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SCIENTIFIC INTELLIGENCE.

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[THIRD SERIES.]

ART. I.—*Contributions to Meteorology: being results derived from an examination of the observations of the United States Signal Service, and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Fourteenth paper, with Plates I, II, III.

[Read before the National Academy of Sciences, New York, Nov. 18, 1880.]

THE object of this paper is to investigate the course and velocity of storm centers in Tropical regions and also in the middle latitudes, and hence to deduce the causes which control their movements.

Course and velocity of storm centers in Tropical regions.

In my fifth paper (this Journal, vol. xii, p. 15,) I gave a table showing the course of those hurricanes which have originated near the West India Islands. That table was prepared in pursuance of a plan to determine the course of storms under the greatest variety of circumstances; and since the table exhibited but a small part of the information which I desired to obtain, I did not attempt to develop the conclusions which it naturally suggested. Soon after the publication of that paper, I prepared another table showing the course of hurricanes in the India and China Seas; but as this did not furnish all the information that I desired, I have hitherto withheld it from publication in expectation of more complete information. The system of International Meteorological observations has in part supplied the desired information, so that I propose now to consider the results already attained.

I have compared all the storm tracks delineated on the maps of the Monthly Weather Review, and also those delineated on the International charts. I first examined the storms which have prevailed in the neighborhood of the American continent, confining myself to those cases in which the storm center (during at least a part of its course) was south of the parallel of 30° latitude. I have divided these storms into three classes; I, those whose course was for some days towards the west: II, those whose course was towards some point between the south and east; III, those whose course was towards some point between the north and east.

The following table shows the leading particulars respecting the first of these classes. Column 1st shows the number of reference; column 2d shows the dates of beginning and end of the observed movement as long as the course continued westerly; column 3d shows the latitude at the beginning and end of this portion of the path; column 4th shows the longitude at the beginning and end of this portion of the path; column 5th shows the prevalent direction of the path while moving westerly; column 6th shows the average velocity of progress of the storm center (in miles per hour) while the course continued westerly; column 7th gives a brief indication of the subsequent course of each storm. On plate I these tracks are delineated and are designated by the same numbers as in the table.

American storms advancing Westerly.

No.	Date.		Latitude. beg. end.	Longitude. beg. end.	Course.	Vel., miles.	Subsequent course.
			° °	° °			
1	1873.	June 1.1– 2.3	24–32	80– 86	N.N.W.	12·5	Became extinct.
2		Oct. 2 – 4.2	22–24	82– 86	N.W.	9·5	Moved N.E.
3	1874.	Feb. 7 – 8.1	24–27	82– 83	N.N.W.	15·4	Moved N.E.
4		July 2.3– 4.2	27–29	87– 98	W.N.W.	13·1	Became extinct.
5		Sept. 4.3– 5.3	25–32	65– 70	N.N.W.	22·5	Moved N.E.
6	1875.	Sept. 8.3–17.1	14–29	59– 96	W.N.W.	13·2	Moved N.E.
7	1876.	Sept. 15 –18.1	21–43	69– 80	N.N.W.	25·9	Moved E.
8	1877.	Sept. 22.2–30.3	12–26	65– 88	W.N.W.	11·1	Moved N.E.
9	1878.	Aug. 12 –18	14–21	75– 97	W.N.W.	14·4	Unknown.
10		Sept. 1 – 8	11–28	59– 81	W.N.W.	9·3	Moved N.
11		Sept. 12 –18	14–29	47– 60	N.W.	9·6	Moved N.E.
12		Sept. 24 –30	14–28	70– 73	N.N.W.	5·3	Moved N.E.
13		Sept. 29 –34	22–30	58– 70	N.W.	9·1	Moved N.E.
14		Oct. 9 –13	15–26	40– 52	N.W.	7·2	Moved N.E.
15		Oct. 13 –18	17–30	36– 55	N.W.	13·2	Moved N.
16		Nov. 25 –30	15–17	52– 73	West.	11·7	Unknown.
17	1879.	Aug. 13 –17	18–30	60– 77	N.W.	8·2	Moved N.E.
18		Aug. 15 –16	14–14	43– 51	West.	?	Unknown.
19		Aug. 20 –23	16–29	87– 94	N.W.	8·2	Moved E.
20		Oct. 3 – 7	15–31	78– 90	N.W.	8·1	Became extinct.
21		Oct. 10 –17	14–43	70– 90	N.W.	11·1	Moved E.
22	1880.	Aug. 6 –14.2	12–32	77–103	W.N.W.	12·9	Disappeared.
23		Aug. 15 –19	13–20	62– 78	W.N.W.	12·0	Moved N.E.
24		Aug. 24 –31	26–33	60– 89	W.N.W.	10·0	Disappeared.

The general results of this table correspond very closely with those deduced from the table in my 5th paper. The lowest latitude of any storm center shown in this table is 10°·6 N. The lowest latitude shown in my 5th paper was 10°·3 N. The average velocity of these storms while moving westerly was 11·9 English statute miles per hour; the average velocity of the storms mentioned in my 5th paper while moving westerly was 17·4 miles per hour. In nine of these cases the course of the storm became due north before reaching the parallel of 30°.

Storm No. 18 apparently moved directly west; and storms Nos. 9 and 16 apparently moved for a day or two a little south of west. The table in my 5th paper shows 31 cases in which the course of storms was towards the north of west, and only two cases in which the course was south of west, viz: one case in which the course was two degrees south of west, and the other eleven degrees south of west. From the two tables we perceive that the cases in which tropical storms move in a direction north of west are fifteen times as frequent as the cases in which they move in a direction south of west, and in none of the cases here reported was the southerly motion very decided. Since in the middle latitudes the average progress of storm centers corresponds pretty nearly with the average direction of the wind, it might have been inferred that within the region of the northeast trade winds the average progress of storms should be towards the southwest.

In order to determine whether, during the period here considered, there may not possibly have been other storms which moved in a direction south of west, I have made a careful comparison of the International Observations. Five-sixths of all the storms enumerated in the table on page 2, occurred in the months of August, September and October. I therefore selected these three months for special comparison. For the years 1876, 7, 8 and 9 the barometric curves were drawn for these months for all the stations reported in the International Bulletin between the equator and lat. 26° N.

An examination of these curves shows that at all of these stations the fluctuations of the barometer are very small, particularly for the stations nearest to the equator. At Paramaribo, lat. 5° 45′ N. the entire range of the barometer for these twelve months was only 0·20 inch, and there was no oscillation which can be identified with an oscillation at either of the other stations. At Bridgetown, lat. 13° 4′ N., the entire range of the barometer for these twelve months was 0·23 inch. Two or three of the barometric oscillations at this station can probably be identified with oscillations at some of the other stations. The track of storm No. 9 can apparently be traced back to Bridgetown on the 10th of Aug., 1878. At Fort de France, lat. 14° 40′ N., the entire range of the barometer for these twelve months was 0·42 inch, and six or seven of the barometric oscillations at this station can probably be identified with oscillations at some of the other stations.

Besides the areas of low barometer enumerated in the table on page 2, there are but few others during this period which can be traced with confidence from one station to another. In 1876, the number of stations of observation in the tropical regions was small, and the storm of Sept. 15–18 is the only one which can be satisfactorily traced from these observations.

In 1877, the center of storm No. 8 passed at a considerable distance from all of the reporting stations, and is only obscurely indicated by the published observations. On the 26th of August, a small but well-marked barometric depression occurred almost simultaneously at all of the stations from Fort de France to Havana. On the 17th and 18th of October, there was a noticeable fall of the barometer, which apparently advanced from San Juan de Porto Rico to Havana.

In 1878, from Sept. 15th to 16th, a small barometric depression traveled from Bridgetown to Santiago de Cuba. From the 2d to the 3d of October, a small barometric depression traveled from Fort de France to Nassau. On the 21st of October, there was a decided barometric depression at Vera Cruz and Havana, which advanced northerly along the coast of the United States, and was marked by great violence.

In 1879, from the 16th to the 18th of August, a small barometric depression traveled from Bridgetown to San Juan de Porto Rico. This was perhaps a continuation of No. 18, of the table on page 2, and if so, it shows that this storm veered a little to the north of west, like most of the storms of this region. On the 28th of August, a small barometric depression appeared almost simultaneously at all the stations from Navassa to Tlacotalpam, on the coast of Mexico. This depression apparently advanced northward, but the published observations are not sufficient to enable us to trace its course satisfactorily.

This examination has disclosed a few barometric depressions in addition to those enumerated in the table on page 2, but their courses were generally towards the north of west. We therefore seem authorized to conclude that nearly all the areas of low barometer which occur within the tropics and advance westward, in the neighborhood of the West India Islands, instead of following the ordinary course of the Trade Winds, advance in a direction somewhat north of west.

American storms advancing in a Southeasterly direction.

During the colder months of the year, storms while crossing the United States frequently advance, during a portion of their course, in a direction from northwest to southeast. This direction is not confined to any particular section of the country, but occurs most frequently in the region between the Rocky Mountains and the Mississippi River. This course is seldom maintained as far south as the parallel of 30°, and after reaching its most southerly point, the storm frequently changes its course towards the northeast. The following table shows those cases in which storms have advanced towards the southeast as far as the parallel of 28°. The arrangement is similar to that of the preceding table. The first six columns describe each storm as long as its course continued southeasterly; the last column gives some indication of the subsequent course of each storm. The tracks of these storms are all delineated on Plate II, and are designated by the same numbers as in the table.

American storms advancing Southeasterly.

No.	Date.		Latitude. beg. end.	Longitude. beg. end.	Course.	Vel., miles.	Subsequent course.
1	1874.	Feb. 17.2–18.2	33°–27°	86°– 79°	S.E.	21·8	Unknown.
2		April 15.3–16.3	41–26	101– 89	S.E.	21·1	Unknown.
3	1875.	Jan. 15.1–16.2	44–27	106– 91	S.E.	27·1	Unknown.
4	1876.	Feb. 3 – 4.1	33–28	98– 80	S.E.	28·4	Unknown.
5		March 6.2–12.1	47–27	127– 89	S.E.	15·7	Unknown.
6		May 6.3– 7.3	33–27	100– 93	S.E.	25·0	Unknown.
7	1877.	Jan. 4.2– 5.3	46–28	100– 90	S.S.E.	40·4	N.E.
8		Mar. 21.2–24.1	42–28	100– 95	S.S.E.	22·5	N.E.
9		Dec. 19 –20	44–28	102– 98	S.E.	10·0	N.
10		Dec. 22 –27.2	47–27	102– 95	S.E.	29·7	N.E.
11	1878.	Feb. 1.1– 2.3	33–26	96– 84	S.E.	18·3	N.E.
12		Aug. 20.2–24.2	38–22	83– 81	S.S.E.	15·1	Became extinct.
13		Nov. 16.2–17.2	28–24	102– 93	S.S.E.	24·0	N.E.
14	1879.	Jan. 6.3– 7.3	38–27	110– 98	S.E.	39·2	N.E.
15		Jan. 8.3–11.1	49–27	119– 98	S.E.	30·4	N.E.
16		May 4.1– 6.1	34–24	101– 96	S.S.E.	16·1	Became extinct.

We see from this table that the average velocity of these storms while pursuing their course towards the southeast, was twenty-four miles per hour, which differs but little from the average velocity of storms in other parts of the United States. The lowest latitude attained by any of these storms was $22\frac{1}{2}$ degrees; and in only three cases did the low center reach the parallel of 25 degrees. In eight cases the storm center, after completing its course towards the southeast, changed its course and proceeded towards the north or northeast. In two of the remaining cases the intensity of the storm declined in advancing southward, and they apparently became extinct soon after the dates given in the table. The same was probably true in the six remaining cases, but the observations are not sufficient to establish this with certainty.

Storm No. 12 was quite peculiar, having pursued a path almost directly opposite to that of ordinary storms. During the afternoon of Aug. 20th, 1878, there was an area of low pressure (29·75) over West Virginia, being part of a greater depression whose center was over Newfoundland, and there was a slight tendency to the formation of an independent system of circulating winds. Owing to a slight increase of pressure on the north side, this low area was crowded southward, and in the afternoon of Aug. 21st assumed the character of an independent low area (29·78) with a feeble system of circulating winds. At 7.35 A. M. Aug. 22d, this low center had been crowded south to lat. 30°, the greatest observed depression being now 29·88. After this the pressure increased, and the low center could not be distinctly traced. This example appears to illustrate the general character of areas of low pressure, and shows that their progressive movement is not due to a simple drifting of the atmosphere, but rather to a diminution of pressure on one side of the low area and an increase of pressure on the other side. In the present case, there was scarcely any appreciable diminution of pressure on the south side, and only a slight increase of pressure on the north side.

American Storms advancing Northerly and Easterly.

The storms which cross the United States north of the parallel of 38 degrees, generally pursue a course a little to the north of east; while those which come from the region south of lat. 38 degrees generally pursue a course nearly northeast, especially in the neighborhood of the Atlantic coast. During the summer months few storm-centers travel south of the parallel of 38°, and during this period the average course of storms is almost exactly towards the east.

The following table shows those cases in which storms have traveled northward and eastward, and came from a point as far south as lat. 26°. The arrangement of the table is similar to that of the preceding. Columns 3 and 4 show the position of the storm-center at the beginning and end of the northeasterly motion, as far as is indicated by the observations; column 7th shows the lowest pressure reported, and column 8th gives a brief indication of the previous course of the storm. On Plate III these tracks are delineated and are designated by the same numbers as in the table.

We see from this table that storms of this class occur most frequently in the autumn, and least frequently in summer. One of these storms began near lat. 15°; two began near lat. 20°; and seventeen of them began south of lat. 24°.

American storms advancing Northerly and Easterly.

No.	Date.			Latit'e. beg. end	Long. beg. end	Course.	Vel., miles.	Lowest Barom.	Previous course.
				° °	° °				
1	1872.	Nov.	6.1– 7.3	26–47	95–65	E.N.E.	60·4	29·71	Unknown.
2		Nov.	7.3– 9.3	25–30	95–78	E.N.E.	21·1	29·74	Unknown.
3		Dec.	9.2–13.3	26–47	101–57	N.E.	28·6	29·86	Unknown.
4		Dec.	23.2–27.2	25–44	95–58	N.E.	29·8	29·17	Unknown.
5	1873.	Feb.	19.1–22.1	21–45	98–64	N.E.	35·1	29·17	Unknown.
6		May	4.1–10.1	24–43	98–81	N.E.	15·8	29·57	Unknown.
7		Sept.	18.1–20.1	24–34	92–74	N.E.	24·3	29·57	Unknown.
8		Sept.	22.3–24.1	25–36	86–72	N.E.	28·5	29·78	Unknown.
9		Oct.	5.1– 8.2	25–43	87–62	N.E.	32·9	29·02	Towards N.W.
10		Dec.	24.2–27.1	24–43	88–62	N.E.	30·4	29·37	Unknown.
11	1874.	Jan.	5.2– 9.1	25–49	87–68	N.N.E.	18·0	29·42	Unknown.
12		Feb.	7.2–11.1	25–46	82–58	N.N.E.	25·0	28·95	Towards N.W.
13		April	17.3–24.1	24–46	94–59	N.& N.E.	29·7	29·36	Unknown.
14		Sept.	2.3–10.2	22–50	99–89	North.	21·5	29·47	Unknown.
15		Sept.	27.1–30.2	25–50	87–66	N.N.E.	26·0	28·94	Unknown.
16		Dec.	18.2–21.1	25–39	96–62	N.E.	34·6	29·33	Unknown.
17	1875.	Nov.	6.1– 7.3	25–31	98–78	E.N.E.	32·9	29·82	Unknown.
18	1876.	Oct.	19.1–21.1	21–32	82–72	N.N.E.	19·5	29·51	Not traceable.
19	1877.	Sept.	16.1–21.3	25–31	96–76	E.N.E.	10·7	29·40	Unknown.
20	1878.	Jan.	6.1–12.2	24–46	100–56	N.E.	26·4	28·85	Not traceable.
21		Feb.	26.2–28.1	24–30	92–71	E.N.E.	31·1	29·71	Came from N.W.
22		Mar.	17.1–17.2	23–25	85–78	E.N.E.	?	29·79	Not traceable.
23		Mar.	19.3–22.3	25–27	95–78	East.	15·0	29·71	Came from W.
24		July	2.1– 2.3	25–27	85–78	E.N.E.	22·9	29·77	Not traceable.
25		Sept.	24 –33	15–32	76–61	N.& N.E.	10·1	29·70	Not traceable.
26		Oct.	21.1–24.2	20–38	81–57	N.& E.	27·5	28·83	Not traceable.
27		Nov.	13.3–20.1	22–44	97–57	E.& N.E.	24·5	29·83	Not traceable.
28		Nov.	17.2–21.1	24–47	93–57	N.E.	40·3	29·47	Came from N.W.
29	1879.	Nov.	19.1–20.3	23–49	74–60	N.N.E.	48·8	29·00	Not traceable.
30	1880.	Jan.	24 –28.1	21–36	86–75	N.	14·3	29·68	Not traceable.
31		March	7.3– 9.2	26–32	99–74	E.N.E.	38·0	29·86	Not traceable.
32		May	3.1– 6.2	26–47	93–59	N.E.	23·8	29·79	Unknown.
33		Aug.	19 –20	20–27	78–74	N.N.E.	12·4	29·86	Towards N.W.

Three of these storms had been traveling towards the northwest, previous to the dates given in the table, and two of them came from the northwest; but in the other cases the barometric depression was too small to allow us to trace their course previous to the dates here given. For most of the cases in the last half of the table this is clearly shown by the International Observations, and we may therefore infer it to be true in the other cases. As long as these storms continued south of lat. 30°, the barometric depression was generally small, but it increased as the storm advanced northward. In fifteen cases the barometer fell below 29·5 inches, and in four cases it fell below 29·0 inches. The average velocity of progress of these storm-centers while advancing northward and eastward was 26·9 miles per hour. From a comparison of these three tables we perceive that the American storms which originate between the equator and lat. 20° N. generally travel towards a point between north and west, but occasionally they advance almost exactly northward.

Course of hurricanes originating near the Bay of Bengal, China Sea, etc.

The following table contains various particulars respecting those hurricanes in Southern Asia and its vicinity, whose paths have been best determined. It includes all those which were most carefully investigated by Henry Piddington, together with those which have been since investigated by Blanford, Elliott and others. Column 1st gives the number of reference; column 2d shows the date of commencement, so far as indicated by the published observations; column 3d shows the latitude of the storm's center when it first became violent; column 4th shows the average course of the storm while advancing westward; column 5th shows the velocity of progress in English statute miles per hour while moving westward; column 6th shows the latitude at which the course of the storm became due north; column 7th shows the velocity while moving north; column 8th shows the average course of the storm after turning eastward; column 9th shows the hourly velocity of progress while moving eastward; column 10th shows whether rain was mentioned as accompanying the storm, and whether the rain-fall was violent or not; column 11th indicates the name of the person by whom the phenomena of the storm were investigated. (P.) stands for Henry Piddington; (B.) for Henry F. Blanford; (E.) for J. Elliott; (R.) for William C. Redfield; (F.) for J. Floyd; (M.) for Matthew F. Maury; (L.) for G. von Liebig; (G.) for Colonel J. E. Gastrell and Henry F. Blanford; and (W.) for W. G. Willson. Column 12th shows where the record of the investigation may be found. J. A. S. stands for Journal of the Asiatic Society of Bengal; J. S. for the American Journal of Science; S. D. for Maury's Sailing Directions; the other references are to special reports made by the investigators to the Government of Bengal.

It will be seen that 52 per cent of these cases occurred in the months of September, October and November, and 43 per cent occurred in the months of April, May and June, leaving only 5 per cent of the cases for the six remaining months of the year. Of the West India hurricanes reported in my fifth paper, 88 per cent occurred in the months of August, September and October, leaving only 12 per cent for the remaining nine months of the year: that is, the Asiatic hurricanes occur in the spring almost as frequently as in the autumn; but the American hurricanes are almost exclusively confined to the period near the autumnal equinox.

Course of Hurricanes originating near the China Sea, Bay of Bengal, etc.

No.	Date of Commencement.	Latitude of Origin.	Course while moving Westward.	Velocity in miles per hour.	Latitude when moving North.	Velocity moving North.	Course while moving Eastward.	Velocity moving Eastward.	Rain-fall.	Investigator.	Where recorded.
1	1803. Sept. 21	16°·0	W. 15 N.	9·1					Heavy	P.	J. A. S., v. 11
2	1810. Sept. 28	18·1	W. 12 S.	7·3					Heavy	P.	J. A. S., v. 11
3	1835. Aug. 5	20·5	W. 18 N.	17·0					Heavy	R.	J. S., v. 35
4	1838. April 8	22·6					S. 37 E.	5·0	Hail	F.	J. A. S., v. 7
5	1839. June 3	20·0	W. 13 S.	3·9					Violent	P.	J. A. S., v. 8
6	Sept. 20	22·0	W. 52 N.	9·5					Violent	P.	J. A. S., v. 9
7	Nov. 12	13·3	W. 23 N.	6·2					Heavy	P.	J. A. S., v. 9
8	1840. April 27	11·6	W. 54 N.	9·8					Violent	P.	J. A. S., v. 9
9	Sept. 22	15·6	W. 83 N.	10·0					Violent	P.	J. A. S., v. 10
10	1841. May 15	10·0	W. 25 N.	14·7					Heavy	P.	J. A. S., v. 11
11	1842. June 2	20·5	W. 69 N.	4·8					Violent	P.	J. A. S., v. 11
12	Oct. 1	17·7	W. 31 N.	7·5	24·3	4·6			Violent	P.	J. A. S., v. 12
13	Oct. 22	12·0	West.	12·1					Violent	P.	J. A. S., v. 12
14	1843. May 20	8·8	W. 38 N.	12·1					Heavy	P.	J. A. S., v. 13
15	Nov. 28	6·1	W. 40 N.	4·6					Rain	P.	J. A. S., v. 14
16	1844. Nov. 9	11·1	W. 16 N.	3·4					Heavy	P.	J. A. S., v. 14
17	1845. Oct. 7	17·1	W. 19 N.	13·5					Rain	P.	J. A. S., v. 18
18	Nov. 29	6·7	W. 12 N.	6·0					Violent	P.	J. A. S., v. 14
19	1847. April 16	7·9	W. 86 N.	9·4					Violent	P.	J. A. S., v. 17
20	Nov. 18	17·0	W. 49 N.	6·2	18·5	5·8	N. 53 E.	5·0	Rain	P.	J. A. S., v. 18
21	1848. Oct. 12	17·8	W. 50 N.	4·8					Rain	P.	J. A. S., v. 18
22	1850. April 23	8·7	W. 50 N.	8·1	18·0	9·1			Violent	P.	J. A. S., v. 20
23	Nov. 17	12·2	W. 70 N.	6·0					Heavy	P.	J. A. S., v. 23
24	1851. May 2	10·6	W. 54 N.	3·6					Violent	P.	J. A. S., v. 21
25	Oct. 21	17·6			17·6	10·9	N. 42 E.	5·7	Rain	P.	J. A. S., v. 23
26	1852. May 12	15·7			20·0	10·1			Rain	P.	J. A. S., v. 24
27	1854. April 22	13·2					N. 39 E.	9·8	Heavy	P.	J. A. S., v. 27
28	1856. Dec. 7	10·0	W. 24 N.	11·7					Violent	M.	S. D., v. 1
29	1858. April 9	14·2					N. 39 E.	12·1	Violent	L.	J. A. S., v. 27
30	1864. Oct. 3	16·0	W. 56 N.	9·2	21·3	12·0	N. 29 E.	15·0	Violent	G.	Report.
31	1869. May 13	16·0	W. 44 N.	7·6	20·5	14·0	N. 25 E.	17·0	Rain	B.	Report.
32	June 5	16·4	W. 83 N.	4·0	24·0	9·5	N. 39 E.	11·0	Violent	B.	Report.
33	Oct. 7	20·5	W. 34 N.	12·5					Violent	B.	Report.
34	1870. Nov. 4	16·5	W. 11 N.	12·0					Violent	B.	Report.
35	1872. April 28	7·5	W. 50 N.	5·0					Heavy	B.	Report.
36	June 28	20·5	W. 21 N.	7·1					Violent	B.	Report.
37	Sept. 19	21·0			23·0	12·7	N. 43 E.	13·7	Violent	B.	Report.
38	1874. May 3	9·0	W. 39 N.	7·0					Violent	B.	Report.
39	Oct. 13	16·6	W. 60 N.	6·9	22·1	8·3	N. 40 E.	9·4	Violent	W.	Report.
40	1876. Oct. 6	14·4	W. 25 N.	7·5	17·6	6·0	N. 16 E.	8·0	Heavy	E.	Report.
41	Oct. 27	11·0			14·0	10·0	N. 17 E.	20·0	Violent	E.	Report.
42	1877. May 14	9·3	W. 63 N.	5·0	15·0	7·9	N. 45 E.	10·4	Violent	E.	Report.

