of rock are pressed together, and when heat is so applied that the flux lines are parallel to the faces of the two parts, we had the same result, so far as the thermal conduction is concerned, as if we had taken a single slab of the same size as the two together, with long fine perforations to receive the electric junctions. The compound slab was placed with the perforations horizontal, and their plane vertical. Its lower side, when thus placed, was immersed under a bath of tin, kept melted by a lamp below it. Its upper side was flooded over with mercury in our later experiments (pars. 6, 7, 8), as in Hopkins's experiments on the thermal conductivity of rock. Heat was carried off from the mercury by a measured quantity of cold water poured upon it once a minute, allowed to remain till the end of a minute, and then drawn off and immediately replaced by another equal quantity of cold water. The chief difficulty in respect to steadiness of temperature was the keeping of the gas lamp below the bath of melted tin uniform. If more experiments are to be made on the same plan, whether rocks or metals, or other solids, it will, no doubt, be advisable to use an automatically regulated gas flame, keeping the temperature of the hot bath in which the lower face of the slab or column is immersed at as nearly constant a temperature as possible, and to arrange for a perfectly steady flow of cold water to carry away heat from the upper surface of the mercury resting on the upper side of the slab or column. It will also be advisable to avoid the complication of having the slab or column in two parts, when the material and the dimensions of the solid allow fine perforations to be bored through it, instead of grooves, which we found more readily made with the appliances available to us.

(4.) Our first experiments were made on a slate slab, 25 cm. square and 5 cm. thick, in two halves, pressed together, each 25 cm. by 12·5, and 5 cm. thick. One of these parts cracked with a loud noise in an early experiment, with the lower face of the composite square resting on an iron plate heated by a powerful gas burner, and the upper face kept cool by ice in a metal vessel resting upon it. The experiment indicated, very decidedly, less conductivity in the hotter part below the middle than in the cooler part above the middle of the composite square slab. We supposed this might possibly be due to the crack, which we found to be horizontal and below the middle, and to be complete across the whole area of 12½ cm. by 5, across which the heat was conducted in that part of the composite slab; and to give rise to palpably imperfect fitting together of the solid above and below it. We therefore repeated the experiment with the composite slab turned upside down, so as to bring the crack in one half of it now to be above the middle, instead of below the middle, as at first. We still found for the composite slab less conductivity in the hot part below the middle than in the cool part above the middle. We inferred that, in respect to thermal conduction through slate across the natural cleavage planes, the thermal conductivity diminishes with increase of temperature.

(5.) We next tried a composite square slab of sandstone of the same dimensions as the slate, and we found for it also decisive proof of diminution of thermal conductivity with increase of temperature. We were not troubled by any cracking of the sandstone, with its upper side kept cool by an ice-cold metal plate resting on it, and its lower side heated to probably as much as 300° or 400° C.

(6.) After that we made a composite piece, of two small slate columns, each 3·5 cm. square and 6·2 cm. high, with natural cleavage planes vertical, pressed together with thermoelectric junctions as before; but with appliances (par. 10 below) for preventing loss or gain of heat across the vertical sides, which the smaller horizontal dimensions (7 cm., 3·5 cm.) might require, but which were manifestly unnecessary with the larger horizontal dimensions (25 cm., 25 cm.) of the slabs of slate and sandstone used in our former experiments. The thermal flux lines in the former experiments on slate were perpendicular to the natural cleavage planes, but now, with the thermal flux lines parallel to the cleavage planes, we still find the same result, smaller thermal conductivity at the higher temperatures. Numerical results will be stated in par. 12 below.

(7.) Our last experiments were made on a composite piece of Aberdeen granite, made up of two columns, each 6 cm. high and 7·6 cm. square, pressed together, with appliances similar to those described in par. 6; and, as in all our previous experiments on slate and sandstone, we found less thermal conductivity at higher temperatures. The numerical results will be given in par. 12 below.

(8.) The accompanying diagram [here omitted] represents the thermal appliances and thermoelectric arrangement of pars. 6, 7. The columns of slate or granite were placed on supports in a bath of melted tin with about 0·2 cm. of their lower ends immersed. The top of each column was kept cool by mercury, and water changed once a minute, as described in par. 3 above, contained in a tank having the top of the stone column for its bottom and completed by four vertical metal walls fitted into grooves in the stone and made tight against wet mercury by marine glue.

(9.) The temperatures, $v(B)$, $v(M)$, $v(T)$ of B, M, T, the hot, intermediate, and cool points in the stone, were determined by equalizing to them successively the temperature of the mercury thermometer placed in the oil-tank, by aid of thermoelectric circuits and a galvanometer used to test equality of temperature by nullity of current through its coil when placed in the proper circuit, all as shown in the diagram. The steadiness of temperature in the stone was tested by keeping the temperature of the thermometer constant, and observing the galvanometer reading for current when the junction in the oil-tank and one or other of the three junctions in the stone were placed in circuit. We also helped ourselves to attaining constancy of temperature in the stone by observing the current through the galvanometer, due to differences of temperature between any two of the three junctions B, M, T placed in circuit with it.

(10.) We made many experiments to test what appliances might be necessary to secure against gain or loss of heat by the stone across its vertical faces, and found that *kieselguhr*, loosely packed round the columns and contained by a metal case surrounding them at a distance of 2 cm. or 3 cm., prevented any appreciable disturbance due to this cause. This allowed us to feel sure that the thermal flux lines through the stone were very approximately parallel straight lines on all sides of the central line BMT.

(11.) The thermometer which we used was one of Cassella's (No. 64,168) with Kew certificate (No. 48,471) for temperature from 0° to 100°, and for equality in volume of the divisions above 100°. We standardized it by comparison with the constant volume air thermometer* of Dr. Bottomley with the following result. This is satisfactory as showing that when the zero error is corrected the greatest error of the mercury thermometer, which is at 211° C., is only 0·3°.

Reading. Air thermometer.	Reading. Mercury thermometer.	Correction to be subtracted from reading of mercury thermometer.
°	°	
0	1·9	1·9
120·2	122·2	2·0
166·8	168·6	1·8
211·1	212·7	1·6
265·7	267·5	1·8

(12.) Each experiment on the slate and granite columns lasted about two hours from the first application of heat and cold; and we generally found that after the first hour we could keep the temperatures of the three junctions very nearly constant. Choosing a time of best constancy in our experiments on each of the two substances, slate and granite, we found the following results:

Slate: flux lines parallel to cleavage.

$$v(\mathrm{T}) = 50^\circ{\cdot}2 \text{ C.}$$
$$v(\mathrm{M}) = 123^\circ{\cdot}3.$$
$$v(\mathrm{B}) = 202^\circ{\cdot}3.$$

The distances between the junctions were BM = 2·57 cm. and MT = 2·6 cm. Hence the formula of par. 2,

$$\frac{k(\mathrm{M, B})}{k(\mathrm{T, M})} = \frac{73{\cdot}1 \div 2{\cdot}6}{79{\cdot}0 \div 2{\cdot}57} = \frac{28{\cdot}1}{30{\cdot}7} = 0{\cdot}91.$$

Aberdeen granite:

$$v(\mathrm{T}) = 81^\circ{\cdot}1.$$
$$v(\mathrm{M}) = 145^\circ{\cdot}6.$$
$$v(\mathrm{B}) = 214^\circ{\cdot}6.$$

* Phil. Mag., August, 1888, and Edinb. Roy. Soc. Proc., January 6, 1888.

The distances between the junctions were BM $=1{\cdot}9$ cm. and MT $=2{\cdot}0$ cm.

$$\frac{k(\text{MB})}{k(\text{TM})}=\frac{64{\cdot}5\div 2{\cdot}0}{69{\cdot}0\div 1{\cdot}9}=\frac{32{\cdot}2}{36{\cdot}3}=0{\cdot}88.$$

(13.) Thus we see, that for slate, with lines of flux parallel to cleavage planes, the mean conductivity in the range from 123° C. to 202° C. is 91 per cent of the mean conductivity in the range from 50° C. to 123° C., and for granite, the mean conductivity in the range from 145° C. to 214° C. is 88 per cent of the mean conductivity in the range from 81° C. to 145° C. The general plan of apparatus, described above, which we have used only for comparing the conductivities at different temperatures, will, we believe, be found readily applicable to the determination of conductivities in absolute measure.—*Proc. Roy. Soc.*, No. 349.

2. *United States Geological Survey: 14th Annual Report for 1892–'93;* by J. W. Powell, Director. Part I, Report of the Director, pp. 1–321. Part II, Accompanying papers, pp. 1–597. Plates i–lxxiv, figures 1–75. Washington, 1894.—This report of the annual progress of the work of the government survey contains more than the usual number of valuable contributions to geological science. The following is the list of accompanying papers, viz:

W. J. McGee: Potable waters of Eastern United States.
A. C. Peale: Natural mineral waters of the United States.
F. H. Newell: Results of stream measurement.
Whitman Cross: The Laccolitic mountain group of Colorado, Utah, and Arizona.
Waldemar Lindgren: The gold-silver veins of Ophir, California.
Arthur Keith: Geology of the Catoctin belt.
J. S. Diller: Tertiary revolution in the topography of the Pacific Coast.
H. W. Turner: The rocks of the Sierra Nevada.
Charles D. Walcott: Pre-Cambrian rocks of the Unkar terrane, grand cañon of the Colorado, Arizona; with notes on the petrographic character of the lavas, by Joseph Paxon Iddings.
T. Nelson Dale: On the structure of the ridge between the Taconic and Green Mountain ranges in Vermont; The structure of Monument Mountain in Great Barrington, Massachusetts.
Joseph D. Weeks: The Potomac and Roaring Creek coal fields in West Virginia.

The first three papers are of general economic value and are more or less directly connected with investigation of the hydrographic conditions of the various regions of the United States. Mr. Newell's paper on stream measurements is the fifth of a series of papers on the discharge of rivers, the other four having been published in the 10th, 11th, 12th and 13th annual reports; the first three of them in the sets of Irrigation survey reports.

Mr. Cross's paper is a valuable contribution to the petrography of intrusive rocks. "The object and plan of the discussion," the author defines to be twofold: "On the one hand it is desired to establish more clearly than has previously been attempted the various phases characteristic of the intrusion of a certain class of igneous masses into the sedimentary complex; on the other hand, the rock type produced by the consolidation of these magmas has been found to have characteristics worthy of special note in the bearing upon the principles of petrography." The author has had not only his own investigation in the Colorado region, but the admirable work of Gilbert, Peale, Holmes, and others to furnish him with the facts necessary to a comprehensive discussion of the phenomena concerned.

Mr. Keith's paper is an exhaustive discussion of a typical piece of geological structure in the midst of the Appalachian region. "The Catoctin belt," the author states, "has shown itself to be an epitome of the leading events of geological history in the Appalachian region. It contains the earliest formations whose original character can be certified; it contains almost the latest known formations; and the record is unusually full, with the exception of the later Paleozoic rocks. Its structures embrace nearly every known type of deformation. It furnishes examples of every process of erosion, of topography derived from rocks of nearly every variety of composition, and of topography derived from all types of structure except the flat plateau type. In the recurrence of its main geographic features from pre-Cambrian time till the present day it furnishes a remarkable and unique example of the permanence of Continental form." In the paper the leading geological events which have left their impress on the region are traced and their effects recorded.

Mr. Diller's paper is another comprehensive study of the geological history of a region, that of Northern California, the borders of the Sacramento Valley, in the Klamath Mountains and the western slope of the Sierra Nevada. The author finds this region practically reduced to a baselevel condition during the early portion of the auriferous gravel period. "The mountain ranges were low, and the scenery was everywhere characterized by gentle flowing slopes. . . . The topographic revolution consisted in the development out of such conditions of the conspicuous mountain ranges of to-day. The northern end of the Sierra Nevada has since been raised at least 4,000 feet, and possibly as much as 7,000 feet, and a fault of over 3,000 feet developed along the eastern face of that portion of the range. The Klamath Mountains may in some portions have experienced at the same time an equal upheaval. From both sides the amount of uplift decreases rapidly toward the Sacramento Valley. In the initial part of this revolution the earlier auriferous gravels were found. The source of their material, of which, next to gold, quartz is the most important, was found in the thick deposit of residuary detritus which had accumulated upon the surface of the land during the baselevel period. The large mass of disintegrated rock substance rendered the loading of the streams so easy that when rejuvenated by orogenic movements they readily became overloaded and filled their ancient channels with auriferous gravels."

The two papers, by Messrs. Lindgren on the gold-silver veins of

Ophir and Weeks on coal-fields of West Virginia, have special mining interest; and the remaining papers are discussions of more local or special geological problems. In reading these papers it must be borne in mind that although issued in 1895, due to the tardy working of the Government printing office, they were completed and given to the director two years ago. An important new feature in the Report of the Director is the publication of synopses of the publications of the survey during the period 1892–'93. In the present case outlines of the contents are given of Monographs XVII, XVIII and XX and of the Bulletins 84, 85, 86, 90, 92, 93, 94, 95, 96, 98, 99 and 100. H. S. W.

3. *The gold fields of the Southern Appalachians.*—The report of GEORGE F. BECKER* on the gold fields of the Southern Appalachians, based upon investigations made in 1894, is issued as a separate brochure and contains a summary account of the gold-bearing regions of the Carolinas and Georgia, to which is added a digest of the geology of the gold deposits of the Maritime Provinces of British America and the Green Mountains, thus making a comprehensive sketch of the gold deposits of the Atlantic slope.

4. *Columnar sandstone.*—In an article "On the structure and composition of a Basalt from Bondi, New South Wales," by J. MILNE CURRAN, a beautiful figure, reproduced from a photograph, is given of columnar sandstone. The author states that "this structure was no doubt induced by the proximity of the igneous rock. Some of the sandstones, that were in contact with the molten basalt, show very little trace of metamorphism, while in other parts the same sandstones are rendered quartzose in texture and prismatic in structure." Although no statement is made of the size of the columns, from comparison with other objects in the figure, it is estimated that the columns are at least twenty feet in length and two to three feet in diameter.—*Jour. Roy. Soc. N. S. W.*, vol. xxviii, p. 221, and pl. ix.

5. *Petrology for Students;* by A. HARKER. 12°, 306 pp. Figs. in text. Cambridge University Press, 1895.—This little volume supplies a long-felt want. There are many geologists and geological students who, while not intending to make petrology their chief aim, yet desire sufficient knowledge of the subject to enable them to understand it and to comprehend in a general way the most recent results in this field of science. To these the appearance of the present work will prove most acceptable. The use of the microscope and the study of rocks in thin sections is of course assumed, as indeed it must be to achieve any results in this field. While many minor details are, from the scope of the work, necessarily omitted, the main features of the science are comprehensively and broadly, though simply handled, and a careful

* Reconnaissance of the gold fields of the Southern Appalachians, by George F. Becker. Extract from 16th Ann Rept. of the Director. U. S. Geol. Survey, 1894–95. Part II, Min. Resources of U. S. Calendar year 1894, pp. 1–85. Washington, 1895.

study of the work will give an excellent grounding in the science. We note that the author, for purposes of classification, divides the igneous rocks into *plutonic*, *intrusive* and *volcanic*, a method that (with some disadvantages) has much to commend it. L. V. P.

6. *Introduction to the study of Rocks;* by L. FLETCHER. 118 pp. 8vo, 1895. (British Museum of Nat. History, Mineral Dept.)—This little work is designed chiefly as a guide to the study of the rock collections in the British Museum. The general principles of petrology are clearly and compactly stated, though in an elementary manner, in keeping with the plan of the work. It should prove of service to the general public visiting the museum and may well serve as a model guide-book for similar institutions elsewhere. L. V. P.

7. *Calaverite from Cripple Creek, Colorado;* correction by W. F. HILLEBRAND. (Communicated.)—In my paper on calaverite from Cripple Creek, Colorado, published in the August number of this Journal, I referred to papers by F. C. Knight and by Richard Pearce in the Proceedings of the Colorado Scientific Society for 1894. My information as to their contents had to be obtained at second hand. Now that I have had opportunity to read those papers I find to my great regret that I have unintentionally done the gentlemen an injustice in failing to give them further credit. Mr. Knight identified calaverite by analysis and showed the iron-tellurium oxidation product to be a ferric tellurite. My work was therefore but an elaborate confirmation of his prior identification of calaverite. Mr. Pearce is confident that sylvanite is a constituent of portions at least of the Cripple Creek ores, and his opinion is entitled to great consideration. While my paper in no way denies the possible existence of a telluride richer in silver than calaverite, it might be inferred that I attributed no great weight to Mr. Pearce's evidence on this point.

8. *Minerals from New South Wales;* Professor A. LIVERSIDGE has recently announced the discovery of the rare minerals *boleite* and *nantokite* at the Broken Hill silver mine in New South Wales. The former occurs in interpenetrating cubes, 4 to 7^{mm} on the edge, of an indigo-blue color; these are implanted upon or imbedded in a matrix of hematite and quartz; hardness, 3·5; specific gravity 5·02. An analysis by Carmichael and Armstrong gave:

Cl	Pb	Cu	Ag	O(calc.)	H_2O(calc.)
13·50	47·20	19·20	8·25	[6·10]	5·44

The amount of water found by Liversidge in an independent trial was 6·39, but this is probably too high. The analysis quoted agrees closely with those of the original boleite given by Mallard and Cumenge. The *nantokite* occurs in pale sea-green particles, apparently crystals but indistinct and with a slightly effloresced surface; on exposure the color becomes darker, and the surface opaque and powdery; hardness 2·5; specific gravity 4·7. An analysis by Carmichael and Armstrong gave:

Cu 64·28 Cl 35·92 = 100·20

This corresponds to Cu_2Cl_2 the composition of the original nantokite from Chili.—*Proc. Roy. Soc. N. S. Wales*, vol. xxviii.

9. *A contribution to the Mineralogy of Wisconsin;* by W. H. Hobbs. Bulletin of the University of Wisconsin Science Series, vol. i, No. 4, pp. 109–156, pl. 4–8. Madison, 1895.—Professor Hobbs has given in this bulletin an account of some minerals from Wisconsin, especially of the species calcite, galena, cerussite, sphalerite, etc., found in cavities in the Galena limestone in the southern part of the state. A number of new forms are noted, as on sphalerite, calcite, cerussite and azurite. Some interesting notes are added in regard to the diamonds found in the glacial drift of Wisconsin; these include three large stones (16, $3\frac{7}{32}$, $21\frac{1}{4}$ carats) and a number of small ones.

10. *Tabellarische Uebersicht der einfachen Formen der 32 krystallographischen Symmetriegruppen* zusammengestellt und gezeichnet von Dr. E. A. Wülfing. Stuttgart, 1895 (E. Schweizerbart'sche Verlagshandlung—E. Koch).—In seven large plates the author has presented the forms with their several grades of symmetry belonging to each of the crystalline systems. A spherical projection accompanies each group and a brief explanatory text is added.

11. *The Mineral Industry, its Statistics, Technology, and Trade in the United States and other countries to the end of 1894* (Statistical Supplement of the Engineering and Mining Journal), vol. iii, edited by Richard P. Rothwell. 748 pp. 8vo. New York and London, 1895 (The Scientific Publishing Company).—This large volume is the third of the series and brings the summary of the state of mineral industries in this country and abroad down to the close of 1894. It has developed out of the series of annual statistical numbers of the *Engineering and Mining Journal* and gives evidence of the energy and enterprise of its editors. The editor-in-chief, R. P. Rothwell, has had the assistance of a large number of collaborators, sketches of about fifty of whom are given in the introduction. The result of their combined labors is this comprehensive volume, remarkable for its breadth of treatment as for the fullness of detail. Thus, in the case of each metal and other substances, not only is the amount mined given, but also the methods of mining and general metallurgical processes; also the methods of manufacture in the case of such products as alkalis, alum, sulphuric acid; both departments have numerous illustrations; finally a statement is given of the course of the market, as for copper, silver, etc. A vast amount of material of interest to different classes of people is thus brought together. The discussions are not limited to the products of the United States, but embrace also the world at large; for example, we note that a chapter of some length gives an account of the occurrence of phosphates in Tunis and Algeria by M. D. Levat.

12. *Field Columbian Museum:—Handbook and Catalogue of the Meteorite Collection*, by Oliver C. Farrington, Ph.D., Cur-

ator, Dept. of Geology. 65 pp. with plates. Chicago, 1895.—This Handbook, which forms No. 1, of volume I, of the Geological Series of publications by the Field Columbian Museum of Chicago, gives a catalogue of the remarkable collection of meteorites which the museum has already acquired. This includes 180 falls or finds aggregating in weight 4,721 pounds. Conspicuous among the rest are two specimens from Kiowa County, Kansas, weighing 466 and 345 pounds; a large mass with several hundred smaller fragments from Phillips County, Kansas, aggregating 1,184½ pounds; also two masses from Cañon Diablo, Arizona, weighing 1,013 and 256 pounds. Besides the catalogue proper, Mr. Farrington has given in the introduction an interesting popular summary of the subject, while a series of six excellent plates show the external appearance and structure of typical specimens of the different types.

III. Botany.

1. *Synoptical Flora of North America*, Vol. I.—Part 1, fascicle 1, Polypetalæ from the Ranunculaceæ to the Frankeniaceæ, by Asa Gray, LL.D., and Sereno Watson, Ph.D., continued and edited by B. L. Robinson, Ph.D., Curator of the Gray Herbarium of Harvard University. Issued Oct. 10, 1895. It is well-known that the Synoptical Flora was undertaken by the late Professor Gray as a revision of the early work issued by him and Dr. Torrey, in 1838 to 1843. For reasons which need not be now alluded to, Professor Gray decided to begin the publication of his revision with certain Gamopetalæ, and this work appeared in 1884, with a second issue in 1886. Other orders of Gamopetalæ and the Apetalæ were entrusted to his assiduous collaborator, the late Sereno Watson, while he himself turned back to those orders of Polypetalæ which stand first in linear sequence. In the investigation of these orders he was engaged when struck down by death. Dr. Watson then carried on the double task of proceeding with the later orders and revising some of the Polypetalæ which Professor Gray had left untouched in his review. With this work he was busy in his last days. After his death, in 1892, the fragmentary notes were committed to the present Curator of the Gray Herbarium, who has embodied in his revision the results of his extensive studies of old and of recent material. He promises a second fascicle at an early day: this will include the remaining Polypetalous orders as far as the Leguminosæ. He has the assurance of aid from various specialists who are to revise certain orders.

The two hundred pages which we have now before us constitute a composite publication in which the parts are well co-ordinated by skillful and exact editing. The contributions of each of the authors are properly credited, and the proportions are excellently kept. In nomenclature, Dr. Robinson has adhered to the practice adopted by his predecessors in the work, following, as he says, in the matter of specific names, "the so-called Kew Rule, except where it leads to indefiniteness. The recent efforts to place botanical nomenclature upon a different basis have led to the hasty restoration in American botany of a considerable number of names, such as *Neckeria*, *Capnorchis*, *Beurera*, etc., which have been as quickly abandoned. The detailed citation of these names, and the numerous combinations to which they have led, forms no part of Dr. Gray's original plan, shown by the following words from his first preface: 'Compactness being essential, only the leading synonymy and most important references are given, and these briefly.' An effort has been made, however, to cite as synonyms such names as are at present indorsed by the Rochester and Madison Rules, and are included in the recently issued 'list of Pteridophyta and Spermaphyta growing without cultivation in northeastern North America, that is if such names do not coincide with those in the text."

The present fascicle will be welcomed as an earnest of the intention, so nearly frustrated by many untoward circumstances, of completing Professor Gray's monumental work. Even a cursory examination of the fascicle shows that the task has enlisted Dr. Robinson's hearty interest, and that he has brought to the task uncommon powers of analytical and descriptive treatment.

G. L. G.

2. *Another example of Chalazogamy.*—Dr. S. Nawaschin, of Kiew, Russia, in Botanisches Centralblatt, Sept. 25, 1895, gives an interesting account of his discovery that *Juglans regia* affords a distinct case to be added to those presented by Casuarineæ, Myricaceæ, etc., of impregnation not through the micropyle, but through the tissue at the chalazal contact. This special case has confirmed Dr. Nawaschin in the belief that the groups of plants which have this remarkable peculiarity constitute a transitional series between the Gymnosperms and the other Angiosperms.

G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *Meeting of the British Association.*—The annual meeting of the British Association for the Advancement of Science was held at Ipswich, county town of Suffolk, during the week beginning September 11th. The meeting was not a large one as regards numbers, but it was most successful with respect to the scientific interest and value of the papers presented. The President, Sir Douglas Galton, delivered the inaugural address, treating of the origin of the British Association, with a summary of the condition of the sciences at the time of its formation in 1831 with special reference to the progress made since then. This address is given in full in the copy of *Nature* for September 12, while the following issues give the other addresses, several of them of great interest, delivered before the several sections. A digest of the more important papers in the different depart-

ments is also given. The meeting for 1896 is to be held at Liverpool and the president elected is Sir Joseph Lister.

2. *On the origin of thunderstorms.*—A new theory of thunderstorms was advanced by Prof. Michie Smith in his paper before the British Association on Indian thunderstorms. His observations, made at Madras, showed that sheet-lightning occurs there every evening during several months of the year, always in the southwest and near the horizon. Lightning phenomena in the morning occur, on the other hand, in the northeast. The phenomena consist of actual discharges between two clouds, or two portions of the same cloud, and are not reflections of distant lightning; they take place in the upper portions of low-lying cumulus clouds. Professor Smith attributes them to the clouds formed in the regions of still air at the meeting of the land and sea breezes, and has observed in these regions the simultaneous rise of two close parallel clouds from the edge of the cumulus; such clouds are scarcely distinguishable except with oblique illumination, and it is within, or between, them that the discharges occur. The time of their formation depends on the hour at which the sea breeze sets in, being roughly three hours later. The land breeze being dry and dusty is negatively charged, while the sea breeze is known to carry a strong positive charge; equalization of the electrical states of the clouds formed out of these will, therefore, give rise to lightning. Professor Smith referred to the iridescence or nacreous appearance of the edges of the clouds when rapidly sinking, and considered this effect to be due to the dust left behind by them.

This paper gave rise to an interesting discussion, chiefly with reference to the origin of dust in clouds, and the source of their electricity. Mr. John Aitken pointed out that thunderstorms are most probably the effect, not the cause, of purifying the air. He gave instances of thunderstorms on several successive days, all of which left the air dusty and impure; eventually the air cleared, and no more thunder occurred. Professor Schuster alluded to the fact that twenty-five theories of thunderstorms had been put forward in a dozen years, and in a single year five appeared. He attributed the positive charge of the sea breeze to the electrification of the air by the spray from the breaking waves; Lenard has shown that the spray of pure water gives a negative charge to the air, while that of salt water communicates a positive charge. He believed the dust of clouds to be acquired locally, except that at high altitudes, which we know to be carried long distances. A proof of this is to be found in the Himalayas, where certain valleys are dusty and others fairly free from dust, although all receive the wind from the Indian plains. His observations of nacreous clouds in England had led him to connect them rather with the ice particles of cirrus clouds than with dust. To this latter point Prof. Michie Smith replied that the nacreous appearance fits the edge of the cumulus so closely that he believes the two to be connected.—*Nature*, lii, 534.

3. *The uniformity of size of pages of Scientific Societies Publications.*—The committee appointed by the British Association, of which Professor S. P. Thompson was chairman, to consider the most desirable size of page for scientific publications, has made a report from which the following recommendations are taken. The importance of these will be readily understood:—

Standard octavo size.—Paper *demy*, the pages measuring $14^{cm} \times 22^{cm}$, or, when uncut, $5\frac{5}{8}$ in.$\times 8\frac{3}{4}$ in. The width, *c*, measured from the stitching to the edge of the printed matter, to be 12^{cm}, or $4\frac{5}{8}$ in., and the height, *d*, of the printed portion, including the running headline, to be 18^{cm}, or 7 in.