The lowest latitude of any storm-path here recorded is 6·1°, and there are fourteen cases as low as 12°. The lowest latitude of any of the West India hurricanes is 10°·3, and there are only three cases as low as 12°.

Hard gales and violent squalls of wind do, however, sometimes occur directly under the equator. This is shown by various logs quoted in Piddington's Memoirs. The following is an example from the log-book of the Winifred, quoted in Piddington's 11th Memoir, pages 30 to 40:

1843, Nov. 26,	lat.	9°	40′ N.	Dark and threatening—strong, heavy squalls.
Nov. 27,	"	7	4 N.	Sudden and dangerous gusts and violent squalls.
Nov. 28,	"	4	27 N.	Heavy rain and most terrific squalls.
Nov. 29,	"	1	20 N.	Succession of dangerous squalls.
Nov. 30,	"	1	1 S.	Dismal weather and violent squalls.
Dec. 1,	"	3	15 S.	Dark, gloomy weather and violent squalls.

The following is from the log-book of the Fyzul Curreem, for the same period:

1843, Nov. 27,	lat.	5°	11′ N.	Heavy squalls, N.N.W.
Nov. 28,	"	2	6 N.	Fresh gale, west.
Nov. 29,	"	0	54 S.	Gale from west, increasing steadily to midnight.
Nov. 30,	"	3	50 S.	Steady at west.
Dec. 1,	"	5	39 S.	Strong sea from W.S.W.
Dec. 2,	"	6	41 S.	Heavy head sea.

The courses of these storms while moving westward, range from 13 degrees south of west to 86 degrees north of west. In two cases the course was reported to be south of west, and in one case it was exactly west, which result accords very closely with that before found for West India hurricanes. The average velocity of progress of these storms while advancing westward was 8·1 English statute miles per hour, which is less than half the average velocity of West India hurricanes.

The average latitude of the storm-centers when the course became due north was 19·8, and the latitudes range from 14° to 24°·3, which is ten degrees more southerly than the latitude before found for the West India hurricanes. The average velocity of progress of these storms when advancing northward was 9·3 miles per hour.

The average course of these storms after turning eastward, was 35° east of north, and their velocity of progress was 9·8 miles, which is scarcely half of the velocity found for West India hurricanes.

Column 10th shows that rain accompanied every one of these storms, and generally the rain-fall was excessively great. These observations were generally made from vessels on the ocean, and the amount of the rain-fall could not be measured, but the rain was generally characterized by the strongest terms which the English language furnishes, such as: very heavy rain—constant heavy rain—ceaseless rain—excessively heavy rain—incessant heavy rain—sheets of rain—deluge of rain—rain poured down in torrents—dense, thick, impenetrable rain—rain with a vengeance—rain and very large hail—rain and sleet—hard sleet—torrents of rain and sleet, etc.

When a storm-center passed overland, where a rain-gauge was observed, the measurements showed that the preceding terms were no exaggeration. The following table shows the amount of rain-fall in twenty-four hours at certain stations:

Rain-fall in Tropical Cyclones.

Date.		Place.	Lat.	Long.	Rain, inches	Authority.
1839.	June 4	Dacca	23°·7	90°·5	6·00	Piddington, 1st Memoir, p. 37
1842.	June 3	Calcutta	22·5	88·3	5·17	7th Memoir, p. 35
	June 3	Kissenuggur	23·4	88·4	9·00	7th Memoir, p. 42
	Oct. 3	Pooree	19·8	85·9	5·10	9th Memoir, p. 27
1843.	May 23	Cannanore	11·9	93.2	5·95	10th Memoir, p. 32
	May 23	Madras	13·1	80·3	10·50	10th Memoir, p. 20
	May 23	Hyderabad	25·3	68·4	9·00	10th Memoir, p. 29
1851.	May 5	Madras	13·1	80·3	11·44	21st Memoir, p. 17
1864.	Oct. 6	Contai	21·8	87·8	10·00	Rep. of Gastrell & Blanford, p. 82
	Oct. 6	Bograh	24·8	89·4	7·10	p. 82
	Oct. 6	Goalparah	26·2	90·7	60·00	p. 82
	Oct. 6	Moisgunj	23·4	88·5	7·50	p. 82
1874.	May 4	Madras	13·1	80·3	7·10	Willson's Report, p. 127
	Oct. 15	False Point	20·3	86·8	6·30	p. 9
	Oct. 15	Jellasore	21·5	86·9	5·82	p. 9
	Oct. 15	Midnapore	22·4	87·2	10·27	p. 8
	Oct. 16	Burdwan	23·2	87·9	7·43	p. 8
	Oct. 16	Lalgolla	24·5	88·3	16·30	p. 8
	Oct. 16	Jungipore	24·5	87·8	8·00	p. 8
	Oct 16	Bood Bood	23·	88·	8·40	p. 8
	Oct. 17	Rungpore	25·9	89·3	6·97	p. 9
1876.	Oct. 7	Vizagapatam	17·7	83·4	5·60	Elliott's Report, p. 48
	Oct. 8	Vizagapatam	17·7	83·4	12·60	p. 48
	Nov. 1	Noakholly	22·8	91·0	5·12	p. 153
	Nov. 1	Putuakhally	22·3	90·4	5·85	p. 153
1877	May 18	Madras	13·1	80·3	13·01	p. 42
	May 20	Gya	24·6	85·1	5·06	p. 75
	May 20	Nowada	23·9	88·4	8·00	p. 75
	May 20	Aurungabad	19·9	75·3	8·68	p. 75
	May 20	Rajmahal	25·0	87·7	5·20	p. 75
	May 20	Raigunge	25·	88·	5·71	p. 75
	May 20	Jawai	25·	91·	9·70	p. 75
	May 21	Barrh	25·5	85·7	6·43	p. 77
	May 21	Chanchal	25·0	88·2	6·14	p. 77
	May 21	Rungpore	25·9	89·3	11·16	p. 77
	May 21	Kurigram	25·	89·	5·70	p. 77
	May 21	Bogdogra	25·	89·	12·19	p. 77
	May 21	Julpigoree	26·5	88·7	5·53	p. 77
	May 21	Boda	26·	89·	8·52	p. 77
	May 21	Cooch Behar	26·3	89·5	9·77	p. 77
	May 21	Dhubri	26·0	90·0	5·60	p. 77
	May 21	Jawai	25·	91·	14·20	p. 77

From this table we see that these hurricanes were accompanied by an amount of rain such as seldom occurs, even within the tropics, and we seem authorized to conclude that excessive rain invariably accompanies the most violent hurricanes. This conclusion accords with that deduced from the investigation of the West India hurricanes.

I next examined all the maps of the International Observations for additional materials, showing the course of storms in Southern Asia and the adjacent oceans. The following are the most important cases which I have found :

Asiatic storms moving Westerly.

No.	Date.			Latitude. beg. end.	Longitude. beg. end.	Course.	Vel., miles.	Subsequent course.
1	1878.	Sept.	15–19	16°–29°	134°–124°	N.W.	10·8	Moved N.E.
2		Oct.	7– 9	19–19	122–112	West	14·3	Unknown.
3		Nov.	17–21	12–15	95– 82	West	6·6	Disappeared.
4		Nov.	29–38	10–18	97– 83	W.&N.W.	5·8	Disappeared.
5	1879.	May	17–26	14–35	85– 75	S.&W.&N.	12·4	Disappeared.
6		May	30–32	20–22	88– 90	West	7·2	Disappeared.
				Asiatic storms moving Southeasterly.				
7	1877.	Dec.	27–30	27–20	65– 80	E.S.E.	18·1	Moved N.E.
8	1878.	Feb.	6–12	39–22	60– 92	E.S.E.	16·7	Disappeared.
9		May	3– 8	33–17	77– 79	South	10·0	Disappeared.
10		June	2– 7	66–26	110–112	South	15·4	Moved N.E.
				Asiatic storms moving Northeasterly.				
11	1879.	Mar.	2– 6	6–34	118–152	N.E.	21·8	Unknown.
12		Mar.	15–22	10–40	113–157	N.E.	15·4	Unknown.

In several of these cases the depression of the barometer, so far as reported, was not very great, and the storms do not appear to have been of remarkable violence, nevertheless the results here found accord reasonably well with those before found, except that the velocities while the storms were moving easterly, are greater than the average of those shown in the table on page 9.

On comparing all these tables it is remarkable that but few cases have been found in which a storm-center has advanced towards any point between west and south. Including the table in my fifth paper, we have found 98 cases of tropical storms which advanced westerly, and of these only five moved towards any point between south and west. The first of these advanced in a direction about two degrees south of west; the second advanced eleven degrees south of west; the third advanced twelve degrees south of west; the fourth advanced thirteen degrees south of west; and the fifth, starting from lat. 30°, advanced for three days in a direction nearly south, then one day nearly west, and subsequently towards the northwest.

I next endeavored to ascertain what was the prevalent direction of the wind which preceded each of these tropical storms, and also the prevalent wind which succeeded the low center, and how these two winds generally compared in respect of force. It is impossible to make a satisfactory comparison from the observations in the International Bulletin, on account of the small number of stations, and because the observations are reported only once a day. The following tables show the direction and force of the wind in the case of five of the low areas enumerated on page 2, for the stations nearest the center of low pressure. The numbers without brackets show the velocity of the wind in miles per hour; the numbers in brackets show the force of the wind estimated in units of Beaufort's scale (1 to 10). In each line the direction and force for one day are printed in large type, to indicate the day when the barometer at that station was lowest.

1876, *September.*

	14th.	15th.	16th.	17th.	18th.	19th.
Kingston	Calm	**S.E.5**	S.E.8	S.E.8	Calm	Calm
Nassau	N.E.(3)	N.E.(8)	**S.E.(6)**	S.(3)	N.E.0	N.E.(5)

1878, *August.*

	10th.	11th.	12th.	13th.	14th.	15th.
San Juan	S.E.2	**E.12**	S.E.4	S.E.8	S.E.0	S.E.2
Navassa	S.E.12	N.E.10	**N.19**	S.E.29	E.17	E.17
Kingston	Calm	Calm	Calm	**S.E.10**	S.E.20	Calm
Nassau	S.E.(1)	N.E.(2)	N.E.(2)	S.E.(1)	**S.E.2**	S.E.(2)
Havanna	E.4	E.S.E.4	E.S.E.3	E.N.E.4	**E.9**	S.E.16

1878, *September.*

	3d.	4th.	5th.	6th.	7th.	8th.
Navassa	S.19	N.20	**S.22**	S.E.20	E.14	E.15
Santiago de Cuba	N.E.7	N.6	**S.E.(6)**	S.E.4	S.E.6	Calm
Kingston	Calm	Calm	**E.3**	S.13	S.E.18	Calm

1878, *September.*

	24th.	25th.	26th.	27th.	28th.	29th.
San Juan	N.E.6	**S.E.11**	S.E.1	S.E.6	S.E.4	S.E.4
Navassa	N.W.12	N.N.E18	E.8	N.W.12	**S.25**	S.15
Santiago de Cuba	N.(1)	N.N.E.8	N.NE(1)	N.(1)	**NW(1)**	S.W (1)

1879, *October.*

	10th.	11th.	12th.	13th.	14th.	15th.
San Juan	S.E.4	S.E.7	**S.E.0**	S.E.0	S.E.0	S.E 0
Navassa	N.E.5	E.10	S.E.16	**E.20**	S.E.15	S.E.18
Santiago de Cuba	N.7	N.2	**S.E.10**	S.E.6	S.E.8	S.E.6
Kingston	Calm	Calm	**S.E.4**	S.E.18	S.E.6	Calm
Nassau	N.E.	N.E.	N.E.	**E.**	S.E.	S.E.
Havanna	E.N.E10	E.6	E.N.E.8	E.12	**E.20**	S.S.E.18

It will be seen that in every case the passage of the low center was followed by a southerly wind, and in two-thirds of the cases this had been immediately preceded by a northerly wind; and in nearly every case the southerly wind which followed the low area was stronger than the northerly wind which preceded it. This result, I believe, accords with what has generally been observed in tropical cyclones, and appears to suggest the explanation of the origin of the cyclone, and the direction of its progressive movement. The prevalent direction of the wind in the neighborhood of the West India Islands, is from the northeast. Occasionally a strong wind sets in from a southerly quarter. The interference of these winds gives rise to a gyration, and sometimes rain-fall is the result. When rain commences, the latent heat which is liberated, causes the wind to flow in from all quarters, by which the rain-fall is increased; and since the winds are deflected by the rotation of the earth, an area of low pressure is produced, and the force of the winds is maintained as long as the rain-fall continues. The effect of this strong wind from the south is to transport the low center in a northerly direction; and by the combined action of this south wind and the normal wind from the northeast, the center of low pressure is usually carried in a direction between the north and west.

The following summary presents some of the results derived from this investigation:

1. The lowest latitude in which a cyclone has been found near the West India Islands is ten degrees, and the lowest latitude in the neighborhood of Southern Asia is six degrees. Violent squalls and fresh gales of wind have however been encountered directly under the equator.

2. The ordinary course of tropical hurricanes is towards the west-northwest. In a few cases they seem to have advanced towards a point a little south of west, and in a few cases their course has been almost exactly towards the north.

3. Tropical hurricanes are invariably accompanied by a violent fall of rain. This rain-fall is never less than five inches in twenty-four hours for a portion of the track, and frequently it exceeds ten inches in twenty-four hours.

4. Tropical storms are generally preceded by a northerly wind, and after the passage of the low center the wind generally veers to the southeast at stations near the center; and the southerly wind which follows the low center is generally stronger than the northerly wind which preceded it. This fact appears to suggest the explanation of the origin of the cyclone and the direction of its progressive movement.

5. None of the storms which have pursued a southeast course across the United States and its vicinity, have been traced further south than latitude 22½ degrees, and only three have been traced as far south as latitude 25 degrees. These storms during their progress southward generally decline in intensity. Some of them decline to such an extent that their course can

no longer be traced, while others change their course and turn towards the northeast. In my eleventh paper I have shown that storms which advance from north to south across the United States, are generally attended by a very slight fall of rain; and this seems to explain the fact that they generally decline in intensity as they advance southward.

Storms in the Middle latitudes advancing in a Westerly direction.

The infrequency of the cases in which tropical storms have advanced towards the southwest, has led me to search for corresponding cases in the middle latitudes of America and Europe. For this purpose I have examined all the cases in which the charts of the U. S. Signal Service indicate the movement of a storm center towards any westerly point. I have also examined Hoffmeyer's daily charts from Dec., 1873, to Oct., 1876; the charts of the Deutsche Seewarte from Jan., 1876, to March, 1879, and from Jan., 1880, to April, 1880; also the charts of the International Observations from Nov., 1877, to Dec., 1879. Many of the cases of this description which are shown on the charts of the U. S. Signal Service are cases in which the depression of the barometer was small, when there was no single well-defined storm center, but there were two or three centers of slight depression within a few hundred miles of each other, so that a slight change in the force of the winds would cause one of the centers to predominate a little, and thus the center of greatest depression might be carried in an unusual direction.

The following table shows the most decided cases in which storm-centers in the United States have advanced in a westerly direction:

Storms in the United States advancing Westerly.

No.	Date.			Latit'e. beg. end	Long. beg. end	Course.	Vel., miles.	Lowest barom.	Subsequent course.
1	1873.	Oct.	20.1–21.3	39°–46°	75°–86°	N.W.	20·7	29·35	Unknown
2	1874.	May	9.1– 9.3	49–42	97–104	S.W.	37·3	·29	N.E.
3	1876.	Jan.	8.3– 9.1	44½–43	84–87	S.W.	22·2	·14	E.N.E.
4		Feb.	25.3–26.3	41–38½	95–97	S.S.W.	8·5	·40	Eastward
5		June	17.3–18.2	44–47	86–88	N.W.	12·7	·37	Southerly
6		Sept.	16.1–17.3	25–41	77–79½	N.N.W.	28·8	·47	Eastward
7	1877.	Feb.	21.2–22.1	48–41½	89–93	S.S.W.	33·9	·35	Eastward
8		Nov.	22.3–24.3	32–42	79½–84	N.N.W.	15·7	·63	Disappeared
9	1878.	Feb.	19.2–20.1	43–34	95–98	S.S.W.	43·0	·33	N.E.
10		Mar.	10.1–11.1	43–42	96–104	W.S.W.	18·0	·47	Eastward
11		Mar.	23.1–24.1	50–42	57½–72	S.W.	36·7	·22	E.N.E.
12		April	28.2–29.1	37–41	77–79½	N.N.W.	18·5	·58	Disappeared
13		June	22.2–23.1	42–44	76–79	N.N.W.	15·7	·60	E.N.E.

The number of these cases is 13; and 4 of these pursued a course about N.N.W.; 2 advanced towards the N.W.; 1 towards the W.S.W.; 3 towards the S.W.; and 3 towards the S.S.W. Case No. 1 was particularly noticed in my seventh and eleventh papers. It was there shown that this storm was accompanied by an excessive fall of rain; also that the winds on the east side were uncommonly strong, and observations of the upper clouds indicated that these winds extended to an unusual height above the earth's surface. Nos. 5, 6, 8, 12 and 13 were also accompanied by a great fall of rain, especially No. 6, and in all of the cases the winds from the south and east were remarkably strong. This will appear more distinctly from the following table, in which column second shows the highest wind reported for cases 1, 5, 6, 8, 12 and 13 at the given dates from any quarter between N. and W.; and column third shows the highest wind from any quarter between S. and E.

Highest winds reported.

Date.	N. and W.	S. and E.	Date.	N. and W.	S. and E.
1873. Oct. 20.1	N. 28	S.E. 32	1877. Nov. 22.2	N.W. 25	S.E. 20
20.2	N. 36	E. 42	22.3	N.W. 16	S.E. 22
20.3	N. 28	S.E. 32	23.1	N. 15	S.E. 32
21.1	N. 32	S. 24	23.2	N.W. 16	S.E. 30
21.2	N. 20	S. 28	23.3	W. 12	E. 32
21.3	N. 32	S. 32	24.1	N.W. 12	E. 44
1876. June 17.3	N. 24	S.E. 29	24.2	N. 10	E. 42
18.1	N.W. 30	S.E. 32	24.3	N.W. 8	E. 28
18.2	N.W. 38	S.E. 24	1878. April 28.2	N. 20	E. 18
Sept. 16.2	N.W. 24	E. 24	28.3	N. 15	E. 14
16.3	N.W. 10	E. 32	29.1	N.W. 12	E. 30
17.1	W. 13	E. 24	June 22.2	N. 20	E. 48
17.2	N.W. 10	E. 16	22.3	N.W. 12	E. 40
1877. Nov. 22.1	N.W. 13	S.E. 32	23.1	W. 12	E. 17

The average of the greatest velocities for the northwest quarter is 19 miles per hour, and for the southeast quarter it is 29 miles per hour.

In the following table, column second shows the highest wind reported for cases 2, 3, 4, 7, 9, 10 and 11 at the given dates for any quarter between S. and W.; and column third shows the highest wind reported from any quarter between the north and east.

Highest winds reported.

Date.	S. and W.	N. and E.	Date.	S. and W.	N. and E.
1874. May 9.1	S.W. 30	N.E. 12	1877. Feb. 22.1	S. 21	N. 25
9.2	S. 32	N.E. 12	1878. Feb. 19.2	S. 27	N.E. 8
9.3	S. 40	E. 17	19.3	S. 22	E. 15
1876. Jan. 8.3	S. 25	N.E. 26	20.1	S.W. 32	N. 18
9.1	S.W. 18	N.E. 29	Mar. 10.1	S. 20	N.E. 40
Feb. 25.3	S. 22	N.E. 44	10.2	W. 30	N.E. 55
26.1	S. 14	N.E. 50	10.3	S. 11	N.E. 36
26.2	S. 24	N.E. 44	11.1	S.W. 8	E. 16
26.3	S. 18	N.E. 44	24.1	S.W. 22	N. 40
1877. Feb. 21.3	S. 21	N. 20			

The average of the greatest velocities for the southwest quarter is 23 miles per hour, and for the northeast quarter it is 29 miles per hour. There are several instances in which the mode of comparison here adopted does not fairly indicate the relative force of the winds on the opposite sides of a low center, especially when the low center happens to be situated near the margin of the Signal Service map, but the average of the results when the storms were advancing towards the northwest, and also when they were advancing towards the southwest, appears very decided, and seems to indicate distinctly that the centers of least pressure advanced in that direction towards which the winds pressed in with the greatest force.

In my first paper I gave the result of two years' observations, which showed that the average velocity of the wind on the west side of a low center (within the isobar 29·90) was 10·1 miles, and on the east side 8·3 miles; being 22 per cent greater on the west side than on the east side. We have now found that when a low center advances westward, the velocity of the wind is generally greatest on the east side of the low center. The progressive movement of storms probably depends upon meteorological conditions which prevail at a considerable distance from the low center. Hoffmeyer's charts and the International maps sometimes inform us what these conditions are. The following summary shows certain conditions which prevailed at each of the cases contained in the table on page 15, as far as is shown by the maps which I have received.

No. 3. High on the north and east (765) with low (735) near South Greenland.
No. 4. High on the northeast (775 to 785) with low (735) near Newfoundland.
No. 5. High on the east (770) with low (740) near Iceland.
No. 6. High on the northeast (775) with low (750) over the Atlantic.
No. 8. High on the northeast (30·40) with low (29·80 to 29·20) over the Atlantic.
No. 9. High on the east (30·20) with low (29·20) near Newfoundland.
No. 10. High on the northeast (30·60) with low (29·40) over the Atlantic.
No. 11. High on the north and northeast (30·20) with low (29·00) over Northern Europe.
No. 12. High on the north and northeast (30·20) with low (29·40) near South Greenland.
No. 13. High on the north and east (30·20 to 30·40) with low (29·60) near Iceland.

Thus we see that in the preceding cases there generally prevailed a considerable area of low pressure over the Atlantic Ocean, while on its western or northwestern side a cold wind from the north, with high pressure, was forcing its way southward, and this may be presumed to have crowded westward the low areas prevailing at the same time over the United States.

The following summary presents some of the conditions prevailing at these dates on the Western side of these low areas.

No. 1. Low center (29·70) on the Northwest side which gradually approached and coalesced with No. 1.
No. 2. Isobars protruded very much towards S.W.
No. 3. Isobars protruded very much towards S.W.
No. 6. Low center (29·50) on the Northwest side.
No. 7. Isobars protruded towards S.S.W.
No. 8. Low center (29·50) on the Northwest side.
No. 9. Isobars protruded to a great distance towards S.W.
No. 10. Low center (29·80) in the Gulf of Mexico.
No. 11. Isobars protruded to a great distance towards S.W.
No. 12. Low center on the N.W.
No. 13. Subordinate low center on the N.W.

Thus we see that while on the East side of these low areas there were causes which tended to increase the pressure on that side, there were different conditions on the Western side which tended to divert the winds Westward, and this is apparently the most important reason why, in these cases, the centers of least pressure advanced Westward.

Storms advancing Westerly over Europe and the Atlantic Ocean.

The following table shows the most decided cases in which storm centers have advanced in a Westerly direction over Europe and the Atlantic Ocean.

European storms advancing Westerly.

No.	Date.			Latitude. beg. end.	Longitude. beg. end.	Course.	Vel., miles.	Low't bar'm	Subsequent course.
1	1875.	Mar.	14–16	50° –46°	37°W.–43½°W.	S.W.	8·3	730	Absorbed
2		Dec.	17–19	64 –64	29W.–43W.	West	8·8	720	Easterly
3	1876.	April	19–20	52 –56	3W.–5W.	N.N.W.	12·2	735	N.E.
4		June	19–20	57½–60½	23¼W.–27W.	N.W.	10·1	730	Subdivided
5		June	22–23	57¼–59	26W.–33½W.	N.W.	12·1	740	Disappeared
6		Sept.	9–12	55 –60	21E.–7E.	N.W.	8·0	735	Subdivided
7		Sept.	22–23	54½–56	26½W.–30W.	N.W.	6·7	740	Subdivided
8		Oct.	20–21	56¾–64	34½W.–49W.	N.W.	28·7	720	Eastward
9		Nov.	12–14	50 –52	7W.–16W.	W.N.W.	8·8	730	Northward
10		Dec.	21–23	53 –56	1W.–8W.	W.N.W.	3·8	729	Southerly
11	1877.	April	4– 8	56 –50	9W.–13W.	S.S.W.	4·8	733	N.E.
12		May	3– 6	52 –64	44E.–18E.	N.W.	17·2	744	Disappeared
13		July	15–16	54 –54	2W.–5W.	West	3·4	737	N.E.
14		Aug.	9–9½	54 –57	0–4W.	N.W.	19·2	745	Disappeared
15	1878.	Mar.	31–32	59 –59	10E.–0	West	14·3	729	North
16		May	30–32	60 –60	27E.–17E.	West	7·1	741	N.E.
17		Nov.	4– 6	54 –59	25E.–19E.	N.N.W.	8·6	737	N.E.
18		Nov.	11–13	59 –49	7E.–3E.	S.S.W.	14·4	733	S.E.
19		Nov.	14–16	47 –54	10E.–4E.	N.N.W.	11·5	734	South
20		Dec.	10–11	52 –56½	25E.–23E.	N.N.W.	14·9	739	N.E.
21	1880.	Feb.	16½–17	54 –56	7½W.–10W.	N.W.	17·2	720	Unknown

The first eight cases are derived from an examination of Hoffmeyer's charts. Six of these cases occurred near the middle of the Atlantic ocean; one on the western borders of Europe, and the other in the eastern part of Europe. They are cases in which the depression of the barometer was considerable; in which the low center was pretty sharply defined; and in which no neighboring low center is represented on Hoffmeyer's maps. Cases 9 to 21 have been derived from the charts of the Deutsche Seewarte, and all have been carefully compared with the International Observations, excepting No. 21, for which the International Observations have not yet been received. Of these 21 cases, 14 advanced towards some point between north and west, 3 advanced towards some point between south and west, and 4 advanced almost exactly west.

I have endeavored to compare the force of the wind on that side of each low area towards which the storm was advancing, with the force on the opposite side according to the observations delineated on Hoffmeyer's charts. The number of the observations over the Atlantic Ocean is so small that the results for that region are not entitled to much weight. The following shows the comparison of the observations within the isobar 750 for cases 3 and 6, the force of the winds being represented by the numbers of Beaufort's scale (0 to 6).

		Front.	Rear.			Front.	Rear.
1876.	April 19	1·76	2·27	1876.	Sept. 10	2·20	3·33
	Sept. 9	1·42	1·50		Sept. 11	1·83	2·87

Thus we see that on the rear of these low areas the average force of the wind was 38 per cent greater than on the front side.

The following summary shows the state of the barometer on the east side and also on the west side of storms Nos. 1–8 and Nos. 15–20.

	On the East side of the low area.	*On the West side of the low area.*
1	775 on the north and east increasing to 780 on the northeast.	29·4 to 29·0 in the United States. Isobars protruded westward.
2	735 on the east.	29·6 to 29·2 near Newfoundland.
3	770 on the east.	755 to 740 near Newfoundland.
4	765 to 770 on the east.	29·6 in the United States. Isobars protruded westward.
5	770 on the northeast side.	755 to 745 near Hudson's Bay.
6	770 on the east and 750 on the north-northeast.	765 to 770 on the west, with 755 to 735 near Newfoundland.
7	765 on the east and southeast.	755 to 750 on the northwest.
8	770 to 775 on the east.	Subordinate low (735) near South Greenland. Also 745 in the United States.
15	30·4 to 30·6 on the east.	29·7 to 29·4 near Newfoundland.
16	Barometer slightly below normal throughout nearly all of Asia.	29·7 near Greenland.
17	30·6 on the east.	30·2 falling to 30·0 on the west. Also 29·6 near Newfoundland.
18	30·4 on the southeast.	30·4 on the southwest.
19	30·4 on the east.	Subordinate low (29·4) on the northwest side; also 29·1 in Greenland.
20	30·8 to 31·0 on the east.	29·8 to 30·0 on the west and northwest.

In all but two of these cases there was an area of high pressure on the east side of the storm center, and in several of the cases this pressure was above 30·5 inches. Such a pressure is sufficient to produce a wind of considerable force. On the west side of these storm centers there was generally a second area of barometric depression, and in several cases the two depressed areas approached each other until they coalesced, by which means the eastern low center was apparently transported westward. Nos. 1, 2, 8 and 19 were of this description, and probably also No. 5. In several other cases the two low areas approached each other until they formed a single low area of an elongated form, with two low centers which remained for several days distinct from each other. Such were Nos. 3, 4, 7 and 15. In No. 6 the storm was apparently diverted Northward by the low area on the north-northeast. In No. 16 the pressure was generally below 30 inches throughout north America, the North Atlantic Ocean, as well as Europe and Asia. In such a case, slight local causes are sufficient to divert the winds in a new direction. In No. 17 there was apparently an area of low pressure on the north beyond the stations of the International Observations. In No. 18 there was a high area on the southeast and another on the southwest, and the low area pushed in between them. In the United States it is frequently observed that when two areas of high pressure approach within a few hundred miles of each other, a low center is developed between them. A similar case occurred in No. 6 between Sept. 11th and 12th. In No. 20 the observations do not indicate any decided low center on the north or west, yet the pressure was every where either below or but little above the normal over the North Atlantic Ocean and North America.

Thus we see that in Europe and over the Atlantic Ocean as well as in the United States, the influence of one area of low pressure upon another is a very common cause of abnormal movements of storm centers.

In preparing the materials for this article I have been assisted by Mr. Henry A. Hazen, a graduate of Dartmouth College of the class of 1871.

NOTE.—Since the preceding was in type, I have received Hoffmeyer's charts for November, 1876, from which it appears that on the 12th of November, 1876, there was an area of low pressure (730 to 725) west of Ireland; and the apparent westward movement of No. 9 on page 18 was plainly due to the influence of this low center. I have also received the International Bulletin for October, 1880, from which it appears that on February 16th there was a low center (28·40) west of Ireland, and the apparent westward movement of No. 21 on page 18 was plainly due to the influence of this low center.

Art. II.—*The Albany Granite, New Hampshire, and its Contact Phenomena;* by George W. Hawes, New Haven.

In the studies that have been directed to the end of discovering the nature and origin of our great granitic masses, the contact phenomena have received but little attention. The application elsewhere of the modern methods of lithological research to the rocks upon the limits of granitic masses has, however, been fruitful in developing facts of geological interest. The study which I present indicates that no more striking phenomena have been observed anywhere than those which are found upon the boundaries of one of the New Hampshire granitic masses. These phenomena have additional interest since they occur in a region of highly crystalline schists, which usually are not susceptible to influences of this nature. In the Vosges, for example, the granites, which have produced the most marked and wide-reaching effects upon clay slates, have had no influence upon the crystalline schists which they have intersected.* As the New Hampshire granite here considered exhibits very striking modifications in character, dependent upon the neighborhood of the contact, and as a spot was found where the arrangement of the rocks is favorable for a careful consideration of the effects of the contact both upon the schists and the granite, I have investigated these rocks with a view of presenting this study as a contribution to White Mountain Geology.

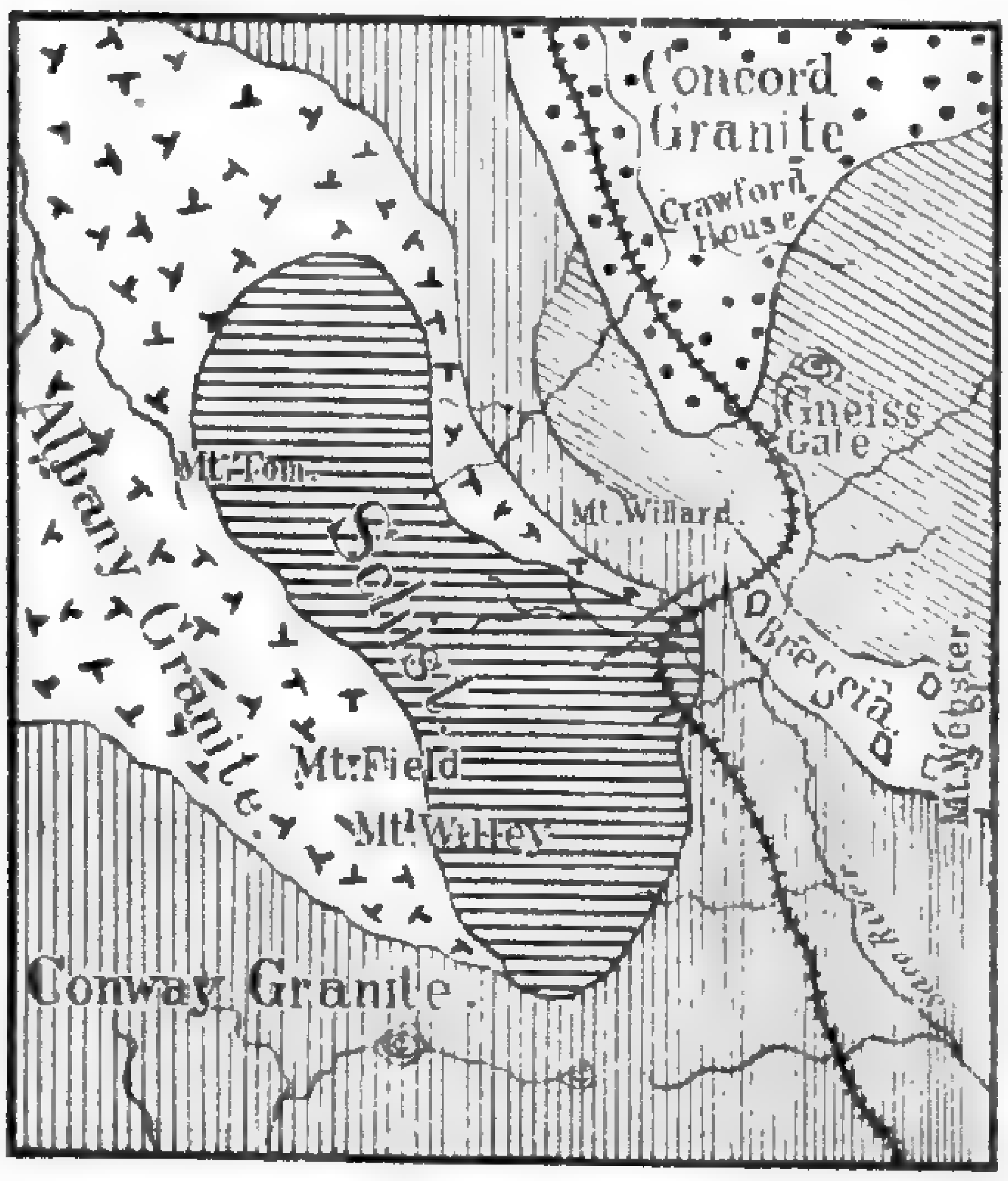
The line of contact between the Albany granite and an area of argillitic mica schist crosses Mt. Willard in the Crawford notch. The normal rocks with their contact modifications are familiar to many of our geologists. The beauty of the natural scenery, combined with the geological interest, has attracted many to this spot, and these rocks have accordingly had frequent mention. For the opinions in regard to the nature and origin of the granites at this point, and the interpretation of the effects that are due to the contact, I refer to the second volume of the Report on the Geology of New Hampshire, by Professor C. H. Hitchcock. As the relation of these peculiar rocks to one another, and the nature of the changes that they have undergone, can however be discovered only by chemical and microscopical study, it is neither necessary nor just to submit to critical consideration the opinions formed without the aid of these methods.

The general arrangement of the rocks upon Mt. Willard is

* H. Rosenbusch, Abhandlungen zur geologischen Special Karte von Elsass-Lothringen, Bd. I, Heft II, p. 89.

shown in fig. 1.* Although but a small mountain several of the most characteristic New Hampshire granites take part in its composition. In this paper it is proposed to confine the attention to the Albany granite,† which forms an immense mass covering many square miles to the west, but which crosses Mt. Willard in the form of a dike about three hundred feet wide. The Conway granite, a coarse-grained biotite granite, forms the hanging wall, and argillitic mica schists form the foot wall of this dike. Mt. Willard presents a bold cliff nearly a thousand feet high toward the south, and the contact lines of these three rocks run diagonally across this cliff, exposing themselves most favorably for study and observation. We have here then a small and narrow granitic mass which is connected with a great mass, and this forms in a modified way a parallel to the celebrated "Bodegang," which is a small narrow dike that connects the Ramberg and Brocken, two granite mountains in the Harz, the phenomena connected with which have been described by Lossen.‡

1.



Map of the Mt. Willard region. Scale 2½ miles to one inch.

The Albany granite is a very distinctly and definitely characterized rock. It is called by Hitchcock the spotted or trachytic granite.§ In all its areas it has the same peculiar

* This map is essentially a reproduction from the large geological map of New Hampshire, prepared by Professor C. H. Hitchcock, and forming a part of the atlas accompanying his geological report. Under his direction the area marked "breccia granite" has been added. This is a distinct granite mass which includes in certain portions immense blocks of gneiss. Such inclusions occur in the granite elsewhere in New Hampshire, and are also known abroad. The figures on page 225 in vol. i of Naumann's Geognosie, drawn from a cliff on the Einank in Norway, might just as well have been drawn from a cliff in the Crawford notch. It is to the granite which *includes* these fragments that Professor Hitchcock has given the title of breccia granite. Upon his geological map he has considered the Albany and the Conway granites as eruptive, and the Concord as metamorphic. In this paper I deal simply with the Albany granite, and introduce this map to show the relationship in which the schists and this granite stand with reference to one another, and especially the form of the area occupied by the Albany granite. If contact phenomena take precedence over details of internal structure, the origin of all the other granites including the Concord granite and the gneiss are open questions.

† So named by Professor Hitchcock on account of its extensive development in Albany, N. H.

‡ Zeitschr. d. d. Geol. Ges., 1874, p. 856.

§ For distribution of this granite see Hitchcock's Geol. New Hampshire, vol. ii, p. 143.

appearance due to the development of Carlsbad twins of orthoclase with rounded contours, in a gray fine-granular aggregate of granitic minerals, which are said to form a mixture resembling pepper and salt. Whether red or white, it is equally characteristic in appearance, and from its extensive development it is to be considered as one of the important granitic masses of New England.

Nor in its microscopic characters is this granite less characteristic. Its twin crystals of feldspar in polarized light are seen to have the peculiar structure of perthite, and consist of interlaminated orthoclase and albite.* Individual grains of a triclinic feldspar are often seen. The quartz is in formless grains and possesses the usual fluidal inclusions, and the position in angular corners due to the order of crystallization. The chief accessory is hornblende which is black in the rock, but green, yellow, dichroic, in thin sections, and peculiarly impure from the enclosure of quartz grains. Biotite, magnetite and apatite are constant, augite and fluor spar are frequent, constituents.

But what gives to this rock a very marked microscopic individuality is the uniform presence in it of well-crystallized square prisms of zircon. Of the many sections that have been cut, not one has been found free from these pretty crystals. They are large enough to be examined optically under the microscope, and are easily recognized by their tetragonal crystallization, their high index of refraction. Their uniaxial and positive character can be easily determined in convergent light. Out of twenty-five grams of the rock from Mt. Willard, I separated several hundred of these crystals, by means of hydrofluoric acid. They are white, clear and glassy, but are sometimes tinged with yellow. They are often $\frac{1}{10}$ mm. in diameter and $\frac{4}{10}$ mm. long. Their surfaces are bright, but cavities often penetrate far into their interiors. They are doubly terminated, and in addition to the planes of the prism and pyramid of the first order, they frequently have the planes of a ditetragonal pyramid which is probably the form 3–3. They contain many inclusions. Some of these are the inverted forms of zircon crystals, some are zircons with different terminal faces, and some are empty cavities with very irregular forms.

In the middle of the arm of Albany granite which extends across the summit of Mt. Willard, the rock is of this normal character, but both to the right and the left differences are evi-

* Sections parallel to the base hardly show these interlaminations owing to the approach in the elasticity planes of the two species. Sections parallel to the clino pinacoid possess an elasticity plane making an angle of 6° with the basal cleavage, and in the interlaminations an elasticity plane makes an angle of 17° in the same direction, with the basal cleavage.

dent. These differences are of the same character upon both sides, but they are very much more marked upon the side of the schist. At a distance of 100 feet from the contact, the crystals that form the granite have become smaller with the exception of the large feldspar crystals, which are in consequence more conspicuous. At a distance of sixty feet a tendency in the quartz to assume crystalline forms is noticed, and the rock begins to appear porphyritic. At fifteen feet from the contact with the schists, the quartz is found in well-defined dihexagonal pyramids, as large as peas, and these with the Carlsbad twins of orthoclase are imbedded in a ground mass no longer resolvable by the unaided eye or lens. Upon the contact the ground mass is nearly black in color, flinty in texture, and apparently homogeneous. The Albany granite has become a quartz porphyry.*

The accompanying microscopic changes are as striking. Approaching the contact there is a continual diminution in the amount of the hornblende and the size of its crystals. There is a corresponding increase in the amount of the biotite, which finally entirely replaces the hornblende. These biotite crystals are at first quite large, but they diminish rapidly in size near the contact, and upon the contact are reduced to a dust. The ground-mass which makes its appearance between the quartz and orthoclase crystals, grows finer, but upon the contact though of extreme fineness, it is still entirely crystalline. In this ground-mass all the minerals of the granite found in specimens distant from the contact are recognizable, but near the contact no individual crystals can be determined.

In this series of changes all the minerals have taken part with two exceptions. The Carlsbad orthoclase twin crystals and the zircon crystals have the same shape and size in all parts of the rock. That is, with these exceptions the condition or existence of the mineral components depends upon position with reference to the contact.

These modifications, which are repeated in a less conspicuous manner upon approaching the contact with the granite upon the opposite side of the mass, are such as might be induced in a molten eruptive mass, which, like modern lavas, contained some crystals already formed at the time of eruption by the effect of contact with cold walls, the hydrous nature of

* The Bodegang previously referred to is filled with quartz porphyry which however has a coarser ground mass in the center.

In the Vosges the granites which have altered the slates are upon their side usually unaffected. At one spot however in the Weihermattenthal the granite became porphyritic upon the contact. Rosenbusch, Die Steiger Schiefer und ihre Contactzone an den Granititen von Barr-audlan und Hohwald, p. 156.

In the Pyrenees near Case de Brousette a contact occurs between clay slate and a porphyry which farther south gradually changes into granite. Zirkel, Zeitschr. d. d. Geol. Ges., 1867, p. 106.

one and the anhydrous nature of the other being factors modifying the extent of the effect.

Any chemical changes that may be connected with these modifications are represented in the following table of analyses.

	Normal Albany Granite.	Granite Porphyry 3 ft. from contact.	Granite Porphyry 2 in. from contact.
SiO_2	72·26	73·09	71·07
Al_2O_3	13·59	12·76	12·34
Fe_2O_3	1·16	1·07	2·25
FeO	2·18	4·28	4·92
MnO	*tr.*	·08	*tr.*
CaO	1·13	·30	·55
MgO	·06	·09	·19
K_2O	5·58	5·10	5·53
Na_2O	3·85	3·16	2·84
TiO_2	·45	·40	·27
H_2O	·47	·73	·72
	100·73	101·06	100·68
Sp. Gr.	2·65	2·66	2·68

Of the differences here shown some fall within the evident errors of the analyses; and so many of the others can be referred to differences introduced in sampling such coarse-grained compounds, that I do not think that any changes can be definitely referred to the effect of contact, unless it be the accession of iron, and the slight hydration. If we assume that no chemical change has taken place, and that the first analysis represents the whole, a calculation shows that it may contain:

	Quartz.	Orthoclase.	Albite.	Anorthite.	Hornblende.	Biotite.	Magnetite.	Titanic Iron.
	25·99	32·95	32·61	1·35	4·83	---	1·68	·85
Or,	26·79	30·76	31·01	5·65	---	5·44	---	·85

The biotite has the composition $(K,Na)_2(Fe,Mg)_4AlSi_4O_{16}$ (= one molecule K and one M of Tschermak) and the hornblende will be $11(R\,SiO_3)+Al_2O_3$. This calculation can not claim to be accurate since there are no data for dividing the lime between the anorthite (which is supposed to be combined with some of the albite to make a triclinic feldspar) and the hornblende. It is introduced to show that the results of the chemical investigation do not at all contradict the microscopic results, since a recrystallization and a rearrangement in the proportions between the feldspars, furnishes all the material necessary to convert the hornblende into biotite.

The schists that occupy the area indicated upon the map, form portions of Mts. Tom, Field, Willey and Willard, elevations in the vicinity of the White Mountain Notch. Their age is unknown. Their reference to the Silurian on account of a supposed fossiliferous character being based upon an error, it is only certain that they are older than both the Albany and the Conway granites, both of which intersect them. In composition they are not at all constant, but the prevailing variety is a dark compact argillitic mica schist with andalusite crystals scattered through parts of it. Upon the summit of Mt. Willard they appear to be very uniform over a large area, and for this reason the specimens for chemical study were taken from this spot.