Limit of octavo size.—The paper page not to be less than $14^{cm} \times 21{\cdot}5^{cm}$, or $5\frac{1}{2}$ in.$\times 8\frac{1}{2}$ in., and the letterpress not to exceed the measurements $c = 12{\cdot}5^{cm}$, or $4\frac{7}{8}$ in, $d = 18{\cdot}5^{cm}$, or $7\frac{1}{4}$ in. Reprints and unbound numbers of journals to be issued with their edges uncut, or cut not more than $0{\cdot}25^{cm}$, or $\frac{1}{8}$ in., all round.

Standard quarto size.—Paper *demy*, the pages measuring, when uncut, $22^{cm} \times 28{\cdot}5^{cm}$, or $8\frac{3}{4}$ in. wide$\times 11\frac{1}{4}$ in. high. Reprints and unbound numbers of this size to be uncut, or cut $0{\cdot}25^{cm}$, or $\frac{1}{8}$ in. Measurements of letterpress to be $c = 18{\cdot}5^{cm}$, or $7\frac{1}{4}$ in, $d = 21{\cdot}5^{cm}$, or $8\frac{1}{2}$ in.

Limits of quarto size.—Paper pages not to measure less than $21{\cdot}5^{cm}$, or $8\frac{1}{2}$ in., wide$\times 28^{cm}$, or 11 in., high. Letterpress not to exceed the measurements $c = 19^{cm}$, or $7\frac{1}{2}$ in., $d = 23^{cm}$, or 9 in.

To avoid the mutilation of plates in binding the committee recommend that the dimensions of the illustrations should never exceed $13^{cm} \times 20^{cm}$, or $5\frac{1}{8}$ in.$\times 7\frac{3}{4}$ in., for octavo plates, and $21^{cm} \times 25^{cm}$, or $8\frac{1}{4}$ in.$\times 10$ in., for quarto, the width being measured from the back of the book. Where plates have to be folded, the fold should be $12{\cdot}5^{cm}$, or 5 in., from the stitching in octavo, and $20{\cdot}5^{cm}$, or $8\frac{1}{8}$ in., in quarto papers. Any folding plate should, when referred to elsewhere than in the opposite page of letterpress, have a blank space equal to the breadth of the paper page at the left hand, so that when open it can be referred to without closing the portion of the book being read that refers to it. This should be carried out even when the diagram or plate would not otherwise have to be folded, in order to reduce the trouble of reference.

Each article should begin a page. If possible it should begin a right-hand page. It is then possible to bind up any article with others on the same subject without having also to bind up the last half page of another paper.

4. *Map of the wooded area of Connecticut.*—Among the series of maps of Connecticut being prepared by the U. S. Geological Survey in coöperation with the State of Connecticut represented by its Commissioners, Wm. H. Brewer, James H. Chapin and Jonn W. Balou, the one expressing the areas covered by woods has appeared, published under date of 1893. The scale of the map is $\frac{1}{125000}$ with 100 foot contours.

5. *Principles and Practice of Agricultural Analysis*, vol. i, *Soils*, pp. 607, vol. ii, *Fertilizers*, pp. 332; by H. W. Wiley, Chemist of the U. S. Department of Agriculture.

Dr. Wiley's two volumes amply fulfill the promise of their title. The work which he proposes, and of which these two volumes are parts, is unique. There is certainly nothing in the English language which is at all similar in scope.

The preparation of the volume on soils is beset with more difficulty than any other part is likely to be, yet here we think the author has succeeded in treating the subject with good judgment and in a way that is very helpful and suggestive.

The origin and formation of soils and their physical properties are discussed with sufficient fullness for the purposes of the analyst, and the methods which have proved best suited to the physical and chemical examination of soils are accurately and minutely described. Necessarily methods of very different accuracy and value are described together, and no two authors would fully agree as to the material which should be received or rejected in a work like this. Some methods have been described, apparently for their historic interest, which are quite worthless for laboratory use.

We doubt whether the data given in part vii regarding bacteriological work will "enable the analyst to intelligently study the soil phenomena depending on these organisms" (the soil bacteria), "and to determine the extent and character of their biological and chemical functions," unless he is a bacteriologist of considerable experience, in which case the directions given would be quite superfluous.

The volume on fertilizers follows the same plan as the one on soils, and will be found of more immediate and practical value on account of the increasing demand in all parts of the country for fertilizer analysis and control. It is a laboratory guide in this department, which is invaluable to analysts who have this sort of work to do.

An admirable feature of both volumes, particularly acceptable to those who will use them as something more than a receipt book, is a full list of references to the authorities cited. E. H. J.

OBITUARY.

Professor Charles V. Riley, whose sudden death, due to an accident, was announced in our last number, was born in London, England, Sept. 18, 1843. He was educated first in England and later in France and Germany, and when hardly more than a boy came to the United States and settled on a farm in Illinois. His interest in natural history and especially in Entomology, which he had shown very early in life, was developed here, and still more later when, at the age of twenty-one, he became editor of the Entomological Department of an agricultural paper in Chicago. His work here brought him into notice, and in 1868, when only twenty-five, he was made entomologist to the State of Missouri, and from that time until 1877 he carried on under these auspices a series of important investigations upon the insects injurious to agriculture, a field up to this time almost completely new. A very important part of this work was in connection with the locust, which did great harm throughout the West between the years 1873 and 1877. Of the nine annual reports which he published, several were largely devoted to this subject, and the excellence of this work led to his being made chief of the newly created United States Entomological Commission, an organization effected largely through his influence and established in 1877. In this he was associated with Dr. A. S. Packard and Prof. Cyrus Thomas. A number of exhaustive and highly valuable reports were published by this commission. Riley's investigations extended, especially in 1879 and 1880, to the cotton worm, and here also his labors proved of the highest service to the country.

In 1878 he had been made entomologist to the United States Department of Agriculture, but soon resigned the position to be re-appointed under more favorable conditions in 1881. In regard to his labors in building up the department of Entomology, Mr. L. O. Howard writes as follows in a sketch published in the Farmer's Magazine in 1890, from which are taken most of the facts of this notice:—

"The present efficient organization of the division of entomology was his own original conception, and he is responsible for its plan down to the smallest detail. It is unquestionably the foremost organization of its kind at present in existence. It has a small permanent corps of scientific workers, who have been trained under him, and who assist in the preparation and editing of reports, in the care of insects the life-histories of which are being studied, in the making of elaborate notes, in the mounting and arranging of specimens for permanent economic and classificatory collections, in making drawings for illustrations to the reports, and in the very large correspondence. The training of these assistants and their present efficiency and standing in the scientific world is only another instance of the thoroughness of Professor Riley's methods. Several of them have gone out from his office to accept important positions under the State governments, and thus the influence of his training has become widespread. Other entomologists are employed from time to time, and the clerical and other force is very efficiently arranged and systematically employed. A small number of permanent field agents are stationed in different parts of the country, working on the habits of insects in the field, and conducting experiments with remedies. . . ."

He also held the office of curator of the Department of Insects in the National Museum, and to this he presented his collection of one hundred and fifteen thousand mounted specimens of upwards of fifteen thousand species—a collection of the highest value to science. His researches included most of the insects especially injurious to American agriculture, and also the phylloxera. His work in connection with the latter led to his receiving, in 1873, a gold medal from the French government." That he was always an indefatigable worker will be apparent from what has been said of the work which he accomplished, but it would be made more apparent by an enumeration of the long list of his writings. The untimely ending of a career so full of active, useful work, is a great loss to science and his country. We close this notice with another quotation from the same source, which is interesting as giving an insight into one side of his character:

"One other trait which we have not mentioned is his persistency in overcoming obstacles. Nothing daunts him, and the more difficult an end is to attain, so much the more energy and perseverance does he put forth in its pursuit. A recent instance of this quality we may cite: The Fluted Scale (*Icerya Purchasi* Maskill) has done great injury to citrus fruit in Southern California of late years. Ascertaining that it is kept in check by natural enemies in its native home, Australia, Dr. Riley foresaw the importance of endeavoring to introduce these enemies. Not only did Congress refuse to appropriate money for the purpose, but it refused to do away with a clause in the appropriation bill restricting all expenditures to the United States. In this state of affairs most men would have given up the fight; but Dr. Riley, after great trouble, succeeded in accomplishing his end by inducing the Secretary of State to allow the sending of two assistants on the Melbourne Exposition Commission, and through their labors the desired result was reached. Hundreds of specimens of an Australian lady-bird (*Vedalia cardinalis*) were introduced into California, and the dreaded pest is now being speedily reduced to absolute harmlessness. Professor W. A. Henry of Wisconsin, in a recently published article, says of this matter, in speaking of the enthusiasm of the people of California over the result of this importation: 'Without doubt it is the best stroke ever made by the Agricultural Department at Washington.'"

M. Louis Pasteur, whose researches in chemistry and bacteriology have proved of such incalculable benefit to humanity, died on September 28, at the age of sixty-three. It may be questioned whether it has ever been the privilege of any other scientist to accomplish so much for the welfare of his fellow men and the alleviation of their sufferings, as he did through his own labors and those which he inspired.

Eli Whitney Blake, Professor of Physics in Brown University, died on October 1st, at the age of fifty-nine.

Dr. Albert E. Foote, the indefatigable mineral collector, whose active labors through many years have contributed largely to the development of a widespread interest in mineralogy throughout the country, died at Atlanta, Georgia, on the 10th of October, in his 49th year. He had suffered long from ill health, but notwithstanding physical disability he carried on his work with unceasing energy and enterprise up to the very last.

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[THIRD SERIES.]

ART. XLVII.—*The Temperature Variation of the Thermal Conductivities of Marble and Slate;* by B. O. PEIRCE and R. W. WILLSON.

IN the course of an investigation on the absolute thermal conductivities of certain poor conductors, which has occupied us for the last two years, we have obtained some preliminary measures of the temperature variation of conductivity, which we are permitted by the Rumford Committee of the American Academy of Arts and Sciences to present here in advance of the publication of the complete paper.

Our experiments were made by the so-called "Wall Method" upon square prisms. In one form of apparatus which we have used the prism to be tested is enclosed between two planed iron plates, one of which forms the top of a jacketed chamber through which steam may be passed for some hours at a time, while the other is the bottom of a vessel containing a little water and a large quantity of ice, with suitable stirrers and scrapers to insure the constant removal of the film of water immediately against the surface. These plates are fastened firmly together by bolts around their edges to insure close contact with the body under experiment. It is thus possible to keep the boundary planes at temperatures nearly a hundred centigrade degrees apart; the continuous observation of the interior temperatures renders it easy to see when the stationary state is reached and to insure that it is maintained.

The actual measurement of the interior temperatures is a matter of more difficulty. Inasmuch as the prism must be thin, it is necessary to determine with considerable accuracy the position of the point at which the temperature is taken, and there can be no question, we think, that this compels the use of thermal junctions for that purpose. We did not attempt to employ fine platinum resistance coils, on account of difficulties which arise from the use of leads of considerable dimensions.

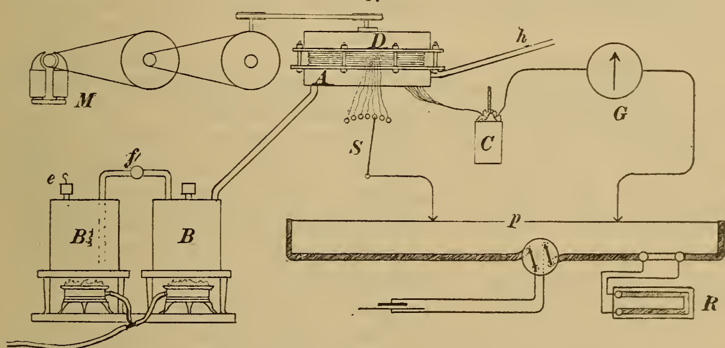
In the case of certain substances, such as sulphur or cement, which can be made to solidify about a system of stretched wires carefully spaced, it is possible to imbed thermopiles in fairly homogeneous prisms with the leads lying in what will be isothermal surfaces, so that there need be no fear of direct conduction of heat to or from the junctions, but such a process as this is manifestly inapplicable in the case of stone. After discussing the possibility of boring holes from the edges of a stone slab, we determined that it would be worth while to try the experiment of building up the prism out of separate slabs, clamped firmly together by means of the outside plates, with thermopiles fitting closely in fine grooves in the faces of the slabs, made with the help of a milling machine. It would not be easy, however, to make such grooves in glass plates, and we saw no better way of proceeding than to clamp the thermopiles between the plates. This, of course, raises some serious questions as to the difference between the indications of the thermal junctions and the true temperatures at the two surfaces with which the wire is in contact. It is obvious that the spaces between the slabs should be as small as possible and therefore that the thermopiles should be of fine wire. In advance of any experiment on the subject, it seemed that the communication of heat from radiation alone across a film of air, at most a small fraction of a millimeter in thickness, would be sufficient to prevent any great inequality of temperature, and that the thermopiles would give a close approximation to the mean of the temperatures at the two surfaces.

On these considerations we decided to make preliminary experiments in this manner, using marble as the experimental substance. How far the event has justified these considerations will appear later. The apparatus used in our first experiments was as follows:

Upon a heavy table was placed the hot chamber A [figure 1] connected with the copper boilers B, B′, for generating steam. The boiler B, which held about 40 liters, was constantly heated and was refilled when nearly empty without stopping the constant flow of steam, by filling B′, heating to the boiling point, suddenly closing the opening at *e* with a weight which acted as a safety valve, and opening the communication at *f*. The generation of steam in B′ served to drive the water over into B without causing a cessation of the flow of steam through the hot chamber, and the communication between the two boilers was then cut off. This process was necessary at least once in each heating. The steam, after passing through a hot chamber A, was led to the outer air by a jacketed pipe, *h*, descending* from the bottom of A.

The planed upper surface of the chamber is about 70^{cm} square and inside the bolt holes of its flanges there is a clear space of 65^{cm} square. Directly upon this face was laid the first slab of marble about 60^{cm} square and 1^{cm} thick. The leads from two thermal junctions of platinoid-copper were then stretched across the middle of the slab so that the junctions were on the transverse middle line of the slab, about 1^{cm} from the vertical axis. The second slab placed upon these held them firmly in place, bearing on the slightly thickened junctions; upon the second slab were placed two more thermopiles, and the pile of slabs thus built up, to the number of seven, formed a prism about 60^{cm} square and 7^{cm} thick. Upon the upper slab was placed the planed lower surface of the square iron box D, which held the ice and water to cool the upper surface. The flanges of the upper and lower castings were then bolted firmly together and the slabs pressed as closely into contact as possible, the average thickness of the slabs being 1^{cm} and of the spaces $0{\cdot}3^{mm}$.

1.



A portion of the upper pan was isolated by soldering a brass cylinder $12{\cdot}3^{cm}$ in inside diameter with its axis vertical in the centre of the pan. This served as a center for a horizontal six-armed stirrer actuated by the motor M and provided with stiff brushes, which swept over the bottom of the pan twice a minute, and which carried about 15 kilograms of ice in a wire basket reaching within 5^{mm} of the bottom. The cylinder, which was provided with its own stirrer inside and had an elaborate system of guards and jackets, which we do not need to describe here, served to isolate the heat coming out from a considerable surface at practically a uniform temperature near the axis of the prism. The amount of ice melted in the cylinder in a given

* In the diagram, *h* is represented as *ascending* and as inserted in the *side* of A

time gave the amount of heat conducted through the slab per second per unit of area.

The platinoid ends of the thermal junctions were soldered together and placed in an oil bath, C, immersed in melting ice. To them was soldered a copper wire leading to the (copper) wire of a potentiometer. The copper ends of the couples led to a mercury switch, by which any one of them might be quickly connected with a second copper wire leading to the potentiometer.

With a comparison cell having an E. M. F. of 2 volts and with about 200 ohms in the circuit, the wire of the potentiometer 2^m in length gave about 1^{cm} for a difference of 1° C. in the temperature of the thermal junctions. The galvanometer was sensitive enough to determine with ease the balance within less than a millimeter on the bridge wire, and the temperatures of the junctions were certainly determined within 0·1° C.

The thermopiles were calibrated after the prism had been taken to pieces, by removing the junctions from the slabs to a frame immersed in an oil pot, which contained a standard thermometer* and was placed in a water bath which could be brought to various temperatures up to nearly 100° C. That this was a safe proceeding appears from a paper printed last year in this Journal.†

In conducting the experiments the steam was passed through the steam box continuously; the upper box packed with ice and water, and the stirring apparatus started.

Readings on the potentiometer were made at intervals, until each of the thermopiles had attained a fixed temperature. This state was reached after from five to eight hours, and continued as long as the conditions were properly maintained, the indications of the thermopiles remaining satisfactorily constant for hours. The reading of all the 12 thermopiles, when some skill had been attained, required about 3 minutes.

A prism of this sort was heated many times while we were perfecting‡ our apparatus for the determination of absolute thermal conductivities, and the following is given as showing the nature of the consistent results thus obtained:

Interspace.	Distance in millimeters from the bottom of the Cold Box.	Temperature.
1	10·3	17·1°
2	21·0	32·8
3	31·9	48·3
4	42·9	62·5
5	54·0	75·8
6	64·7	89·4

* Our final standard was Tonnelot No. 11,142, upon which a very complete set of tests has been made at the International Bureau of Weights and Measures.

† Vol. xlviii, pp. 302-306.

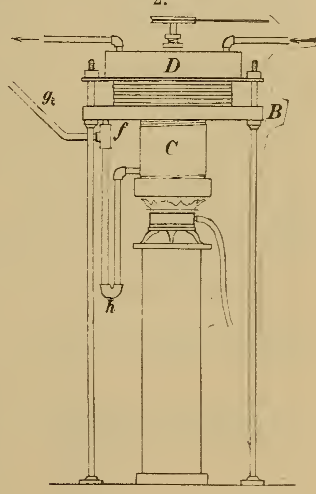
‡ We are much indebted to Mr. G. W. Thompson, the mechanician of the Jefferson Physical Laboratory, for the skillful help which he gave us in this work.

From this preliminary investigation we drew the conclusion that the conductivity of our specimen of marble was practically constant between 0° and 100°. On plotting the curve it appears that the apparently greater conductivity at higher temperature is due to a real difference of conductivity at all temperatures between the four hotter and three colder slabs, though all were cut from a single block of white Carrara marble.

Readings were occasionally taken of thermopiles in the different interspaces placed within 2^{cm} or 3^{cm} of the edges of the slabs. The agreement was so close with those taken at the middle of the slab that it was evident that the law of temperature distribution on the edges exposed to the air was such that a much smaller slab might have been used.

In order to extend the limit of our investigation to higher temperatures we were obliged to make some changes in the details of our apparatus. The use of a slab 30^{cm} square made it possible to construct a much more convenient apparatus, which is shown in fig. 2. As it was not intended to observe the absolute conductivity, the troublesome ice box was replaced by a closed iron drum, D, containing a rotary stirrer and scraper turned by a motor. A large volume of water, upwards of 20 kilograms per minute, flowed through the drum, D. Special arrangements for obtaining a large supply of water at a constant temperature were at our service in the laboratory, but a simple connection with the city supply gave us a very uniform temperature of about 20°.

2.



The hot chamber was the iron box, B, planed on its upper surface and communicating at the bottom with a retort chamber, C, in which about 20 kilograms of mercury were kept boiling. The outlet at *f* allowed the vapor to escape to the tube *g* connecting with a large wrought iron chamber, where it condensed and flowed back into the retort through the trap *h*.

It was thus found possible to maintain a temperature of about 355° C. for many hours at a time. A very elaborate system of inch-thick asbestos jackets was found necessary on the hot box and all parts of the distilling apparatus. This is not shown in the figure. The arrangement of the thermopiles was the same as in the larger apparatus. They were made, however, of much smaller wire, only 0·1^{mm} in thickness, and, owing to the difficulty of keeping our platinoid free from kinks, we made use of German silver. As soft solder melts at too low a temperature and it is not easy to use hard solder on such small wire, the junctions were made by electroplating the wires together with copper.

The calibration was accomplished by heating the junctions in a large iron, triple-walled, quadruple-jacketed stove in the near vicinity of a platinum coil, the resistance of which was used as a standard of comparison. The resistance of the platinum coil at various temperatures was determined by placing it (either directly or enclosed in a thin tube of glass or metal) in ice, steam, and the vapors of chemically pure anilin, napthalin, diphenylamine, mercury, etc. A curve thus obtained gave the relation between resistance and air thermometer temperatures. Direct measures on several thermopiles were made at the same time and in the same manner, by immersing them in the different vapors. It was necessary to reduce the current flowing through the potentiometer (2 meters in length) so that 1^{cm} corresponded to 2° C. A temperature difference of 0·1° in the junction was still easily visible.

Various heatings were made with marble cut from two of those slabs which the first experiment had shown to be of nearly equal conductivity. It was much easier with the smaller size of slabs to obtain smooth surface and uniform thickness. The following is a specimen of the results obtained :

Dist. in millimeters from Cold Face.	Temperature.
0·0	39°·5
10·9	78·5
21·8	117·4
32·7	157·1
43·6	198·9
54·5	235·6
65·4	271·8
76·3	310·7

In order to obtain the temperatures on the outsides of the extreme slabs, a layer of asbestos paper was interposed on each side between the iron plates and the marble, so that the total fall of temperature in the marble is some 60° less than the difference in temperature of the hot and cold chambers.

A curve plotted from these observations shows that the temperature gradient was practically uniform throughout the whole range.* A similar curve taken with the slabs in reversed order gave the same result. The different slabs, though cut from the same block of marble, differ slightly in conductivity,

* It will be seen that this agrees with results obtained by Dr. Robert Weber (Nature, March 7, 1895, p. 439).

but we can find no evidence of change of conductivity with the temperature.

In order to form an estimate of the difference in temperature between the adjacent faces of two slabs separated by one of the interspaces, we made a series of experiments by increasing the width of one of the spaces by various amounts. We found that this difference increased rapidly with the width of the space, being about 10° C. for a space 1^{mm} wide and nearly 30° for a space 1·65^{mm} wide. Our observations seemed to show that the temperatures on two sides of a crack 0·2^{mm} wide did not differ by so much as 2° C. and that the thermal junction gave either temperature within 1° C.

Two sets of experiments were made with the second form of apparatus upon slabs cut parallel with the cleavage from the same block of slate. Although further measurements, which we hope to make soon by other methods, are desirable, our results seem to indicate an increase of conductivity of about 30 per cent between 70° C. and 300° C. They are as follows:

Distance in millimeters from the Cold Face.	Temperature in Case I.	Temperature in Case II.
0·0	49·5	45 5
9·9	91·6	96·1
19·6	128·8	140·5
29·4	161·0	182·5
39·2	196·0	219·9
48·9	229·6	258·9
58·8	260·5	295·0
68·9	291·2	333·1

The range of temperature in the second series was increased by decreasing the thickness of the sheet of asbestos between the hottest slab and the iron plate next it.

Our acknowledgments are due to the American Academy of Arts and Sciences, who have made an appropriation from the Rumford Fund in aid of our work.

The Jefferson Physical Laboratory, Cambridge.

Art. XLVIII.—*Central Michigan and the Post-Glacial Submergence;* by E. H. Mudge.

From time to time during the past four or five years articles from the pen of Dr. J. W. Spencer, in advocacy of the theory of a great depression and submergence of the great lake region at the close of the glacial epoch, have appeared in this Journal. Dr. Spencer's conclusions are based principally upon the position and deformation of what he considers to be deserted high-level beaches in the vicinity of the great lakes. Whatever may be the value of the theory with reference to the eastern part of the lake region, I have been quite unable to harmonize it with certain phenomena in central Michigan. While I have no desire to detract from the real value of Dr. Spencer's labors, I wish to call attention to the conditions which here exist.

Across the Michigan peninsula, from the mouth of Grand river on the west to Saginaw bay on the east, there is a marked depression or valley. It is evidently the unfilled portion of a much deeper valley, eroded in pre-glacial times by Spencer's Huronian river. The conditions to be considered are found in connection with a portion of this depression, extending from the watershed in Gratiot county to the vicinity of Grand Rapids, a distance of about fifty miles. Through this entire distance, except near the watershed, the lowest part of this depression is occupied by a wide river valley, the dimensions of which are much greater, in proportion to the size of the stream occupying it, than those of any other river valley in the state. Its principal features must be noted. Its average width is perhaps two-thirds of a mile, and throughout its length, except where broken down by the entrance of tributaries, it is bordered by steep drift bluffs averaging fifty feet in height. The present flood plain is broad and flat, and a well-marked terrace is usually present above it. The conditions are such, in fact, that there can be no doubt that this valley was excavated in the drift by a stream much larger than that which now meanders through it. Whence came this greater stream?

Grand river, rising far to the south, enters the wide central valley at a point in the eastern part of Ionia county. Above this point its valley is narrow and exceedingly crooked, without terraces—features denoting comparative newness, and in striking contrast with the greater valley which it here takes possession of. As the central valley, with its characteristic features as above described, extends far to the east of this point, as well as to the west, it is clear that the Grand was not the agent of excavation.

I have heretofore* adopted the theory that this central valley owed its origin to the presence of a strong glacial stream, supplied by the wastage of the Saginaw valley glacial lobe, as laid down on Prof. Chamberlin's glacial maps. If, however, this territory was deeply submerged during the period of glacial disappearance, no such glacial stream could have existed.

Dr. Spencer hints† that the direction of the drainage of this region after its emergence was towards the east, but that it was afterward reversed by the eastward differential elevation of the country. This conclusion is based on the differential elevation of the Ridgeway beach, which he calculates at a little less than one foot per mile across the region in question. "From Grand Rapids to Pewamo," he says, "the beach passes through a strait between high lands on both sides," although it is not identified at any point between the places mentioned, an interval of fifty miles. Let us compare the elevation of this beach with other known elevations. The elevation of the D., L. & N. railway track at the Ionia station, on the valley bottom, is 658 feet. The general level of the country immediately adjoining the valley margin is 50 feet or more higher, making the elevation probably more than 710 feet. The nearest point at which the beach has been identified is at Pewamo, 12 miles to the east, where its elevation is placed at 724 feet. As the beach descends to the west at the rate of nearly one foot per mile, its elevation at Ionia must be about 10 feet lower, or 714 feet. This practically coincides with the level of the valley margin, as above calculated. Now the declivity of the central valley throughout the 50 miles is a little less than one foot per mile—almost exactly equivalent to the westward slope of the Ridgeway beach. It follows, therefore, that when the beach was formed, the river valley throughout its whole length was also level, and if it then existed it was filled just even full of water.

It may be contended that it was at this period that the valley was excavated. The drainage from the adjacent territory on either side would be sufficient to create a gentle current, and the direction of flow would necessarily be to the east, toward the open sea. However, as the eastern and western bodies of water were joined into one at the north, the current must have been extremely feeble—quite incapable of performing the work. Besides, I have found evidence which

* "Observations along the Valley of Grand River," Am. Geol., Nov., 1893; and "Drainage Systems of the Carboniferous Area of Mich.," Am. Geol., Nov., 1894.

† This Journal, March, 1891, p. 208.

seems to me to prove conclusively that the agent of excavation was a powerful westerly-flowing stream.