The schists at the summit have a strike very nearly north and south, and they dip 60° to the west.* The line of contact with the granite runs in an irregular northwest direction. At a distance of 100 feet from this contact, with the exception of the rather rare andalusite crystals, no minerals are visible in this schist to the unaided eye, unless the glistening surface be considered as an indication of mica. Under the microscope it is seen to consist of quartz, muscovite (probably the variety containing combined water), and chlorite. Titanic iron partially decomposed into leucoxene, some magnetic iron which can be drawn from the powder with a magnet, and particles resembling coal or graphite, constitute opaque black ingredients. A little biotite and a very few crystals of tourmaline, recognized by form and the direction of strong absorption, are accessory constituents. No marked change is visible in the rock at a distance of fifty feet from the contact, but nearer than this point the effect of the contact becomes very soon evident. As the specimens described and analyzed were all, with the exception of the normal schist at 100 feet, taken from the same stratum, I think that all the differences noted may be with certainty regarded as due to the effect of contact.

Twenty-five feet from the contact the schists are much changed in microscopic structure. They are more definitely and coarsely crystalline; biotite becomes a more prominent constituent, and tourmaline crystals, blue within and brown without, have become a prominent constituent.

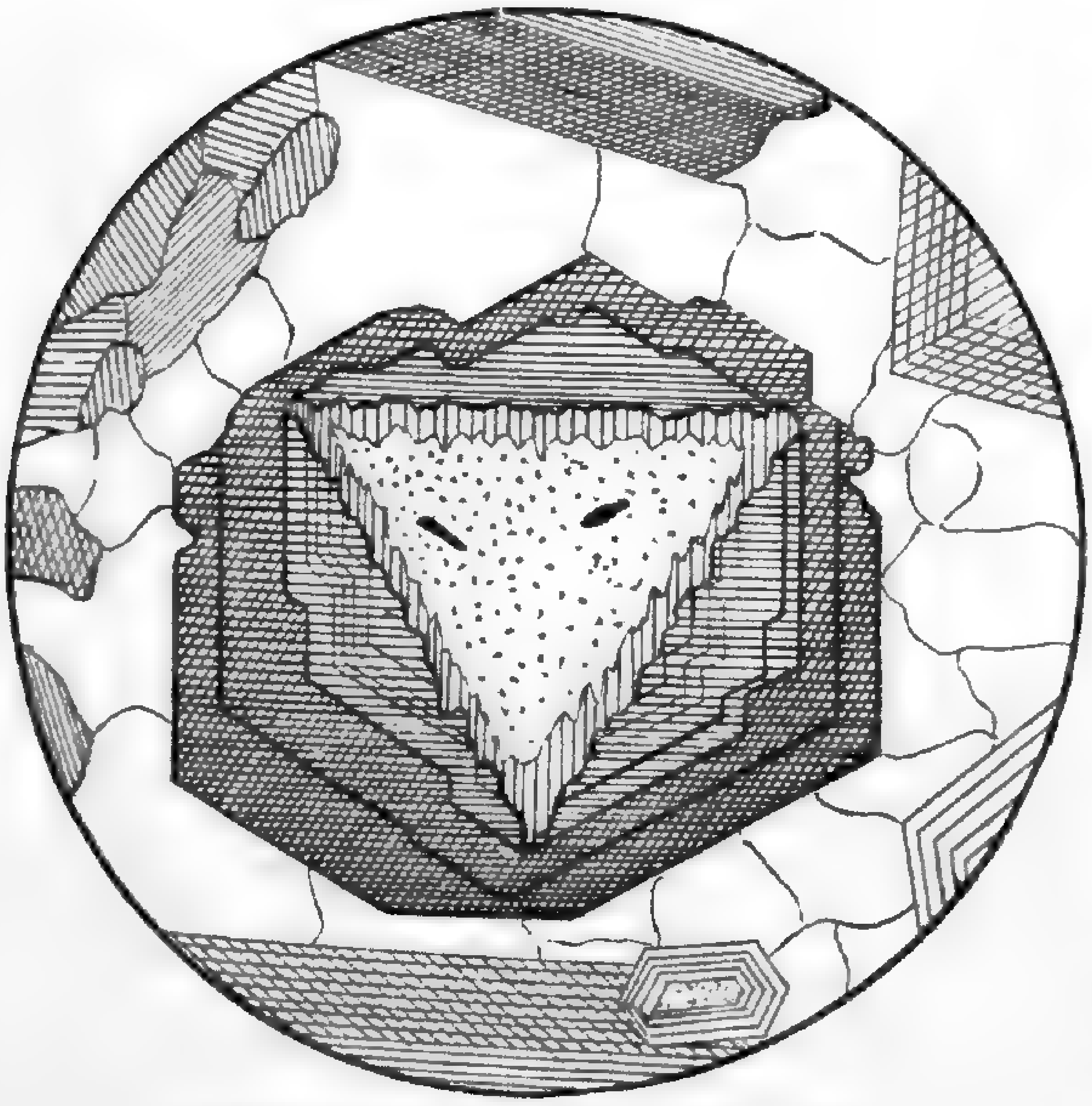
Between this point and the contact the changes apparent to the eye are marked and rapid. At fifteen feet, the rocks are still schistose, but they are hard, much fractured, and full of shining dots that indicate a new crystallization. At this point the rock is a mica schist. Under the microscope, a decrease in the amount of chlorite and an increase of biotite are noted, also the presence of many tourmalines and of large clear quartz grains with fluidal enclosures. The titanic iron is entirely altered into a dull white opaque substance.† Between this point and the contact the schist loses entirely its schistose

* Strike of slate 12–22 W., strike of contact N. 77 W. Hitchcock's Geology of New Hampshire, vol. ii, p. 177.

† I can not regard the conclusion of Prof. v. Lasaulx that this substance is titanite of lime, titanomorphite, as certainly correct in all cases, for in rocks like this that are nearly free from lime the same decomposition takes place. In this case there is not enough lime in the whole rock to make titanomorphite with the titanic acid.

structure, and is converted into a black hornstone, which breaks into small angular fragments. The little bright crystalline grains of quartz increase in quantity, and the tourmalines become much more numerous. From the schists ten feet from the contact a qualitative reaction for boric acid can be obtained. The rock, which thus far has been growing coarser in texture, from this point grows gradually finer, and is converted near the contact into flinty, compact hornstone, thin sections of which are resolved by the microscope into an aggregate of quartz, biotite, tourmaline, and iron oxide.

2.



Section of tourmaline veinstone.
× 100 diameters.

But between this hornstone and the granite another well defined zone exists. This is a dark-gray mass which is filled with reticulated black veins. Scarcely noticeable on the top of the mountain, this zone becomes wide and prominent below. The veins which fill this mass divide and subdivide, giving to the whole a fused, slaggy appearance. Under the microscope, however, this mass is resolved into a nearly pure mixture of tourmaline and quartz. While in the hornstone zone last described, the tourmalines are in extremely minute formless grains, here they are in more or less well defined crystals, and possess a concentrically banded structure. White, blue, light brown and dark brown layers follow one another in the order named. Fig. 2 (× 100) represents a section possessing these zones. These crystals are bounded by the planes $-\frac{1}{2}R. -\frac{iR}{2}. i2.$ This mass I characterize as the zone of the tourmaline veinstone to distinguish it from the last, or the zone of the tourmaline hornstone. There is reason for this in the circumstance that the impregnating material has wholly altered the character of the schist.

The chemical changes that have taken place, both in ultimate composition and mineral constituents, are indicated in the following table of analyses:

	Schist 100 ft. from contact.	Schist 50 ft. from contact.	Schist 15 ft. from contact.	Tourmaline Hornstone 1 foot from contact.	Tourmaline Veinstone on contact.
SiO_2	61·57	63·35	66·30	67·88	66·41
Al_2O_3	20·55	19·69	16·35	14·67	16·84
Fe_2O_3	2·02	·72	·95	2·37	1·97
FeO	4·28	5·48	5·77	3·95	5·50
MnO	·10	·16	*tr.*	·11	·12
CaO	·24	*tr.*	·24	·30	·37
MgO	1·27	1·77	1·63	1·29	1·71
K_2O	4·71	3·47	3·40	4·08	·56
Na_2O	·68	1·12	1·11	3·64	1·76
TiO_2	1·10	1·00	1·28	·93	1·02
B_2O_3	----	----	*tr.*	·97	2·96
Fl	----	----	----	*tr.*	·25
H_2O.	4·09	3·73	3·02	1·01	1·31
	100·61	100·49	100·05	101·20	100·78
Sp. Gr.	2·85	2·84	2·82	2·74	2·73
Quartz	36·87	39·17	45·15	50·82	50·03
Muscovite	49·30	44·53	} 43·89	} 29·67	----
Biotite	----	----			
Chlorite	8·62	13·70	6·65	----	----
Titanic iron	2·09	1·90	2·43	1·77	1·94
Magnetite	2·93	1·04	1·38	3·44	2·86
Tourmaline	----	----	----	14·92	45·95
Excess of H_2O.	·80	·15	·55	·58	----
	100·61	100·49	100·05	101·20	100·78

In these analyses a systematic and progressive series of changes indicates that there has been an addition to the schists by reason of contact with the granite. The dehydration, and the accession of boric and silicic acids are positive features, and the addition of alkali directly upon the contact, in consideration of the circumstance that the second, third and fourth samples were taken from the same stratum, may be regarded as certain also. The series of analyses given by Professor Rosenbusch in his work upon the contact phenomena in the Vosges* prove, in his opinion, that, whatever may have been the physical changes, nothing (except in one case a little boric acid) has been added to the schists, and the analytical results obtained by others from contact schists lead to the same result. The kind of changes indicated by my analyses, if of less degree, are of the same kind as those that have been observed in the contact of granites with limestones, as for example in the Harz where the limestones about the Ramberg† have their CO_2 replaced by SiO_2, forming a broad zone of lime silicates about the contact; and on the contact of limestone with Monzonit‡ at Predazzo, where a similar lime-silicate hornstone zone is found to be rich in alkali directly upon the contact.

* Die Steiger Schiefer und ihre Contactzone. Strassburg, 1877, p. 257.
† Lossen, Zeitschr. d. d. Geol. Gesellschaft, xxiv, p. 777.
‡ J. Lemberg, Zeitschr. d. d. Geol. Gesellschaft, xxiv, p. 234.

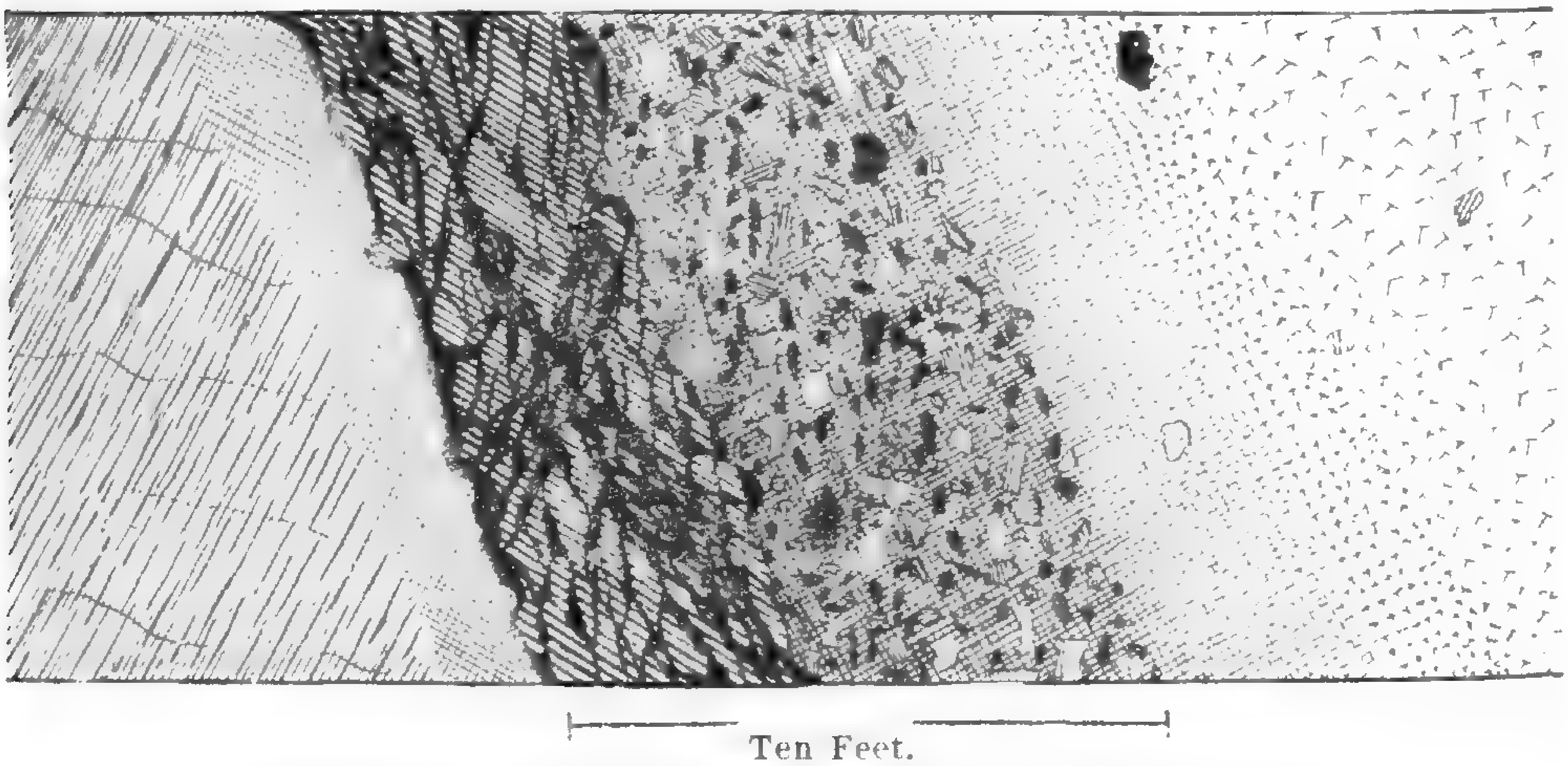
The effect of the contact becomes much more striking when the percentages of the constituent minerals are calculated from the analyses. This was done in the first two analyses as follows. The titanium dioxide was first reckoned into titanic iron, and the iron sesquioxide calculated into magnetite, since the magnet attracts black particles from the powder. The remaining iron protoxide, with the manganese oxide, and the magnesia were then calculated into a chlorite of the formula of ripidolite ($Mg_5Al_2Si_3O_{14}+4H_2O$). Then if the remainder of the alumina is calculated into muscovite ($(K,H)_2Al_2Si_2O_8$), nothing at all is left save the small percentages of water indicated in the table, which are not much more than what may be supposed to be hygroscopic, or included. In the third analysis, the protoxides before calculated as belonging wholly to chlorite have been divided equally between chlorite and biotite in accordance with the microscopic indication. The tourmaline hornstone is a nearly pure mixture of tourmaline and quartz, as shown by the microscope, hence in the last analysis, after calculating the amount of titanic iron and magnetite, the remaining bases were calculated as forming a tourmaline of the formula $\left\{\begin{matrix} m\ \dot{R}_6SiO_5 \\ n\ R_3SiO_5. \\ r\ R\ SiO_5 \end{matrix}\right.$ In accordance with this the composition of the tourmaline is as follows:

SiO_2	Al_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O	H_2O	B_2O_3	Fl
35·65	36·66	8·03	·26	·79	3·72	1·22	3·83	2·85	6·45	·54 = 100

The fourth analysis can now be calculated like the third, after deducting the percentage of tourmaline calculated from the boron trioxide. If biotite is considered as a combination of the muscovite molecule $(K,H)_2\cancel{Al}Si_2O_8$ with the molecule $Mg_4Si_2O_3$ (according to Tschermak) we have the data only for obtaining the sum of the muscovite and biotite, but not the amount of each. If the data of these calculations are not absolutely correct, the results agree well with the microscopic observations, and the table I think indicates clearly both the chemical and mineralogical changes, and make it plain that they are progressive in approaching the granite.

Just between the schist and granite, upon the summit of the mountain, a very insignificant zone exists which consists of granite in which numerous fragments of a variety of rocks are included. This zone, scarcely noticeable upon the summit, becomes larger and better defined as one descends the cliff, and I shall show what a weighty part this little zone, here but a foot or two wide, plays elsewhere. This zone I call the *mixed zone.* At a short distance below the summit it becomes a very sharply defined band three feet wide, and consists of fragments of various kinds of schist, and angular fragments of a foreign variety of quartz porphyry, and all are cemented together with the granitic material. The feldspar crystals in this granite are all broken to fragments,* and the whole mass is impregnated with tourmaline, but the constituent minerals

3.



Ten Feet.

Junction of Argillitic mica schist and Albany Granite.

are all easily recognized. Fig. 3 illustrates the appearance of the contact, as seen upon the cliff at an easily accessible point, about 150 feet below the summit. The different zones that I have described are here all sharply defined. To recapitulate, these zones are as follows:

1. Zone of the argillitic mica schist (chloritic).
2. Zone of the mica schist (biotitic).
3. Zone of the tourmaline hornstone.
4. Zone of the tourmaline veinstone.
5. Zone of the mixed schists and granite.
6. Zone of the granite porphyry (biotitic).
7. Zone of the granite (hornblendic).

It will thus be seen that the succession of zones is different from those that have been described about other granitic masses, but that the effects observed are of the same nature and referable to the same causes.†

Following the line of contact down the cliff, the phenomena of the contact ever become more extensive and remarkable. At a point just above the spot figured, a long arm of the porphyritic granite, from two to three feet wide and eighty feet long, extends into the schist at nearly a right angle to its

* The crystals of orthoclase found in the small branches of granitic masses where they would be subjected to friction have been often found broken. In the Fichtelgebirge and Elba for example. Credner Geologie. p. 285.

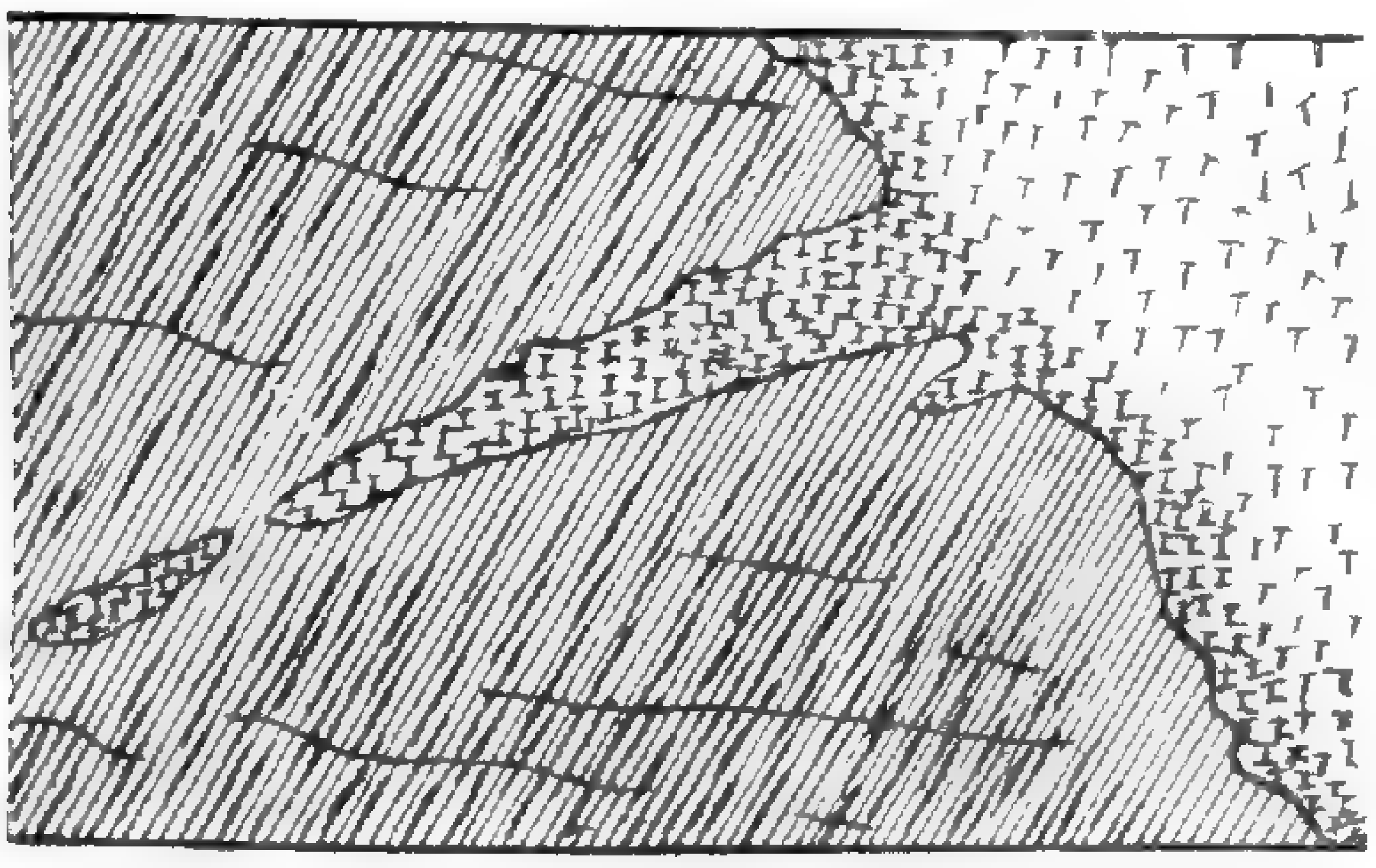
† The zones in the Vosges as described by Rosenbusch are

1. Clay slate.
2. Knotty clay slate.
3. Knotty mica schist.
4. Hornstone, usually Andalusite hornstone.

The knotty character is here entirely absent.

stratification. This arm is shown in fig. 4. The impregnation of the schists with tourmaline has been much more effectual below than upon the summit. Two hundred feet below the summit the schists distant 100 feet from the contact contain as many tourmalines as at fifteen feet from the contact upon the top. The mixed zone steadily increases in width as it descends, and at the base of the huge cliff it is more than twenty feet wide.

4.



Junction of schist and Albany granite, showing extension of the granite into the schist. Scale 75 feet to one inch.

These are the main features of this remarkable contact. I think they show that the Albany granite is an eruptive mass younger than the Conway granite, and younger than the andalusite schists, and that the main portion of its mass had not crystallized at the time of eruption. The inclusion of such varied products in the mixed zone indicates that it moved no inconsiderable distance through fissures in very diverse rocks. The kind of impregnation indicates that it was accomplished by vapors and solutions that emanated from the fissures filled by the granite; but the impregnation of schists embedded in the granite, and the impregnation of the schists attendant with a dehydration of the same, indicates the action of very hot vapors which accompanied the eruption; not the action of vapors subsequently emanated through the cleft.*

The line of division forming the contact is microscopically fine. Over this line the minerals of schist or granite do not pass except in the form of inclusions. There is therefore no relationship between the schist and the granite.

These results are of importance in White Mountain geology since the effects are often repeated. All about this area, and other areas of Albany granite as far as observed, the effects of the contact are found upon the edges of the granite. At Bemis Brook the same apparent effects are seen on the side of the granite, but the schists, which are hard siliceous mica schists, have not been affected. The porphyry which at this

* In the Vosges andalusite is the mineral characteristic of the contact, and the question having been raised whether andalusite ever occurs save as a contact mineral, this has been considered. The apparently systemless method of distribution of andalusite crystals over the whole area gives no basis for referring these macled crystals to the effect of contact.

The cavities in the quartz of the granite contain most variable amounts of fluid. Some are full and some are empty. The calculation of temperatures and pressures upon measured size of bubble and cavity can be of little value when, as is here plain, other unknown quantities beside those commonly considered are factors.

spot adjoins the schist has the granophyre* structure. This structure may therefore be induced as a contact phenomenon.

Ascending Mt. Kearsarge by the bridle path from the Intervale station, the base of the mountain is seen to be composed of Conway granite.† At a height of 500 feet one finds the peculiar gray porphyry with Carlsbad twins of orthoclase and dihexagonal pyramids of quartz, as on Mt. Willard, and which we recognize as the zone of the quartz porphyry, which gradually changes and finally becomes typical Albany granite. Here again we see that the Conway granite was a cool body influencing the crystallization of a later eruption. After climbing for a short while over the Albany granite, the zone of porphyry again appears; then follows in proper sequence the mixed zone, but this zone which upon Mt. Willard attains to a width of twenty feet, here forms the whole grand mass of Kearsarge, Bartlett and Moat Mountains. These mountains from base to summit consist of angular pieces of schists intermingled with and cemented by granite porphyry. The schists have been modified by the contact but to a less degree, since there has been here no impregnation with tourmaline. The mixed mass adjacent to the schists consists of a very large amount of broken schist, cemented by a small amount of the granite, which has been accordingly much modified by the effect of the schist, and has a ground mass very fine in texture, and homogeneous and flinty in appearance. Above, where there is a smaller proportion of schist in the porphyry, this ground-mass becomes more coarsely crystalline, and approaches granite in texture. The microscopic peculiarities however remain constant and the large zircon crystals never fail.

I have endeavored to show that the contact phenomena connected with the Albany granite are very beautifully developed upon a small scale, affording thus exceptional facilities for study and observation; but that on the other hand they reach an unequalled grandeur of proportion. The evidence previously offered by others has not been decisive in determining the eruptive or metamorphic origin of this rock, and I point to the fact that many other important granitic masses have been referred to the one or the other of these groups upon the same insufficient evidences of structure and internal stratification. From observations incidental to this work I am, however, quite certain that the study of the contact phenomena of the other great granitic masses in New Hampshire would develop as many interesting lithological facts, and furnish the proper evidence for a determination of their origin.

* Used in the sense of Rosenbusch. That is, the quartz and feldspar of the ground mass are arranged with reference to one another, as in graphic granite.

† See also Atlas to the Report on New Hampshire Geology, Hitchcock.

ART. III.—*A Theory of the Constitution of the Sun, founded upon Spectroscopic Observations, original and other;* by CHARLES S. HASTINGS.

FRAUNHOFER discovered the lines in the solar spectrum, known by his name, in 1814. Many efforts to determine their origin followed. One of the most ingenious and carefully considered was that of Professor Forbes in 1836.* He concluded that, if their origin is in the solar atmosphere, the light from the limb must exhibit stronger lines than that from the center. His method was to examine the spectrum before and during an annular eclipse; as he found no recognizable change, his deduction was, "that the sun's atmosphere has nothing to do with the production of this singular phenomenon."

The point was again touched upon by Sir David Brewster and Dr. Gladstone in a joint study of the spectral lines, published in 1860.† Here "each of the authors came independently to the conclusion that there is no perceptible difference in this respect between the light from the edge and that from the center of the solar disk."

In 1867 Ångström‡ repeated the experiment with negative results. Lockyer's‖ efforts also, in 1869, were attended with no better results.

In 1873, four years later, I devised and made an apparatus by which a perfect juxtaposition of the spectra of the center and limb was secured. This apparatus and certain of the results gained by its use were described in a note "On a comparison of the Spectra of the limb and the center of the Sun," published in this Journal, vol. v (1873), pp. 369–371. I was then a student at Yale College and soon after left New Haven, when the research was necessarily interrupted. I hoped, however, that the novelty and interest of the observations might lead others, possessed of the necessary apparatus, to develop the results of this method of investigation. But as nothing has been published on this subject since that time, I was glad to have an opportunity to continue the investigation in the summers of 1879 and 1880. The results of my labor are embodied in this paper.

The method adopted in the recent observations is exactly the same as that described in the article cited; instead, however, of the equatorial of the Sheffield Scientific School, I used a Clark equatorial of 9·4 in. aperture and 120 in. focal

* Notes relative to the supposed Origin of the Deficient Rays in the Solar Spectrum. Phil. Trans., 1836, pp. 453–456.

† On the Lines of the Solar Spectrum. Phil. Trans., 1860, pp. 149–161.

‡ Phil. Mag., 1867, p. 76.

‖ Proc. R. S., vol. xvii, p. 350.

length, which was kindly placed at my disposal by the gentlemen in Hartford, to whom it belongs.* The New Haven spectroscope too, of 12 effective prisms, was replaced by one of which the dispersing member was a Rutherfurd grating on speculum metal, either of 8648 or 17296 lines to the inch at will. These gratings were of the largest size, having a ruled surface of about 1¾ inches square.

The immediate results I give in order of refrangibility of the lines observed, as no observed variations in them can be attributed to anything other than the temporary modifications of transparency in our atmosphere. The numbers are the places on Ångström's maps as nearly as could be ascertained without micrometer.

Line (C) 6561·8 is cleaner and wider at limb, i. e. the haze on either side of the line as ordinarily seen is much reduced.

6431 is slightly stronger at center than at limb.

6371 is visible at center but not at limb.

(D_1) 5894·8 slightly less hazy at limb.

(D_2) 5889·0 decidedly cleaner at limb.

A fine line very close to its more refrangible side is either wanting or much fainter in spectrum of limb.

5577·5 is much stronger at limb.

5440 ± (not on Ångström's chart) is a little stronger at limb.

The Mg lines 5183·0, 5172·0, 5166·5 (b_1 b_2 b_4) are cleaner at limb. The line b_3 belonging to a different element does not show such a peculiarity.

5045 (a faint line not in Å.) is stronger at limb.

4919 ±, a faint line slightly stronger at limb.

(F) 4860·6 is much cleaner, more free from haze at limb.

4702·3 seems cleaner at limb.

4340·0 cleaner at limb.

4226·4 shows less haze at limb.

4101·2 is a very hazy line, so represented by Ångström; but at limb it is practically free from haze—a striking difference.

4045 is slightly less hazy at limb.

Other differences have been recorded, but only these have been observed more than once each.

Any theory of the sun, worthy of attention, must not only explain the above described phenomena, but also others better known, and as yet not accounted for satisfactorily. Of these the most noteworthy is the spectroscopic appearance of a spot and its penumbra. As is well known, such a spectrum exhibits a very strong general absorption, with a very slightly modified elective absorption. A few faint lines appear in the spot spectrum which are not otherwise seen; and a few faint

* My acknowledgments for this courtesy are gratefully accorded to Mr. Edgecomb its former owner, and to Mr. Howard and Mr. Chapin its present owners.

lines of the ordinary spectrum are strengthened. A careful examination has persuaded me that the spectrum of a spot differs from that of the unbroken photosphere, just as the spectrum of the limb differs from that of the center of the disk, save that the variations are more pronounced. Indeed, I could have considerably extended the list of lines strengthened at limb by an examination of the spot spectrum, where the variations appeal to the eye more clearly.

The accepted theory of the spots attributes the phenomenon to the absorption of the solar light by cooler, denser gases of the same nature as those producing the Fraunhofer lines. Familiar experiments teach, however, that as the density of a gas increases, the change in the character of its radiation is shown in its spectrum by the broadening of its distinctive spectral lines, which at the same time grow more ill defined. Therefore it follows that, according to the law connecting radiation and absorption, dark lines produced by such a gas must also, under similar conditions, show increased breadth and diminished sharpness. That no such changes are to be recognized is a fatal objection to the theory.

Another class of unexplained phenomena is the duplicity of certain lines of the solar spectrum, lines which are single in the spectra of terrestrial sources. Of these Prof. Young has discovered E_{11}, b_3 and b_4 with others.

My own observations can be arranged very simply in classes, and will then better lend themselves to theoretical discussion.

I. The most important fact of all is that the differences in the two spectra of center and limb are extremely minute, escaping all but the most perfect instruments, and all methods which do not place them in close juxtaposition.

II. Certain lines, the thickest and darkest in the spectrum, notably those of hydrogen, magnesium and sodium, which appear with haze on either side, in the spectrum of the center of the solar disk, are deprived of this accompaniment in that of the limb.

III. Certain very fine lines (four observed) are stronger at limb.

IV. Other very fine lines (two or three observed) are stronger at center.

The ordinarily accepted theory of the origin of the Fraunhofer lines fails to explain the phenomena as observed. That is, if we suppose the photosphere, whether solid, liquid, gaseous, or cloud-like, to yield a continuous spectrum which is modified only by the selective absorption of a surrounding atmosphere, then the absorption must be greater at the limb than at the center of the solar disk; and this must be true independently of the thickness of that atmosphere as well as of the form, rough or otherwise, of the surface of the photosphere. This evident consequence, pointed out in the first place by Forbes, nearly half a century ago, cannot be avoided. There is but one way of maintaining the theory and escaping Forbes's conclusion already quoted, and that the course pursued by Kirchhoff in the original statement of his theory of the solar constitution,* namely, by assuming that the depth of the reversing atmosphere is not small compared to the radius of the sun. But innumerable observations during the score of years which have lapsed since that time prove that such a reversing atmosphere must be very thin. The famous observation of Professor Young during the total eclipse of 1870, when he saw appreciably all the Fraunhofer lines reversed, has naturally been received as the strongest confirmation of Kirchhoff's views as to the locus of the origin of the dark lines. But this very observation restricts the effective atmosphere (save for hydrogen and one or two other substances) to a depth of not more than 2″. Thus, singularly enough, the very observation, which led to the firmest belief among spectroscopists in the correctness of Kirchhoff's view, exposed at the same time its most vulnerable point.

Another theory of the solar constitution, that of Faye, assigns a different seat to the stratum producing the Fraunhofer lines, namely, the photosphere itself. Regarding the principal radiation of the sun as coming from solid or liquid particles floating in a gaseous medium, the cloud-like stratum thus formed is necessarily somewhat transparent. According to his views, these particles are the sources of the continuous spectrum, and the medium in which they float is the locus of the selective absorption.† Thus he attempts to reconcile the general theory of Kirchhoff with the observations and deductions of Forbes, which, as we have seen, were a constant stumbling block in the way of accepting Kirchhoff's explanation.

Lockyer seems to have accepted this theory, and to have defended it in the earlier portion of his work;‡ but in 1872 after Young's important observation of 1870 and its confirmation in 1871, he changed his views and regarded the layer just outside the photosphere as the true seat of the selective absorption producing the Fraunhofer lines.§ I supposed in 1873 that my observations then published could be explained on Faye's hypothesis.

* Untersuchungen über das Sonnenspectrum. Berlin, 1862, pp. 14–15.

† Comptes Rendus, vol. lx, 1865.

‡ See "A lecture delivered at the Royal Institution," May 28th, 1869. Quoted in Lockyer's Solar Physics, pp. 220–221; also "The Rede Lecture," May 24th, 1871. Quoted in Solar Physics, pp. 317–318.

§ See revised report of two lectures delivered at Newcastle-upon-Tyne in October, 1872. Solar Physics, p. 409.

There is, however, a fatal objection to the explanation as given by this theory. If the luminous particles are precipitated from the vapors of the photosphere, they cannot be at a higher temperature than the circumambient gases; on the contrary, on account of their greater radiating power they must be slightly cooler. But the fundamental theory of absorption demands a lower temperature for the vapor producing dark lines than that of the principal source of light behind it; consequently this view of Faye cannot be accepted without great modifications.

Before advancing any theory of my own, it may be well to emphasize two principles taught by the theory of absorption, to which all hypotheses must be conformable. That Faye's fails in this is sufficient cause for its rejection.

1st. To produce dark lines in a spectrum by absorption, the source of absorbed light *must* be at a higher temperature than that of the absorbing medium.

2d. There is an inferior limit of brightness below which the course of absorbed light cannot go without the spectral lines becoming bright.

Of these, the first is familiar and requires here neither proof nor comment; the second, though not less evident, is less familiar because less important. As we shall make use of it, however, it may be well to enforce it by reference to common experience. Were it not true it would be impossible to see bright lines in the spectrum of any flame to which daylight had access, for in this case the conditions demanded by the first principle are fully met, the sun being the origin of the daylight. That we do not see absorption lines is due then alone to the lack of necessary brilliancy in the daylight.

Thus much premised we can frame a theory which explains all the observed phenomena exhibited by the spectroscope, and is also rendered highly probable by the revelations of the telescope.

As is well known, the solar surface when examined with a powerful telescope of large aperture presents a granulated appearance, the granules in general subtending an angle of a fraction of a second only. Probably this appearance is better known to the majority of astromoners by means of Professor Langley's admirable drawings* rather than by personal observation. These granules I regard as marking the locus of currents directed generally from the center of the sun. About these currents are necessarily currents in an opposite direction which serve to maintain a general equilibrium in the distribution of mass. Let us consider the action of such an ascending current. Starting from a low level at a temperature which we may regard as

* This Jour., vol. vii, 1874, and vol. ix, 1875. Plates.

above the vaporizing point of all elements contained in it, as it rises to higher levels, it cools, partly by radiation, more by expansion, until finally the temperature falls to the boiling point of one or more of the substances present. Here such substances are precipitated in the form of a cloud of fine particles which are carried on suspended in the current. The change of state marked by the precipitation is accompanied by a sudden increase in radiating power; hence these particles rapidly lose a portion of their heat and become relatively dark, to remain so until they are returned to lower levels by the currents in a reverse direction.

In this theory it will be observed, there is nothing which does violence to our accepted notions of the solar constitution. Indeed, it differs chiefly from that of Faye in localizing the phenomena of precipitation, instead of regarding it as proper to all portions of the photosphere; and, what is quite as important, in supposing the precipitation confined to one or two elements only. I shall attempt to define these elements farther on.

In our theory, then, the granules are those portions of upward currents where precipitation is most active, while the darker portions, between these bodies, are where the cooler products of this change with accompanying vapors are sinking to lower levels.

Having stated the theory we will now apply it to the four classes of phenomena defined above.

From the nature of the condensation, the granules or cloudy masses must be very transparent, because the condensation is confined to elements which have very high boiling points, and because such elements can be but a portion, perhaps but a small portion, of the whole matter contained in the upward currents.

It is not *à priori* improbable that we receive light from many hundreds of miles below the general outer surface of the photosphere. Since these cloud-like sources of intenser radiations are surrounded on all sides by descending currents of colder vapors all the white light which comes to us must have passed through media capable of modifying it by selective absorption. Again, since at the center of the solar disk we can see as far into the photosphere as at the limb and practically no further, the phenomena of absorption ought to be on the whole, the same in both regions.

Thus the fundamental and most important class of phenomena above classified finds a simple and logical explanation.

With regard to the phenomena of class II, we have but to define the problem in order to find the solution at hand. All the lines of class II belong to vapors which lie high in the solar atmosphere, as is evident from their frequent reversal in the chromosphere. On the center of the disk these lines are hazy or "winged," but not so at the limb. To the spectroscopist this aspect is characteristic of greater pressure, that is, of more frequent molecular impact. The observation then proves that the dark lines of hydrogen, magnesium, sodium, etc., as seen at the center of the solar disk are produced by the elements in question at a higher pressure than the corresponding lines at the limb. Accepting our theory this must be so; for, supposing the transparency of the photosphere is such that we can see into it a distance of 2000 miles, than at the center of the disk, we have light modified by selective absorption all the way from the extreme outer chromosphere down to 2000 miles below the upper level of the photosphere; while 10″ from the limb the light, though coming from the same depth of vapor measured along the line of vision has its lowest origin more then 1700 miles farther from the sun's center than in the previous case. Of course the numbers here used have no definite significance, but modify them as we will, within the bounds of probability, the reasoning remains the same.

Suppose now a certain vapor which is confined to the upper stratum of the photosphere, or rather, one of which the lower limit is thus restricted; then according to the reasoning of Forbes, the force of which has been shown, its absorption lines ought to be strongest at the limb. This is the condition which produces the phenomena of Class III.

Before discussing the final class we must recall a fact familiar to the most casual observer of the sun, namely, that lying upon the photosphere is a stratum producing a very strong general absorption, so strong indeed that the disk is probably less than a fourth as brilliant near the edge as at the center. This layer is *very thin*, as proved by the great difference in brilliancy between the upper and lower portions of faculæ. Since the difference of absorption at the two levels is very great, the conclusion follows because the facula itself is so low that it rarely, if ever, appears as a projection on the limb of the sun. For convenience let us call this layer A.

Imagine then, a stratum of vapors, B, above the layer just described, which are not represented at all in the photosphere, and which are of nearly the same temperature as this layer A.*

* This supposition is not opposed to probability, for though we must regard the temperature generally decreasing in passing from the photosphere outward, it does not follow that this decrease is continuous. A similar general law may be stated for our own atmosphere, but in a clear night the air in the immediate vicinity of the ground is colder than that just above. The explanation of this phenomenon is familiar in the theory of dew and hoar frost. Analogous causes for irregularity in the distribution of temperature in the solar atmosphere must be even more efficacious, since the layer A is probably a more vigorous radiator than the earth, and the gases above it are certainly far more diathermous than our atmosphere.

Then (for the sake of simplicity regarding this layer as having no selective absorption) suppose all beneath the two spherical shells in consideration to be removed. In the spectroscope, light from such a source as the two layers A and B would yield a continuous spectrum; for the inner shell (A), radiating only white light, would be robbed of nothing not supplied in equal quantity by radiation from the outer shell (B), since they are of the same temperature. If such layers as these really do exist about the sun, we can now readily state the appearances which would be presented by a sun so constituted, if the threefold system should be studied spectroscopically. In the center of the projected disk, the lines proper to the exterior shell (B) would be reversed, i. e. dark. As we approached the edge, however, *owing to the opacity of the inner shell*, the conditions would approximate to what they would be if the layers A and B existed alone, the central body being removed, and the lines would fade; if faint, they would vanish. This is our explanation of the phenomena of Class IV.

Every theory involves certain conditions. We finally judge of the soundness or unsoundness of any theory largely from the consideration of these implied conditions and of the extent to which they are fulfilled by it. For instance, our explanation of the fact that certain very fine lines are stronger at the center (IV) demands that the substances giving such lines should be found in the chromosphere, indeed, mainly restricted to the chromosphere. Fortunately I can say that one of them (6371) which I first discovered and measured carefully is identical with the 14th line of Young's second Catalogue of Chromosphere Lines. The other one, the wave length of which I took from Ångström's chart without correction, may correspond with Young's 9th (6429·9) line of the same catalogue, which differs in place by only one-sixth the distance between the D lines. This I shall test at the earliest opportunity.

If the theory I have proposed is correct, it affords the first definite evidence of the existence of *chemical compounds* in the sun, for in accordance with it the lines of Class III and Class IV belong to substances which are not found in the lower photosphere. We know, however, that all gases must increase in density in passing from their outer limit toward the center of the sun; and we have seen a proof of this in the case of hydrogen and certain other vapors in the discussion of our observations, which showed that the characteristic lines indicated greater density when they originated at greater depths. The only escape from the contradiction is in the assumption that the lines of the last two cases (III, IV) are due to compound vapors having a dissociation temperature below that of the lower photosphere. Of course the substances of Class IV have a lower dissociation temperature than of Class III.

A naturally suggested and legitimate subject of speculation is as to the nature of the substance which, by precipitation, forms the cloud masses of the photosphere. We may predicate three properties with greater or less positiveness, viz:

1st. The substance has a boiling point above that of iron, for iron vapor at a lower temperature exists in its immediate neighborhood.

2d. The molecular weight is probably not great, for, though precipitated below the upper natural limit of its vapor, there are few elements found in abundance above it, and those in general of low vapor density.

3d. The element is not a rare one. Of these guides the last is of the least value.

The substances which apparently meet all these conditions are carbon and silicon; nor is it easy to name any other which will. Accepting for a moment as an hypothesis that the light coming from the sun is radiated by solid or liquid particles of carbon just at the point of vaporization let us see if the facts of observation fulfill the implied conditions.

As a first consequence, we see that the temperature and light of the photosphere are defined as those of solid carbon at the point of volatilization. In the electric arc there is a very small area of the positive carbon pole at this high temperature. Though this area is in a very disadvantageous position for observation, and can consequently have but a disproportionally small share in producing the total effect, the splendor of the electric light might almost tempt us to believe the guess a valid one. Another consequence implied, however, namely, that the spectral lines proper to simple carbon are absent in the solar spectrum, is doubtless better adapted as a crucial test of the hypothesis than a study of the electric light. There has been evidence recently offered that carbon lines are present in the solar spectrum. Granting this, we perceive that the photosphere contains solid or liquid particles hotter than carbon vapor, and consequently not carbon.

I am then inclined to suspect that the photospheric material may be silicon, which, though denser in the gaseous state than carbon, is not improbably more abundant. There is also good reason to suppose that carbon is precipitated at a higher level, and the analogous but less common element boron may add a minor effect.

In the explanations which I shall give of the remaining phenomena, it may serve to fix the ideas, to think of the granules which characterize the sun's photosphere as clouds of a substance like precipitated silicon. At any rate we are sure that the substance in question, so far as we know it, has properties similar to those of the carbon group.

I have given plausible explanations of all the phenomena included specially in my own observations. It remains to discuss the others, briefly mentioned above.

The substance precipitated cools very rapidly, as it is an excellent radiator, separated from space only by extremely diathermous media. It forms then a smoke-like envelop, which ought to exert just such a general absorption as that observed at the limb of the sun. It is thin because of the relatively great density of the substance in the liquid or solid state; thus the apparent brilliancy of the faculæ is readily understood.

If there is any disturbing cause which would tend to direct currents of gas, over a considerable area of the solar surface, toward a point, this smoke, instead of quietly settling down to lower levels between the granules, would concentrate about this point, there exercising a marked general absorption which would betray itself as a spot. At this place the suspended particles would sink to lower levels with constantly increasing temperature, until finally, heated to intense incandescence, they would revolatilize. Thus the floor or substratum of every spot must be a portion, depressed it is true, of the photosphere. All the spectroscopic phenomena of spots, which have proved so perplexing, are thus naturally and easily explained.

In the immediate neighborhood of a spot, the centripetal currents bend down the ordinary convection or granule-producing currents, so that they are approximately level. Before, the latter cooled suddenly by rarefaction in their upward course, now they cool mainly by the much slower process of radiation; thus, while before the locus of precipitation was restricted, it is now greatly extended. This is the cause of the great elongation of the granules in the penumbra, a real elongation, I imagine, and not merely an apparent one.

Finally, concerning the close duplicity of certain lines, we may reason thus:—If we could surround the sun by a stratum of gas hotter than the photosphere and much rarer than that producing the corresponding Fraunhofer lines, we should, as is shown by a course of reasoning which I have given in another place,* see each dark line divided by a sharp bright line in its center, that is, doubled. But as a consequence of the theory, this supposed condition must be practically met in the case of certain vapors in the sun. The gases just over the granules, in the vertical currents, are at a very high temperature, essentially that of the condensing material itself, consequently much hotter and rarer than the relatively low-lying vapors which, as we have seen, produce the Fraunhofer lines.