On section 23 of Ionia township (T. 7 N., R. 6 W.), the excavation of the valley has uncovered a ledge of Carboniferous sandstone, the only rock exposure along this line between Grand Rapids and the Saginaw valley. It is, perhaps, a portion of the cliff overlooking the ancient Huronian valley. At its eastern or up-stream edge the rock rises abruptly to the height of four or five feet above the adjacent silt bottom lands. Over a considerable area, perhaps 40 acres, the level surface of the rock is exposed, or covered with only a few inches of sand, with occasional granite bowlders up to two feet in diameter scattered about. The down-stream extension of the surface is hidden by a gradually thickening mass of sand and gravel, and it is to the form and position of this mass that I wish to call special attention. From the exposed rock surface it rises very gently to the west, or down stream, for a distance of more than a mile, terminating with a rounded front sloping down to the valley bottom. Its lateral diameter is perhaps one-half a mile. The river flows along the north side, with 40 rods of silt land intervening, while that part of the valley to the south is occupied by a long, narrow strip of swamp land, with black vegetable mould several feet in depth. This elevated tract, near its western end, attains an altitude of about 20 feet above the flats. A railroad cut ten feet in depth at this point shows it to be composed almost entirely of coarse, unstratified gravel. The surface is exceedingly stony, and many large bowlders are found along the northern margin.

The presence and position of this elevated tract within the river valley possesses great significance. It can scarcely be doubted that the river, in the process of lowering its valley, denuded the rock above mentioned, which formed an obstruction in the way of further excavation of the middle of the valley. The force of the stream being thus broken and deflected to either side, this long elevated strip was left stretching down the valley from the rock barrier, and received its evenly rounded contour from the influence of the overflowing waters. Only a large and powerful stream could have produced these conditions, and it is equally plain that this stream flowed to the west.

The problem is to harmonize these deductions with the fact of a general submergence of this region during the close of the glacial epoch. What and where was the source of supply of the powerful current that shaped and moulded the central valley? If no such submergence ever existed, the theory of a glacial origin satisfies all the conditions most perfectly. But if at the close of glacial time this surface was depressed below sea level and flooded with water, the theory must necessarily be abandoned. We can scarcely assume that such depression and submergence did not take place until some time after the disappearance of the glacial sheet, thus affording an opportunity for the valley to be formed in the manner above suggested, for all the known evidences lead to the opposite conclusion. Neither can it be held that the large stream necessary for the work was the result of a much heavier rainfall, in the period following the subsidence of the waters, than at present. Such a course would have resulted also in a corresponding enlargement of the upper Grand river, whose drainage area is much greater than that tributary to the portion of the wide central valley east of its junction with the Grand. The narrow and tortuous upper Grand valley indicates no such enlargement. On the contrary, it especially disproves it. The conditions which produced the large central stream appear to have affected none of its tributaries.

It will be readily seen, therefore, that the submergence theory, in order to fulfill all requirements, must provide an adequate source of supply for so powerful a stream as above indicated; and such source of supply must of necessity be placed either upon or to the east of the Grand-Saginaw watershed. The task is more than I have been able to accomplish.

Ionia, Mich.

Art. XLIX.—*On some Devices for the Separation of Minerals of high specific gravity;* by S. L. Penfield.

Mineralogists and petrographers are certainly greatly indebted to Dr. J. W. Retgers* for the fortunate discovery that the nitrates of silver and thallium, when mixed in the proportion $AgNO_3 : TlNO_3 = 1 : 1$, yield a double salt which fuses at about 75° C. to a clear mobile liquid, having a specific gravity of over 4·5 and capable, while melted, of being mixed with water in all proportions. The material is easily prepared by dissolving a weighed quantity of thallium in nitric acid, evaporating on the water bath until the excess of acid is expelled and then adding sufficient silver nitrate to make a double salt of the composition given above (8·33 grs. $AgNO_3$ to every 10 grs. of thallium). The salt is readily soluble in warm water and may be reclaimed by filtering the solution and evaporating it on the water bath to its maximum concentration, care being taken as far as possible to avoid dust and impurities.

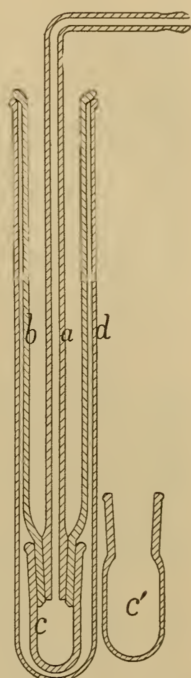
As recommended by Retgers, the operation may be performed in a test tube heated in a water bath, and after the separation is completed the fusion is allowed to cool, when the salt solidifies with the heavier mineral grains at the bottom and the lighter ones on top. On breaking the test tube and dividing the mass the separated minerals may be obtained by dissolving in water. The operation cannot well be performed in the ordinary glass stop-cock separating funnel, and there are disadvantages in using test tubes, because, if in an operation one desires for any purpose to obtain the heavy material which may have separated out, one must interrupt the whole process, while again if considerable water has been added and one is working with the liquid when the specific gravity ranges from 3 to 4 the fusion or solution does not yield, on cooling, a solid cake, but a mass of wet crystals, which it is rather unpleasant to manipulate.

A simple glass stop-cock device, by means of which successive portions of the heavy material can be drawn off from the bottom, has been described by D. A. Kreider and the author,† but a still better apparatus can now be recommended. The idea is not an original one, but was suggested by an apparatus devised by Contollence and exhibited to the author by Prof. F. Fouqué at the Collège de France, Paris. As modified for use with the Retgers double salt it is shown in section, about

* Jahrb. f. Min., 1893, i, p. 90.
† This Journal, III, xlviii, p. 143, 1894.

one-third natural size, in the accompanying figure. The glass tube *b*, about 20cm long by 2·2cm internal diameter, is narrowed below and fitted with well ground joints to the cap *c* and the hollow stopper *a*, and these parts fit loosely within a large test tube *d*. For holding and heating the apparatus the author has found it convenient to make use of a metal test-tube stand, made so as to fit inside of a tall beaker filled with hot water.

1.



When a separation is to be made it is best to previously melt the double salt in a dish or casserole on the water bath until it becomes perfectly clear and to dilute it with water until it is approximately of the specific gravity of the minerals to be separated, when, the stopper *a* being removed, the liquid is poured into the warm separating apparatus until the tube *b* is about one-half full. The mineral powder is next added, and thoroughly mixed, which may readily be accomplished by blowing a stream of air into the liquid through a small glass tube, and then successive portions of water are added until the desired separations are effected. To obtain the heavy material in *c* the stopper *a*, previously warmed, is inserted, when *c* can be removed and washed out with hot water. By replacing *c*, withdrawing *a* and adding more water another portion can be thrown down and separations made almost as quickly and easily as with the ordinary stop-cock separating funnels. When one has had a little experience in using the Retgers liquid and the apparatus, almost the only disadvantage that will be found is that specific gravities cannot be taken with the Westphal balance, while the decided increase in specific gravity over the other heavy liquids makes it exceedingly useful. When it is necessary to work with large quantities and to throw down a considerable quantity of some heavy material, it is best to have a second apparatus with a larger lower reservoir, *c′*, fig. 1, but it will be found that this is not so convenient for ordinary use as one where *c* is small.

In a separation which the author undertook of some monazite sand, it was found that the Retgers double salt was not quite heavy enough to float some zircon and chromite crystals, and an attempt was made to obtain a higher specific gravity by varying the proportion of silver and thallium nitrates. Accordingly preparations were made having the following proportions: $AgNO_3 : TlNO_3 = 3:4$, $2:4$ and $1:4$, and separations with these were made in test tubes. The 3:4 preparation fused below 100° C. and on it most of the zircon and some of the chromite floated, the specific gravity of the separated product being 4·678. The 2:4 preparation was fused in an air bath* heated to 150° C. and on it the remainder of the zircon and some chromite floated, sp. gr. 4·78. The 1:4 preparation was fused at about 200° C. and on it some chromite floated, sp. gr. 4·85. Lastly thallium nitrate was used, when the temperature of the air bath had to be about 250° C. and a final product of chromite was separated having a sp. gr. of 4·94, while only a few dark grains were left with the monazite. Thus in cases of emergency a supply of the above mentioned preparations, enough to make from 5 to 10^{cc} of fused material, may be found convenient.

An attempt was made to separate chalcopyrite, sp. gr. = 4·2, from linnæite, sp. gr. = 4·85, but it was found that the minerals were attacked by the Retgers liquid. Pyrite is also attacked, and it is evident that it is not safe to apply this method to the separation of sulphides, although it may answer in some cases.

In taking the specific gravity of separated mineral fragments the author believes that in many cases the following method will be found more convenient and simpler than the pycnometer. The fragments, boiled in water to expel air, are transferred to a tube with a loop of platinum wire fused into the glass for a handle, shown in natural size in fig. 2, and when suspended by a fine platinum wire the weight in water can be taken on a chemical balance. The powder is then transferred to a watch glass by means of a jet of water and its weight ascertained after drying, while the tube is weighed empty in water. The narrow tube is more favorable for weighing in water than a pan would be, as it offers less resistance to the swinging of the balance.

2.

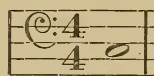
Separating apparatus according to the author's drawings have been made by the firms Alvergniat Frères, 10 Rue de la Sorbonne, Paris, and by Messrs. Eimer and Amend of New York.

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

* One described by J. H. Pratt and the author is a convenient form to use. This Journal, III, xlvii, p. 83, 1894.

ART. L.—*How to find the Key Note of Auditoriums;* by EPHRAIM CUTTER, M.D., New York.

IN a former paper the principle of air physics was laid down that oratorical phonation should be in the *key note* of the auditorium, as the oripulations (os = mouth) of speech are the same as those of song and as the basic vowel sounds are the same in speech and song. Since then an English writer has demonstrated that vowel sounds in speech are musical tones. Complying with a request from a teacher of physics, I will try to give some directions for ascertaining the key note of auditoriums.

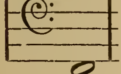
I. Sing the major scale of C  or  = 100 *m*, in a rostrum position facing the audience or empty auditorium. Use care to sing each note with the same power; that is, with a medium voice uniformly as to loudness. Then observe which note is more resonant than any other note (only if the observer sings let him or her not get excited). This note is the key note. Test by singing this note near a piano with damper raised. If the piano answers back better to this note than any other note (for the chords and over-tones will be heard) it is the key note.

Tune an instrument of the violin family so that one of the open strings will be in the supposed key note: then sing it and the instrument will respond audibly.

II. If an organ is present play the scale of C natural on the pedal diapason alone, giving each note an equal force. Observe which note is most resonant and this note will be the "key note," to be tested as above.

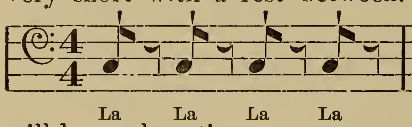
III. Or play this C major scale on an open piano and note carefully the effect. When the key note is struck there will be a liquid reedy tone imitating an organ tone. This is the key note.

IV. Another way practised by Senator W. M. Stewart and (it is said) by Cicero, is to station a man at the other end of the auditorium, who raises his hand and lowers his hand according as the voice rises and falls but keeps it stationary when the voice is best audible, and the speaker then voices his utterances in that key note. The Senator says he did this not knowing this rationale, and Cicero was probably in the same condition.

V. When on the platform, the way the writer tells if he has struck the key note is to observe the effect on his audience and himself. The most common key note of auditoriums is F . He usually begins in that key. If it is the key note, only three or four words suffice as to the audience, which shows by attitude and attention that it hears what is said. Three or four words suffice to the speaker, because he finds that he speaks with ease and feels his voice to impinge on the farthest walls. If he does not find these results his pitch is raised or lowered till he obtains them. Strange as it may seem, the effort of getting and keeping the key note takes away the stage anthrophobia so apt to attack medical men who occasionally orate and who perhaps are about the poorest educated speakers to be found.

VI. A scientific way would be to take into the auditorium a siren or, better, what might be termed Professor Papin's electrical siren. Start it at 120 vibrations per second and then add one to each tone until the octave of 240 vibrations is reached if necessary. The most resonant tone should then be distinguished and the exact number of vibrations given with less of error than with organs or pianos, whose notes may vary from the standard ; so much so that one may strike a piano or organ that has no note exactly corresponding with the key note, but a stringed instrument, where the tones are made by the fingering, can obviate this difficulty, as with a 'cello.

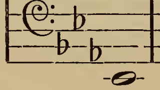
VII. Having the key note of song, to determine that of phonation, simply sing *La* or other words staccato, that is, very short with a rest between. For example, *M* 100 = ♩



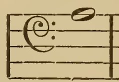
then a little faster and you will have phonation.

VIII. Having the phonation key note, to get the singing note it is only needful to prolong the basic vowel sounds somewhat as in intoning in church. Always bear in mind that the basic vowel sounds are musical tones in both song and speech. Sometime there will be rules for phonational harmony as there are now for musical harmony. Then speech may be as sweet as song.

Illustrations as to Direction I. This was sung in my parlor at Buena Vista Ridge and the key note was found to be E flat, which was sung or vocally played (i. e. sung without words as one plays on an instrument: if the human larynx is not a musical instrument to play on there is none) on before an open piano, which responded in E flat and its over-tones. "Father," said my son Edward, "I could feel the floor vibrate while we were playing Haydn's trio No. 5 for piano, 'cello and violin in E flat. Sounding



on the 'cello alone, the floor

vibrated again. Now the piano was tuned below concert pitch, hence this key note was not exactly E flat, I think it was D natural of concert pitch. But this discrepancy need cause no more confusion than the differences between mean and sidereal time. In my room at Yale, South Middle College, 1849, when I sang  the A string of my 'cello, standing in a corner, would answer back.

As to Direction II. About 1850, Mr. Simmons, an organ builder of Boston, was tuning a 16-foot pedal stop which was added after an organ was built at his factory. It was in the church auditorium. All went smoothly save the F natural pipe. Do what he could, it rounded out into a far stronger tone than any of the other pipes and made the octave uneven. He finally gave it up. Ever afterwards, as long as this organ remained there, it rendered music written in the key of F natural with a harmonic power that made the air outside and inside ring. F was the key note of the auditorium. When a window rattles while the organ plays it thereby announces the key note of the room or its chords. The key note is more resonant than its chords, as a musical ear soon detects.

As to Direction III. I heard this exampled at a faculty concert of the N. E. Conservatory, Boston, Professor Faelten, Director, playing.

As to Direction IV. It is probable that Cicero was a good student of physics.

As to Direction V. Examples: 1888, Cincinnati Music Hall, capacity 6,000. At the Section of Medicine, Am. Med. Association, audience of 200 estimated. The key note was thus found to be F natural. The speaker was heard perfectly, spoke with ease and though tired at the outset was rested at the close!

1889, Leeds, Albert Memorial Hall. Banquet of the British Medical Association, 700 plates. A bad acoustic auditorium. A very few words in the key note F, thus found, were followed by loudest applause and post prandial congratulations from several elderly gentlemen, who thanked the speaker "because we could hear what was said."

1890, Berlin International Congress, Sections met in picture galleries. Securing the key note secured close attention. Professor A. P. Clarke, M.D., Dean of the College of Physicians and Surgeons, Boston, was reading a paper at this Congress, when some one said "louder" in the key note of the gallery; he changed his voice at once to this note and read satisfactorily.

Remark. This idea thus presented grew out of the biological study of music as a property of air. The physiology of speech includes its best use.

October 1, 1895.

ART. LI.—*Stratigraphy of the Kansas Coal Measures;* by ERASMUS HAWORTH. With Plate IX.

Areal Extent.—The eastern fourth of Kansas is covered with Coal Measure rocks. A small triangular area of about thirty square miles, lying in the extreme southeastern corner of the state, is covered with the Mississippian formation. The western limit of the Coal Measures has not yet been fully determined, as the line between the Coal Measures and the Permian has not been definitely located. From paleontologic evidence, according to Prosser*, it is above the Cottonwood shales, but probably less than a hundred feet, so that the eastern limit of the Cottonwood Falls limestone is rarely more than ten to fifteen miles east of the western limit of the Coal Measures, and in many places the two are only a few rods apart. The limits of this limestone are now pretty well known, having already been published,† subject to correction, in map form. Approximately the four eastern tiers of counties lie east of this limit, which would give about nineteen thousand square miles for the Coal Measure area.

The Floor.—The Coal Measures rest directly upon the Mississippian formation, which extends at varying depths below the surface far to the westward. The recent extensive prospecting for oil and gas in the southeastern part of the state has made it possible to study the position and character of the floor to a great extent. In the extreme southeast corner of the state, in the vicinity of Galena where it covers the whole surface, the hill tops are a little over a thousand feet above the sea level. The Coal Measures approach to within four miles of the east state line opposite Galena. The Mississippian surface declines to the west, so that at Oswego, where it has been reached by at least two wells, it is about 500 feet below the surface, or about 400 feet above sea level, which is a decline of fully 475 feet from the valleys along the eastern part of the state twenty five miles away, or of about 600 feet from the hill tops, giving an average decline of about twenty feet to the mile. Wells at Stover and Mound Valley did not reach the Mississippian, but at Cherryvale, fifty miles away, it was reached 1008 feet below the surface, which places it 180 feet below sea level. As this well was made with a diamond drill and an excellent core preserved,‡ there can be no reasonable doubt

* Journal of Geology, vol. iii, p. 702.

† Haworth, Kan. Univ. Quart., vol. iii, pp. 271–309.

‡ This core has recently been lodged in the museum of the University of Kansas in a well preserved form, where it can be examined by any geologist wishing to do so.

about the correctness of these figures. This gives a westward inclination of more than twenty feet to the mile. At present we have no definite data regarding the depth to the surface to

the Mississippian west of Cherryvale. A well three miles west of Independence reached 1100 feet without striking it, one at Niotaza 1158 feet, and one at Wichita 1950 feet, so we can only say it lies below these several depths at the respective places. To the northwest it was reached at Neodesha 135 feet below sea level, at Fredonia 310 feet, and at Fall River 430 feet below sea level, giving a little less than a twenty-foot decline to the northwest. At Osage Mission, thirty nine miles from Galena, a well 700 feet deep failed to reach it. At Chanute, fifty-eight miles away, it was reached 36 feet below sea level, and at a few other points in that vicinity at similar depths. The decline from Galena to Chanute, straight northwest, is consequently about sixteen feet to the mile, considerably less than in a more westerly direction. Northward along the east line of the state it was reached at Girard 493 feet above sea level, at Fort Scott 385 feet above sea level, at Pleasanton 206 feet above sea level, at Paola* 182 feet below sea level, at Kansas City at sea level, and at Leavenworth over 300 feet below sea level. A well 1638 feet deep, or about 775 feet below sea level, at Topeka failed to reach it. The inclination from Galena to Kansas City is, therefore, only about 6·5 feet to the mile. But as the southeastern boundary of the Coal Measures is a line running northeast and southwest, the latter points should be reckoned not from Galena, but from the nearest points of surface exposure of the Mississippian. According to the geological map of Missouri published by Winslow,† the Mississippian occupies the surface at Sweet Springs and a few miles to the west, bringing it to within 50 miles or less of Kansas City. Reckoning in this way, we have a decline of the floor from near Sweet Springs to Kansas City of about 15 feet to the mile, and to Topeka about 14 feet, how much more we cannot say, which is considerably less than the decline along the southern line of the state. From the above data we can calculate the decline in any direction. From Kansas City to the southwest we find almost a level in the floor towards Chanute and Cherryvale.

From these and other similar data we may conclude that the Mississippian formation underlies all or nearly all of the Coal Measures in Kansas, and that its upper surface is strongly inclined westward, equaling 20 feet to the mile for the first fifty miles along the south line of the state, and at least 10 feet to the mile for the whole distance to Wichita, and probably more, while to the north as far as Kansas City the inclination averages only about 6·5 feet to the mile, and an intermediate value in intermediate directions. According to Winslow,‡ in a direc-

* A little doubt has been expressed regarding the correctness of this well record. The record used is preserved in the City Public Library at Paola. The criticism is to the effect that the Mississippian comes about 200 feet nearer the surface, which would correspond better with its depth at Pleasanton and Kansas City.

† Preliminary Report on Coal, 1891, and succeeding volumes.

‡ Ibid., p. 24.

tion northwest from Sedalia the Mississippian floor declines about 1600 feet in 150 miles, or a little more than 10 feet to the mile, but he gives no data regarding the inclination in other directions.

*The Cherokee Shales.**—Immediately overlying the Mississippian floor, and slightly nonconformable with it, are heavy beds of shale which here and there grade into sandstone. In thickness they vary from 350 to more than 700 feet. They are known to extend under the entire area within the state where oil and gas prospecting has been conducted, every well record yet examined showing them so prominently that no doubt can be entertained regarding their existence. At Oswego they are about 450 feet thick, at Cherryvale 415, at Neodesha 425, at Osage Mission more than 415, at Chanute 425, at Paola 750,† at Kansas City 427, at Leavenworth 540, and at Topeka not less than 700, but as the Topeka well did not reach the Mississippian we do not know how much thicker they are. The record of the Wichita well and other wells in the west have not yet been examined by the writer, but from the great and uniform thickness of the shales at the points named, varying from fifty to over a hundred miles from the nearest surface exposure of the Mississippian, it would seem they constitute an important geologic formation, having an extent oceanward from the ancient shore line as it existed during early Coal Measure time equalling that of other formations of similar thickness occurring at different places in the general geologic column. With a thickness of over 700 feet at Topeka, sixty five miles west of Kansas City, where they are only 427 feet, it appears they are thickening westward. We may reasonably suppose, therefore, that they extend at least a hundred miles beyond.

The Cherokee shales extend southward from Kansas into the Indian Territory an unknown distance, and to the northeast into Missouri and probably across into Iowa. The records of a few recently drilled wells in Missouri north of the Missouri river have been examined, each of which shows them to maintain their thickness quite well. Broadhead has published many well records and sections from Missouri, both north and south of the Missouri river, every one of which shows the existence of a heavy shale bed at the base of the Coal Measures. Similarly one generally exists at or near the base of the Coal Measures wherever they occur in America, and for that matter all over the world, and frequently constitute the whole of the lower Coal Measures, although they do not in Kansas, as will be shown later in this article.

* Haworth and Kirk, Kan. Univ. Quart., vol. ii, p. 105, Jan., 1894.
† See foot-note, p. 454.

In character the Cherokee shales vary greatly both vertically and laterally. Portions of them are bituminous, portions are argillaceous, and arenaceous. In color they are as variable as in composition. Some are almost a jet black, others a light grey, and others representing the various colors usually characteristic of Coal Measure shales. They are exceedingly rich in coal, producing at the present time more than two-thirds of the whole amount mined within the state, supporting all the mines in the vicinity of Weir City, Pittsburg, Cherokee, and to the northeast to Arcadia, as well as those about Fort Scott and at Leavenworth. The well records to the west show frequent veins of coal. At Cherryvale a twenty seven inch vein was passed about fifteen feet above the base and several lesser ones above. At Topeka eleven veins were passed, while every well record examined shows three or more.

Here and there throughout the Cherokee shales greater or lesser beds of limestone occur, usually from six to fifteen inches in thickness and of very limited lateral extent, but occasionally four or more feet, although none of them seem to have sufficient lateral extent to be of importance stratigraphically. They generally contain many invertebrate fossils, from a list of which the following are taken :*

Fusulina cylindrica in extreme upper portion ; *Ptilodyctia triangulata ; Rhombopora lepidodendroides ; Athyris lamellosa ; Athyris subtilita*, found in almost every limestone in the Coal Measures; *Chonetes mesoloba ; Discina nitida ; Productus longispinus ; Productus costatus ; Spirifera camerata ; Spirifera planoconvexus ; Spirifera lineata ; Nucula ventricosa ; Schizodus* —— ; (very large) *Bellerophon carbonaria; Macrocheilus primigenius; Nautilus planovolvis* (*?*)

The Oswego Limestone.†—Above the Cherokee shales are two limestone systems separated by from four to seven feet of an unusually black shale. Each is from five to fifteen feet thick, and they are wonderfully persistent laterally for limestones so thin. The Cherryvale well record shows that they extend that far west. To the northeast they appear on the surface in a sinuous line passing from the south side of the state to the northeast by way of Oswego, Girard and Fort Scott, near which points they cross into Missouri. Many of the different well records to the northwest show them, and quite likely they were passed in the boring at Kansas City and Topeka, although one cannot well decide regarding so thin limestones without more intervening wells. The lower lime-

* Copied from unpublished catalogue of Kansas Coal Measure fossils prepared by Rev. John Bennett, Fort Scott.

† Haworth and Kirk, Kan. Univ. Quart., vol. ii, p. 105, Jan., 1894.

stone is the "cement rock" quarried and manufactured so extensively into hydraulic cement at Fort Scott.

Both of the limestones and the associated black shales are well filled with fossils, from the list of which the following are representatives. The corals and crinoids are particularly abundant and large. *Fusulina ventricosa* (?); *Campophyllum torquium*; *Syringopora multatenuata*; *Zeacrinus mucrospinus*; *Chaetetes milleporaceus*, very plentiful; *Ptilodictia triangulata*, rare; *Rhombopora lepidodendroides*; *Chonetes mesoloba*; *Productus costatus*; *Productus nebrascensis*; *Productus punctatus*; *Retzia mormoni*; *Rhynchonella uta*; *Spirifera lineata*; *Allorisma subcuniata*; *Aviculopecten* ———, first seen in upper limestone; *Nuculana bellistriata*; *Orthis carbonaria*; *Bellerophon montfortanus*; *Naticopsis ventricosa*; *Pleurotomaria sphaerulata*; *Gonetites* ———; *Nautilus ferratus*; *Orthoceras rushensis*; *Phillipsia major*.

*The Pawnee Limestone.**—In the southern part of the state a shale bed which in places reaches a thickness of 60 feet and which carries considerable coal, lies immediately above the Oswego limestone, but it seems to thin out towards the north. Above this a limestone occurs which likewise thins towards the north, but which is very prominent on the uplands around Fort Scott and to the southwest. At one place to the west of Fort Scott it reaches a thickness of 35 feet. It extends westward to beyond Cherryvale and northward to the vicinity of Pleasanton, beyond which it seems to disappear. It affords the following fossils in considerable abundance, with many others not given: *Cyathaxonia distorta*; *Lophophyllum proliferum*; *Fistulapora nodulifera*; *Productus longispinus*; *Spirifera lineata*; *Spiriferina kentuckiensis*; *Pleurotomaria sphaerulata*.

The Pleasanton Shales.†—Above the Pawnee limestone lies a shale bed of considerable importance. In the vicinity of Pleasanton and Boicourt it is fully 200 feet thick. To the south it maintains its thickness tolerably well to beyond the south line of Kansas, but perhaps not in quite as heavy beds as around Pleasanton. Northward it decreases slightly, but regains this thickness at Paola and is 180 feet thick at Kansas City. Westward it seems to maintain its thickness quite well. At Iola, according to the record of the Iola well, it is over 250 feet thick.

In places the Pleasanton shales carry much sandstone, a noted instance of which is within ten feet of a summit at Boicourt. Here extensive quarry operations were once conducted. They carry two coal veins equalling from twenty-

* Swallow, Geology of Kansas, 1866, p. 24.

† Haworth, Kan. Univ. Quart., vol. iii, p. 274, April, 1895.

four to thirty four inches in thickness, from which all of the Linn county coal is obtained; also they frequently have sufficient calcareous material to produce thin limestone beds, that are always well filled with fossils, from which the following are representatives: *Cyathaxonia distorta; Athyris trinuclia*, very rare; *Chonetes mesoloba*, last seen here; *Discina nitida*, becoming rare; *Rhynchonella uta.*

*The Erie Limestone.**—Above the Pleasanton shales a group of three principal limestone systems are met with which in places are so close together that they can well be described as one, but which to the south diverge vertically so much that near the south side of the state their lines of outcropping are ten to twenty miles apart. From the vicinity of Union Town west of Fort Scott northward to Kansas City they are rarely more than ten to twenty feet apart vertically and often much less. Southward, where they diverge so greatly, local names have been used for each member; their use is purely local and geographic. The upper one of the three is considerably the more important. It thickens rapidly westward from the vicinity of Cherryvale, where it caps the hill tops to Independence, where it is from thirty to forty feet thick. In places it has been extensively quarried and is quite well known as the Independence limestone. The lowermost member of the three seems to be the same as the Bethany Falls limestone of Broadhead,† number 78 in his section.