* On Lockyer's Hypothesis, Am. Jour. Chem., vol. i, p. 15.

There are, however, certain evident limitations to these conditions; in other words, we cannot expect to see all the dark lines doubled by any increase of dispersive power. For instance, a line must have a marked tendency to broaden with increased pressure, otherwise the duplication cannot be pronounced. Again, the layer of rare vapor must be thin, or its temperature cannot be relatively high throughout, as demanded by the theory. This evident condition doubtless gives the reason why the hydrogen lines, though the broadest in the solar spectrum, are not sensibly double.

The theory of the constitution of the sun above proposed, may be briefly recapitulated thus:

Convection currents, directed generally from the center of the sun, start from a lower level where the temperature is probably above the vaporizing temperature of every substance. As these currents move upward they are cooled, mainly by expansion, until a certain element (probably of the carbon group), is precipitated. This precipitation, restricted from the nature of the action, forms the well-known granules. There is nothing which has come under my observation which would indicate a columnar form in these granules under ordinary circumstances.

The precipitated material rapidly cools, on account of its great radiating power, and forms a fog or smoke, which settles slowly through the spaces between the granules till revolatilized below. It is this smoke which produces the general absorption at the limb and the "rice grain" structure of the photosphere.

When any disturbance tends to increase a downward convection current, there is a rush of vapors at the outer surface of the photosphere toward this point. These horizontal currents, or winds, carry with them the cooled products of precipitation which, accumulating above, dissolve slowly below in sinking. This body of 'smoke' forms the solar spot.

The upward convection currents in the region of the spots are bent horizontally by the centripetal winds. Yielding their heat now by the relatively slow process of radiation, the loci of precipitation are much elongated, thus giving the region immediately surrounding a spot the characteristic radial structure of the penumbra.

This conception of the nature of the penumbra implies a ready interpretation of a remarkable phenomenon, amply attested by the most skillful observers, and, as far as my knowledge goes, wholly unexplained; namely, the brightening of the inner edge of the penumbra in every well-developed spot.*

* Relating to this phenomenon, see important observations by Professor Langley, this Journal, vol. ix (1875), p. 194; also Le Soleil, par Le P. A. Secchi, Paris, 1875, chap. IV, p. 80, and particularly fig. 46, p. 90, with explanatory text.

This interpretation is perhaps most readily imparted by a comparison of the hot convection currents in the two cases. When the convection current is rising vertically, the medium is cooled by expansion until the precipitation temperature is reached, when all the condensible material appears *suddenly*, save as it is somewhat retarded by the heat liberated in the act. Immediately afterward the particles become relatively dark by radiation. In the horizontal current a very different condition of things obtains. Here the medium does not cool dynamically by expansion, but only by radiation; hence, since the radiation of the solid particles is enormously greater than that of the supporting gas, practically by that of the particles themselves. Thus after the first particle appears, it must remain at its brightest incandescence until all the material of which it is composed is precipitated. From this we see that such a horizontal current must increase gradually in brilliancy to its maximum, and then suddenly diminish, an exact accordance with the facts as observed.

Johns Hopkins Univ., Baltimore, September, 1880.

ART. IV.—*Review of Professor Hall's recently published volume on the Devonian fossils of New York* (constituting Part II, vol. v, of his quarto series on the Paleontology of the State); by DR. CH. BARROIS.*

THE State of New York has recently published the second part of vol. v, of the Paleontology of New York, by Professor James Hall. This volume of 492 pages and 120 plates, 4to, contains the descriptions of the Gasteropods, Pteropods and Cephalopods of the Devonian formation of this part of North America.

Before presenting to the readers of the Revue the scientific results acquired in this important work, it is proper to refer to the volumes which preceded it, and to speak of the immense charge which the State has confided to Professor Hall, a charge which has given to science the geology, and then the Paleontology, of New York.

The first researches of Professor Hall were made in the State of New York in 1837. He was appointed by the Government, with Mather, Vanuxem and Emmons, to collect the materials for a geological description of that region. During the years which followed, the annual reports of these savants

*This review appeared in the number of the Revue Scientifique (Paris) for September, 1880. and has been translated from the French for this Journal. The volume by Professor Hall bears the date December 15, 1879. Albany, New York. (Van Benthuysen & Sons.)

made known their progress and their discoveries; and in 1843, appeared in four quartó volumes the final reports on the Geology of the State. These geologists had divided the State into four districts; and in seven years they had succeeded in making a map of a hitherto unknown region as large as Ireland; they had besides given to their country a work which has since become the foundation of stratigraphical Geology in America.

The part described by Professor Hall was the western portion of the State, that is to say, the portion where the non-metamorphic beds were filled with fossils; thus he found himself prepared to undertake the publication of the Paleontology of the State of New York with which he was officially charged in 1843. This work has become the great work to which Mr. Hall has devoted all his talents and all his energy. Under this modest title, it is not only the description of the fossils found in the formations of the State of New York, which the author would make known to the learned world; he conceived the grand project, now almost entirely accomplished, to illustrate the fauna of all the Paleozoic formations of the United States. This labor necessitated considerable preliminary research. It was necessary first to traverse the Appalachian range from Canada to Alabama, from the ocean to the plains of the Mississippi River, that is to say, an extent of country equal to half of Europe, to observe the order of succession in the strata, their parallelism, their continuity, or their interruptions, and to collect the fossils for future descriptions. These long and toilsome journeys, many of them in regions now civilized but then uninhabited or wild, were made without any official aid. The results have been great.

In 1847 was published vol. i of the Paleontology of New York, a volume of 340 pages and 90 plates. With this commenced the series of Mr. Hall's paleontological publications; a series which has been going on uninterruptedly to the present time; which, besides the eight quarto volumes (certain of them being in two parts) of the Paleontology of the State, include also many memoirs in the octavo Annual Reports of the State Museum of Natural History. Volume i of the Paleontology is devoted to the description of the fauna of the Lower Silurian; volume ii, to the fauna of the Middle Silurian, illustrated by 85 plates; volume iii (two volumes) treats of the Upper Silurian, and contains 120 plates; volume iv contains the descriptions of the Brachiopods of the Devonian formations, with 63 plates; a sixth volume, which is outside of the series, has 137 photographed plates of Devonian fossils. Of the series, the sixth and seventh volumes which have just appeared, constitute part 2 of volume v. The first part, devoted to the Devonian Lamellibranchs will next appear.

In this work, the Devonian fauna of the State of New York is divided as below, in the descending order.

Catskill Group.	
Chemung "	
Portage "	
Hamilton "	Genesee slates. Hamilton beds. Marcellus shales.
Upper Helderberg Group.	Upper Helderberg limestone. Schoharie Grit—(Calcareous sandstone). Cauda-galli grit.

This group of formations is mostly limestone at the base, while slates and sandstones prevail in the upper part. To the Cauda-galli grit and the Catskill group we shall not have occasion to refer, as these divisions do not contain representatives of the forms treated of in this volume. The Schoharie species are imperfectly preserved; those of the Upper Helderberg limestone and the Hamilton group are in good condition; those of the Portage and Chemung are less perfect. We will examine successively these different groups, and endeavor to give an idea of the fauna of Gasteropods, Pteropods and Cephalopods which have been described in this work.

GASTEROPODS.—The Platyceras* of the family of the Capulides, form the most striking feature of the Helderberg limestone; they occur there in great abundance and in an astonishing variety of forms (twenty-three species). The great variations in form and character of the Platyceridæ render their determination very difficult, and there are always specimens which cannot be classified; they are found passing from one form to another, and there are species which perhaps should be united. The Platyostoma form another group of Capulides, comprising fourteen species, among which there are several which pass into the preceding genus. Two species taken from the genus Platyostoma are the types of the new genus Strophostylus of Mr. Hall. The Capulides have not attained in Europe the same development as in America; but it is nevertheless at the same epoch that they appear in the greatest abundance. In Germany the Platyceras and the Platyostoma characterize the "Hercynien" limestone of Kayser, but disappear in the Spirifera sandstone. In the west of France they abound in the "Hercynien" limestones of Erbray and also in the Devonian limestones of Courtoisières, etc., while they are wanting in the synchronous graywackes of Ardennes and of Bretagne. These forms are species of calcareous formations rather than characteristic of the Hercynien epoch; one cannot distinguish the living Capulus from the Devonian Platyceras, and many

* The French of Dr. Barrois is here literally followed in making the name of a genus a noun of multitude.

authors unite these genera. The *Platyceras pyramidatum* (Hall) resembles the *P. hercynicus* (Kayser), the *P. symmetricus* (Hall) the *P. uncinatus* (A. Roemer), and the *P. carinatum* (Hall); the *P. zinkeni* (A. Roemer).

It does not appear that there are identical forms common to the Devonian strata of America and Europe; but if it be impossible to assimilate the species of the two sides of the Atlantic, we should nevertheless have a false idea of these faunas by neglecting all comparison. The American Devonian species have representatives in the same formation in Europe; they are analogous forms, and perhaps geographical varieties. This important fact is observed: that the change in genera and families has been in a great degree the same in the Devonian series of the two continents. Thus the Macrocheilus (Phill.), represented by four species in the Devonian of New York, are Devonian forms common in Europe. It is the same with the Loxonema (nineteen Devonian species in America); the Euomphalus (nine American species); the Pleurotomaria (twenty-four species); the Murchisonia (six species); the Bellerophon (twenty-four species); and the Turbo (one species).

The American *Loxonema Hamiltoniæ* (Hall) resembles the *L. nexilis* (Phill.) of England; the *Euomphalus Decewi* (Hall) the *E. Wahlenbergii* (Goldf.); the *E. clymenoides* (H.) the *E. planorbis* (Goldf.); the *Pleurotomaria lucina* (H.) the *P. rotundata* (Münst.); *P. ella* (Hall) the *P. radula* (Kon.); *P. filitexta* (H.) the *P. clathrata* (Münst.); *P. trilix* (H.) *P. quadrilineata* (Sandb.); *P. quadrilix* (Hall) the *P. lenticularis* (Goldf.); *Murchisonia desiderata* (Hall) *Murchisonia angulata* (de Vern.); *M. micula* (Hall) *M. bilineata* (Goldf.); *M. maia* (Hall) *M. trilineata* (Sandb.); *Bellerophon curvilineatus* (Hall) *B. dubia* (d'Orb.); *B. acutilira* (Hall) *B. Murchisonia* (d'Orb.); *B. brevilineatus* (Hall) *B. Verneuili* (d'Orb.); *B. natator* (Hall) *B. expansus* (Sow.); *B. leda* (Hall) *B. decussatus* (Flem.); *B. Helena* (Hall) *B. hiulcus* (Mart.); *B. rotalinia* (Hall) *B. trilobatus* (Sow.); *B. mœra* (Hall) *B. tuberculatus* (d'Orb.); *Porcellia Hertzeri* (Hall) *Porcellia puzo* of Europe.

There are therefore relations between the Devonian faunas of the two continents. It is to be noticed also that the genus Euomphalus is divided, in the Paleontology of New York, into two sections, having for types the European Straparollus of Montfort and the Phanerotinus of Sowerby; Professor Hall takes from this family the *Euomphalus Decewi* (analogous to our *E. Wahlenbergii* (Goldf.) to make the type of his new genus Pleuronotus. The Bellerophons are as abundant in the Devonian in America as in Europe; there are five species in the Upper Helderberg, fourteen in the Hamilton, and five in the

Chemung. It is interesting to note the complete absence of the allied genus Bucania, which, on the contrary, is so widely distributed in the Silurian of this region.

There are, however, certain genera of Gasteropoda, which appear peculiar to the Devonian formation of America. Such are the Cyrtolites of Conrad (two species), and the Cyclonema (six species)—a new genus of Mr. Hall analogous to Pleurotomaria. The Callonema, another new genus (three species) in which Mr. Hall places certain Isonema, Pleurotomaria, Loxonema had perhaps an analogue in Europe in the *Natica subpiligera* (Le Hon) of the Devonian of Belgium. The same may be said of his new group Palæotrochus (one species), the casts of which resemble the *Pleurotomaria Griffithii* of MacCoy.

Pteropods.—Little has hitherto been known of the Paleozoic Pteropods of America; they had however acquired a great development in the Devonian era, for Mr. Hall has described thirty-two new forms, distributed in seven different genera.

The Tentaculites which are represented in the Silurian Clinton Group of New York, and in the more ancient Trenton group in a neighboring State, have considerable differences from the forms which are found in the Upper Silurian and Devonian formations. Mr. Hall is led to consider these differences as generic; and he limits the genus Tentaculites to forms which are conical, straight, elongated and covered with rings; this genus thus defined first appeared in the Upper Silurian, and is represented by six species in the Devonian. The species of Tentaculites cited from the Lower Silurian appertain to the genus Cornulites, which attained its greatest development at this ancient period, and became extinct at the epoch of the Niagara. The Tentaculites of the American Devonian have relations with the European forms of the same epoch; thus we may compare *T. attenuatus* (Hall) of America with the *T. tenuis* (Sow.) of England; *T. scalariformis* (Hall) with *T. scalaris* (Schlt.).

The genus Styliola is represented in America by two species, one of which presents four varieties; this species, *Styliola fissurella*, is very analogous to *S. clavulus* (Barr.); it has a wide geographical extent in the United States, where it is recognized over an area of 700 miles. It appeared upon this continent as in Europe after the genus Tentaculites; in Europe it appears in the Third Fauna; in America it is limited to the Devonian.

The genus Coleoprion of Sandberger is represented by a doubtful form from the Hamilton group. Professor Hall has designated the genus Coleolus for six forms, of which the type *C. tenuicinctum* had been hitherto connected with the Coleoprion; these are tubular, conical forms, elongated, usually straight, and with thick shell; they are ornamented with striæ or with oblique rings. This genus is limited to the Devonian formation.

The Hyoliths are distinguished from all the other genera of American Pteropods by their geological extent; they appear in the Cambrian (Potsdam) and are found above the Devonian and in the Carboniferous limestone. It is remarkable to see this genus diminish in the Middle Silurian and even disappear in the Upper Silurian, which is so rich in fossils and in other Pteropods, then reappear with six new forms in the Devonian. On the contrary, it is in the second and third Silurian faunas that this genus attains its full development in Europe. There are nevertheless resemblances between the forms of the two continents: the *Hyolithes aclis* (Hall) of the Hamilton, resembles the *Hyolithes discors* of Barrande; the *H. striatus* (Hall) the *H. solitarius* (Barr.); the *H. singulis* (Hall) the *H. striatulus* (Barr.).

There is no room to remark on the new genus Clathrocœlia, established on two imperfectly preserved specimens from the Hamilton group. On the contrary, the European genus Conularia is represented by ten beautiful new species in the Devonian of America. They differ from those which had been previously described from the Silurian of the same region, of which Mr. Hall had already described seventeen specific forms of the second fauna; they differ also from the seven forms which have been recognized in the Carboniferous limestone.

CEPHALOPODS.—Mr. Hall admits entirely, for this part of his work, the generic divisions which have been established with so much talent by our illustrious compatriot M. Barrande. The American Orthoceras compared with those of Europe, and especially with those of Bohemia, present some interesting facts. The ornaments of the shell are in Bohemia generally imbricated lamellose striæ; in America they are reticulated. The curved forms common in Bohemia are rare in America; the Brevicorns of M. Barrande are scarcely represented in America. Among the curved forms there are more relations between the American and Bohemian forms.

The genus Orthoceras appeared in America in the Cambrian (Calciferous sandstone); the sub-genus Endoceras did not pass beyond the second fauna; the Orthoceras proper are found as far as the Permian. There are two principal horizons of Orthoceras in the Devonian formation; the Schoharie grit, which is richest in species and individuals, has only ten meters of thickness, and the Hamilton group, 400 meters thick in the eastern part of the State of New York, is reduced to 100 meters in the western part. The Schoharie grit passes insensibly into the Upper Helderberg limestone, and it is curious to see the fauna of the Cephalopods diminish in proportion as the rock becomes more calcareous. The Orthoceras are distributed in the Devonian formation as follows:

Upper Helderberg group, including the Schoharie grit	30
Hamilton group	29
Portage "	4
Chemung "	19
Waverly "	7

The numerous and varied forms of the Schoharie grit are usually imperfect; they occur in a coarse sediment and are generally in the condition of casts of the interior. Five of these forms are found in the Upper Helderberg limestone; while other species are proper to this horizon, and two of the lower rock are continued into the Hamilton group. There are few Orthoceratites in the Hamilton in the eastern part of the State, where it is shaly, but they are more numerous toward the center of the State, where the sediments are charged with lime. It is interesting to note that the Nautilus have not had the same recurrence; and they are found in the more eastern arenaceous beds of the group. The Portage group has its own proper fauna of Orthoceras, and has few characters in common with the neighboring groups. The Orthoceras of the Chemung group present the singular trait of being intermediate in general form between those of the Upper Helderberg group and those of the Hamilton.

The Bactrites have been but sparingly found in the United States; only a single species is known in the Marcellus shales. The Gomphoceras have nearly the same extent as the Orthoceras, but they are most numerous in the limestones of the Upper Helderberg in the western part of the State. The species in the Schoharie grit are generally small, but there are large ventricose forms in the limestone of the Upper Helderberg; those from the Hamilton to the Chemung are characterized by a large proportion of short, ovoid forms, and by some which are larger and fusiform. The American species, compared with those of Bohemia, differ from these generally in the form of the mouth, it having often two openings, united by a canal, in the Bohemian species, while in the American species the openings are near together and become a single one of trilobate form. The Schoharie grit has furnished six species of Gomphoceras, the Upper Helderberg six, the Hamilton eleven, the Portage one, and the Chemung two: still it is impossible to state exactly the Cephalopod fauna, of this last epoch, for it has furnished a great number of fragments of species which cannot be determined.

The existence of Cyrtoceras in America was first recognized by Conrad in 1838, but it is difficult to define its limits, and it comprises at present, according to Mr. Hall, many species which should be removed from the genus. The Gyroceras, which are Cyrtoceras with volutions more enrolled and separated, present so many relations, in the position of the siphon and the ornamentation, with the American Cyrtoceras, that one cannot really consider them as distinct generic types; but that they may be reunited. Thus the series of *Cyrtoceras alternatum*, *eugenium*, *citum*, is parallel with the series *Gyroceras Nereus*, *trivolve*, *laciniosum*, *Matheri*, *paucinodum*, *undulatum*; we follow all the changes in the two series from a like initial form to a shell several times enrolled. A second group, comprising more massive forms, shows the same relations between the series of the *Cyrtoceras Jason* and the *Gyroceras cyclops.* The generic distinction of all these forms, based upon the degree of curvature of the shells, is entirely artificial, and neglects the essential characters which unite all these shells in the same group. If it is easy to recognize a Cyrtoceras in the Silurian period, it becomes more and more difficult to do it with precision in the Devonian, in proportion as the Gyroceras become developed. The general law is nevertheless that the Gyroceras succeed the Cyrtoceras in time. These forms are represented by six species in the Schoharie grit, twelve in the Upper Helderberg, six in the Hamilton and one in the Chemung.

The genus Trochoceras, established by MM. Hall and Barrande for the Gyroceras enrolled in helix form, is essentially Silurian in America as in Europe. It has attained its greatest development in America at the epoch of the Niagara. M. Barrande has described forty-five species in the Silurian of Bohemia. In the Devonian of America, this genus is limited to the Schoharie grit; it is there represented by nine different species; they appear to hold here the place of Nautilus, which have entirely disappeared, and which on the contrary replace them in the period of the Hamilton.

In the Devonian, the Nautilus are abundant, in place of the Orthoceras which we have seen so predominant in the Silurian; in the Devonian, Gyroceras are developed to the detriment of the Silurian Cyrtoceras; but it is only at the middle of the Devonian period that the fauna of the Nautilus is greatly developed; there are ten species in the Hamilton; all presenting a remarkable unity in the plan of their ornamentation. The subgenus Discites of McCoy should include three Nautilus of America, two of the Upper Helderberg and one of the Hamilton; these differ from the Nautilus proper in the angular form of the shell, the position of the siphon, and the character of ornamentation.

The Goniatites, with the exception of *G. mithrax* found perhaps in the Upper Helderberg of Ohio, first appeared in the beds of the Hamilton. They occur there in abundance; they present a remarkable variety of form (seven species), and the type attains its greatest dimensions in the Hamilton. Their appearance characterizes an epoch which differs much in all its fauna from the preceding. They continue quite abundant during the following periods. There are seven species in the Portage, five in the Chemung.

All the forms which we have passed in review are figured in a style which does great credit to the draughtsmen of Mr. Hall, Messrs. G. B. Simpson and H. M. Martin. The fifth volume of the Paleontology of New York, of which we have endeavored to give some idea to the readers of the Revue, is then essentially a work of paleontological specification. But it contains besides important geological observations: such are the examinations made by Mr. Hall in the vicinity of Louisville, Kentucky, to determine the age of some fossils found near the Falls of the Ohio.

This volume is destined, like the greater part of those preceding it by the same author, to make an epoch in science; for notwithstanding the labors of Rœmer, Sandberger, Kayser and Gessler, upon the Devonian formation, we have not such complete descriptions of the fauna of this period as have now been given in America by Professor Hall. Thus the Paleontology of New York will always occupy an honorable place among the publications of official geological surveys.

ART. V.—*Earthquake at the Philippine Islands, of July*, 1880. (Plate IV.)

THE earthquake of July, 1880, at Luzon, the largest of the Philippine Islands, was one of the most destructive on record. The shocks continued, with greater or less interruption, from the 14th to the 25th of the month, destroying churches and other buildings, and producing some loss of life. Records of the occurrences at Manila, and the other disturbed regions, and of the observations made with seismometers during the eventful period, were published from day to day in the "Diario de Manila;" and these records have since been collected into a small volume, bearing the title, "Los Terremotos en Filipinas en Julio de 1880."* From this volume we translate the following account of the seismometrical observations made—as

* Published at Manila. in a duodecimo of 152 pages. (Establecimiento Tipographico de Ramirez y Giraudier à cargo de C. Miralles, Magallanes, 3.) For the use of the copy of this volume which has supplied the facts here given, this Journal is indebted to Professor E. C. Pickering, Director of the Harvard College Observatory.

the Preface says—by "los illustrados PP. Jesuitas del Observatorio Municipal, à quienes nunca se agradeceran bastante los servicios prestados al pais en situacion tan angustiosa." The provinces of Manila, Cavite, Bulacan, La Laguna, Pampanga, and Nueva Ecija, were the chief victims from the terrible convulsions; and, in many parts, their "solid edifices were converted into shapeless heaps of ruins, and the materials of their prosperity buried beneath the rubbish."

Seismometric observations made at Manila, at the Observatory of the "Ateneo Municipal," from the 14th to the 25th of July, 1880.