These limestones have a great lateral extent, reaching from the south line of the state to Kansas City, from which point, according to Broadhead,‡ they extend northward to the Iowa line, and according to Keyes,§ from there almost entirely across the state of Iowa, making them an unusually extensive limestone formation. Westward they reach as far as the deep borings made in Kansas. They abound in fossils, from the list of which the following species are selected: *Fusulina cylindrica; Axophyllum rudis; Campophyllum torquium; Archiocidaris mucronatus; Archiocidaris triserrata; Erisocrinus typus; Eupachycrinus tuberculatus; Scaphocrinus hemisphericus; Zeacrinus acanthophorus; Serpula incita; Spirorbis carbonaria; Fennestella* ——; *Polypora submarginata; Synocladia biserialis; Chonetes granulifera; Chonetes smithi; Chonetes millepunctatus; Orthis pecosi; Orthis robusta; Orbiculoida* ——; *Productus americana; Productus pertenuis; Productus symmetricus; Syntrilasma hemiplicata; Terebratula bovidens; Allorisma gra-*

* Haworth and Kirk, Kan. Univ. Quart., vol. ii, p. 188, Jan., 1894
† Broadhead, Mo. Geol. Rep., 1872, part ii, p. 97.
‡ Loc. cit.
§ Keyes, this Journal, vol. l, p. 243, 1895.

nosa; Allorisma reflexa; Allorisma subcuneata; Aviculopecten carboniferus; Aviculopecten interliniatus; Aviculopecten providencensis; Aviculopecten americana; Chaenomya leavenworthensis; Conocardium obliquam, very rare; *Edmondia aspinwallensis; Edmondia ovata; Edmondia reflexa; Macrodon carbonarius; Monopteria gibbossa; Myalina subquadrata; Myalina swallowi; Nucula parva; Pinna paracuta; Pleurophorus oblongus; Schizodus wheeleri; Solenopsis solenoides; Bellerophon crassus; Loxonema rugosum; Naticopsis gigantia; Platyceras nebrascense; Pleurotomaria broadheadi; Pleurotomaria speciosa; Pleurotomaria turbiniformis; Peupa vitusta; Conularia crustula; Goneatites lyoni; Nautilus occidentalis; Nautilus ponderosus;* etc.

*The Thayer Shales.**—Above the Erie limestone in the southern part of the state heavy shales occur which in Neosho, Wilson, and Montgomery counties reach a maximum thickness of over 200 feet, but which grow thinner northward until they become less than 30 feet in thickness. They are prominent from Chanute to the southwest and constitute the main mass of the bluffs along the Verdigris and Fall rivers from Benedict and Fredonia southward to beyond Independence. They have been passed through by every prospect well in this part of the state west of their outcropping, so that we know they extend many miles westward under the superimposed strata. They frequently grade into sandstone, so much so that many workable quarries of that rock are found here and there over the country. Ripple marks and other indications of shore deposits are frequently found in the sandstone and arenaceous shales. They also carry two or more seams of coal, which are of considerable economic importance.

The Iola Limestone.†—Above the Thayer shales is the Iola limestone system, the heaviest individual system in the whole Coal Measures of the state. Its outcropping is usually marked by a prominent escarpment, especially in the south, where the Thayer shales are so heavy. West of Elk City it is nearly 100 feet thick, at Iola it is 40, to the northeast it grows thinner so that in places it is perhaps not over 20 feet thick, but in the vicinity of Olathe, particularly a few miles west, it is fully 50 feet thick, while at Kansas City, where it constitutes the heaviest limestone in the bluff, it is about 30 feet thick. The borings at Lawrence and Topeka show that it is to be found in both of those localities with essentially undi-

* These shales were called the Chanute shales by Haworth and Kirk. Kansas Univ. Quart., vol. ii, p. 109, Jan., 1894, but were changed to Thayer shales, Kan. Univ. Quart., vol, iii, p. 276, April, 1895.

† Haworth and Kirk, Kan. Univ. Quart., vol. ii, p. 109, Jan., 1894.

minished thickness, so that it seems probable that it reaches many miles farther west. In places it is very fossiliferous, producing the following species with many others: *Michelinia eugeneœ; Athyris subtilita; Lingula scotica; Productus longispinus; Productus pertenuis; Spirifera camerata; Spirifera lineatus; Aviculopecten carboniferus; Pinna subspatulata; Nautilus occidentalis; Nautilus missouriensis.*

*The Lane Shales.**—Passing upwards from the Iola limestone, and leaving unnoticed in this article a shale bed from 40 to 50 feet thick and a limestone one one-fourth as great, we come to the Lane shales, which in many places reach 150 feet in thickness. They are very prominent all along the Pottawatomie river from its source to Osawatomie, and are known to extend far to the southwest. To the northeast, however, they thin greatly so that at Kansas City they are relatively unimportant, allowing the succeeding limestone to come close down to the Iola. They carry considerable sandstone, which frequently shows many ripple marks, and they show the usual gradations back and forth from shale to sandstone and sandstone to shale.

The Garnet Limestone.†—Immediately above the Lane shales are two limestones separated by from ten to fifteen feet of shales. They appear in the bluffs at Argentine and form the upper limestone westward to Eudora and have been passed by borings at Lawrence and Topeka. They cover the surface over a wide area along the Pottawatomie river and northward to Eudora and Argentine, and extend southwest across the Neosho river and probably to beyond the limits of Kansas. In places they thicken greatly. At the Lane "marble" quarries the upper one has reached the thickness of 30 or 40 feet, as it has also done about three miles east of Greeley. The most common invertebrate fossils found in them are the following: *Campophyllum (?); Fenestella (?); Synocladia biserialis; Derbya (?); Productus americanus; Productus semireticulatus; Syntrialasma hemiplicata*, very abundant in places; *Myalina kansensis; Myalina recurvirostris; Euomphalus subrugosus; Naticopsis altonensis; Pleurotomaria tabulata, Nautilus occidentalis*, and about forty other species.

The Lawrence Shales.‡—These shales in the vicinity of Lawrence are near 300 feet thick if we let the name cover all lying between the Garnet limestone and the Oread limestone above. Occasionally a thin limestone occurs within them, one of which sometimes reaches 6 or more feet in thickness, but none of which have sufficient lateral extent

* Haworth, Kan. Univ. Quart., vol. iii, p. 287, April, 1895.
† Haworth and Kirk, Kan. Univ. Quart., vol. ii, p. 110, Jan., 1894.
‡ Haworth, Kan. Univ. Quart., vol. ii, p. 122, Jan., 1894.

to be of much consequence in stratigraphy. Southward from Lawrence they become thinner, so that along the Neosho river and to the south they gradually lose their great importance. Northward they maintain their thickness much better.

They vary greatly in character in different places. They carry a prominent coal seam, which is mined extensively in Franklin county and to a lesser extent elsewhere, especially in Douglas county and recently near Atchison. They carry a great deal of sandstone, but none of which is of a proper quality to be of much value economically. They are also particularly interesting on account of the large amount of arenaceous shales they have, almost all of which are filled with ripple marks and other indications of shore deposits. In fact from top to bottom they have such markings the most abundantly of any shales thus far passed. They also furnish excellently well preserved specimens of fossil coal plants.

*The Oread Limestone.**—Above the Lawrence shales two limestones are found averaging about 15 feet deep and separated by about 20 feet of shale. They outcrop along the tops of the bluffs reaching from Leavenworth to considerably south of Garnett and take their name from Mount Oread at Lawrence. Westward they extend as far as any drill record has been obtainable. The upper one constitutes the main limestone in the bluff at Lecompton, and at Atchison. Each of the limestones is well filled with fossils, but particularly the upper one, from which forty-nine species were gathered in a few hours time at Lecompton. The following is a partial list: *Fusulina cylindrica; Cyathaxonia distorta; Archiocidaris* —— (?); *Scaphicrionus* —— (?); *Chonetes granulifera; Derbya bennetti; Derbya broadheadi; Meekella striatacostata; Orthis robusta; Productus semireticulatus; Retzia mormoni*, large variety; *Syntrialasma hemiplicata; Allorisma regularis; Astartella* —— (?); *Avicula longa; Edmondia nebrascensis; Entolium avicula; Monoteria marian; Pleurotomaria bonharborensis; Nautilus sangamonensis; Paleocaris tipus.*

Osage City and Burlingame Shales.†—Above the Oread limestones different shales and limestones occur, none of which are of special interest in this connection until about four hundred feet has been passed. Here, near Topeka, a deposit of coal has been found that has been mined considerably. From the record of the Topeka deep well we know that this coal is more than 2,000 feet above the base of the Coal Measures. Above this one hundred feet and west of Topeka seven mines is another coal mining locality. Investigation shows that this

* Haworth, Kan. Univ. Quart., vol. ii, p. 123, Jan., 1894.
† Ibid., vol. iii, p. 278, April, 1895.

coal is in the same geologic horizon with that mined at Burlingame, Scranton, Osage City and numerous other places to the southwest, all of which may well be grouped under the name Osage coal, as the larger proportion of the mines are in Osage county. There are two heavy shale beds here, the one carrying the coal and the other lying above it constituting the main mass of the hills around Burlingame. As the two are separated by a limestone of considerable lateral extent, they have been named separately the Osage City shales and the Burlingame shales. Both shales carry considerable sandstone and present the customary gradation from shale to sandstone and the reverse. They also have many evidences of being shallow deposits, particularly the Burlingame shales, from which so many instances are known of the reptilian tracks in the shaly sandstone. Years ago Prof. Mudge shipped two or more car loads of the stone, principally to Yale University, from which Marsh* has identified the tracks as being produced by *Nanopus candatus*, and other reptiles.

The Waubaunsee Formation.† — Above the Osage City shales we have a continuous succession of limestones and shales to the base of the Permian. Prosser has proposed that the whole group be called the Waubaunsee formation and would include within it the Burlingame shales above mentioned. For the purpose of this article no details need be given. Prosser‡ has already published an interesting description of them, and the writer has contributed an article on the same subject.§ The whole formation is similar in general character to those below, only that there is a gradual transition in physical properties of both the shales and the limestones. The shale beds become thinner and assume their peculiar lighter hue, which must be observed in connection with the shales below in order to be fully understood. Here and there throughout the whole of the Coal Measure beds of shale fully as light as those of the Wabaunsee formation occur, but they are interspersed with black bituminous shales, while the latter kind are rare above. The limestone also takes on a corresponding change. The beds are thinner than below, so that the alternations of limestone and shale are more frequent, but the proportion of limestone is growing less. A peculiar light buff color creeps in, so that the novice could readily distinguish between a Waubaunsee limestone and one from below.

On the accompanying map of Eastern Kansas the surface and outcropping of the more important limestone systems is

* Marsh, this Journal, vol. xlviii, pp. 81–84, and Pls. II and III, 1894. See also Mudge, this Journal, vol. vi, 1873.

† Prosser, Journ. of Geol., vol. iii, p. 688, Oct., 1895.

‡ Ibid, pp. 682–705.

§ Haworth, Kan. Univ. Quart., vol. iii, pp. 271–290.

shown, and the two vertical sections, the one the well at Topeka and the other a generalized section, will show the relative vertical positions of the different formations.

*Division of the Coal Measures.**—The ordinary custom of dividing the Coal Measures into two or three divisions is so well known that it need not be described here. In the different parts of the Mississippi Valley where such divisions have been applied there seems to have been no special reason for placing the lines of demarcation just where they were located rather than either above or below. In Missouri Broadhead† in each case used a sandstone formation which is by no means as extensive laterally as different limestones are. In Iowa Keyes‡ has laid aside the older terms "Lower" and "Upper" and has substituted the geographic names "Des Moines" and "Missouri" for what seems to be practically the same general divisions. In Kansas it has already been suggested§ to use one division plane located at the upper surface of the Pleasanton shale or the base of the Erie limestone and to employ the older terms upper and lower as adjectives placed before the name Coal Measures. These terms have the advantage of priority in American geologic literature, and should be laid aside only when more convenient and expressive ones are offered as substitutes. The location chosen for the division plane is the most strongly marked physically of any plane within the whole Coal Measures of the state. At Kansas City it leaves nearly eight hundred feet of lower Coal Measures, while this thickness is maintained or slightly increased southward. At Kansas City the division is at the base of the Bethany Falls limestone, which correspond with the division plane already chosen in Iowa to separate the Des Moines and Missouri formations.‖ In Kansas the division plane does not lie at the top of the Cherokee shales. The Oswego limestone and the Pawnee limestone both fall within the lower Coal Measures. It is probable these limestones do not extend into Iowa, but their existence in Kansas is incident to the general thickening of the different formations southward. By this mode of division the heavy coal beds in the vicinity of Pleasanton and Boicourt, second in importance only to the Weir City-Pittsburg coal, are left in the lower Coal Measures, while the coals in the Thayer shales, the Lawrence shales, and the Osage City shales are in the upper Coal Measure. As mining is now conducted, about three-fourths of the total coal output of the state comes from the lower Coal Measures.

* Haworth, Kan. Univ. Quart., vol. iii, p. 291, April, 1895.
† Broadhead, Mo. Geol. Rept., 1872, part ii.
‡ Keyes, Iowa Geol. Surv., vol. i.
§ Haworth, loc cit.
‖ Keyes, this Journal, vol. l, p. 243, Sept., 1895.

Ratio of Limestone to Shales.—In the whole of the Coal Measures up to and including the Cottonwood Falls limestone, there is about 544 feet of limestone, or a ratio of limestone to the total thickness of 1 : 5. In the lower Coal Measures there is only about 81 feet of limestone, or a ratio of 1 : 10, while in the upper Coal Measures there is about 460 feet of limestone, giving a ratio of 1 : 4·2.

Conclusion.—A number of interesting points of a general character may be noted, some of which are brought out in the above brief descriptions, while others are well founded on data now being gathered together for publication in greater detail than is possible in an article of this character.*

First. It may safely be said that the Coal Measure strata are in a general way conformable with the upper surface of the Mississippian floor. The almost uniform thickness of the Cherokee shales over such wide areas and the regularity of the succeeding formations indicate this. Nowhere is so great a difference known between the direction of the bedding planes of the Cherokee shales or the Oswego limestone and the floor surface as is to be found in connection with either the Thayer shales or the Lawrence shales, each of which is a wedge-shaped body. The dip of the succeeding strata in general is of the same kind. The Oswego limestone, from Oswego to Independence, a distance of thirty-two miles, dips fully 625 feet, or nearly twenty feet to the mile. The Iola limestone in the southern part of the state dips nearly as much, while from Kansas City to Lawrence and Topeka it dips a little over 10 feet to the mile.

The nonconformity between the Coal Measures and the Mississippian floor is therefore local in character and principally due to surface erosion rather than being widespread and general. Nonconformity has already been pointed out in Kansas, Missouri, and Iowa, but in every instance known to the writer the illustrations have covered but narrow distances, such as those mentioned in Cherokee county, Kansas, St. Louis and Keokuk. Few fields afford such excellent opportunity for studying this phase of stratigraphy as Kansas now does with her scores of deep wells almost all over all the Coal Measure area.

Second. It would seem there can be little question but that the different formations lie one above the other in regular order, similar to the order usually found to obtain in other parts of the geologic column and in other parts of the world. It is exceedingly probable that all of the Cherokee shales were formed before any part of the Oswego limestones, and that

* Vol. i of the University Geological Survey of Kansas.

this in turn is older than any of the shale beds above, a condition which obtains throughout the whole of the Coal Measures, each particular limestone or shale system being older than any and all of the rocks placed above it in our general section (Plate IX) and younger than those placed below.* Every broad fact in the stratigraphy observed during three summers of extended field work by the writer and his assistants imply this. The paleontologic evidence also favors this view. A review of the fauna given shows that there has been a gradual progression from older to more recent forms continuously from the Cherokee shales upwards.

Third. The general character of the shales throughout the whole of the Coal Measures is such that they must have been deposited, in the main, in shallow water, probably ocean water. The great frequency of ripple marks and other physical properties indicate this. The Burlingame shales with their reptilian tracks are at least one hundred and twenty-five miles northwest of the Cherokee shales and geologically about 2200 feet above the base of the Coal Measures. The coastal area must therefore have progressed westward as geologic time advanced.

Fourth. The thickness of the Kansas Coal Measures cannot be much if any less than 2500 feet. In the general section herewith presented (Plate IX) it amounts to 2750 feet, but in it the average thickness of each formation is given as it is known. As some of them, particularly the Thayer, the Lane, and the Lawrence shales, are known to have different thicknesses in different parts of the state, it is presumable that no one point could be found with all the systems as thick as given in the general section. However, at Cherryvale the known thickness from the top of the hills is a little over 1100 feet, while

* This statement may seem unnecessary, but those who have carefully followed the writings of Winslow and Keyes on the Coal Measures of Missouri and Iowa will recall that different views have been expressed. See Winslow, Bulletin Am. Geol. Soc., vol. iii, p. 109, and Mo. Geol. Surv. Preliminary Report on Coal, pp. 19–32, Keyes, Ia. Geol. Sur., vol. i, 1892, pp. 84–85: "At the same time it must be remembered that this does not necessarily imply that the 'lower' measures are to be considered much older than the 'upper,' but rather that along the great and successive planes of sedimentation different beds of the upper and lower divisions were laid down contemporaneously;" and vol. ii, p. 160: "Heretofore the general impression has been that the 'Lower' Coal Measures of the state were deposited prior to the laying down of the rocks of the Upper Division. Recent investigation seems to show that the two were formed contemporaneously;" p. 161, "The 'Lower' Coal Measures are not then a series of beds laid down previous to the deposition of the 'Upper' Coal Measures. Each particular part of the former was deposited at the same time as portions of the latter farther seaward. . . As a whole, the 'Lower' Coal Measures do actually lie beneath the 'Upper' Coal Measures; but the line of separation is not a line drawn parallel, but obliquely to the planes of sedimentation." See also figs. 9 and 10, p. 162; Mo. Geol. Surv., vol. iv, p. 80–81; and this Journal, vol. l, pp. 241–242.

the general section gives it but 950 ; at Kansas City the known thickness from the hill tops is 1000 feet, and that given in the general section is but a little over 1100. At Fall River the known thickness from the valley is 1405 feet, and that given in the section but 1300. At Topeka a hundred and ten miles from the southeast limit the known thickness below the hill tops is 1750 feet with the deep well not having reached the base of the Coal Measures. In the general section the thickness here is 2050 feet. The writer has no doubt but that could a well be drilled in from the top of Buffalo Mound near the Kansas River or from the top of the Flint Hills in the southern part of the state, it would be found that the total thickness of the Coal Measures from the top of the Cottonwood formation would exceed 2500 feet.*

University of Kansas, Lawrence, October 30, 1895.

*See Keyes on thickness of Kansas Coal Measures, this Journal, vol. 1, p. 241, September, 1895.

ART. LII.—*Igneous Rocks of Yogo Peak, Montana;** by W. H. WEED and L. V. PIRSSON.

THE two great geographic provinces of Montana, the Plains and the Cordilleran region, which form the eastern and western parts of the State respectively, are quite as sharply delimited as is usually the case along the Rocky Mountain front. In the central part of the State, however, the broad level expanse to which the Cretaceous rocks have been reduced is broken by several mountainous tracts, rising abruptly above the plains and suggesting the Indian designation of "Island Mountains." To the westward the continuous but irregular front of the Rocky Mountain Cordillera stretches in a sinuous, indented line, in a generally northwest and southeast direction.

In the northern part of the State the Rocky Mountains present an abrupt chain of rugged, serrated peaks, which are visible for a hundred miles eastward. To the southward, where the Missouri emerges from the mountains and enters the open plains, the main chain or continental watershed is flanked by the low and broad mountainous area of the Belt ranges, and still farther south, where the waters of the Yellowstone Lake feed the mountain drainage, the front of the Cordillera is composed of several lesser and detached mountain systems.

The Belt Mountains, although a part of the Rocky Mountain Cordillera, constitute an area between the western limits of the Plains and the mountain valley of the Missouri river. This broad and relatively low mountain district is separated by the wide, intermontane valley of Smith river, a tributary of the Missouri, into two ranges, known as the Big Belt and the Little Belt mountains. Yogo Peak, whose rocks form the subject of the present paper, is a conspicuous summit of the Little Belt Mountains, the easternmost of these two ranges.

The Little Belt Mountains thus form a distinct geographic unit in the topography of the State. They are flanked by the valley of the Musselshell river on the south, and extend, from the Judith Gap on the east, westward to their union with the Big Belt Range in the canyon of the Missouri river. They are embraced between the meridians of 109° 45′ and 112° west longitude, and the parallels 45° 30′ and 47° 15′ of latitude.

The Belt ranges together constitute a broad anticlinal uplift formed by the union of the lesser anticlinal axes of the two ranges. The Little Belt uplift has a southeast and northwest trend and dies out in the eastern point of the range at Judith Gap. In the central portion of the mountains the anticlinal uplift is

* By permission of the Director of the U. S. Geological Survey.

broken by profound faults, while the outer flanks of the range show many subsidiary folds further modified by laccolitic and other forms of igneous intrusions. Metamorphic rocks, which belong to the Archean complex of the region, are exposed in the central portion of the range and are covered by a series of sediments known as the Belt Mountain formation, belonging to the Algonquin (or possibly lower Cambrian) age. The overlying Paleozoic series is well developed, characterized by abundant fossil faunas, and includes all the subdivisions thus far recognized in the northern Rocky Mountains. The Mesozoic does not occur within the mountain region, but is everywhere upturned upon the flanks of the range.

The topography of the area is a consequence of its geologic structure. The heavily-bedded Paleozoic limestones, which are nearly horizontal in the central portions of the mountains, form broad and level, pine-clad plateaus whose average elevation is 8,000 feet above the sea and 4,000 feet above the adjacent plains. These plateaus are trenched by the streams whose valleys vary in character with the nature of the rocks, being especially bold and rugged where cut through the massive, heavily-bedded Carboniferous limestones. This is especially noticeable along the course of Belt Creek and in the canyons of the Judith river, the two principal streams which drain the mountains. The former exposes excellent sections along its course, the stream cutting through the Archean area, flowing in a high-walled canyon across the Cambrian rocks and emerging from the mountains through Sluice Box Canyon, a narrow gorge cut in the heavy Carboniferous beds. A branch of the Great Northern railroad, built along the course of the stream, runs to Neihart, a well-known mining town situated near the head of Belt Creek.

While the range as a whole consists of uplifted sedimentary strata, this structure is greatly modified by igneous intrusions in the northern part of the mountains. Several large typical laccolites, only partly stripped of their sedimentary cover, form the dominant peaks of this part of the range, and two centers of igneous intrusion have been found where massive, granular, igneous rocks occur. One of these is found at Barker, a town at the head of the dry fork of Belt Creek; the other at Yogo Peak, the most striking and nearly the highest peak of the mountains.

Yogo Peak.—Yogo Peak is from many points of view the most conspicuous elevation of the Little Belt range. Although not snow-capped, it projects above the timber line, and its sombre crown of crags, formed of massive igneous rock, is in sharp contrast to the rounded summits and level plateaus adjacent. It is situated 8 miles east of Neihart and on the high divide between the waters of Belt Creek and the Judith river, and reaches an elevation of 9,000 feet above tide. The ridge above which the summit stands has an open and park-like character. The adjacent streams have cut deeply through the horizontal sedimentary rocks, and the broad valley bottom of Dry Wolf Creek on the north and the placer bars of Yogo on the south are 3,000 feet below the crags of the mountain summit. The region about Yogo Peak is formed of Paleozoic rocks in which there are numerous intrusive sheets and occasional dikes of igneous rocks. The mountain mass itself is due to the resistant nature of the massive igneous rock, which forms a stock breaking up through the horizontal sedimentary rocks. The flanks of the mountain show these bedded rocks well exposed and forming benches which mark the more resistant beds. The stock itself is a huge chimney of massive rock that has produced considerable contact metamorphism near its junction with the sedimentary rocks. On the southwest side of the peak an uplifted block of the limestones has been broken off, tilted and injected with a number of intrusive sheets thrust in from the adjacent volcanic neck. The northern slopes are obscured by debris and talus slides which hide the exact contact between the stock and the sedimentary rocks, but on the south face of the mountain a branch of Yogo Creek has cut an amphitheatre, whose massive walls of naked rock rise hundreds of feet above the basin whose deep blue lakelets and perennial snow banks form a pleasing feature of the mountain scenery. The marbleized and altered limestones are here seen in actual contact with the massive rock. In general, the alteration of the sedimentaries adjacent to the stock rock has been accompanied by mineralization, producing ore deposits that have been prospected at a great number of points, although they have thus far proved of too little value to warrant working. The summit of the peak is composed of three knobs or hills, separated by small saddles and grassy Alpine meadows. These summits lie in a nearly east and west line, the two outer knobs being a mile and a half apart. They are covered with projecting crags or piles of debris, with the rock in place below them. To the east the peak ends in a shoulder covered by a heavy mantle of platy slide rock, which extends down to a low saddle separating it from the low mountain ridge which extends eastward to Woodhurst Mountain. The mountain summit shows no evidence of glacial action, and a small moraine in the amphitheatre is the only record of former glaciation. The Yogo Peak core is thus a huge chimney of massive granular rock, having a length of two miles in an east and west direction, and a width of one mile. The study of the region shows that this stock occupies the southwestern and expanded end of a great fracture which has ruptured the sedimentary series, and extends for 10 miles to the northeast in a somewhat irregular line. This fracture is marked by a series of upbreaks of igneous magmas of various types which form intrusions of varying width, accompanied by laccolitic masses, intruded sheets and numerous dikes. The type of rock immediately adjacent to the Yogo Peak mass is a quartz syenite-porphyry, forming the low saddle northeast of the peak and which is succeeded eastward by a repetition of Yogo Peak rock types. Although this rock comes in actual contact with that of Yogo Peak, the line is hidden by debris and its character cannot be determined.

The rock types whose varying phases are discussed in the present article are from the Yogo Peak mass itself, and as the stock shows a constant variation and gradation in its chemical and mineralogical composition along its east and west axis, three types have been selected to show the variation, the specimens coming from the east, middle and western points of the summit of the peak. For purposes of convenience, these will be designated as types from the east, middle, and west knobs respectively.

Petrography of the Yogo Peak Rocks.

Syenite. East knob rock type.—The rock mass composing the high eastern shoulder of Yogo Peak possesses a platy parting which causes it to split readily and to form piles of debris and talus slopes, above which project the low and much-jointed exposures of the rock in place. The joint blocks are short, stout rhomboids, or heavy plates a foot or so long. They are very hard and tough, ring sonorously under the hammer, and are broken with difficulty, the rock being unaltered and fresh. These characters prevail for the entire Yogo Peak mass.

On a freshly fractured surface the rock appears evenly granular, of moderately fine grain, and is compact in character and with few miarolitic cavities. The color is a medium gray with a strong pinkish tone. The rock is clearly a feldspathic one, and of syenitic aspect. Examined with the lens, it is seen to be chiefly composed of light-colored feldspar, dotted with small, dark, formless spots of green pyroxene or hornblende

The microscope shows the following minerals to be present: apatite, titanite and iron ore, pyroxene, hornblende and biotite, orthoclase, oligoclase and quartz. The apatite and titanite are of the usual characters common to such rocks. The iron ore is not abundant and occurs in small grains of about 1^{mm} in diameter. The pyroxene is a very pale green diopside and is much cracked and broken up. It frequently appears like a bundle of rods. It is rarely alone and generally occurs in common with a brownish-green hornblende. The two minerals are very frequently found together in stout, ill-shaped crystals from 1 to 2^{mm} long, the pyroxene forming a core, surrounded by the hornblende. In such cases the amount of pyroxene is inversely proportional to that of the hornblende. The appearance and association of these two minerals clearly show that the hornblende is paramorphic after the pyroxene. The latter rarely occurs alone, while the hornblende frequently does so. Biotite is rare and occurs only as occasional brown pleochroic shreds.

Orthoclase is the predominant feldspar, occurring in irregular masses. A much smaller quantity of plagioclase is also present, the optical characters proving it to be oligoclase. It is more idiomorphic than orthoclase and is, indeed, often surrounded by a mantle of the latter mineral. A small amount of interstitial quartz completes the list of minerals.

In structure the rock is hypidiomorphic, but only partly so, as the pyroxene and hornblende are themselves rather ill-formed and irregular, and the tendency is toward an allotriomorphic structure. The average size of grain is about 1^{mm}.

The following analysis shows the chemical composition of this rock. It has been made by Dr. W. F. Hillebrand of the U. S. Geological Survey, a chemist whose skill and painstaking accuracy have been of such vast service to American petrography.

Syenite from Yogo Peak.

SiO_2	61·65
TiO_2	·56
Al_2O_3	15·07
Cr_2O_3	trace
Fe_2O_3	2·03
FeO	2·25
MnO	·09
MgO	3·67
CaO	4·61
BaO	·27
SrO	·10
Na_2O	4·35
K_2O	4·50
Li_2O	trace
H_2O at 110°	·26
H_2O above 110°	·41
P_2O_5	·33
	100·15

The above analysis is that of a syenite with moderately high lime, iron and magnesia for a rock of the syenite group. The comparatively large amount of soda present cannot be entirely in the oligoclase, and the unstriated feldspar undoubtedly contains the albite molecule to some extent. The barium and strontium are possibly present in the feldspar. The mineral and chemical nature of the rock show it to have a somewhat dioritic tendency.

Yogoite. Middle knob rock type.—West of the eastern knob of Yogo Peak the rock forming the summit of the mountain gradually changes in character until it assumes the type which characterizes the middle knob and which is so well displayed in the crags which form this point. The rock has a parting similar to that of the syenite described above, and is like it in its general characters. On a freshly fractured surface the rock is, however, seen to be of a very much darker gray in color, with a greenish tone, and to be more coarsely crystallized, so that it possesses a mottled appearance, recalling a diorite in its habit. Even at a casual glance the rock is seen to be more basic than the syenite, and the ferro-magnesian minerals appear to make up half the bulk of the rock. The reflection of light from numerous cleavage plates of small biotite crystals is also noticeable.

Microscopically, the minerals are seen to be the same as those in the syenite, but with the following differences: The augite, which was a nearly colorless diopside, is here a clear, light green mineral, quite idiomorphic, and having the usual cleavage and appearance, and containing frequent shreds of biotite and granules of iron ore as inclusions. It is very abundant in rather small, stout crystals, and constitutes, in fact, the main ferro-magnesian component. Paramorphs of augite and hornblende are still seen, but they are rare, and the hornblende has dwindled to a very small amount. Iron ore is more abundant than in the syenite and the grains are larger. Biotite is quite abundant in strongly pleochroic tablets of the usual type. The ratio of the plagioclase to the orthoclase is nearly the same as in the syenite. It is, however, somewhat more basic, approaching andesine. The orthoclase is like that of the syenite, but shows a more marked preference to surround the plagioclase and to appear in broader plates. Quartz is wholly wanting. The two predominating minerals are augite and orthoclase, and the great increase of the former over the latter, as compared with the ratio prevailing in the syenite, is disclosed in the chemical composition, as shown in the following analysis by Dr. Hillebrand:

Analysis of Yogoite.

SiO_2	54·42
TiO_2	·80
Al_2O_3	14·28
Cr_2O_3	trace
Fe_2O_3	3·32
FeO	4·13
MnO	·10
MgO	6·12
CaO	7·72
BaO	·32
SrO	·13
Na_2O	3·44
K_2O	4·22
Li_2O	trace
H_2O at 110°	·22
H_2O above 110°	·38
P_2O_5	·59
	100·19

The features of this analysis are the moderate silica and alumina percentages, with the high amount of iron, lime, magnesia and alkalies. Although the minerals (if not quantitatively expressed) are those of the syenite, its chemical composition removes it very far from any typical syenite. The chemical characteristics are, indeed, those of the lamprophyre group, yet it is a fairly coarse-grained, evenly granular rock, forming a transition phase in the center of a great stock. It is to this type that we have given the name of "*Yogoite*," and the reasons for so doing and its systematic position will be discussed later.

Shonkinite. West knob rock type.—The character of the outcrops occurring on the western end of the peak differs somewhat from those which have been previously described. The rock does not possess the thick, platy parting that prevails to the east, but has an exceedingly massive character, giving rise to bold, heavy crags and castle-like forms, often of curious shapes, which rise abruptly from the small grassy plots lying between them. The rock is exceedingly tough and breaks under the hammer with great difficulty. It has changed gradually in character until here it is as much darker than the Yogoite of the middle knob as the latter is with relation to the syenite. On a fresh fracture the rock is of a very dark stone color, and at first glance recalls many coarse, dark gabbros. On inspection it appears that the quantity of ferro-magnesian minerals is very large, and the eye is caught by the reflection of numerous plates of a dark brownish biotite, which average several millimeters in diameter. With the lens a great abundance of small augites are also seen in the feldspathic constituent.

Under the microscope the same minerals are present as in those of the two types just noted, but the augite, biotite, and iron ore have greatly increased in amount. The increasing tendency of the orthoclase to surround the plagioclase has here resulted in producing broad plates in which small, stout plagioclase laths lie scattered about unoriented. The plagioclase has become more basic and is now andesine. Its amount, compared with that of the orthoclase, has gradually diminished from the syenite down. The broad areas of orthoclase not only contain the plagioclase, but also the other constituents, in a poikilitic manner. Pseudomorphs after olivine are sometimes seen, with an occasional unaltered remnant of olivine substance still remaining. The augite is darker than in the preceding types, and occasional paramorphoses to hornblende still occur. The biotite is fresh, clear, and strongly pleochroic, at times changing to a clear, dark green variety. Apatite is more abundant and is in larger crystals. The structure is a hypidiomorphic, granitoid one. The analysis by Dr. Hillebrand is as follows:

	Shonkinite of Yogo Peak.		Shonkinite of Square Butte.
SiO_2	48·98		46·73
TiO_2	1·44		·78
Al_2O_3	12·29		10·05
Cr_2O_3	trace		----
Fe_2O_3	2·88		3·53
FeO	5·77		8·20
MnO	·08		·28
MgO	9·19		9·68
CaO	9·65		13·22
BaO	·43		undet.
SrO	·08		undet.
Na_2O	2·22		1·81
K_2O	4·96		3·76
Li_2O	trace		trace
H_2O at 110°	·26		1·24
H_2O above 110°	·56		
P_2O_5	·98		1·51
Fl	·22	Cl	·18
	99·99		100·97
O=Fl	·08	O=Cl	·04
	99·91		100·91

The consideration of this analysis shows the relatively low silica and alumina and the very high amounts of iron, lime and magnesia. The alkalies are still present in considerable amount, the potash predominating. The analysis is essentially that of a minette, but recalls also the composition of certain tephrites and leucitites. The rock is, however, a rather coarse, massive, evenly granular, stock form, consisting chiefly of augite and orthoclase with considerable accessory biotite, iron ore, and plagioclase, with a lesser amount of olivine and apatite.

At the west end of Yogo Peak a variation of the above type is found that forms large, irregular masses near the contact, the rock being noticeable for the very large, spongy, biotite crystals which it carries. These biotites are at times 1^{cm} across a cleavage face. They are made up of a number of smaller, nearly similarly oriented individuals mixed in with other constituents. Although the mica is subordinate in amount, it has the appearance of being predominantly present, and the rock appears at first glance to be almost wholly made up of these coarse biotite crystals. Examined in thin section under the microscope, it is seen to be composed of the same minerals as the type last described, but the olivine is fresh, showing little or none of the change into resorption pseudomorphs, and the total amount of iron ore, augite, and biotite is greater. The augite is still the predominating ferro-magnesian mineral. The orthoclase shows a still greater tendency toward the poikilitic structure, occurring in broad plates, enclosing other minerals—that is, filling the interspaces between them in similarly oriented areas. It is noticed also that the biotite occurs at times in this manner with respect to olivine, iron ore, and augite, and hence it is later in formation. Sometimes the olivine is surrounded by orthoclase, an uncommon association of these two minerals. In its period of formation, however, the olivine antedates all the other minerals.

As yet, no analysis has been made of this type, but from a study of the section and its comparison with the foregoing types, and of their analyses with one another, it is clearly evident that the process of differentiation which is under description has advanced somewhat further than in the last analysis, and that this rock would show still lower silica, alumina, and soda, with higher lime, iron and magnesia and considerable potash dominating the soda.

Recently under the name of *Shonkinite** we described a rock type from Square Butte in the Highwood Mountains of Montana, some forty miles to the north of Yogo Peak, where it occurs, as the outer differentiated zone of a laccolite composed chiefly of sodalite syenite.

It is a rather coarse, granular rock composed chiefly of orthoclase and augite with accessory iron ore, apatite and biotite with a very small accessory amount of sodalite and traces of nephe-

* Bull. Geol. Soc. Am., vol. vi, pp. 400–422, 1895.

lite, the appearance of these latter minerals in minute amount being clearly influenced by its association with the sodalite syenite. Its recognition as a distinct rock type is founded on its coarse granular structure and the predominance of the ferro-magnesian minerals over the feldspathic one, orthoclase. For purpose of comparison its analysis is quoted beside that of the type described above.

From what has been said it will be seen that the West Knob type of Yogo agrees very closely with the shonkinite of Square Butte, and this agreement is even more marked in the variation with large micas than in the type analyzed. They agree in structure, mineral composition and chemically. In the hand specimen they have a somewhat different habit, owing to the fact that in the Square Butte type of shonkinite the augite crystals are much larger and more idiomorphic than in that from Yogo Peak, while the actual amount of biotite is somewhat less. Under the microscope they closely resemble each other and both have the broad, poikilitic orthoclase areas and the large skeleton biotites. It gives us pleasure to announce the occurrence of this rock type from a second distinct locality.

Differentiation at Yogo Peak.—From what has already been stated it is evident that at Yogo Peak we have a stock of intruded igneous rock of an oval shape which shows a progressive differentiation along its major axis. The rock mass contains essentially the same minerals throughout, but there is a progressive increase in the ferro-magnesian species toward the western end. This is brought out still more strongly by a comparison of the chief rock-making oxides.

	Syenite.	Yogoite.	Shonkinite.
SiO_2	61·65	54·42	48·98
Al_2O_3	15·07	14·28	12·29
Fe_2O_3	2·03	3·32	2·88
FeO	2·25	4·13	5·77
MgO	3·67	6·12	9·19
CaO	4·61	7·72	9·65
Na_2O	4·35	3·44	2·22
K_2O	4·50	4·22	4·96

Here almost without exception the change is progressive. The silica, alumina and soda diminish; the iron oxides, lime and magnesia increase; the potash remains the same or relatively increases. In this connection it is interesting to observe the conduct of the rarer, less essential oxides, which occur in amounts sufficiently large so that the differences between them are evidently not those which fall within the limits of analytical error.

	Syenite.	Yogoite.	Shonkinite.
TiO_2	·56	·80	1·44
BaO	·27	·32	·43
P_2O_5	·33	·59	·98

The change is of precisely the same character as with the main oxides, there is a progressive increase toward the basic end, the titanium is concentrated in the iron ore and the phosphoric anhydride shows itself in the larger amount of apatite present, while the function of the barium is somewhat uncertain. Instances of intrusive stocks which vary in composition in different parts of the same mass are well known, such as for instance that of Carrock Fell, which has been so ably described by Harker,* where the mass grows steadily more basic toward the margin, or that of Ramnäs mentioned by Brögger,† where the reverse is the case. In his recent important monograph‡ Brögger names a rock series which occurs in one individual mass, and which has been formed by the differentiation of the mass in its final resting place ("laccolitic differentiation"§), a "*Facies suit*" to distinguish it from a series of rocks formed from independent magmatic eruptions which show also a continual progression or gradation in their mineralogical and chemical composition. The series is termed a "*Rock Series*" (*Gesteins serie*) in the latter case. The Yogo Peak mass shows an excellent example of the first class, but it is also to be expected that in many given regions a "facies suit" in one erupted mass will correspond to a "rock series" which may be developed in the region at large.

This may be shown, in part at least, for the Yogo district by taking in addition to the series of analyses of Yogo Peak three others, one of a quartz syenite porphyry constituting an immense uncovered laccolite at Big Baldy Mt., some miles northwest of Yogo, and one of a rather coarse-grained augite minette that forms a thick intrusive sheet a number of miles southwest of Yogo, one of a great series that is genetically connected with it in the Little Belt Mts. series of intrusions. These are taken from very complete analyses by Dr. Hillebrand, but here only the important rock-making oxides are considered. To these is added also the analysis of the shonkinite from Square Butte previously given.

* Quar. Jour. Geol. Soc, vol. l, p. 311, 1894, vol. li, p. 125, 1895.
† Zeitschr. f. Kryst, vol. xvi, page 45, 1889.
‡ Gesteine der Grorudit-Tinguait Serie, p. 179, 1894.
§ Loc. cit, p. 153.

	Quartz syenite porphyry. Big Baldy Mt.	Syenite Yogo.	Yogoite Yogo.	Minette Sheep Creek.	Shonkinite Yogo.	Shonkinite Square Butte.
SiO_2	67·04	61·65	54·42	52·26	48·49	46·73
Al_2O_3	15·25	15·07	14·28	13·96	12·29	10·05
Fe_2O_3	1·69	2·03	3·32	2·76	2·88	3·53
FeO	1·13	2·25	4·13	4·45	5·77	8·20
MgO	1·75	3·67	6·12	8·21	9·91	9·68
CaO	2·17	4·61	7·72	7·06	9·65	13·22
Na_2O	4·09	4·35	3·44	2·80	2·22	1·81
K_2O	5·10	4·50	4·22	3·87	4·96	3·76

The very regular gradation which this series shows is quite remarkable, as may be seen in the above table. There are very few irregularities in it. The variations are all along the same lines as those shown at Yogo Peak itself—the gradual fall of silica, alumina and soda together, with the predominance of potash over soda, may be taken as characteristic of this "petrographical province." From consideration of the analyses and the character of the differentiation that has taken place at Yogo Peak, together with the fact that the coarse mica type of shonkinite shows this differentiation in a higher degree than the type analyzed, it seems probable that it must agree in chemical composition with the Square Butte rock even more closely than the type analyzed does.

Classification of the Yogo rocks.—Here we enter a vexed field. Those who believe in classifying rocks solely by their structure and the *kinds* of minerals they contain without placing any importance upon the *relative quantities* present, or in other words place no stress upon the chemical composition of the magmas from which the rocks are derived, would doubtless call all of the rock varieties at Yogo Peak syenites, since they are composed chiefly of augite and orthoclase.

It seems to us that the time has come when a sharp distinction must be drawn between the use of general terms used by field geologists, such as granite, porphyry, trap, greenstone, etc., and the more exact and definite nomenclature demanded by the needs of petrology. Such general terms have a definite and proper value just as tree, bush and vine have in botany, but the science of petrology demands at present a terminology which will not only be *qualitative* but also *quantitative* in its meanings. While it is neither possible nor desirable to classify rocks on a strictly chemical basis, it is clearly evident that the lines of mineral and consequently of chemical variation must be more strictly drawn than has hitherto been done. This will find its natural manifestation in a more strict regard to the relative quantities of the various minerals which are present and these quantities within reasonable limits must be expressed.*

*See also the discussion of this subject by Brögger (Gest. der Grorudit-Tinguait Serie, p. 91, with whose excellent presentation of the subject we, in the main, heartily agree).

The present work has shown that, starting with the most acid form, we have at Yogo Peak a series of partial magmas with gradually rising lime, iron and magnesia, falling silica, alumina and soda, with potash as the dominant alkali. These crystallized into a series of massive, evenly granular rocks composed chiefly of augite as the ferro-magnesian mineral, but with accessory iron ore, biotite and possibly amphibole and olivine, while the feldspathic component is essentially orthoclase with which may be associated accessory plagioclase. For this series (adding the natural extremes not found at Yogo) we propose the following classification:

All orthoclase, no augite = Sanidinite.
Orthoclase exceeds augite = Augite-syenite.
Orthoclase equals augite = Yogoite.
Augite exceeds orthoclase = Shonkinite
All augite, no orthoclase = Pyroxene and peridotite rocks of various types.

Such a method of classification is a natural one and it does not present hard and fast arbitrary boundaries, but leaves a certain amount of elasticity in the determination of the types. Within certain lines it must also determine the chemical composition. Under the term augite is, of course, included the other accessory ferro-magnesian minerals, as the accessory feldspathic ones are included under the orthoclase.

Summary and Conclusion.—While there are many points of interest connected with the Yogo massif, which in the brief limits of this article have not been touched upon, such as its contact phenomena, the occurrence of aplitic dikes cutting it and its connection with radial dikes and encircling intrusive sheets of various rocks as well as questions of theoretic petrology to which its discussion must give rise, we have endeavored to present the following facts, which will be of general interest.

That Yogo Peak is composed of a core or stock of massive, granular, igneous rock, and that this rock is composed chiefly of augite and orthoclase. That the mass shows a progressive differentiation along its east and west axis, with a continual increase in the ferro-magnesian elements over the feldspathic ones. The resultant rock types have been classified into three groups: syenite, where feldspar exceeds augite; yogoite, where they are practically equal, and shonkinite, where the augite dominates, the latter being similar to a rock type previously described.

Washington and New Haven, October, 1895.

ART. LIII.—*Preliminary Note on a new Alkali Mineral;** by WARREN M. FOOTE.

WHILE searching recently at Borax Lake, California, for the new species sulphohalite,† Mr. C. H. Northup discovered small crystals of what he considered to be a new form of that mineral. Mr. Northup reports that they are very rare, having been found during a laborious working of the "tailings" or debris from an exploratory boring known as the "New Well," made by the Borax Lake Mining Company, and that they were undoubtedly formed in a stratum of clay reached at a depth of about 450 feet.

The entire find was forwarded to Dr. A. E. Foote, to whom the writer is indebted for the material used in this brief examination.

Crystallization, etc.—The mineral crystallizes in regular octahedrons, whose diameter rarely reach one centimeter. They occasionally exhibit triangular markings and a habit of parallel grouping in more or less regular aggregates. Fractured crystals show in the interior a cross of faint lines running perpendicularly to the crystal faces. These are divided by darker planes lying parallel to cubic symmetry, and passing through the angles of the octahedron, dividing it into eight parts. The same thing is noticeable in the clearest of the complete crystals, a bundle of striæ coming from the center of the crystal to the center of each face with the dividing planes clearly visible. This phenomenon is strikingly similar to that observed in cubes of boléite (figured by Bombicci in a memoir on mimetical pyrite, Bologna, 1893). The markings in the present instance are probably due to inclusion of organic matter, as in chiastolite.

The color varies from dirty white, pale yellow and greenish gray to dark brown; the lighter colored crystals closely resemble senarmontite. Cleavage is imperfect. It is brittle and shows uneven fracture. Luster, vitreous on broken surfaces, occasionally bright on crystal planes. Hardness, 3·5 to 4.

Chemical examination.—In powdering the mineral a fetid odor is distinctly perceptible. It is easily fusible before the blowpipe; in the closed tube it blackens and gives off a burnt odor with violent decrepitation and liberation of water (which subsequently proved to be mechanically included), finally fusing to a gray mass. Boiling water effects partial decomposition of the powdered mineral, with separation of a bulky white

* A revision of a paper read before the meeting of the Philadelphia Academy of Natural Sciences, Aug 27th, 1895.

† This Journal, xxxvi, p. 463.

residue, consisting mainly of basic carbonate of magnesia. It is decomposed with effervescence in cold dilute hydrochloric acid, with slight residue insoluble.

A careful qualitative analysis of crystal fragments showed it to consist essentially of sodium, magnesium, hydrochloric and carbonic acids, indicating a *double chloride and carbonate of sodium and magnesium.* Traces of phosphoric acid, silica, iron, calcium and organic matter were also found. This composition is quite as remarkable as that of other species peculiar to the Borax Lake region.

The name "*Northupite*" is proposed for this new species, since it was entirely due to Mr. Northup's indefatigable zeal in collecting that the mineral was brought to light. Professor Penfield has promised to make a quantitative analysis of this and several other interesting minerals found in association, at least one beside the Northupite being new.

ART. LIV.—*Three-toed Dinosaur tracks in the Newark Group at Avondale, N. J.;* by J. B. WOODWORTH.

A "track stratum" appears first to have been recognized in the quarries along the west bank of the Passaic River, in New Jersey, in the Newark rocks, by Mr. Frank L. Nason, of the N. J. Geol. Survey, in 1888. In his description, the general stratigraphic relations of these quarries are set forth, but nothing more is said regarding the tracks other than that they are referred to "reptiles, birds and insects."*

The object of this notice is to confirm Mr. Nason's observations as to the existence of tracks, and to describe a track-covered slab seen in the quarry at Avondale in September of this year. Having come fresh from the collection of dinosaur tracks at Amherst, the writer began a search in the now little-worked Newark quarries. Ill-defined impressions were here seen, but nothing that was satisfactory. At Avondale, markings, due neither to current-mark nor to ripple-mark, were at once seen on the brownish-red shale-covered surfaces of several blocks of freestone. In addition to these equivocal impressions, the following described foot-prints are essentially identical with those found in the Connecticut valley area:

On a triangular block about 7 feet on a side, 15 tracks were seen. These were of two kinds, with the exception of one isolated print, in three lines as follows:

* Annual Report of the State Geologist for 1888, Camden, 1889, pp. 22, 28.

1. Three foot-prints about 8 inches long; stride from toe to toe of 1 and 2 about 19 inches; from toe to toe of 2 and 3, about 31 inches. The tracks resemble the form named *Anomœpus major* by Edw. Hitchcock, the print embracing the impression of the foot together with that of the lower part of the tarso-metatarsus, which latter would make the prolonged, indefinitely-ending, heel-like projection wherever the animal crouched upon the beach.* If this explanation be applicable in this case, the foot proper has a length of about 5 inches.

2. Three-toed prints from 2·5 to 3 inches long, digital impressions jointed ; one line of these prints contained five distinct tracks, with a stride of about one foot. The second line of tracks was similar, with six prints.

A heart-shaped impression about four inches on a side and sharply defined was seen on another slab. A similar impression, in the Amherst collection, is in a relation to foot-prints to indicate that it was made by an animal crouching on the beach. Other vague impressions, due to the moulding of the bottom as if by the rolling contact of a flexible, wrinkled body, are probably to be explained as made by dinosaurs in a recumbent position. Long straight and curved furrows also exist both at Avondale and on the track layers in the Newark quarries.

So far as one can judge from tracks, these impressions afford nothing not already known in the Connecticut area. Their existence in the section which has been taken for the type of the Jura-Trias basins along the Atlantic coast, is of importance as serving to remove the criticism which has been made against the revival of Redfield's term,—the Newark group,—that the characteristic fossil tracks of the better known Connecticut area do not occur in it.

I am indebted to my friend, Prof. Geo. C. Sonn, of Newark, N. J., for essaying to have the large slab with fourteen tracks preserved in the High School of that city.

Harvard University, September 18th, 1895.

* I am indebted to Professor Emerson for this explanation of the similar tracks in the collection at Amherst.

ART. LV.—*On the Affinities and Classification of the Dinosaurian Reptiles;** by O. C. MARSH. (With Plate X.)

INTRODUCTION.

FOR several years I have been engaged in the study of the Dinosaurs of North America, and the main results of the investigation have been published both in that country and in Europe. The material for this study consisted of the extensive collections made during my explorations in western North America, especially in the Rocky Mountain region, and the type specimens are nearly all preserved in the museum of Yale University. I first attempted in 1881 to make a classification of the series of specimens thus secured, and in the following year I extended this classification to include the European forms, and again in 1884 I expanded it still further to include all the *Dinosauria* then known.†

Since that time, many new discoveries have been made, and some very strange forms have been brought to light in America, which render a revision of this classification necessary. Besides the American forms, I have studied with care nearly every important specimen of Dinosaurs preserved in the museums of Europe, and as a result of all this investigation, I shall present to you an abstract, bringing the subject down to date. This will include a short statement as to the affinities of the Dinosaurs, so far as I have been able to make them out, and a synopsis of the classification, based mainly upon the characters of the Dinosaurs I have myself examined.

To bring the subject directly before you, I have prepared the chart here shown (Plate X), which gives restorations of the skeletons of the twelve best known Dinosaurs, so far as I have been able to reconstruct them. Of these twelve forms, eight are from America; *Anchisaurus*, a small carnivorous type from the Trias; *Brontosaurus*, *Camptosaurus*, *Laosaurus*, and *Stegosaurus*, all herbivorous, and the carnivorous *Ceratosaurus*, from the Jurassic; with *Claosaurus* and *Triceratops*, herbivores from the Cretaceous. These American forms, with four from Europe, types of the well-known genera *Compsognathus*, *Scelidosaurus*, *Hypsilophodon*, and *Iguanodon*, complete the series represented on this chart. They form together an instructive group of the remarkable Reptiles we are now considering.

* Abstract of paper read before the International Congress of Zoologists, at Leyden, September 17, 1895.

† This Journal, vol. xxi, p. 423, May, 1881; vol. xxiii, p. 81, January, 1882; Report British Association for the Advancement of Science, for 1884, p. 763.

Affinities of Dinosaurs.

The extinct reptiles known as Dinosaurs were for a long time regarded as a peculiar order, having, indeed, certain relations to Birds, but without being closely allied to any of the other groups of known Reptiles. *Megalosaurus* and *Iguanodon*, the first Dinosaurian genera described, were justly considered as representing two distinct families, one including the carnivores, and the other the herbivorous forms.

With the discovery and investigation of *Cetiosaurus* and its allies in Europe, and especially of the gigantic forms with similar characters in America, it became evident that these reptiles could not be placed in the same families with *Megalosaurus*, or *Iguanodon*, but constituted a well-marked group by themselves. It was this new order, the *Sauropoda*, as I have called them, that first showed definite characters allying them with other known groups of Reptiles. In 1878, I pointed out that the *Sauropoda* were the least specialized of the Dinosaurs, and I gave a list of characters in which they showed such an approach to the Mesozoic Crocodiles as to suggest a common ancestry at no very remote period.*

1.

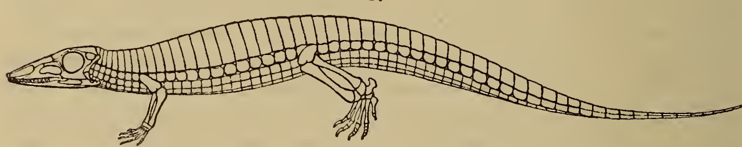


Figure 1.—Restoration of *Aëtosaurus ferratus*, Fraas; with dermal armor of the limbs removed. One-eighth natural size.

Again in 1884, I called attention to the same point, and also to the relationship of Dinosaurs with the *Aëtosauria*, as I had named them, a group of small reptiles from the Triassic of Germany, showing strong affinities with Crocodilians.† A restoration of one of these small animals is shown in the diagram before you (figure 1). In the same communication I compared with Dinosaurs another allied group, the *Hallopoda*, which I had described from the lower Jurassic of America, but had not then fully investigated. Subsequent researches proved the latter group to be of the first importance in estimating the affinities of Dinosaurs, and in another diagram (figures 4–5), I have placed before you restorations of the fore and hind limbs of the type species (*Hallopus victor*).