The figures which accompany this Report (see Plate IV) are the records of the seismometer during the principal shocks of the earthquake. They were traced by a pendulum six meters long, suspended from a point at the termination of four metallic rods, and placed within a glass case. The pendulum could oscillate freely in all directions, not only under the impulse of violent shocks, but also of the slow and gentle undulations caused by movements in the walls of the building—to which it was rigidly attached. It oscillated over a spherical concavity made in a thick piece of wood, whose radius of curvature was equal to the length of the pendulum. The concave surface was sprinkled lightly with lycopodium powder, to receive the tracings made by the pendulum in its various movements. At the center of the concavity there was a small ring which was dragged by the pendulum in its first impulse, and which was left at a spot opposite to that from which the first seismic wave came. This apparatus is that called the *horizontal seismometer.*

The *vertical* seismometer used consists of a rigid metal rod, having a brass wire in the form of a spiral spring soldered to its upper end. To the last turn of the spiral is attached a cylindrical piece of lead, placed transversely to the rod, and at such a distance from it as would allow of its moving freely under any oscillations. Below the piece of lead is a small index of cork, also transverse to the rod, which is dragged on by the lead in any movements, and stops always at the point of maximum vertical oscillation.

The object of these instruments is, *first,* to determine the direction of the first horizontal undulation, and this is done by means of the ring at the end of the pendulum, which is pushed before it on the first impulse; *secondly,* to find out the general direction of the horizontal undulations, and their amplitude, by means of the lines traced by the same pendulum in the lycopodium powder; *thirdly,* to ascertain the greatest amplitude of the maximum vertical undulation by means of the index of the vertical seismometer; *fourthly,* to obtain, by the combination of these two elements, the magnitude and direction of the oblique undulations.

From the indications of these two instruments the following results were obtained, during the successive days of the great earthquake. We do not attach to them an absolute value, since the seismometers cannot make perfectly correct observations, when such movements are of great violence and complication. Yet we believe that they afford quite a good registration of the phenomena, and will be useful for comparison with those of other earthquakes. The facts obtained are as follows.

The vibrations began during the months of April and May, in the northern provinces of Luzon. The center of oscillation, as indicated by the directions registered at Manila, appears to coincide with a volcano, which has been long extinct, situated between Lepanto and Abra, in the central Cordillera of Luzon, in latitude 16° 22′ N., and longitude 127° E. from the Spanish Observatory of San Fernando. At first the movements were weak and little frequent; yet in the month of June they became quite intense, and extended from *north to south* over a large zone. This direction never changed; and the few discordances recorded appear to have been a result of haste or want of care in the method of taking the observations, exactness being hardly attainable without special instruments for the purpose.

Early in July some vibrations were felt; yet from the 5th to the 14th none were recorded at Manila for any point on the island.

On the 14th, at 12^h 53′ P. M., when a storm from the northeast of Luzon was threatened, as indicated by an extraordinary fall of the barometer, the first shock occurred in which it was observed that there were two centers of oscillation (see figure 1); one in the second quadrant from the point where the oscillation of the pendulum of the horizontal seismometer commenced, and the other in the third, in which the oscillation of this first movement—mainly horizontal in direction—ended. The total amplitude of the oscillation reached 5° 25′. The horizontal pendulum left inscribed a cross whose arms intersected at a right angle, the first set, from S. 55° E. to N. 55° W., and the other, from S. 40° W. to N. 40° E.

The first impulse was in the direction from S.E. to N.W., and the amplitude of the oscillation in this direction covered an arc of 5° 25′, all apparently a result of the first shock; then the pendulum was violently oscillated in a direction perpendicular to this, and with an amplitude a little less than in the former case. The index of the vertical seismometer was moved 4^{mm} from its position.

After this first movement there were two more shocks at the end of an hour and a half. On the 15th and 16th no perceptible shocks occurred; and on the 17th, only two small shocks.

On the 18th, at 12^h $40'$ P. M., occurred the great shock—one of oscillation and also of "trepidation," and spoken of commonly at the time as one of rotation. Its duration was 70 seconds. The movements of the pendulum were so many and various that it is not possible to indicate them all, and we limit our descriptions to the principal directions and the amplitudes of the same. For the rest the reader may refer to fig. 2. It may however be stated that, in our opinion, only the great oscillation from E. to W., which was the most regular and without violent shocks, corresponds to the actual inclinations of the disturbed buildings toward the west.

1. Maximum oscillation, from S. 85° E. to N. 85° W. (*b b′*, the direction of most intense oscillation); amplitude of the greatest oscillation in this direction 22°—or 11°, E. and 11°, W.

2. Maximum oscillation, from S.W. to N.E. true; amplitude 19°, but 10° 10′ to the S.W., and 8° 50′ to the N.E.

3. Maximum oscillation, from N. 4° W. to S. 4° E.; amplitude 16°, but 9° N. and only 7° S., whence it appears that the impulse was from the north to the south. The index of the vertical seismometer was moved 34^{mm} from its position.

From this time there was an uninterrupted series of small shocks, until the 20th at 3^h $40'$ P. M., and then occurred a repetition of extraordinary violence, though only movements of oscillation and trembling ("trepidation)" occurred. Its duration was 45 seconds. The direction of oscillation was from S. 60° E. to N. 60° W.; the amplitude 12° 30′, but with the following peculiarities: there was no one total oscillation, but three semi-oscillations, indicative of the great violence of the shocks, (see, in fig. 3, the lines *a a′*, *b b′*, *c c′*); the pendulum, at the first impulse from S.E. to N.W., reached the height indicated by the line *a a′*; on returning to its point of departure, it received a new impulse which not only destroyed the velocity that it had acquired in its descent, but forced it to go a second and third time to the same height that it had reached after the first impulse. The vertical pendulum was moved 24^{mm}. The direction SS (see figure) was one of intense oscillation.

The pendulum continued oscillating during all the evening in a N.E. and S.W. direction. At 10^h $40'$ P. M., occurred a second violent repetition, which lasted 55 seconds; and this shock had its peculiarities. In the preceding, the focus of most intense seismic radiation was in the second quadrant; in *this*, it began in the E. true, yet with much less intensity than before; and the focus before observed in the first quadrant continued to operate but with greater violence. In figure 4, we observe that the oscillation from E. to W., true, had an amplitude of 10°—5° to the E. and 5° to the W., but that in the direction from N.E. to S.W. the amplitude was 17°, 9° to the S.W. and 8° to the N.E. $a\ a'$, $b\ b'$, $c\ c'$ are directions of the first, second and third intense oscillations. In the vertical seismomenter the index moved 28^{mm}.

Vibrations continued; yet there was a marked diminution in frequency and intensity. The pendulum, which had not been quiet since the 18th until 3 P. M. of the 21st, was motionless for long intervals in the three following days. On the 25th, at $4^h\ 2'$ A. M., another shock was felt; it was of feeble intensity, yet of interest since the record bears evidence as to the gradual change in the center of seismic radiation which had been in progress. The direction of the undulation (fig. 5) was N. 64° E. to S. 64° W.; the amplitude of the oscillation was only 3° 54′. No vertical movement was appreciable, the vertical seismometer indicating a change of only $0{\cdot}7^{mm}$ from the normal position.

After this exposition of the results, we will recapitulate briefly the points established by the tracings on the lycopodium powder as shown in the figures

(1.) In the registration of the 14th (as represented in fig. 1), two radial centers are shown; the first in the second quadrant, from the point at which the movement began, and the second in the first quadrant where it ended.—(2.) In that of the 18th, also, we find the same two centers, but, besides these, other new ones, the pendulum moving in all imaginable directions. (See fig. 2.)—(3.) In that of 3 P. M. of the 20th (fig. 3), the focus of the second quadrant worked with wonderful violence, and the others had disappeared.—(4.) In that of $10^h\ 40'$ P. M. of the 20th (see fig. 4), a very great variation in the seismic foci is shown: the oscillations from E. to W., which correspond to the foci that before operated with so great violence, were gradual and of much less intensity, while, on the contrary, those from N.E. to S.W. indicate powerful undulations between these points. —(5.) Finally, in that representing the last oscillation on the morning of the 25th (see fig. 5), there is manifested only the one seismic focus of the first quadrant, and this of slight intensity, the others having wholly disappeared. In each of the figures the small circular dot one side of the center shows the position of the ring given by the first impulse.

We will not now offer any deductions from the facts observed, desiring only to place them before those versed in these subjects that they may themselves study them without prejudice from our opinions.

NOTE 1.—It should be understood that when we speak of the movement of the pendulum from one side to the other of the center of reference, we do not intend to say that the buildings swayed equally with the pendulum, for, as is clear, the motion in one of the semi-undulations is not an effect of the impulse or inclination of the edifice, but of the velocity acquired in the first semi-oscillation. The divergences of the pendulum on each side from the center of reference have been indicated because this fact bears on the question whether the seismic waves resemble sound-waves in the air, or whether they are rather the effect of upward or downward movements in the earth at points more or less distant from the place of observation.

NOTE 2.—The figures have many lines that do not combine regularly with the rest. This has resulted from the shocks in a vertical direction, causing the pendulum to leap in a violent way and forcing it sometimes to abandon one curve in order to follow another started by the new impulse.

In conclusion, we assure our readers that the curves as presented in the figures were transferred from the lycopodium powder with the greatest possible fidelity.

These figures have been copied for this Journal by photography, in order that they might be a correct transfer from the original plate. Figures 1 and 5 are of the same size as on the original plates; 2, 3, 4, have been reduced one-half.—EDS.

ART. VI.—*Papers on Thermometry from the Winchester Observatory of Yale College*; by LEONARD WALDO.

I.—*On the Errors of the Kew Standards*, 578, 584 and 585.

IN order to avoid, as far as possible, any uncertainty as to what constitutes the mercurial standard thermometer to which the instruments sent here are referred, the following definition of this standard has been adopted and is printed upon the certificates of examination issued with standard thermometers sent here to be verified.*

"The theoretical mercurial standard thermometer to which this instrument has been referred, is graduated by equal volumes upon a glass stem of the same dimensions and chemical constitution as the Kew standards 578 and 584. The permanent freezing point is determined by an exposure of not less than 48 hours to melting ice, supposing the temperature of the standard has not been greater than 25° C. = 77° F. during the preceding six months. The boiling point is determined from the temperature of the steam of pure water at a barometric pressure of 760^{mm} = 29·9215 in. (reduced to 0° C.) at the level of the sea and in the latitude of 45°."

* The Kew thermometers are supposed to have their boiling points as nearly as practicable at 212° F. = 100° C. at the temperature of steam under Laplace's standard atmospheric pressure, or the atmospheric pressure corresponding to the following number of inches in the barometric reading, reduced to 32° F.,

$$29{\cdot}9218 + 0{\cdot}0766 \cos 2\phi + 0{\cdot}00000179\ H,$$

Where ϕ = the latitude and H is the height in feet above the sea level.—Rep. Br. Ass. Adv. Sci., 1854, p. xxxii.

We have not yet received from the Kew Observatory any further statement as to what the chemical constitution of the glass used in "Kew 578" and "Kew 584" is, than that they are blown from "Powell's best flint glass." This does not enter into the subject of our present paper and will be discussed in a subsequent one in connection with the comparison of the Kew standards with the standard thermometers of the Kaiserliche Normal-Eichungs-Kommission.

The thermometers, Kew 578 and Kew 584, are almost exactly alike with the exception of their graduations. Kew 585 is so much longer and of so much larger tubing, that it was not thought wise to include it in the standard to be established between 0° and 100° C. The following is the description of these instruments.

Designation.	How Graduated.	Length of 1°.	Smallest Graduation.	Tube. Length.	Tube. Diameter.
Kew 578	− 9° to + 105° C.	3·46 mm	0°·5	455 mm	6·0 mm
Kew 584	+ 14° to + 220° F.	1·87 "	1	455	6·1 "
Kew 585	− 34° to + 275° C.	1·73 "	1	618	7·4 "

Designation.	Cylindrical Bulb. Length.	Cylindrical Bulb. Diameter.	Remarks.
Kew 578	23 mm	6·0 mm	Graduated at the Kew Observatory, Jan., 1880. Filled in July, 1874.
Kew 584	23 "	5·5 "	Graduated at the Kew Observatory, May, 1880. Filled in July, 1874.
Kew 585	27 "	6·2 "	Graduated at the Kew Observatory, May, 1880. Filled in July, 1874.

They are each provided with a chamber at the upper end for the purpose of calibration. The measured bulbs of similar thermometers broken at Kew, give, approximately, a thickness of the walls of the bulb of 0·025 inch. With similar thermometers the average maximum depression of the freezing point observed after the boiling point, is found to be 0°·17 C.

The following pieces of apparatus were used in the investigation, and they will be referred to by the Roman numeral.

I. The Crouch microscope comparator, elsewhere described,* provided with an eye-piece micrometer by Powell & Leland, and an objective of 1 inch equivalent focus.

II. A pair of microscopes provided with eye-piece micrometers and objectives of 4 inches equivalent foci, by Beck. These microscopes can be adjusted so that their stages are in the same

* Proc. Am. Acad. Arts and Sci., Bost., vol. xiii, 1877–78, p. 352.

plane, and can be placed at varying distances from each other in order to bring the two ends of the column of mercury used in calibration into view at the same time.

III. A small vertical cathetometer by Wm. Grunow, graduated upon its vertical triangular bar to single millimeters and read by a vernier directly to $0{\cdot}2^{mm}$; $0{\cdot}05^{mm}$ can be readily estimated. The graduation extends over 220^{mm}. The telescope is provided with an objective of 4 inches focal length by Beck and an eye-piece micrometer by Rogers. The smallest division of the eye-piece micrometer subtends an apparent angle of 39 minutes, and the telescope magnifies 20 diameters at the distance at which it is commonly used. The vertical motion of the telescope is by means of a rack and pinion.

IV. The standard barometer, "Jas. Green, N. Y., 957." The mercury column in this instrument has a diameter of 0·50 inches nearly, and the glass tube has an exterior diameter of 0·63 inches. The exterior diameter of the glass cistern at its base is 1·60 inches. The vernier reads by estimation to 0·001 inches, and the scale is set about 0·01 inches lower than the measured height above the ivory point which is adjusted on Fortin's principal at the base, in order to correct for capillarity of the tube. The length of the brass tube is expressed in terms of the standard United States Coast Survey yard, to within any errors appreciable in its readings. It read within 0·001 inch of the standard barometer kept by Mr. Green as representing the standard of the Kew Observatory, in October of this year. After comparison it was carefully transferred to New Haven by hand, and since that date has been hung at the level of the boiling-point apparatus to be described. The attached thermometer has a correction of $-0^{\circ}{\cdot}2$ at the freezing-point, and of $-0^{\circ}{\cdot}7$ at 80° F. The barometer from the cistern upward is wrapped in cotton-wool to keep the temperature as constant as possible and to insure an accurate determination of it by means of the attached thermometer.

V. The freezing point apparatus, which consists of a tinned iron vessel within another, the space between them filled with cotton wool. The inner vessel holds two liters of melting snow or ice. There is provision for the escape of the water into a space at the bottom of the inner vessel, protected from radiation.

VI. A boiling-point apparatus constructed of brass after Regnault's plan. The diameter of the inner steam chamber is 13^{cm}, and the apparatus is provided with a water manometer to keep the pressure constant.

VII. A boiling-point apparatus, constructed entirely of glass, with a single steam chamber extending to a height of 71^{cm} above the surface of the boiling water. A water manometer has its connection at the level of the thermometer bulbs, and a small thermometer is inserted at the top of the steam chamber to assure the observer that the temperature at the top is at 100° C. The escape of the steam is through a small vent at the top of the tube, and the amount of its opening is controlled by a small brass plate.

The details of the calibration of the Kew thermometers have been furnished us by the courtesy of Mr. Whipple; it has been so carefully done that it seemed necessary only to rigorously examine the thermometer at long intervals, for errors depending on this cause. The results of our calibration are given in the following table. The observations were made with apparatus II, and special care was taken to guard against any changes of temperature. The reduced results are as follows, where each line is the mean of three observations:—

Thermometer	Date.	Extreme readings.		Computed length of column.	Correction for calibration error.	Remarks.
	1880					
Kew 578	Oct. 15	−1°·1	+33°·6	32°·487	At 32°C. = +0°·007	The observations were all made by daylight and at one sitting for each thermometer. The extreme variations of the temperature of the room during the observations, as measured by two thermometers, one at each end of the tube being measured, was as follows: Kew 578 = 0°·0 F. 584 = 0·1 585 = 0·1
		+31·0	+65·1	32·507	65°C. = −0·014	
		+63·7	+98·6	32·487	99°C. = +0·007	
Kew 584	Oct. 15	+32·2	+82·3	49·040	79°F. = +0·021	
		+76·1	+127·3	49·068	123°F. = −0·006	
		+119·1	+170·1	49·078	166°F. = −0·016	
		+162·2	+213·2	49·060	212°F. = +0·001	
Kew 585	Oct. 15	−1·0	+50·9	49·813	50°C. = +0·015	
		+49·0	+100·9	49·843	100°C. = +0·000	
		+99·1	+151·7	49·820	150°C. = +0·008	
		+148·9	+201·0	49·807	150°C. = +0·029	
		+199·2	+250·8	49·747	250°C. = +0·110	

The length of the column used for the Kew calibration, and by which the thermometers were graduated, was 5°·026 C. for Kew 578, 10°·405 for 584, and 10°·673 for Kew 585. We may, therefore, conclude that between 0° and 100° C. the errors of the three Kew standards, depending on the calibration, are practically insensible; for the errors shown above are too small to be certainly detected, owing to the width and irregularity of the lines which make up the graduation of the thermometer scales.

Accidental errors of graduation could not be guarded against except by the direct examination of every degree, and that accordingly has been done.

The tedious examination of each degree was accomplished with the aid of Professor J. E. Kershner, now of the Franklin and Marshall College, but who was until recently connected with the observatory. We used the apparatus I, and each degree was measured twice. The resulting means were expressed in terms of hundredths of one division of the eye-piece micrometer, and gave a subdivision of about $\frac{1}{4350}$, $\frac{1}{2330}$ and $\frac{1}{2100}$ of 1° in the cases of Kew 578, 584 and 585 respectively. There were about 2300 separate micrometer readings made, and the result of the reductions shows that no sensible accidental errors have been introduced into the graduations of these standards. The necessary width of the single graduations, taken in connection with the comparatively rough construction of a thermometer tube, prevents any very accurate measures being made; I had prepared for publication the measures we made upon these standards, in order to show what degree of precision we might fairly expect with etched lines of a coarseness sufficient to be readily visible to the naked eye. So much space was occupied by these results however that it now seems hardly expedient to publish them in this place.

The following determination of the boiling and freezing points have been corrected for exposure of stem, and have been reduced to the level of the sea in the latitude of 45°. The latitude of the observing station is 41° 18′; the height of the barometer cistern (and of the boiling point apparatus) is 53 feet above the mean high water of Long Island Sound. Each determination is the mean of from three to five cathetometer readings, and with the exception of the freezing point determinations succeeding the boiling point determinations in the same day, the freezing points were observed after a long exposure (48 hours or more) to a temperature of freezing.

Thermometer.	Date. 1880.	Correction at freezing point.	Correction at boiling point.	Remarks.
Kew 578	Nov. 25	0°·00	----	
	Dec. 1	0·00	----	
	" 1	----	+0°·01	Apparatus VII.
	" 1	+0·18	----	
	" 3	----	+0·04	" VII.
	" 6	----	+0·03	" VII.
Kew 584	Nov. 25	+0·10 F.	----	
	" 26	----	+0·19 F.	" VI.
	" 26	+0·38	----	
	" 26	----	+0·19	" VI.
	" 29	----	+0·20	" VI.
	" 30	----	+0·22	" VI.
	Dec. 1	----	+0·21	" VII.
	" 1	+0·32	----	
Kew 585	Oct. 16	0·00	----	
	Nov. 2	----	+0·15	" VI.
	" 2	+0·10*	----	
	" 29	----	+0·15	" VI.
	" 30	----	+0·15	" VI.
	Dec. 1	+0·22	+0·11	" VII.
	" 1	+0·22		

[To be continued.]

Art. VII.—James Craig Watson.

James Craig Watson, Professor of Astronomy in the University of Wisconsin, and Director of the Washburne Observatory at Madison, Wis., died on the morning of Nov. 23, 1880, after an illness of one week, at the age of forty-two years and ten months. Professor Watson was one of the most gifted and distinguished of modern astronomers, and his life-work is identified with the name of the University of Michigan.

He was born of American parentage, during a sojourn of his parents in Middlesex (now Elgin) County, Ontario, January 28, 1838. The mathematical genius revealed by the boy at the early age of nine, determined the father to secure him a liberal education; and the family accordingly removed to Ann Arbor, in 1850. Here James displayed equal aptitude for mathematical and linguistic studies, and being prepared for college, almost without the evidences of effort, he entered the University of Michigan in the autumn of 1853. He attained equal scholarly distinction as a student of ancient and modern languages, and of mathematics. It is said that before the close of his Junior year, he had performed the phenomenal feat of reading from beginning to end the Mécanique Céleste of Laplace. During his Senior year, he was the solitary pupil of Dr. Brünnow, and graduated in 1857. His mechanical tact was such that in the absence of a mathematical bent he would have become an eminent mechanician and inventor. While in college, some of his spare hours were spent in grinding lenses and the construction of a telescope. Other portions of his time he was compelled to devote to the earning of means to defray collegiate expenses.

During the two years succeeding his graduation, he was employed as assistant in the Observatory, and in the prosecution of studies for his second degree. In this work he displayed such remarkable aptitude as an observer, and such marvelous rapidity in his computations that, on the retirement of Dr. Brünnow, in June, 1859, young Watson succeeded him in the chair of Astronomy. He was already known as a frequent contributor to the American Journal of Science, Brünnow's Astronomical Notices, Gould's Astronomical Journal, and the Astronomische Nachrichten of Altona. Not less than twelve communications written before he was twenty-one are recorded in the Royal Society's Catalogue of Scientific Papers, which also enumerates twenty-one others between 1859 and 1874. His wonderful keenness as an observer was signalized, while yet an undergraduate, by the discovery of a comet on the 29th day of April, 1856, and four months after graduation, by the discovery of a planet on the 20th of October, 1857, which, however, proved to have been observed by Luther a few days before, and has been named *Aglaia.* His observations of Donati's comet, in 1858, possess a standard value, and his computation of the orbit is recognized as authoritative. The interest awakened by this comet prompted to the preparation of "A Popular Treatise on Comets," published early in 1860.

In 1860, Dr. Brünnow resumed the directorship of the observatory, and young Watson was assigned to the chair of Physics in the University, which he retained for three years, when, on the final retirement of Dr. Brünnow, Watson was made Professor of Astronomy and Director of the observatory—a position which he held and honored for sixteen years. Scarcely had he been clothed with full control of the instruments when he resumed his remarkable career of discovery. There seemed almost a magic in his powers. Unrecognized celestial objects seemed to crowd spontaneously upon his notice. On September 14, 1863, he made his first independent planetary discovery. This was *Eurynome.* On January 9, 1864, he discovered the comet since known as 1863, VI, which Respighi, as it proved, had already noted. On the 9th of October, 1865, he discovered a planet which also proved to have been announced by Peters, and has since been named *Io.* He discovered *Minerva*, August 24, and *Aurora*, September 6, 1867. During 1868, he added no less than six minor plants to the solar system, furnishing the only instance in which the list of planetary discoverers presents the same name four times in immediate succession.