* This Journal, vol. xvi, p. 412, November, 1878.
† Report British Association, Montreal Meeting, 1884, p. 765.

Another group of extinct Reptiles, which may be termed the *Belodontia*, were considered in the same paper, as allies of the *Dinosauria.* They are known from the Trias of Europe and America, and the type genus *Belodon* has been investigated by many anatomists, who all appear to have regarded it as Crocodilian; an opinion that in the light of our present knowledge may fairly be questioned.

2. 3.

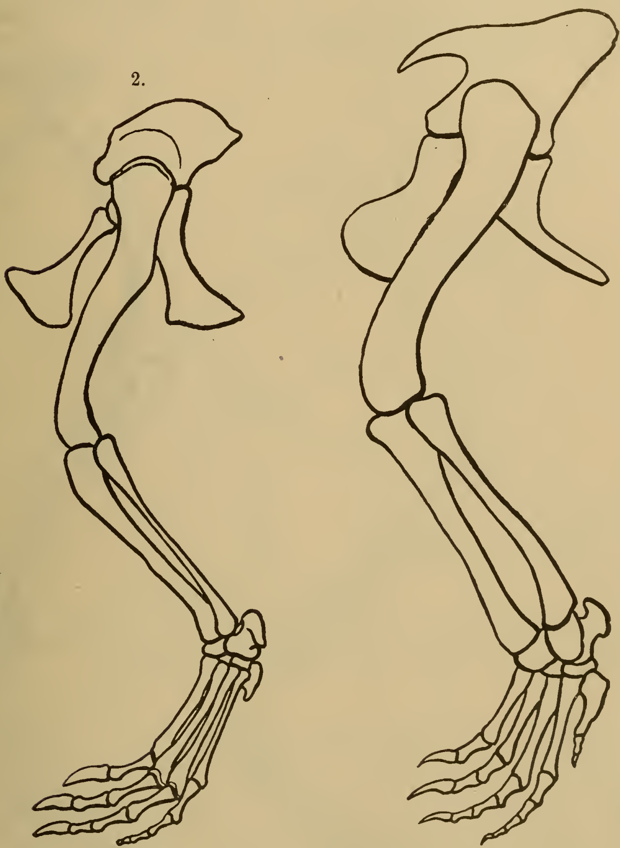


FIGURE 2.—Diagram of left hind limb of *Alligator Mississippiensis*, Gray; seen from the left; in position for comparison with Dinosaurs. One-fourth natural size.

FIGURE 3.—Diagram of left hind limb of *Aëtosaurus ferratus;* in same position. One-half natural size.

The relations of these various groups to the true Crocodiles on the one hand and to Dinosaurs on the other is much too broad a subject to be introduced here, but I may at least call your attention to some points of resemblance between the Dinosaurs and these supposed Crocodilian forms, that seem to indicate genetic affinities.

If we compare some of the characteristic parts of the skeletons of these groups; e. g., of the true *Crocodilia* as existing to-day, the *Belodontia*, the *Aëtosauria*, and the *Hallopoda*, and all with the corresponding portions of the more typical Dinosaurs, the result may indicate in some measure the relationship between them. Taking first the

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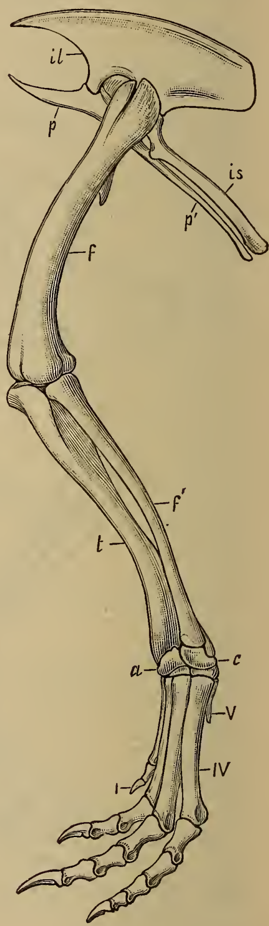

5.

4.

FIGURE 4.—Diagram of left fore limb of *Hallopus victor*, Marsh; seen from the left.
FIGURE 5.—Diagram of left hind limb of same individual. Both figures are one-half natural size.
FIGURE 6.—Left hind leg of *Laosaurus consors*, Marsh; outside view. One-sixth natural size. *a*, astragalus; *c*, calcaneum; *f*, femur; *f'*, fibula; *il*, ilium; *is*, iscnium; *p*, pubis; *p'*, postpubis; *t*, tibia; *I*, *IV*, *V*, first, fourth, and fifth digits.

pelvis and hind limb, as being especially characteristic, we find in the existing *Alligator*, as represented in the diagram (figure 2), that the pubic bone is excluded from the acetabulum, articulating alone with the ischium, and not at all with the ilium. The calcaneum, moreover, has a posterior extension. In *Aëtosaurus*, as shown in the corresponding diagram (figure 3), the pubic bone forms part of the acetabulum, as in Dinosaurs and Birds, and this is a noteworthy difference from all the existing Crocodiles. The hind foot, however, is of the Crocodilian type, with the calcaneum showing a posterior projection.

7.

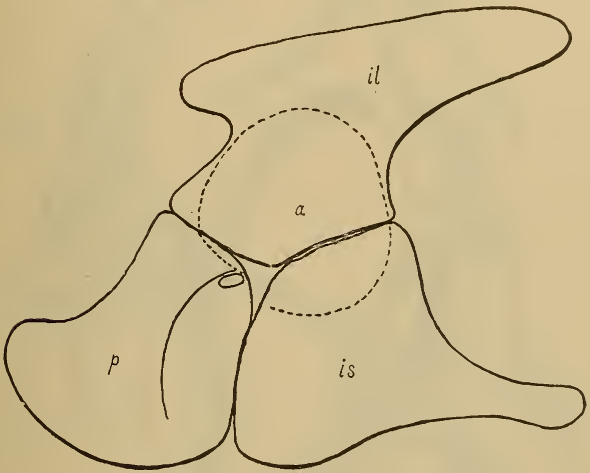

FIGURE 7.—Diagram of pelvis of *Belodon Kapffi*, von Meyer; seen from the left. One-fourth natural size.

a, acetabular surface, within dotted line; *il*, ilium; *is*, ischium; *p*, pubis.

In *Belodon*, the pelvis of which alone is here represented (figure 7), the pubis contributes a very important part to the formation of the acetabulum, and to the entire pelvic arch. The latter differs from the pelvis of a typical Dinosaur mainly in the absence of an open acetabulum, but a moderate enlargement of the fontanelle at the junction of the three pelvic elements would essentially remove this difference. A more erect position of the limb, leading to a more distinct head on the femur, might possibly bring about such a result. The feet and limbs of *Belodon* are Crocodilian in type.

Bearing these facts in mind, the diagram representing the restored fore and hind limbs of the diminutive *Hallopus* (figures 4–5) shows first of all the true Dinosaurian pelvis, with the pubic bone taking part in the open acetabulum, and forming an important and distinctive element of the pelvic arch. The delicate posterior limb and foot, evidently adapted

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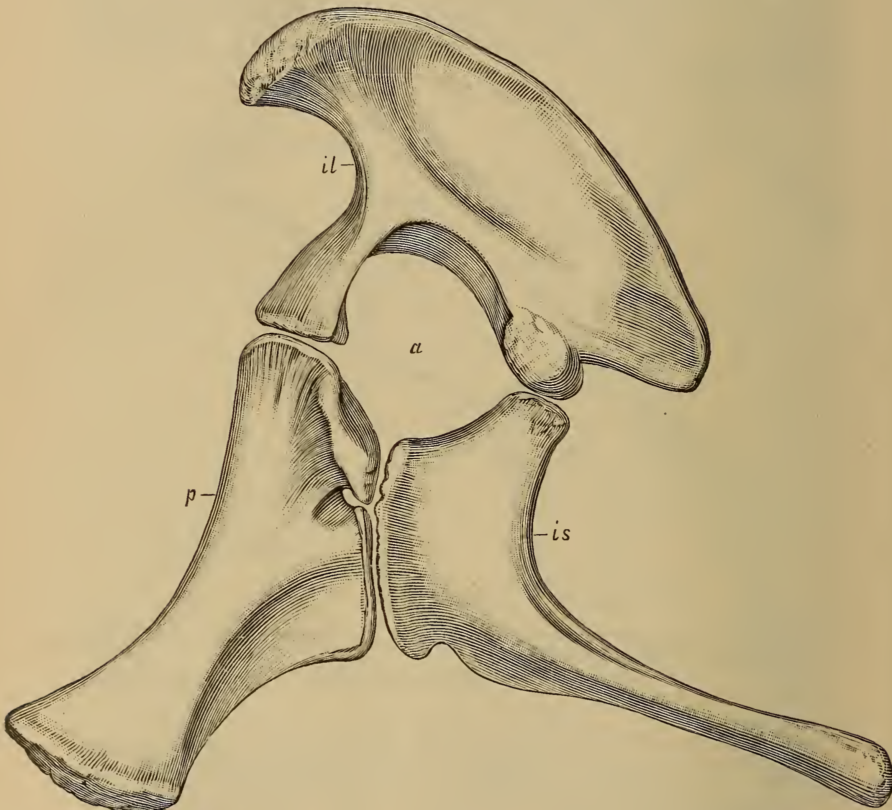
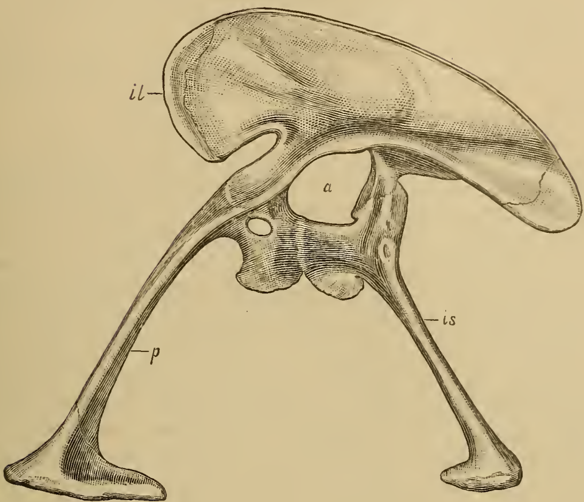


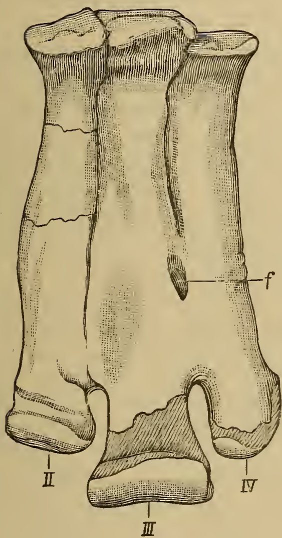
FIGURE 8.—Pelvis of *Morosaurus lentus*, Marsh; seen from the left. One-eighth natural size.
a, acetabular opening; other letters as in figure 7.

mainly for leaping, as the generic name suggests, are quite unique among the *Reptilia*, but the tarsus, especially the calcaneum, recalls strongly the same region in the orders already passed in review.

9.



10.



11.

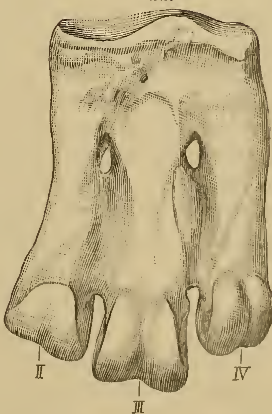


FIGURE 9.—Pelvis of *Ceratosaurus nasicornis*, Marsh; seen from the left. One-twelfth natural size. Letters as in figure 8.

FIGURE 10.—United metatarsal bones of *Ceratosaurus nasicornis*; left foot; front view. One-fourth natural size.

FIGURE 11.—United metatarsal bones of great Penguin (*Aptenodytes Pennantii*, G. R. Gr.); left foot; front view. Natural size.

Just what this posterior extension of the calcaneum signifies in this case, it is difficult to decide on the evidence now known. It may be merely an adaptive character, as *Hallopus* appears in nearly every other respect to be a true carnivorous Dinosaur. It may, however, be an inheritance from a Crocodilian ancestry, and preserved by a peculiar mode of life. Whatever its origin may have been, it was certainly, during the life of the animal, an essential part of the remarkable leaping foot to which it belonged, and in which it has since kept its position undisturbed. The presence of such an element in the foot of this diminutive Dinosaur certainly suggests that the group *Hallopoda*, which I have considered an order, stands somewhat apart from the typical *Theropoda*, but not far enough away to be excluded from the subclass *Dinosauria*, as I have defined it in the present communication.

In the genus *Zanclodon*, which is from essentially the same geological horizon in Germany as *Aëtosaurus* and *Belodon*, we have one of the oldest true Dinosaurs known, and a typical member of the order *Theropoda*. In the pelvic arch of this reptile, the ilium and ischium are in type quite characteristic of the group to which it belongs, but the pubic elements are unique. They consist of a pair of broad, thin plates united together so as to form an apron-like shield in front, quite unlike anything known in other Dinosaurs. The wide pubic bones of *Belodon*, and the corresponding plates in some of the *Sauropoda* (*Morosaurus*, figure 8), indicate that this feature of the reptilian pelvis may have been derived from some common ancestor of a generalized primitive type. The known transformations of this same pelvic element in one other order of Dinosaurs (the *Predentata*) make the modifications here suggested well within the limits of probability. The hind limb of one genus of this order is shown in figure 6.

The skulls of *Aëtosaurus* and *Belodon* both show features characteristic of some of the Dinosaurs, especially of the *Sauropoda*, but these features need not be discussed here.

The relation of Dinosaurs to Birds, a subject of importance, must also be postponed for another occasion. One point, however, may be mentioned in this connection. The pelvic bones of all known Birds, living and extinct, except the genus *Archæopteryx*, are coössified, while in all the known Dinosaurs they are separate, excepting *Ceratosaurus* (figure 9) and *Ornithomimus*. Again, all known adult Birds, living and extinct, with possibly the single exception of *Archæopteryx*, have the tarsal bones firmly united (figure 11), while all the *Dinosauria*, except *Ceratosaurus* (figure 10), have these bones separate. The exception in each case brings the two classes near together at this point, and their close affinity is thus rendered more probable.

These few facts will, I trust, throw some light on the affinities of the Reptiles known as the *Dinosauria*. The problem is certainly one of much difficulty, and I hope soon to discuss it more fully elsewhere.

Classification of Dinosaurs.

In the present review of the Dinosaurs, I have confined myself mainly to the type specimens which I have described, but have included with them other important remains where these were available for investigation. The extensive collections in the museum of Yale University contain so many of the important type specimens now known from America, that they alone furnish an admirable basis for classification, and it was upon these mainly that I first established the present system, which has since been found to hold equally good for the Dinosaurs discovered elsewhere. In the further study of these reptiles, it was also necessary to examine both the European forms and those from other parts of the world, and I have now studied nearly every known specimen of importance. These investigations have enabled me to make this classification more complete, and to bring it down to the present time.

Many attempts have been made to classify the Dinosaurs, the first being that of Hermann von Meyer, in 1830. The name *Dinosauria*, proposed for the group by Owen, in 1839, has been generally accepted, although not without opposition. Hæckel, Cope, and Huxley followed, the last in 1869 proposing the name *Ornithoscelida* for the order, and giving an admirable synopsis of what was then known of these strange Reptiles and their affinities. Since then, Hulke, Seeley, and Lydekker, Gaudry, Dollo, Baur, and many others, have added much to our knowledge of these interesting animals. The remarkable discoveries in North America, however, have changed the whole subject, and in place of fragmentary specimens, many entire skeletons of Dinosaurian reptiles have been brought to light, and thus definite information has replaced uncertainty, and rendered a comprehensive classification for the first time possible.

The system of classification I first proposed in 1881 has been very generally approved, but a few modifications have been suggested by others that will doubtless be adopted. This will hardly be the case with several radical changes recently advocated, based mainly upon certain theories of the origin of Dinosaurs. At present these theories are not supported by a sufficient number of facts to entitle them to the serious consideration of those who have made a careful study of these reptiles, especially the wonderful variety of forms recently made known from America.

Further discoveries may in time solve the problem of the origin of all the Reptiles now called Dinosaurs, but the arguments hitherto advanced against their being a natural group are far from conclusive. The idea that the *Dinosauria* belong to two or more distinct groups, each of independent origin, can at present claim equal probability only with a similar suggestion recently made in regard to mammals. This subject of the origin of the Dinosaurs and the relation of their divisions to each other will be more fully treated by me elsewhere.

A classification of any series of extinct animals is of necessity, as I have previously said, merely a temporary convenience, like the book shelves in a library, for the arrangement of present knowledge. In view of this fact and of the very limited information we now have in regard to so many Dinosaurs known only from fragmentary remains, it will suffice for the present, or until further evidence is forthcoming, to still consider the *Dinosauria* as a subclass of the great group of *Reptilia.*

Regarding, then, the Dinosaurs as a subclass of the *Reptilia*, the forms best known at present may be classified as follows:

Subclass Dinosauria, Owen.

Premaxillary bones separate; upper and lower temporal arches; no teeth on palate; rami of lower jaw united in front by cartilage only. Neural arches of vertebræ joined to centra by suture; sacral vertebræ united. Chevrons articulated intervertebrally. Cervical and thoracic ribs double-headed. Clavicles wanting. Ilium prolonged in front of the acetabulum; acetabulum formed in part by pubis; ischia meet distally on median line. Fore and hind limbs present, the latter ambulatory, and larger than those in front. Head of femur at right angles to condyles; tibia with procnemial crest; fibula complete; first row of tarsals composed of astragalus and calcaneum only, which together form the upper portion of ankle joint; reduction in number of digits begins with the fifth.

Order Theropoda (Beast foot). Carnivorous.

Skull with external narial openings lateral; large antorbital vacuity; brain case incompletely ossified; no pineal foramen. Premaxillaries with teeth; no predentary bone; dentary without coronoid process; teeth with smooth compressed crowns, and crenulated edges. Vertebræ more or less cavernous; posterior trunk vertebræ united by diplosphenal articulation.

Each sacral rib supported by two vertebræ; diapophyses distinct from sacral ribs. Sternum unossified. Pubes projecting downward, and united distally. Fore limbs small; limb bones hollow; feet digitigrade; digits with prehensile claws; locomotion mainly bipedal.

(1) Family *Megalosauridæ.* Lower jaws with teeth in front. Anterior vertebræ convexo-concave; remaining vertebræ biconcave; five sacral vertebræ. Ilium expanded in front of acetabulum; pubes slender. Femur longer than tibia. Astragalus with ascending process. Five digits in manus and four in pes.

Genus *Megalosaurus* (*Poikilopleuron*). Jurassic and Cretaceous. Known forms European.

(2) Family *Dryptosauridæ.* Lower jaws with teeth in front. Cervical vertebræ opisthocœlian; remaining vertebræ biconcave; sacral vertebræ less than five; ilium expanded in front of acetabulum; distal ends of pubes coössified and much expanded; an interpubic bone. Femur longer than tibia; astragalus with ascending process. Fore limbs very small, with compressed prehensile claws.

Genera *Dryptosaurus* (*Lælaps*), *Allosaurus*, *Cœlosaurus*, *Creosaurus.* Jurassic and Cretaceous. All from North America.

(3) Family *Labrosauridæ.* Lower jaws edentulous in front. Cervical and dorsal vertebræ convexo-concave; centra cavernous or hollow. Pubes slender, with anterior margins united; an interpubic bone. Femur longer than tibia; astragalus with ascending process.

Genus *Labrosaurus.* Jurassic, North America.

(4) Family *Plateosauridæ* (*Zanclodontidæ*). Vertebræ biconcave; two sacral vertebræ. Ilium expanded behind acetabulum; pubes broad, elongate plates, with anterior margins united; no interpubic bone. Femur longer than tibia; astragalus without ascending process. Five digits in manus and pes.

Genera *Plateosaurus* (*Zanclodon*), ? *Teratosaurus*, *Dimodosaurus.* Triassic. Known forms European.

(5) Family *Anchisauridæ.* Skull light in structure, with recurved, cutting teeth. Vertebræ biconcave. Bones hollow. Ilium expanded behind acetabulum; pubes rod-like and not coössified distally; no interpubic bone. Fore limbs well developed. Femur longer than tibia. Five digits in manus and four in pes. (See Plate X, figure 1.)

Genera *Anchisaurus* (*Megadactylus*), *Ammosaurus*, ? *Arctosaurus*, *Bathygnathus*, and *Clepsysaurus*, in North America; and in Europe, *Palæosaurus*, *Thecodontosaurus.* All known forms Triassic.

Suborder Cœluria (Hollow tail).

(6) Family *Cœluridæ.* Teeth much compressed. Vertebræ and bones of skeleton very hollow or pneumatic; anterior cervical vertebræ convexo-concave; remaining vertebræ biconcave; cervical ribs coössified with vertebræ; an interpubic bone. Femur shorter than tibia. Metatarsals very long and slender.

Genera *Cœlurus*, in North America; and *Aristosuchus*, in Europe. Jurassic.

Suborder Compsognatha.

(7) Family *Compsognathidæ.* Skull elongate, with slender jaws and pointed teeth. Cervical vertebræ convexo-concave; remaining vertebræ biconcave. Bones very hollow. Femur shorter than tibia. Ischia with long symphysis on median line. Three functional digits in manus and pes.

Genus *Compsognathus.* Jurassic. Only known specimen European. (Plate X, figure 3.)

Suborder Ceratosauria (Horned saurians).

(8) Family *Ceratosauridæ.* Horn on skull. Cervical vertebræ plano-concave; remaining vertebræ biconcave. Pelvic bones coössified; ilium expanded in front of acetabulum; pubes slender; an interpubic bone. Limb bones hollow. Manus with four digits. Femur longer than tibia; astragalus with ascending process; metatarsals coössified; three digits only in pes. Osseous dermal plates. (Plate X, figure 5.)

Genus *Ceratosaurus.* Jurassic, North America.

(9) Family *Ornithomimidæ.* Pelvic bones coössified with each other and with sacrum; ilium expanded in front of acetabulum. Limb bones very hollow. Fore limbs very small; digits with very long, pointed claws. Hind limbs of true avian type; feet digitigrade and unguiculate.

Genus *Ornithomimus.* Cretaceous, North America.

Suborder Hallopoda (Leaping foot).

(10) Family *Hallopidæ.* Vertebræ and limb bones hollow; vertebræ biconcave; two vertebræ in sacrum; acetabulum formed by ilium, pubis, and ischium; pubes rod-like, projecting downward, but not coössified distally; no postpubis; ischia with distal ends expanded, meeting below on median line. Fore limbs very small, with four digits in manus. Femur shorter than tibia; hind limbs very long, with three digits only in pes, and metatarsals greatly elongated; astragalus without ascending process; calcaneum much produced backward; feet digitigrade, unguiculate.

Genus *Hallopus.* Jurassic, North America.

Order Sauropoda (Lizard foot). Herbivorous.

External nares at apex of skull; premaxillary bones with teeth; teeth with rugose crowns more or less spoon-shaped; large antorbital openings; no pineal foramen; alisphenoid bones; brain case ossified; no columellæ; postoccipital bones; no predentary bone; dentary without coronoid process. Cervical ribs coössified with vertebræ; anterior vertebræ opisthocœlian, with neural spines bifid; posterior trunk vertebræ united by diplosphenal articulation; presacral vertebræ hollow; each sacral vertebra supports its own transverse process, or sacral rib; no diapophyses on sacral vertebræ; neural cavity much expanded in sacrum. Sternal bones parial. Ilium expanded in front of acetabulum; pubes projecting in front, and united distally by cartilage; no postpubis. Limb bones solid; fore and hind limbs nearly equal; metacarpals longer than metatarsals; femur longer than tibia; feet plantigrade, ungulate; five digits in manus and pes; second row of carpal and tarsal bones unossified. Locomotion quadrupedal.

(1) Family *Atlantosauridæ.* A pituitary canal; large fossa for nasal gland. Distal end of scapula not expanded. Sacrum hollow; ischia directed downward, with expanded extremities meeting on median line. Anterior caudal vertebræ with lateral cavities; remaining caudals solid.

Genera *Atlantosaurus*, *Apatosaurus*, *Barosaurus*, *Brontosaurus.* Include the largest known land animals. Jurassic, North America. (Plate X, figure 2.)

(2) Family *Diplodocidæ.* External nares superior; no depression for nasal gland; two antorbital openings; large pituitary fossa; dentition weak, and in front of jaws only; brain inclined backward; dentary bone narrow in front. Ischia with shaft not expanded distally, directed downward and backward, with sides meeting on median line. Sacrum hollow. Caudal vertebræ deeply excavated below; chevrons with both anterior and posterior branches.

Genus *Diplodocus.* Jurassic, North America.

(3) Family *Morosauridæ.* External nares lateral; large fossa for nasal gland; small pituitary fossa; dentary bone massive in front. Shaft of scapula expanded at distal end. Sacral vertebræ nearly solid; ischia slender, with twisted shaft directed backward, and sides meeting on median line. Anterior caudals solid.

Genera *Morosaurus*, *?Camarasaurus* (*Amphicœlias*). Jurassic, North America.

(4) Family *Pleurocœlidæ.* Dentition weak; teeth resembling those of *Diplodocus.* Cervical vertebræ elongated; centrum hollow, with large lateral openings; sacral vertebræ solid, with lateral depressions in centra; caudal vertebræ solid; anterior caudals with flat articular faces, and transversely compressed neural spines; middle caudal vertebræ with neural arch on front half of centrum. Ischia with compressed distal ends, meeting on median line.

Genus *Pleurocœlus.* ? Jurassic, North America.

(5) Family *Titanosauridæ.* Fore limbs elongate; coracoid quadrilateral. Presacral vertebræ opisthocœlian; first caudal vertebra biconvex; remaining caudals procœlian; chevrons open above.

Genera *Titanosaurus* and *Argyrosaurus.* ? Cretaceous, India and Patagonia.

European forms of the order *Sauropoda* are *Bothriospondylus*, *Cardiodon* (*Cetiosaurus*), *Chondrosteosaurus*, *Eucamerotus*, *Ornithopsis*, and *Pelorosaurus.* All probably Jurassic.*

Order Predentata. Herbivorous.

Narial opening lateral; no antorbital foramen; brain case ossified; supra-orbital bones; teeth with sculptured crowns; maxillary teeth with crowns grooved on outside; lower teeth with grooves on inside of crown; a predentary bone; dentary with coronoid process. Cervical ribs articulating with vertebræ; each sacral rib supported by two vertebræ. Ilium elongated in front of acetabulum; prepubic bones free in front; postpubic bones present; ischia slender, directed backward, with distal ends meeting side to side. Astragalus without ascending process.

Suborder Stegosauria (Plated lizard).

No teeth in premaxillaries; teeth with distinct compressed crowns, and serrated edges. Fore limbs small; locomotion mainly quadrupedal. Vertebræ and limb bones solid. Pubes projecting free in front; postpubis present. Femur longer than tibia. Feet plantigrade, ungulate; five digits in manus and four in pes; second row of carpals unossified. Osseous dermal armor.

(1) Family *Stegosauridæ.* Vertebræ biconcave. Neural canal in sacrum expanded into large chamber; ischia directed backward, with sides meeting on median line. Dorsal ribs T-shaped in cross section. Astragalus coössified with tibia; metapodials very short. Five digits in manus; three functional digits in pes. (Plate X, figure 8.)

* The Wealden is here regarded as upper Jurassic, and not Cretaceous. See this Journal, vol. 1, p. 412, November, 1895.

Genera *Stegosaurus* (*Hypsirhophus*), *Diracodon*, *?Dystrophæus*, *Palæoscincus*, *Priconodon*, all from North America; and in Europe *Omosaurus*, Owen. Jurassic and Cretaceous.

(2) Family *Scelidosauridæ.* Astragalus not coössified with tibia; metatarsals elongated; three functional digits in pes.
Genera *Scelidosaurus*, *Acantholis*, *Hylæosaurus*, *Polacanthus.* Jurassic and Cretaceous. Known forms all European. (Plate X, figure 6.)

(3) Family *Nodosauridæ.* Heavy dermal armor. Bones solid. Fore limbs large; feet ungulate.
Genus *Nodosaurus.* Cretaceous, North America.

Suborder CERATOPSIA (Horned face).

(4) Family *Ceratopsidæ.* Premaxillaries edentulous; teeth with two distinct roots; skull surmounted by massive horn-cores; a rostral bone, forming a sharp, cutting beak; expanded parietal crest, with marginal armature; ? a pineal foramen. Vertebræ solid; anterior cervical vertebræ coössified with each other; posterior dorsal vertebræ supporting on the diapophysis both the head and tubercle of the rib; lumbar vertebræ wanting; sacral vertebræ with both diapophyses and ribs. Pubes projecting in front, with distal end expanded; postpubic bone rudimentary or wanting. Limb bones solid; fore limbs large; femur longer than tibia; feet ungulate; locomotion quadrupedal.
Genera *Ceratops*, *Agathaumas*, *Monoclonius*, *Polyonax*, *Sterrholophus*, *Torosaurus*, *Triceratops*, in North America; and in Europe *Struthiosaurus* (*Cratæomus*). All are Cretaceous. (Plate X, figure 10.)

Suborder ORNITHOPODA (Bird foot).

Premaxillaries edentulous in front. Vertebræ solid. Fore limbs small. Pubes projecting free in front; postpubis present. Feet digitigrade; three to five functional digits in manus and three to four in pes; locomotion mainly bipedal.

(5) Family *Camptosauridæ* (*Camptonotidæ*). Premaxillaries edentulous; teeth in single row; a supra-orbital fossa. Anterior vertebræ opisthocœlian; sacral vertebræ with peg and notch articulation. Limb bones hollow; fore limbs small. Postpubis reaching to the distal end of ischium. Femur longer than tibia, and with pendent fourth trochanter; hind feet with four digits. (Plate X, figure 7.)
Genus *Camptosaurus* (*Camptonotus*). Jurassic, North America.

(6) Family *Laosauridæ.* Premaxillaries edentulous; teeth in single row. Anterior vertebræ with plane articular faces; sacral vertebræ coössified. Sternum unossified. Limb and

foot bones hollow; fore limbs very small; five digits in manus; femur shorter than tibia; metatarsals elongate; four digits in pes.

Genera *Laosaurus* and *Dryosaurus*. Jurassic, North America. (Plate X, figure 4.)

(7) Family *Hypsilophodontidæ*. Premaxillaries with teeth; teeth in single row. Anterior vertebræ opisthocœlian; sacral vertebræ coössified. Sternum ossified. Limb bones hollow; five digits in manus; femur shorter than tibia; hind feet with four digits.

Genus *Hypsilophodon*. Wealden, England. (Plate X, figure 9.)

(8) Family *Iguanodontidæ*. Premaxillaries edentulous; teeth in single row. Anterior vertebræ opisthocœlian. Sternal bones ossified. Postpubis incomplete. (Plate X, figure 11.)

Genera *Iguanodon*, *Vectisaurus*. Jurassic and Cretaceous. Known forms all European.

(9) Family *Trachodontidæ* (*Hadrosauridæ*). Premaxillaries edentulous; teeth in several rows, forming with use a tessellated grinding surface. Cervical vertebræ opisthocœlian. Limb bones hollow; fore limbs small. Femur longer than tibia.

Genera *Trachodon* (*Hadrosaurus*, *Diclonius*), *Cionodon*. Cretaceous, North America.

(10) Family *Claosauridæ*. Premaxillaries edentulous; teeth in several rows, but a single row only in use. Cervical vertebræ opisthocœlian. Limb bones solid; fore limbs small. Sternal bones parial. Postpubis incomplete. Feet ungulate; three functional digits in manus and pes. (Plate X, figure 12.)

Genus *Claosaurus*. Cretaceous, North America.

(11) Family *Nanosauridæ*. Teeth compressed and pointed, and in a single, uniform row. Cervical and dorsal vertebræ short and biconcave. Limb bones and others very hollow; fore limbs of moderate size. Sacral vertebræ three; ilium with very short pointed front, and narrow posterior end. Femur curved, and shorter than tibia; fibula pointed below; metatarsals very long and slender. Anterior caudals short.

Genus *Nanosaurus*. Jurassic, North America. Includes the smallest known Dinosaurs.

EXPLANATION OF PLATE X.

Restorations of Dinosaurian Reptiles.

In this plate, the scientific name, the size, geological formation, and country where found, are given under each of the twelve figures. The skeletons here restored are represented in the same general position, to aid in comparing them with each other.

This plate is a reduced copy of the chart shown at Leyden, when the present paper was read. The same chart was also shown at the meeting of the British Association, Ipswich, September 14, 1895.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *A Method for completely dehydrating Alcohol* is recommended by H. Wislicenus and L. Kaufmann, which seems very convenient and practical, and which will probably fill a long-felt want in the laboratory. The reagent used is amalgamated aluminium, which can be prepared in a few moments by treating aluminium filings, free from oil, with caustic soda solution until a brisk evolution of hydrogen is produced, then washing once superficially with water and allowing a $\frac{1}{2}$ per cent solution of corrosive sublimate to act for one or two minutes upon the metal, which is still moist with weak alkali solution. The whole operation is rapidly repeated to remove a black scum which forms, and the product is quickly and thoroughly washed with water, alcohol and ether in succession, and is preserved, if necessary, under low-boiling petroleum-ether. Aluminium filings are on the market, at least in Germany, at a reasonable price. The amalgamation of this metal changes its chemical properties in a remarkable manner, so that it decomposes water violently, and it even becomes hot spontaneously from the action of the moisture of the air, with formation of white flakes of aluminium hydroxide. The reagent has no action upon alcohol and ether, but it reacts promptly with any water contained in them. The authors especially recommend the substance for use in organic chemistry as an entirely neutral reducing-agent.—*Berichte deutsch. chem. Ges.*, xxviii, 1323, June, 1895. H. L. W.

2. *Carbon in Meteoric Irons.*—The well-known finding of diamonds in the Cañon Diablo meteorite has led Moissan to examine several other holosiderites. Five irons, from Texas, Scotland, Chili, Mexico and Russia were studied, but in no case were diamonds found. The author concludes from this investigation that in some metallic meteorites there is no carbon, in others carbon exists either in an amorphous condition or mixed with graphite, and finally, that up to the present time the Cañon Diablo meteorite is the only one known which contains three forms of carbon, viz., black and transparent diamond, graphite and amorphous carbon.—*Compt. Rend.*, cxxxi, 483. H. L. W.

3. *A Study of Amorphous Boron.*—Moissan has investigated the nature of this substance, as prepared by reduction with an alkali-metal according to previously described methods, and finds that such products are very impure. He has succeeded, however, in preparing almost absolutely pure amorphous boron by igniting an excess of anhydrous boracic acid with magnesium powder in a crucible by means of a gas-furnace, then treating the product with acids and igniting it with more boracic anhydride, to remove some remaining magnesium boride, and washing the final product with acids. Special precautions were taken to exclude atmospheric

nitrogen, which combines with boron at high temperatures, forming the nitride. The pure amorphous boron is a powder of a light chestnut color having a density of 2·45. Its electrical conductivity is very weak, and it does not fuse at the temperature furnished by the electric arc. This observation on the infusibility of boron places this element beside carbon as an infusible substance, whereas previous observations, made with impure material, had indicated that it fused in the electric arc. The substance combines more readily with non-metals than with metals. Sodium and potassium can be distilled in contact with it without action, It burns in the air and especially in oxygen with great brilliancy. and it combines with sulphur with incandescence. It has an especially great affinity for oxygen, forming an explosive mixture with lead peroxide, and producing an active gun-powder when mixed, in place of charcoal, with sulphur and potassium nitrate. It reduces sodium carbonate with incandescence at a low red heat, potassium carbonate is reduced at a higher temperature, while calcium and barium carbonates are not reduced. It has a greater affinity for oxygen than have carbon and silicon, for it reduces the oxides of these elements at high temperatures. The powder reduces cold potassium permanganate and ferric solutions, and, by warming, it precipitates silver in a crystalline condition from silver nitrate solutions.—*Ann. Chim. Phys.*, VII, iv, Oct., 1895. H. L. W.

4. *The preparation of Tin Tetrachloride and Tetrabromide.*—The handbooks of chemistry recommend the preparation of these substances by the action of the halogens upon molten tin, but Lorenz finds that no artificial heating is necessary, and in fact, that the action is most favorable near the ordinary temperature. For the preparation of tin tetrabromide the author places solid pieces of tin in a distilling-flask and allows liquid bromine to drop upon them from a capillary opening at the end of a separatory funnel. The addition of the bromine is so regulated that the temperature of the flask is kept between 35° and 59° C. The liquid tetrabromide collects at the bottom of the flask. The product is finally distilled from the same flask in the presence of some remaining metallic tin, giving a perfectly pure, white product. For the production of the tetrachloride in large quantity a glass tube closed at the bottom, like a large test-tube, 30 or 40 inches long and 2 or 2½ inches wide, is provided with a stopper having two holes, through one of which a chlorine delivery tube extends to near the bottom of the large tube. Through the other hole, for a short distance, extends the end of an upright condenser for preventing the loss of the product towards the end of the operation. The large tube is nearly filled with granulated tin, and chlorine is passed in through the delivery-tube. It is best to have a little previously prepared tin tetrachloride in the bottom of the apparatus so that the delivery-tube dips under this liquid. Chlorine is now passed in at the ordinary temperature. Its disappearance is extraordinarily prompt, and the speed with which

the gas can be passed in is almost unlimited. As the amount of tetrachloride increases in the tube, it is necessary to raise the delivery-tube to avoid too great a pressure. The liquid is finally poured off and distilled, no purification on account of dissolved chlorine being necessary.—*Zeitschr. für Anorgan. Chem.*, ix, 365; x, 47. H. L. W.

5. *Argon and Helium.*—BOUCHARD has collected gases emanating from certain sulphur springs in the Pyrenees Mountains and has found that these consist chiefly of nitrogen, with both argon and helium. TROOST and OUVRARD, working with the argon and helium just mentioned, claim that the spectrum lines of both these elements disappear when a magnesium wire is very strongly heated by electricity in contact with the gases in a Plücker tube. The authors assume that argon and helium are capable of combining with magnesium at very high temperatures, and they state that platinum gives in argon phenomena of volatilization and combination analogous to those presented by magnesium. These conclusions evidently conflict with previous observations upon these new elements.—*Compt. Rend.*, cxxi, 392 and 394. H. L. W.

6. *Photography of Colors by the indirect method.*—A. and K. LUMIÈRE take three negatives through orange, green, and violet ray filters. To obtain a positive they employ a film on glass which contains ammonium bichromate and bromide of silver. The negative is printed upon this, and the subsequent washing develops a transparent, hardly percepible image, which only through color is strengthened to the requisite depth. This first image is flowed with collodion, which is sensitized in the same manner as the glass, and is exposed to the second negative, and, in the same manner, to the third. Repeated layers can be used to strengthen the one or the other color until the required effect is obtained.—*Comptes Rendus,* cxx, pp. 875–876, 1895. J. T.

7. *Spectrum of Carbon of the electric oven.*—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 self-purification comes from a species of distillation of the volatile impurities. The purest carbon is found at the negative pole. The following spectrum is obtained between $\lambda = 480$ and $\lambda = 220$.

Intensity.	λ.		Intensity.	λ.
8	426·70		8	283·64
5	392·17		4	274·75
4	391·97		8	264·12
2	316·83	} ?	8	251·15
1	316·57	}	8	250·79
2	299·34		10	247·88
1	296·77		8	229·70
8	283·75			

—*Comptes Rendus,* cxx, pp. 1259–1260, 1895. J. T.

8. *Measurement of high Temperatures.*—In a second paper L. HOLBORN and W. WIEN discuss the use of the increased resistance of platinum, and the use of a thermal junction of platinum and platinum-rhodium (10 per cent rhodium). They enter into a discussion of the constancy of the indications of the thermal junction. The determination of a number of boiling points of different metals by different methods was undertaken, and it was shown that the thermo element gave very constant indications, if it is protected from the action of carbon; and that the formation of platinum silicate at high temperatures in the protecting cylinders of porcelain or clay do not influence it to a marked degree. It was found with the method of the resistance of platinum, that the temperature-coefficient of the resistance was much more sensitive toward outside influences than the thermo element and that many precautions had to be taken to measure this coefficient. The formation of platinum silicate lowers not only the temperature-coefficient but also increases the resistance of the platinum. By means of an oven of clay of peculiar construction a temperature of 1570° was reached. The following table of melting points gives their results in comparison with other observers:

	Violle.	Barus.	Barus.	Holborn and Wien.
Silver	954°	986°	985°	971°
Gold	1045	1091	1093	1072
Copper	1054	1096	1097	1082
Nickel	....	1476	1517	1484
Palladium	1500	1585	1643	1587
Platinum	1775	1757	1855	1780

Violle used a calorimetric method and interpolated the specific heat of platinum from 1200° upward.

Barus used a thermo element of platinum iridium and placed the element not in the interior of the air chamber but outside. His measures extend to 1050°. The higher melting points are extrapolated. Holborn and Wien claim that very different temperatures are obtained in the inside and outside of the chamber. In order to obtain a better equilibrium of temperature, Barus causes the muffel of the oven to rotate. The constancy of the thermo element used by the authors of this paper was tested by the comparison of many determinations of melting points. With different thermo elements the determination at 1000° did not vary more than ±5°. The thermal function does not vary from year to year or from use or disuse.

Keiser and Schmidt of Berlin make, under direction of the authors, a D'Arsonval galvanometer of which the pointer moves over two scales, on one of which can be read the difference of potentials in volts; on the other the degrees of temperature indicated by the thermo element. The paper concludes with a statement of the superiority under different conditions of the method of the thermo element over the method of the resistance of platinum.—*Ann. der Physik und Chemie*, No. 10, 1895, pp. 360–396. J. T.

9. *Absorption of Kathode rays.*—The phenomenon of kathode rays is receiving much attention from various observers in Germany and England. The current number of the "Annalen der Physik und Chemie" contains two papers on this subject. P. Lenard investigates the permeability, so to speak, of many gaseous and also solid media to the kathode rays and endeavors to frame a law which will express a relation between the absorption power and the thickness of the layers. O. Lehmann criticises the results of Plücker, Hittorf, Goldstein, Crookes, Hertz, E Wiedeman and H. Ebert.—*Ann. der Physik und Chemie*, No. 10, 1895, pp. 255–275 and pp. 304–346. J. T.

II. Geology and Mineralogy.

1. *On underground temperatures at great depths;* by Alexander Agassiz (from a letter to the editors, dated Calumet, Mich., Nov. 14, 1895.)—For several years past I have with the assistance of our engineer, Mr. Preston C. F. West, been making rock temperature observations as we increased the depth at which the mining operations of the Calumet and Hecla Mining Co. were carried on. We have now attained at our deepest point a vertical depth of 4712 feet, and have taken temperatures of the rock at 105 feet, at the depth of the level of Lake Superior, 655 feet, at that of the level of the sea, 1257 feet, at that of the deepest part of Lake Superior, 1663 feet, and at four additional stations each respectively 550, 550, 561 and 1256 feet below the preceding one, the deepest point at which temperatures have been taken being 4580 feet. We propose, when we have reached our final depth, 4900 feet, to take an additional rock temperature and to then publish in full the details of our observations.

In the mean time it may be interesting to give the results as they stand. The highest rock temperature obtained at the depth of 4580 feet was only 79° F., the rock temperature at the depth of 105 feet was 59° F. Taking that as the depth unaffected by local temperature variations, we have a column of 4475 feet of rock with a difference of temperature of 20° F. or an average increase of 1° F. for 223·7 feet. This is very different from any recorded observations; Lord Kelvin, if I am not mistaken, giving as the increase for 1° F., fifty-one (51) feet, while the observations based on the temperature observations of the St. Gothard Tunnel gave for an increase of 1° F., sixty (60) feet. The calculations based upon the latter observations gave an approximate thickness of the crust of the earth, in one case of about 20 miles, the other of 26. Taking our observations, the crust would be over 80 miles and the thickness of the crust at the critical temperature of water would be over 31 miles, instead of about 7 and 8·5 miles as by the other and older ratios. With the ratio observed here, the temperature at a depth of 19 miles would only be about 470°, a very different temperature from that obtained by the older ratios of over 2000° F.

The holes in which we placed slow registering Negretti and Zambra thermometers were drilled, slightly inclined upward, to a depth of ten feet from the face of the rock and plugged with wood and clay. In these holes the thermometers were left from one to three months. The average annual temperature of the air is 48° F., the temperature of the air in the bottom of the shaft was 72° F. A. A.

2. *Geological Atlas of the United States.*—The first number of this great work of the United States Geological Survey has been completed and issued in twelve separate folios. Each folio contains, on sheets of heavy paper, 18½ by 21½ inches in size, two or more pages of description, four maps, and sometimes a fifth, illustrating the topography, the areal geology, the economic geology and the structural geology of the particular area surveyed; a fifth map-sheet, containing column sections, is added in several of the folios. On the inside of the stiff manilla covers is printed explanations of the topographic map, the geologic map and their uses. The scale of the maps in this atlas is mainly of the medium size adopted, viz. $\frac{1}{125,000}$; the sheets of the Livingston folio are of the smaller scale, $\frac{1}{250,000}$, and those of Anthracite-Crested Butte folio are of the $\frac{1}{62,000}$ scale. The Cripple Creek special map (in folio 7) is on the still larger scale of $\frac{1}{25,000}$. Contour intervals of 200 feet are expressed on the maps of the smaller scale, of 100 feet in the medium and larger scale, and of 50 feet in the special Cripple Creek map.

The geological features of the regions are expressed on the maps by colors and various patterns of dots and circles, and tints, overprinted or underprinted, and letter symbols, the meaning and use of which are clearly defined in the general explanation on the covers and in the special legend of each map. The maps are models of artistic beauty and perfection, and were engraved and printed by the U. S. Geological Survey, Bailey Willis editor, and S. J. Kübel chief engraver.

In the first number of the Atlas are the following twelve folios:

1. Livingston folio, Montana, by Iddings and Weed geologists, Arnold Hague in charge.
2. Ringold folio, Georgia-Tennessee, by C. W. Hayes.
3. Placerville folio, Cal., by Lindgren and Turner, Becker in charge.
4. Kingston folio, Tenn., by C. W. Hayes.
5. Sacramento, Cal., by Lindgren, Becker in charge.
6. Chattanooga, Tenn., by C. W. Hayes.
7. Pike's Peak, Col., by Whitman Cross.
   With a special sheet, the Cripple Creek special map also by Mr. Cross.
8. Sewanee, Tenn., by C. W. Hayes.
9. Anthracite-Crested Butte, Col., by Cross and Eldridge, Emmons in charge.
10. Harpers Ferry, Va., Md., W. Va., by Arthur Keith.
11. Jackson, Cal., by H. W. Turner, Becker in charge.

12. Esteville, Ky., Va., Tenn., by M. R. Campbell, B. Willis in charge

The following folios are also ready for distribution :

13. Fredericksburg, Md., Va.
14. Staunton, Va., W. Va.
15. Lassen Peak, Cal.
16. Knoxville, Tenn., N. C.
17. Marysville, Cal.
18. Stuartsville, Cal.
19. Stevenson, Ala., Ga., Tenn.
20. Cleveland, Tenn.

They are prepared by the U. S. Geological Survey and may be had for the price of twenty-five cents each from the Director of the Survey. The sheets of the Atlas began to appear in 1873.

H. S. W.

3. *Economic and Geologic Map of New York State.*—Mr. F. J. H. MERRILL, the Director of the New York State Museum, has prepared a small map, on a scale of about 14 miles to the inch, in which are indicated by colors and symbols the geological formation and the localities of economic minerals of the state. The geological features are based upon the map of 1844, with additions and corrections derived from maps and papers more recently published, and the unpublished material furnished by H. P. Cushing, W. B. Dwight, H. L. Fairchild, P. F. Schneider, F. J. H. Merrill, C. S. Prosser, Heinrich Ries and C. H. Smyth, Jr. The chief modifications of the geology from the older maps are seen in the areas of Cambrian and Pre-Cambrian, and of Devonian. In regard to the former the recent clearing up of the "Taconic controversy" has resulted in a more accurate delineation of the areas along the eastern border of the state. The results of recent studies in classification and areal distribution of the Devonian formations, is seen in the more accurate delineation of the areas of its three chief formations ; the Upper Helderberg, Hamilton and Chemung. We notice that no attempt is made to distinguish the Olean from the underlying Upper Devonian formations, and a single color is used for all the formations from the top of the Hamilton upward to the Carboniferous, The upper limit of the Hamilton is evidently traced through the central part of the state by the Tully limestone, and as this is wanting in the western and eastern parts of the state, the limit is apparently placed at the point in the succession where the first representatives of neo-Devonian faunas begin, rather than where the meso-Devonian species cease. This draws the line at the one point in the series where the faunal change is evident in such sections as lack the lithological change from shales to limestone. If geologists, studying this part of the series, will bear in mind that the Tully limestone faunally belongs with the upper (Chemung) rather than with the lower (Hamilton) faunas, they will not be confused in determining their horizon in Chenango County and the counties eastward, where the Tully limestone

phase is wanting, and some of the lower species occur above the base of the Chemung formation. H. S. W.

4. *Lakes of North America;* by ISRAEL C. RUSSELL, pp. 1–125, figs. 1–9, Plates 1–23, Boston, 1895 (Ginn & Co.).—This little book, which its author modestly calls "a reading lesson for students of geography and geology," is more than a geological treatise on the nature and significance of lakes in the surface topography of the country. While it lacks nothing of scientific precision, and the orderly arrangement of the subject-matter is all that a specialist could wish, there is, also, something of that indescribable literary flavor found in Humboldt's "Ansichten der Natur" which indicates not only a thorough knowledge and appreciation of the details of the topography, but an esthetic sense of what constitutes the beautiful in a landscape.

As an illustration, in the midst of a description of the location and dimensions of Lake Tahoe, the author observes: "On looking down on Lake Tahoe from the surrounding pine-covered heights, one beholds a vast plain of the most wonderful blue that can be imagined. Near shore, where the bottom is of white sand, the waters have an emerald tint, but are so clear that objects far beneath the surface may be readily distinguished. Farther lakeward, the tints change by insensible gradation until the water is a deep blue, unrivaled even by the color of the ocean in its deepest and most remote parts. On calm summer days, the sky with its drifting cloud banks and the rugged mountains with their bare and usually snow-covered summits, are mirrored in the placid waters with such wonderful distinctness and such accuracy of detail that one is at a loss to tell where the real ends and the duplicate begins, etc." This is immediately followed by a scientific definition of the transparency as rendering a white disc 9·5 inches in diameter visible at a depth of 108 feet, the light traversing twice that distance through the water to reach the eye. The various chapters discuss in a brief but satisfactory manner the origin of lake basins, the movements of lake waters and their geological functions, the topography of shores, and the relation of lakes to climate and to time. The facts are largely derived from the author's own observations, which have been more elaborately described in the various publications of the United States Geological Surveys. He has also drawn from the observations of other workers in this field, as Gilbert, Davis, Dawson, Dutton, King, LeConte, Upham, Warren and others. A supplementary note on the classification of lakes by Wm. M. Davis closes this very readable book. H. S. W.

5. *Phonolitic Rocks from Montana;* by WALTER HARVEY WEED. (Communicated.)—The writer has recently returned from a reconnaissance trip through the Bear Paw mountains, Montana, where the two phonolitic rocks described in the November number of this Journal (vol. l, p. 394, 1895) were found in place. The mountains present a fine example of a group of dissected volcanoes. A large part of the area is covered by extrusive basaltic

rocks, scorias, breccias, and lava flows, while in the central portion of the range massive igneous rocks are well exposed as stocks, breaking up through but slightly disturbed Cretaceous strata. The basalts are probably leucitic and closely resemble those of the Highwood mountains. The rocks described occur as dikes cutting metamorphosed Cretaceous beds, and are found in the central portion of the mountains.

A further account of the geology and of the unusual rock types of this mountain group will be published jointly with Professor Pirsson at a future date.

6. *Crystallography: A Treatise on the Morphology of Crystals;* by N. Story-Maskelyne, M.A., F.R.S., Professor of Mineralogy, Oxford. 521 pp., Oxford, 1895 (The Clarendon Press).—More than fifty years have passed since Professor W. H. Miller published his classical work on Crystallography, which he based in part upon methods already known, but at the same time developed from them in a manner wholly his own, a system which has ever since borne his name. Early adopted by a limited school of Austrian crystallographers, it has gradually won for itself recognition, until now there are few workers who have not given proof of their conviction as to its superiority by adopting it. During this time many important works on Miller's System have been published both in German and French, but until now no notable contribution to it has been made in his own language. The present work of Professor Story-Maskelyne goes far to reconcile us for this long gap since in thoroughness and fullness of treatment it leaves nothing to be desired. The public may congratulate itself that the gifted author has felt finally ready to give to it the manuscript that he has had so long in preparation. The volume is limited to the Morphology of Crystals, discussing in detail the relations between the planes of a system, the properties of zones, the kinds of symmetry, the six crystalline systems and the methods of measurement and calculation of crystals. The whole is developed with admirable clearness and system, and will be studied carefully by all interested in this branch of science. The author promises a companion volume, dealing with the physical side of crystallography, and it is to be hoped that this may not be long delayed.

III. Botany.

1. *Missouri Botanical Garden. Sixth Annual Report.* St. Louis, 1895.—From the present report will be missed, but by no means as a real want, the full account of the proceedings at the two annual banquets instituted by Mr. Shaw, and the annual "Flower Sermon," which has not been, as a rule, particularly edifying. The trustees have been wise in dropping these matters and bringing out into their deserved prominence the excellent botanical contributions by the Director and others. Professor Trelease gives an admirable monograph on the interesting mono-

typic Leitneria, hitherto known with certainty only in Florida, but now discovered in the lowlands of southeastern Missouri. Mr. Jared G. Smith contributes a revision of the North American species of Sagittaria and Lophotocarpus, describing rather more than twenty of the former. He also, in a separate paper, notes a few facts relative to some new or little known species. Mr. Herbert J. Webber publishes some striking observations regarding the dissemination of certain species of Yucca, and comments on its relation to leaf-reflexion. Mr. B. F. Bush contributes interesting notes in regard to the plants which occur on the mounds in Atchison county, Missouri. The illustrations by Miss Johnson are, like those from her pencil in previous reports, remarkably spirited as well as accurate. G. L. G.

2. *Index Kewensis.*—An enumeration of the genera and species of flowering plants from the time of Linnaeus to the year 1885 inclusive, together with their authors' names, the works in which they were first published, their native countries and their synonyms; compiled at the expense of the late Robert Charles Darwin, under the direction of Joseph D. Hooker, by B. Daydon Jackson. Part IV, Oxford, Clarendon Press. 1895.

This part finishes the treatise which botanists in all departments owe to the generosity of Mr. Darwin. Sir Joseph Hooker gives in the preface the following interesting account of the inception of the work:

"Shortly before his death, Mr. Darwin informed me of his intention to devote a considerable sum in aid of the furtherance of some work of utility to biological science; and to provide for its completion should this not be accomplished during his lifetime. He further informed me that the difficulties he had experienced in accurately designating the many plants which he had studied and ascertaining their native countries had suggested to him the compilation of an index to the names and authorities of all known flowering plants and their countries as a work of supreme importance to students of systematic and geographical botany, and to horticulturists, and as a fitting mode of fulfilling his intentions.

"I have only to add that at his request I undertook to direct and supervise such a work, and that it is being carried out at the Herbarium of the Royal Gardens, Kew, with the aid of the staff of the establishment."

Even taking into account the errors both of date and name which unavoidably creep into a nomenclator planned on a scale so broad as to comprehend the generic and specific appellations bestowed during almost a century and a half, this work has fully carried out the liberal intentions of its patron. It is, as he predicted, indeed of supreme importance to the students of botany in every field. It is, moreover, a lasting monument to the sagacity of Sir Joseph Hooker, who framed the page with full regard to convenience and rapidity of reference, and, lastly, it gives evidence, throughout, of conscientious work on the part of Mr. Jackson and his associates. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *Le Pétrole, L'Asphalte et le Bitume au point de vue géologique* par A. Jaccard. 292 pp. Paris, 1895 (Félix Alcan)—Bibliotheque scientifique, lxxxi.—The subject to which this volume is devoted is one of high scientific interest as well as great economic importance. The author, M. Aug. Jaccard, who died at Locle, Switzerland, on the 5th of January of the present year, had devoted much of his life to the study of this department of geology and his clear, systematic presentation will be found interesting and valuable. He gives a critical history of the various scientific theories in regard to the origin of petroleum, from the time of von Buch (1801); he also discusses its mode of formation and the important deposits. A later account is given of bitumen, asphaltum, natural gas, etc. The closing chapter contains some statistics in regard to the production of petroleum and suggestions in regard to its future. The author declares himself strongly in favor of the sedimentary and organic origin of the deposits of hydrocarbons as opposed to the eruptive and inorganic; he also repeatedly argues that it is unnecessary to invoke violent causes to explain the observed facts. Further he urges that many authors have confounded the original formation of bitumen with the subsequent phenomenon of its reappearance at the surface.

2. *Les Aurores polaires* par Alfred Angot. 318 pp. 8vo. Paris, 1895 (Félix Alcan)—Bibliothèque scientifique internationale publiée sous la direction de M. Ém. Alglave, lxxx.—An interesting and popular account is given of auroras in their many forms; numerous excellent illustrations show some of the most remarkable occurrences. The various theories advanced to account for auroras are detailed, and preference is given to that of Edlund, based on unipolar induction, as being most satisfactory (Swedish Acad., vol. xvi, 1878). An appendix, of 90 pages, gives a catalogue of auroras observed in Europe below lat. 55° from 1700 to 1890.

3. *Une Excursion en Corse*—Prince Roland Bonaparte. 273 pp. Paris, 1891.—This handsome volume is an interesting account of a visit by Prince Roland Bonaparte to Corsica in 1887. The scientific observations made, in physical geography, geology, anthropology, etc., were presented at a meeting held in Berne on December 18, 1889. The story of the trip, its incidents, the picturesque features of that charming region, are here presented in most readable form. Several beautiful views add charm to a very attractive volume. An extensive bibliography of works relating to Corsica fills the latter half of the work.

William Wesley & Son: The Natural History and Scientific Book Circular, No. 124: Astronomy, including works from the Libraries of Sir G. B. Airy, F.R.S., and A. C. Ranyard, F.R.A.S. 56 pp, including 1789 numbered works.

INDEX TO VOLUME L.*

* This Index contains the general heads, BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS, and under each the titles of Articles referring thereto are mentioned.

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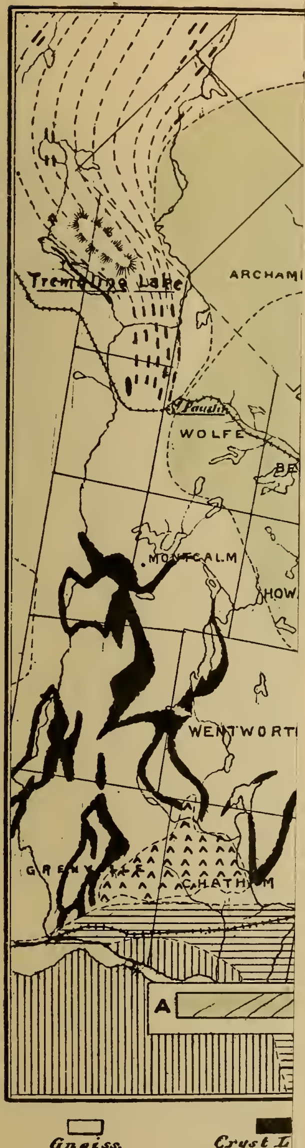
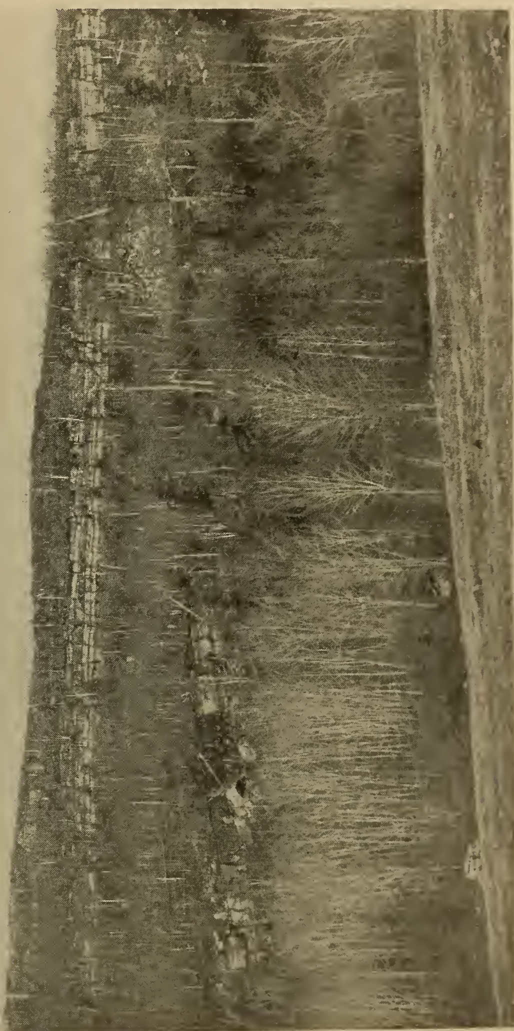


MAP OF A PORTION OF TH

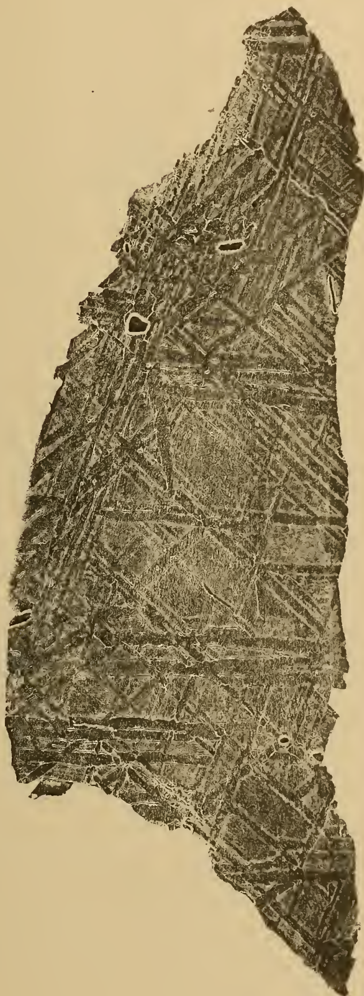
Gneiss, Cryst Limestone, Anorthosite, Syenite & Granite, Cambrian, Lower Silurian,

0 5 10 20 Miles

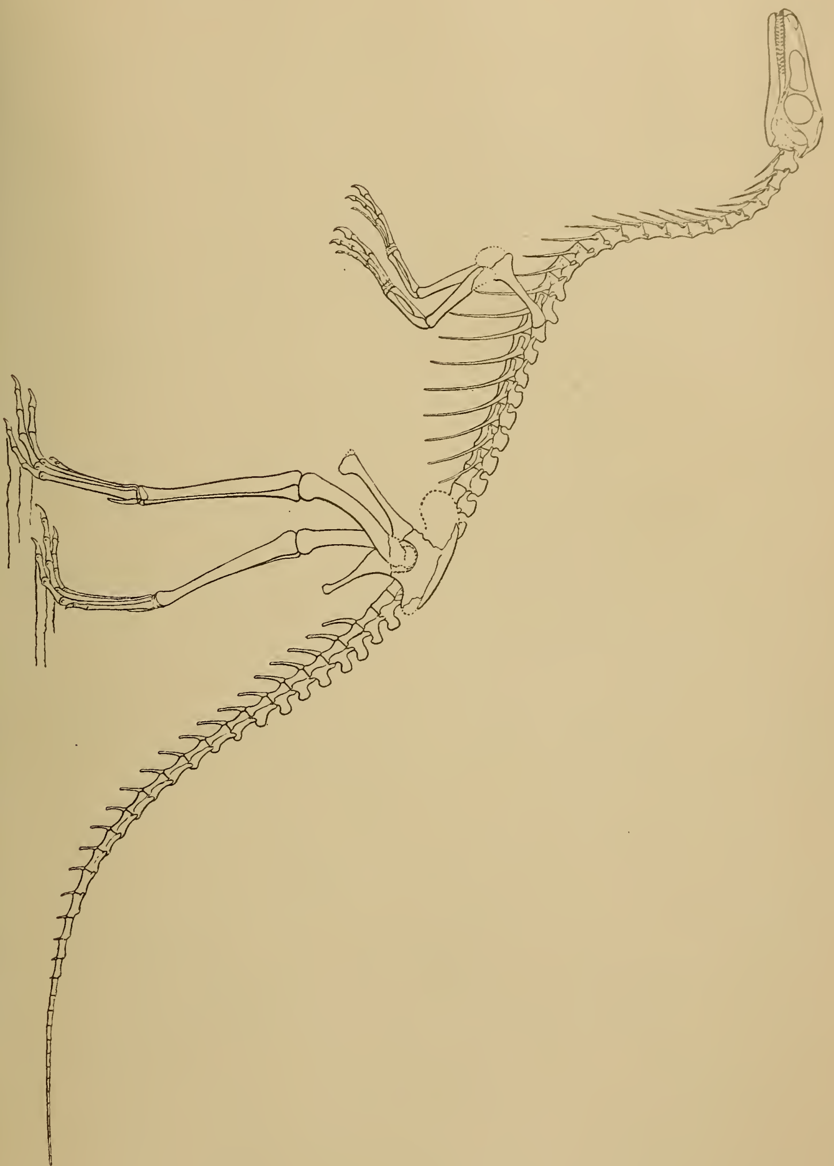
MAP OF A PORTION OF THE EDGE OF THE ARCHEAN PROTAXIS NORTH OF THE ISLAND OF MONTREAL, QUEBEC.



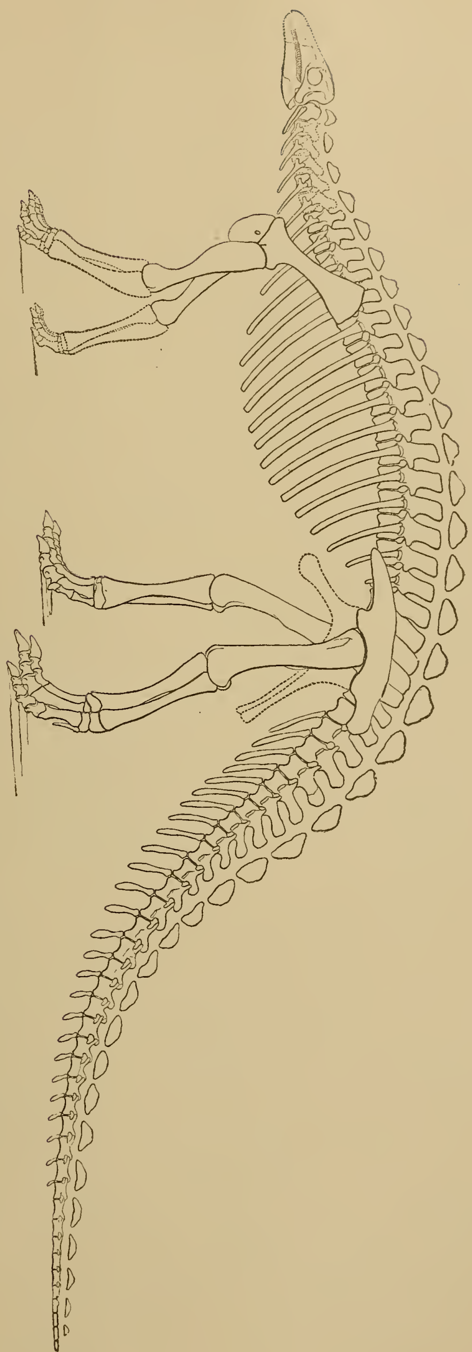
CLIFF COMPOSED OF WHITE GARNETIFEROUS QUARTZITE INTERBANDED WITH GARNETIFEROUS AND SILLIMANITE GNEISSES, NEARLY FLAT (LAURENTIAN). 2 MILES N. W. OF ST. JEAN DE MATHA, QUEBEC.



The Cherokee Meteorite.



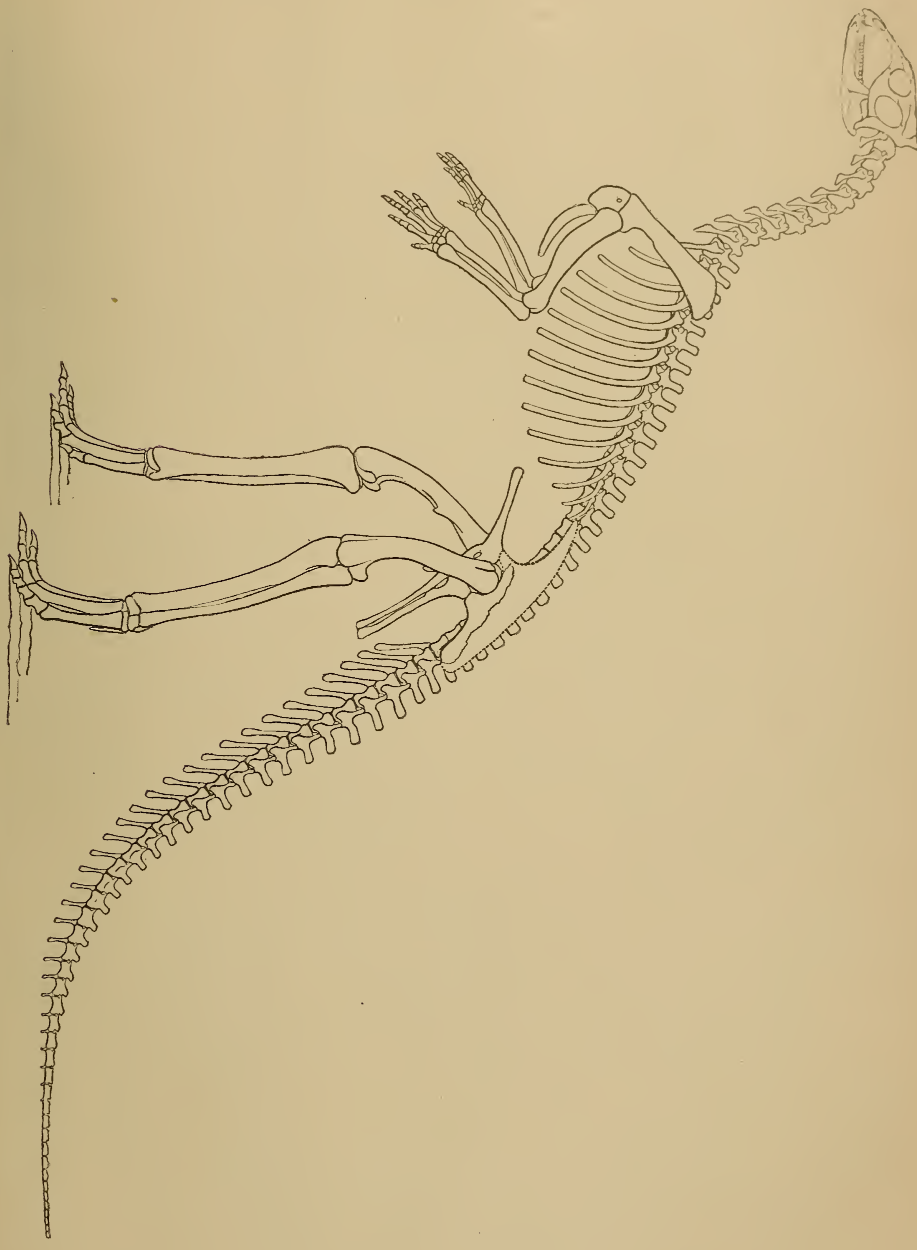
Restoration of COMPSOGNATHUS LONGIPES, Wagner. One-fourth natural size. Jurassic, Bavaria.



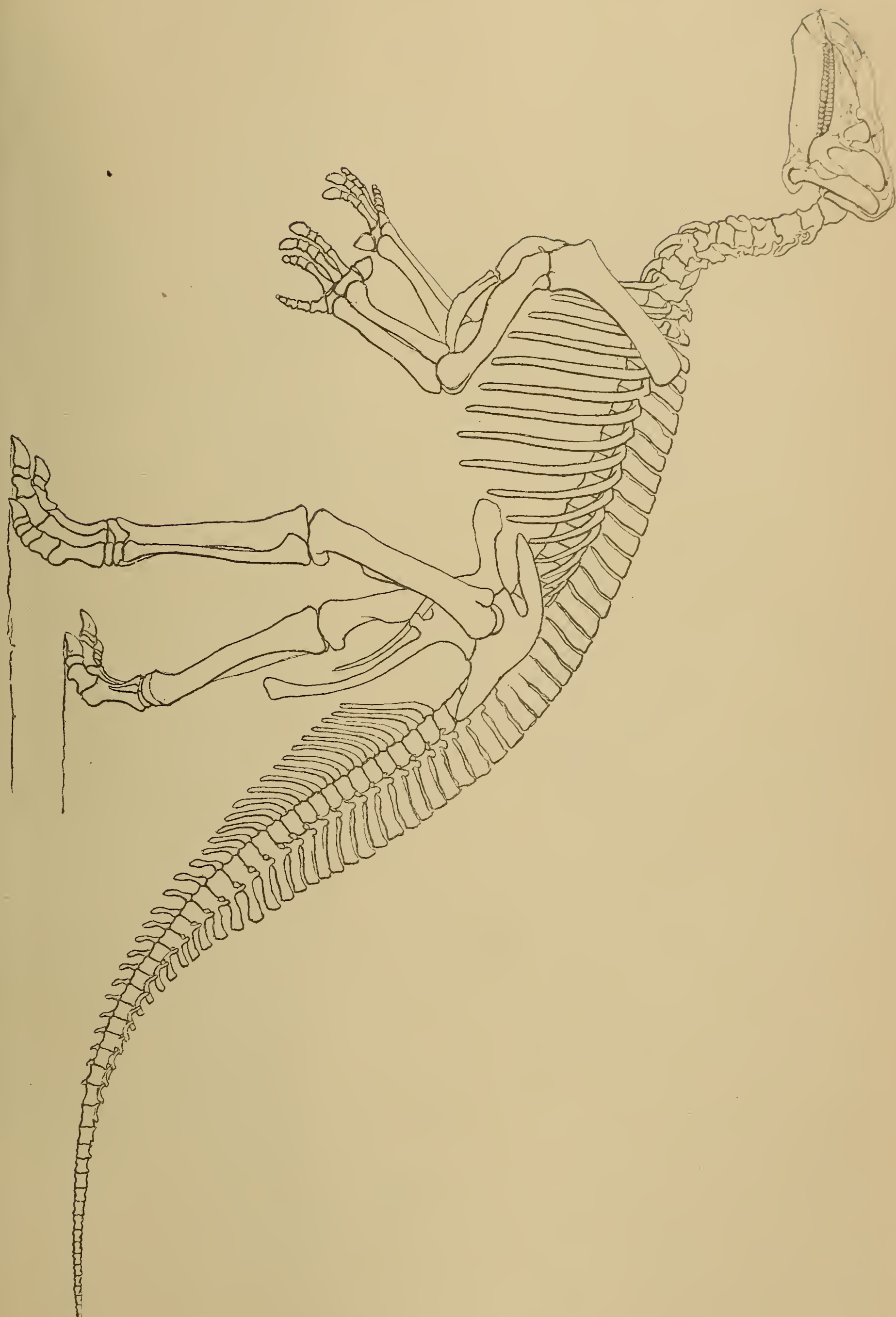
Restoration of SCELIDOSAURUS HARRISONII, Owen. One-eighteenth natural size. Jurassic, England.

Am. Jour. Sci., Vol. L, 1895.

Plate VII.

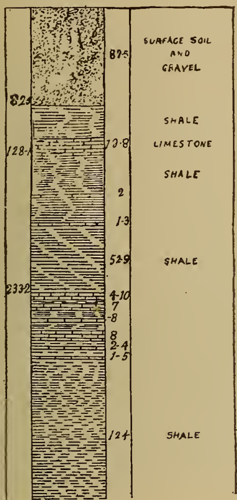


Restoration of Hypsilophodon Foxii, Huxley. One-eighth natural size. Wealden, England.

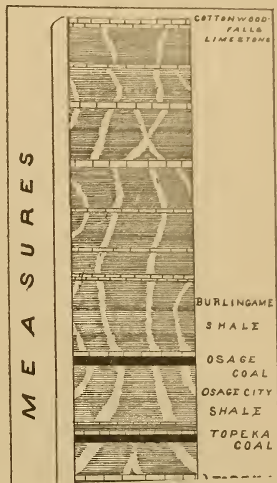


Restoration of Iguanodon Bernissartensis, Boulenger. One-fortieth natural size. Wealden, Belgium.

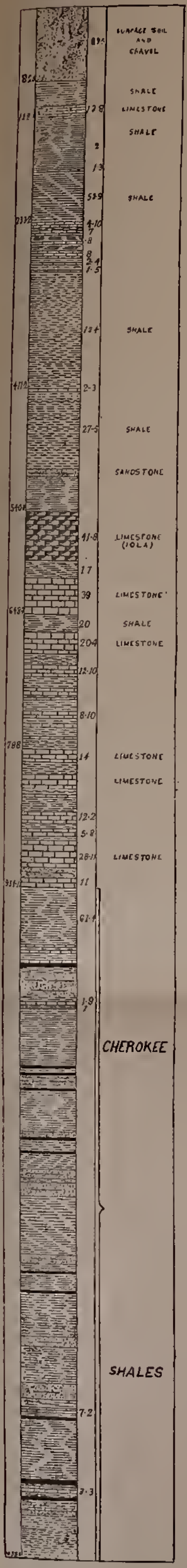
Topeka Well,
Diamond Drill Core.
Scale 150 feet = 1 inch.



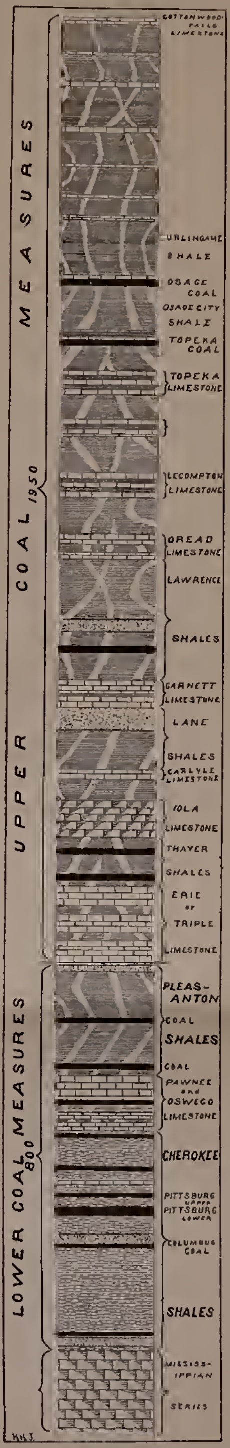
General Section of
Coal Measures.

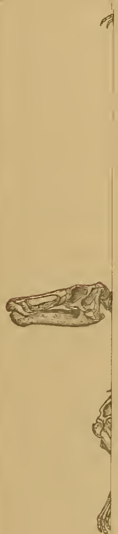


Topeka Well,
Diamond Drill Core.
Scale 150 feet=1 inch.



General Section of
Coal Measures.





12.-

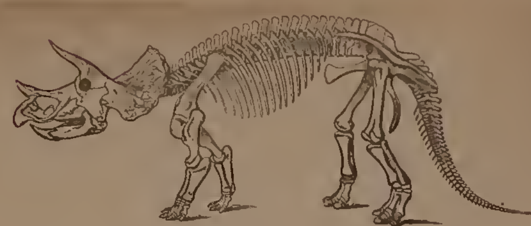
ARSH.

1.—ANCHISAURUS COLURUS, Marsh. [illegible] Triassic, Connecticut.

2.—BRONTOSAURUS EXCELSUS, Marsh. [illegible] Jurassic, Wyoming.

3.—COMPSOGNATHUS LONGIPES, Wagner. [illegible] Jurassic, Bavaria.

9.—HYPSILOPHODON FOXII, Huxley. [illegible] Cretaceous, England.

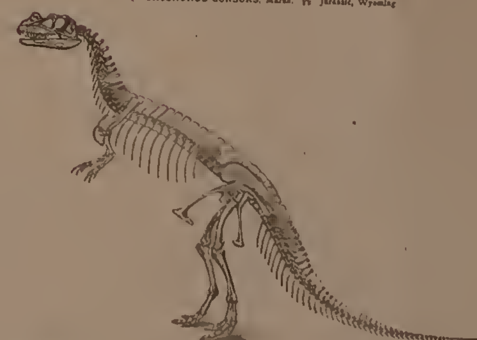


10.—TRICERATOPS PRORSUS, Marsh. [illegible] Cretaceous, Wyoming.

4.—LAOSAURUS CONSORS, Marsh. [illegible] Jurassic, Wyoming.

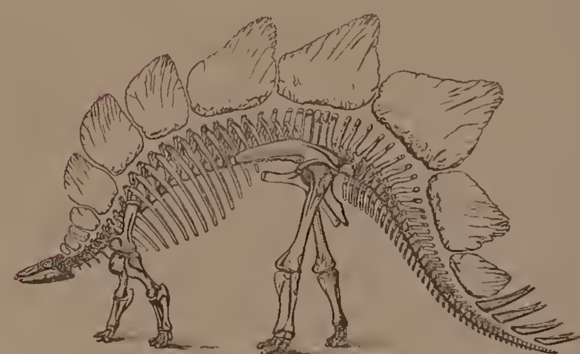
7.—CAMPTOSAURUS DISPAR, Marsh. [illegible] Jurassic, Wyoming.

6.—SCELIDOSAURUS HARRISONII, Owen. [illegible] Jurassic, England.



5.—CERATOSAURUS NASICORNIS, Marsh. [illegible] Jurassic, Colorado.

11.—IGUANODON BERNISSARTENSIS, Boulenger. [illegible] Cretaceous, Belgium.



8.—STEGOSAURUS UNGULATUS, Marsh. [illegible] Jurassic, Wyoming.

12.—CLAOSAURUS ANNECTENS, Marsh. [illegible] Cretaceous, Wyoming.

RESTORATIONS OF DINOSAURIAN REPTILES; BY O. C. MARSH.

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☞ In the references to volumes xli to l, only the numerals i to ix are given.

NOTE.—The names of minerals are inserted under the head of MINERALS; all obituary notices are referred to under OBITUARY. Under the heads BOTANY, CHEMISTRY, GEOLOGY, ROCKS, the references to the topics in these departments are grouped together; in many cases, the same references appear also elsewhere.

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