Meantime he was engaged upon a work which might well have engrossed all his powers, and must have quite exceeded the abilities of any but a gifted mathematical genius. It was no less than a complete digest of the results and methods of all the great writers on theoretical astronomy, and an independent development of the great principles of the science. "Having carefully read the works of the great masters," he says in his preface, "my plan was to prepare a complete work on the subject, commencing with the fundamental principles of dynamics, and systematically treating, from one point of view, all the problems presented." This broad plan, conceived by a young man of twenty-eight, and completed when twenty-nine, was executed with ability so commanding, that the work, on its appearance, in 1869, was immediately accepted as an authoritative exposition of the higher principles and processes of dynamical astronomy, and was made a text-book at Leipzig, at Paris and at Greenwich. The same year he was sent by the General Government on an expedition to observe the solar eclipse at Mt. Pleasant, Iowa; and in 1870, to Carlentini, Sicily, for a similar purpose. In 1874 he was appointed to the charge of an expedition to Peking, China, to observe the transit of Venus. His observations were favored by the weather and conducted with consummate skill. The results, though reduced and discussed, are not yet published. Even at the antipodes, fresh discoveries awaited him. He had already raised his list of planetary discoveries to seventeen, and now added *Juewa*, the eighteenth. In 1876, he was one of the Judges of Awards at the Centennial Exposition, and wrote the celebrated "Report on Horological Instruments." In 1878 also appeared his Tables for the Calculation of Simple and Compound Interest—a work which, in spite of the subject, is marked by great originality, and demanded a vast amount of wearisome labor. The same year he was sent by the General Government in charge of an expedition to Wyoming, to observe the total solar eclipse. Professor Watson, having long entertained a belief in the existence of an intra-mercurial planet, as well as of an extra-neptunian one, gave special attention, at this time, to a search for the former, and was the first astronomer to note certainly (July 29, 1878) the existence and position of the planet Vulcan. He also satisfied himself of the existence of a second intra-mercurial planet. This brought the number of his original planetary discoveries to twenty-six (including one lost July 29, 1873, and two anticipated). He was now animated by an intense desire to control instruments of suitable power and adjustment to confirm his last observations, and enable him to detect the outlying planet beyond Neptune. Coincidently came the invitation to assume the charge of the Washburne Observatory at Madison, Wisconsin, which was to be improved and newly equipped with instruments far more efficient than those at Ann Arbor. The temptation was great, but he naturally clung to his Alma Mater, whose authorities made such efforts as they thought authorized to content their astronomer. But the requisite means could only be obtained by a grant from the legislature—a measure defeated by an inadequate appreciation of the honor shed upon the State by such a name as Watson's. Reluctantly, but sustained by a high and noble aspiration, he removed, in the summer of 1879, to Madison, and immediately devoted himself with intense energy to remodeling the observatory structure, and introducing some original provisions thought to be suited to the special researches on which he was bent. A cellar twenty feet deep was sunk at the bottom of the first slope of observatory-hill. Into this, light was to be thrown through a long tube, from powerful reflectors on the top of the hill. This, with other accessory work, was actually in progress, when a severe cold brought on peritonitis, which over-confidence in his physical powers permitted to reach a fatal stage before medical aid was summoned. His remains, accompanied by an escort from the University of Wisconsin, were removed to Ann Arbor, where they lay in state, in the university, during the 25th of November, and on the following day, with due honors and imposing ceremonies conducted by his late colleagues, were reverently laid beneath the shade of Oakwood Cemetery.

Professor Watson possessed extraordinary intellectual endowments. His quickness of perception nothing escaped. His mathematical intuitions scorned the ordinary processes of calculation, and gave him a masterly command of mathematical logic and formulæ, which made so many portions of his work on Theoretical Astronomy strictly original, and all parts virtually his own. Yet he never mentions any claim to originality, but pursues his majestic intellectual march with the dignity almost of an inspiration. His memory served him equally well. It was both circumstantial and philosophical. Every new observation was immediately illuminated by all which he had previously observed or known, and he saw instantly the proper conclusions. His mechanical gifts gave him perfect command of instruments and their construction, and the Washburne Observatory would have been equipped with several of his inventions. His versatility extended to matters of business. He was for years the Actuary of the Michigan Mutual Life Insurance Company, and performed service pronounced invaluable. He managed his private means with such success that he died possessed of a considerable fortune which his will secures to the National Academy of Science. Physically, he was vigorous and healthy, and reached in the last years of his life, a weight of two hundred and forty pounds. His religious nature held fast to the fundamental religious beliefs. He used to say it is impossible for a mathematician to be an atheist; and his works offer frequent recognition of the being of the supreme Creator and Governor of the Universe.

The world was not slow to recognize his worth. He was elected a member of the National Academy of Science, in 1867, and of the Royal Academy of Sciences in Italy, in 1870. He received the degree of Doctor of Philosophy from the University of Leipzig, in 1870; and the French Academy of Sciences conferred upon him the Lalande gold medal for the discovery of six new planets in one year. Yale College honored him with the degree of Doctor of Philosophy, in 1871. In 1875, the Khedive made him Knight Commander of the Imperial Order of Medjidich of Turkey and Egypt. He was elected member of the American Philosophical Society in 1877, and received, the same year, the degree of Doctor of Laws from Columbia College.

A. WINCHELL.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the existence of Ozone in the Atmosphere.*—In an elaborate paper upon the reactions hitherto relied on to prove the presence of ozone in the atmosphere, Schöne has discussed the value of the chemical evidence, and concludes that we have at present no test by which the existence of ozone, in the small quantity likely to be present in the air, can be established. Since the author has previously shown that hydrogen peroxide is a normal constituent of atmospheric air, the question now raised is whether ozone is also present. The tests used therefore must discriminate between these two substances. Schönbein proposed three of these tests; the production of free iodine and potassium hydrate from potassium iodide; the oxidation of thallous to thallic oxide; and the oxidation of manganous to manganic oxide. The author has proved that the first two reactions take place readily with hydrogen peroxide; and that the latter requires a trace of ammonium carbonate; the paper then turning brown not only by the peroxide but even by oxygen alone. Houzeau's test, red litmus paper, dipped in potassium iodide solution, also reacts with H_2O_2 as with ozone. The proofs offered by Andrews, that air which acted on potassium iodide, lost this property on heating to 260° or by contact with manganese dioxide, are as well, if not better explained by the existence of H_2O_2 in the air. The only reagent known by which ozone could be absolutely detected is metallic silver. But no observer has yet noticed the blackening of metallic silver in atmospheric air free from sulphur compounds. The author exposed pure silver plates near Moscow for five, six, and seven weeks without change. As to the odor, Schöne says that in 1876 he had the opportunity of trying this, a lightning stroke having taken place in his vicinity. Though entirely familiar with the odor of ozone, there was not the "remotest similarity" between this and the odor produced by the lightning; which recalled more that produced by burning gunpowder. Moreover, it is in proof that, like the electric spark, lightning causes the nitrogen and oxygen to unite, but does not produce ozone, which is formed only by the silent discharge. Again, direct tests with thallium-paper showed no direct relation between the odor and the oxidizing power of a given portion of air. The author by no means denies the existence of ozone in the atmosphere, even coëxistent with hydrogen peroxide, the two reacting on each other very slowly. But he maintains that there is no experimental evidence of its presence.—*Ber. Berl. Chem. Ges.*, xiii, 1503, Sept., 1880. G. F. B.

2. *On the Meteorological use of Thallium-papers.*—Schoene has given in a subsequent paper, the results of an extended series of experiments on the use of thallium-paper for estimating approximately the oxidizing material in the atmosphere, whether

it be hydrogen peroxide alone, or mixed with ozone, or perhaps also with other constituents hitherto unknown. The objection to Schönbein's ozonometer (potassium iodide on starch paper) and to Houzeau's ozonometer (potassium iodide on red litmus paper) lies in the fact that their materials are hygroscopic and their indications vary widely with the moisture of the air. Since dry ozone does not act on these papers, they must be moistened; and then the amount of moisture varies the result quite as much as the amount of ozone. Indeed, attention has been called to the larger amount of ozone near salt-works and waterfalls, and the erroneous opinion advanced that ozone is formed when water is finely divided. And Böttger has stated that ozone is formed when ether is atomized; the fact being that the reaction he observed was due to the H_2O_2 always present in ether. Direct experiments with the Schönbein ozonometer and the psychrometer gave parallel curves; whence the author regards the former as only a crude hygrometer. These objections do not lie against the thallium-paper, the oxidation to brown oxide by either ozone or hydrogen peroxide, not requiring the presence of moisture, and the color therefore being independent of the hygrometric state of the air. Moreover, when well cared for the papers undergo no farther change of color and may be preserved indefinitely. The author prepares the thallium-paper a few days before use, by dipping strips of swedish filtering paper in a solution of thallous hydrate, and drying. The solution is prepared by pouring a solution of thallous sulphate into a boiling solution of barium hydrate, equivalent quantities being taken, the resulting solution of thallous hydrate being concentrated in vacuo until 100 c.c. contains 10 grams Tl(OH). For use the strips are hung in the free air in a close vessel, preferably over caustic lime, for twelve hours. Other papers are used, made with a two per cent solution. These are exposed for thirty-six hours. The coloration is determined by comparison with a scale having eleven degrees of intensity upon it. Compared with Schönbein's ozonometer, the results are in general directly opposite. The thallium papers show that the greatest effect is in the daytime, the iodide papers that it is at night. Yearly curves show that the former generally indicate a rise when the latter give a fall. The iodide curve follows closely that of relative humidity, clouds and rain; the thallium curve stands in no relation to it. A table of results for the year 1879 is given in monthly means, of the two thallium papers, the ozonometer, the relative humidity, cloudiness, rain, and velocity of wind.—*Ber. Berl. Chem. Ges.*, xiii, 1508, Sept., 1880. G. F. B.

3. *On the nature of the Petroleum from the Caucasus.*—BEILSTEIN and KURBATOW have examined the more volatile portions of the petroleum obtained at Baku in the Caucasus, in order to compare this material with American petroleum. It had been observed that the Caucasus fractions had a greater specific gravity than American fractions of the same boiling point; and this fact led to a distrust of the illuminating oils prepared from the

former. But Wilm and Biel showed that these Russian oils had an illuminating power ten per cent higher than the American oils and Biel observed that these oils of higher gravity rose more easily through the wicks. This removed the public prejudice and importation of American petroleum has almost ceased. The samples now examined by the authors were prepared by careful distillation from the natural oil. After nine fractionings, using Glinsky's dephlegmators, no fractions were obtained of constant boiling points, although for the same boiling point, the products showed considerably higher specific gravities than American oils. Thus below 80° the Russian oil had a gravity of 0·717, while American petroleum gives hexane of gravity 0·669. From 80° to 85°, the gravity was 0·733; 85° to 90°, 0·741; 90° to 95°, 0·745; 95° to 100°, 0·748; 100° to 105°, 0·752. American petroleum yields heptane between 95° and 100°, of gravity 0·699. Thinking that this difference might be due to a mixture of the hydrocarbons C_nH_{2n-6} with the ordinary C_nH_{2n+2} series, the fraction 80° to 85° was agitated with fuming sulphuric acid; but no trace was detected. Analysis gave C 85·23, H 15·11; which corresponds more nearly to C_nH_{2n}; showing that the Caucasian petroleums are poorer in hydrogen than the American. But these hydrocarbons are not homologues of ethylene, since bromine does not act on them in the cold. When warmed, decolorization ensues but with evolution of HBr, proving substitution. Further study proved that the hydrocarbons of Caucasian petroleum were identical with the addition-products of hydrogen to the aromatic hydrocarbons C_nH_{2n-6}. As examined by Wreden, these are:—hexahydrobenzene C_6H_{12}, gravity 0·76 at 0°, boiling point 69°; hexahydrotoluene C_7H_{14}, gravity 0·772 at 0°, boiling point 97°; and hexahydroisoxylene C_8H_{16}, gravity 0·777 at 0°, boiling point 118°. The petroleum-products confirmed Wreden's data entirely, being exceedingly indifferent to chemical reagents. From the fraction 115° to 120°, containing hexahydroisoxylene, trinitroisoxylene was prepared identical with that from metaxylene. Heated on the water bath with fuming sulphuric acid, the hydrocarbon is charred and destroyed, yielding no sulpho-acid. When the fraction 90° to 95° is dissolved in a mixture of one part nitric and two parts sulphuric acid, CO_2 is steadily evolved and nothing separates on dilution with water. One part of the fraction 95° to 100° boiled with four parts nitric acid of 1·38 until red vapors cease, gave an acid liquid containing acetic acid, considerable succinic acid and a large quantity of oily non-volatile acids. The supernatant oily layer gave on fractioning, a distillate between 101° to 103°, essentially hexahydrotoluene; and a second, 210° to 215°, having the formula $C_6H_{11}NO_2$ either a nitro-product or a nitrous ether.—*Ber. Berl. Chem. Ges.*, xiii, 1818, October, 1880. G. F. B.

4. *On a new Hydrocarbon from Sequoia gigantea.*—Lunge and Steinkauler have published a preliminary note on certain products obtained from *Sequoia gigantea* Torr. Stems about three meters long, furnished by Fröbel & Co., gardeners in

Zürich, were used for the preparation of these products. The needles, in which the peculiar odor seemed to be most abundant, were stripped from the twigs and distilled with water in a large copper retort in a current of steam from a boiler. The distillate was agitated with ether and the ether distilled off. The early portions of the distillate gave only a solid residue, the next gave a mixture of solid and liquid, and the last portions only an oil. The solid substance was with some difficulty obtained crystallized. It is very soluble in alcohol, ether, benzene and chloroform. In ligroin (petroleum naphtha) it is less so. In glacial acetic acid, it is soluble only on heating. By covering its solution in this acid with a layer of water, the gradual solution of the acid caused a deposition of this body in small crystal plates, fusing at 105°. They are white, have a bluish fluorescence, and possess the penetrating aromatic odor of Sequoia in a high degree. When thus concentrated, it recalls the odor of peppermint. Its boiling point was between 290° and 300°, and it gave on analysis C 93·55, H 6·09, corresponding to the formula $C_{13}H_{10}$. Its vapor density by v. Meyer's method, was 81·7; the above formula requires 83. This empirical formula is that of fluorene; but its fusing point and general properties distinguish it from this body. The authors give it the name *sequoiene* and are engaged in its study. The liquid distillates gave: (1) a colorless oil boiling at 155°; (2) a slightly yellow oil, fusing point 190°–200°; (3) a yellow oil fusing at 240°; and (4) a solid body fusing at 290°–300° evidently sequoiene.—*Ber. Berl. Chem. Ges.*, xiii, 1656, Sept., 1880.

G. F. B.

5. *On Bäyer's Synthesis of Indigotin.*—ROSENSTIEHL has given a summary of the processes discovered and patented by Bäyer for the synthesis of indigotin. The point of departure in both of these is cinnamic or phenyl-acrylic acid, C_6H_5 $(C_3H_3O_2)$. Nitric acid produces from this nitrocinnamic acid, the nitryl occupying the ortho position in that form of the acid which yields indigotin. The orthonitrocinnamic acid is transformed by known processes either into orthonitrophenylpropiolic or into orthonitrophenyloxyacrylic acid, according to the process to be followed subsequently. To transform it into orthonitrophenylpropiolic acid, the orthonitrocinnamic acid is brominated, giving C_6H_4 $(NO_2)(C_3H_3Br_2O_2)$. By the action of alkali in boiling alcoholic solution $(HBr)_2$ is removed, leaving $C_6H_4(NO_2)(C_3HO_2)$ orthonitrophenylpropiolic acid. To produce orthonitrophenyloxyacrylic acid, the orthonitrocinnamic acid is treated with hypochlorous acid, which by addition gives orthonitrophenylchlorolactic acid, $C_6H_4(NO_2)(C_3H_4ClO_3)$. This, treated with boiling alkali in alcohol, gives orthonitrophenylacrylic acid $C_6H_4(NO_2)(C_3H_3O_3)$. By the action of heat alone orthonitrophenylacrylic acid is converted into indigotin, thus:

$$C_9H_7NO_5=C_8H_5NO+CO_2+H_2O+O.$$

The reaction takes place at 110° C. The mass swells, its color gradually darkens, and, treated with alcohol, it leaves a residue of indigotin. The yield is small, however, owing to the formation of secondary products. With orthonitrophenylpropiolic acid however, the united action of an alkali and of a deoxidizing body is required, the reaction proceeding regularly:

$$C_9H_5NO_4+H_2=C_8H_5NO+CO_2+H_2O.$$

Bäyer recommends the use of a mixture of glucose and an alkali carbonate. The transformation takes place at 110° C. and the indigotin separates in the crystalline form. Hence Bäyer prefers the second process. But it has a still greater advantage, since the above reaction may be effected directly upon the cloth. The fiber is printed with a mixture of the orthonitrophenylpropiolic acid, glucose and the alkali carbonate and is then exposed to superheated steam. The indigo blue is developed directly upon the fiber permanently. This fact will give the artificial indigo a great advantage over the natural product. The possibility of producing other indigotines by effecting substitutions in the phenyl group which it contains, promises important results.—*Ann. Chim. Phys.*, V, xxi, 286, Oct., 1880. G. F. B.

6. *On Isopropylene-neurine.*—Morley has prepared, in the laboratory of Ad. Wurtz, a neurine containing oxyisopropyl in place of the oxethyl in normal neurine. By the action of 20 grams isopropylene-chlorhydrin upon 37 grams of a 33 per cent solution of trimethylamine for several hours on the water bath, a neutral liquid resulted which gave a platinum salt of the composition $C_{12}H_{32}N_2O_2PtCl_6$. The propylene-neurine chloride crystallizes in colorless transparent crystals, very deliquescent, and which turn brown in the air.—*Ber. Berl. Chem. Ges.*, xiii, 1805, Oct., 1880. G. F. B.

7. *Notice of the investigation of* Dr. J. W. Bruhl *on the Relations between the Molecular Structure of Organic Compounds and their Refractive Power.* (Liebig's Annalen, cxcix, 139 and cciii, 1.)—The study of the relations between the physical properties of chemical compounds and their molecular structure has opened a new field to the science of chemistry. A remarkable investigation of Thomsen into some of the thermal relations of molecular structure, we shall notice in another number of this Journal. We now call attention to an attempt to study the molecular structure of bodies by optical means. Unfortunately the results of the two investigations do not wholly harmonize with one another; yet in both cases the new method of investigation is the chief point of interest, and we have every reason to hope that by carefully comparing the different methods of solving the same problem the truth may ultimately be reached.

If we denote by μ the index of refraction of a body the excess of this index over unity or $(\mu-1)$ represents what has been called the refracting power of a body, and since the refracting power increases in general with the density (δ) we obtain by dividing the refracting power by the density a quantity $\left(\frac{\mu-1}{\delta}\right)$ which is, essentially, independent of mere changes of physical condition, and depends on the chemical relations of the substances. This quantity has been called the specific refracting power, and if we now multiply by the molecular weight of the substance we have in $M\left(\frac{\mu-1}{\delta}\right)$ the specific refracting power of the molecule, or as it has also been called the refractive equivalent of the substance. In 1864 (Pogg. Ann., cxxiii, 595) Landolt showed that a difference of one atom of carbon, hydrogen or oxygen, between two organic compounds corresponded to a constant difference for each elementary substance in the specific refracting power of the molecule, and having thus fixed what he called the refractive power of each atom he made the generalization that the refractive power of the molecule was simply the sum of the refractive powers of its constituent atoms. For example:

TABLE I.

Differing in composition by C_1.

		$M\left(\frac{\mu-1}{a}\right)$	Diff.
Methyl alcohol	CH_4O	13·17	5·41
Aldehyde	C_2H_4O	18·58	
Differing in composition by H_2.			
Aldehyde	C_2H_4O	18·58	2·12
Ethyl alcohol	C_2H_6O	20·70	
Differing in composition by O_1.			
Aldehyde	C_2H_4O	18·58	2·53
Acetic acid	$C_2H_4O_2$	21·11	

The differences show the refractive power of one atom of carbon, one atom of oxygen and two atoms of hydrogen and the following values are in each case, the mean of a very large number of comparisons similar to those just given.

TABLE II.

	r_a	r_A
C	5·0	4·86
H	1·3	1·29
O	3·0	2·90

Of course these values are based on the determination of the index of refraction, and the density of each of the substances thus compared. The observations of density were readily reduced to standard conditions which might be arbitrarily selected, but in consequence of the very unequal and irregular dispersive power of the different substances compared it was by no means a matter of indifference which of the lines of the spectrum was selected for the index of refraction. In his own experiments Bruhl determined the index of refraction for the sodium line D and also for the three bright hydrogen lines, and by means of these data he calculated according to Cauchy's formula the index of refraction corresponding to a wave length of indefinite length, and from these calculated indices the values r_A are derived. Data thus reduced are regarded by Bruhl as furnishing the more correct basis for all comparisons of molecular refractive powers, but the results are nearly as satisfactory when deduced from the indices observed with the red light of the hydrogen spectrum. The values r_a were thus obtained.

If now we compare the molecular refractive powers calculated from the atomic composition (R_a) with those deduced from direct observations on the densities and indices of refraction of the compounds—$M\left(\frac{\mu_a - 1}{\delta}\right)$—we shall find that in the case of a large number of organic products the generalization of Landolt is very closely confirmed, thus:

TABLE III.

		$M\left(\frac{\mu_a-1}{\delta}\right)$	R_a	Diff.
Propylalcohol	C_3H_8O	28·6	28·4	+0·2
Propylaldehyde	C_3H_6O	26·0	25·8	+0.2
Propylethyl ether	$C_5H_{12}O$	43·8	43·6	+0.2
Propylacetate	$C_5H_{10}O_2$	44·0	44·0	0·0
Propylchloride	C_3H_7Cl	34·1	33·9	+0·2
Isobutyric acid	$C_4H_8O_2$	36·3	36·4	−0·1
Hexan	C_6H_{14}	48·6	48·2	+0·4
Tri-ethylamine	$C_6H_{15}N$	55·3	55·3	0·0

If then the molecular refractive power is simply the sum of the atomic refractive powers it must be the same for all isomeric bodies and therefore independent of their molecular structure, and so Landolt thought. In 1870, however, it was shown by Gladstone (London Chem. Soc. Jour., viii, 147) that there were many organic compounds, especially those belonging to the aromatic family, whose molecular refractive powers differed from the values calculated by Landolt's formula so widely, that the discrepancies could not possibly be referred to errors of observation. The residuals thus observed although not satisfactorily explained by Gladstone form the starting point in the investigation of Bruhl, who traces the effect to the mode of linking of the multivalent atoms in the molecule. He concludes in general that, while the univalent atoms of hydrogen, chlorine, bromine and iodine, have an invariable refracting power, the refracting power of multivalent atoms changes when they unite with each other by more than one bond. The values given in table II only hold rigorously, when no two atoms are united by more than a single bond, and the close agreement shown in table III depends on the circumstance that the molecules of all the substances therein named, however variable their structure in other respects, have this one feature in common. Hence all isomeric bodies have the same molecular refractive power, provided the differences of molecular structure do not extend to the relation we have named; and the discrepancies observed by Gladstone arose from the circumstance that in the molecules of the bodies he chiefly studied two or more of the carbon atoms were linked by double or treble bonds.

By comparing the molecular refractive powers of bodies containing doubly or trebly linked multivalent atoms, after the method illustrated by table I, Bruhl has determined the effect of the double and treble links in the case of carbon, and of the double links in the case of oxygen, on the atomic refracting power, and has thus obtained the data for the following table. In this table C′ C″ C‴ indicate carbon atoms singly, doubly and trebly linked with each other, and O″ an atom of oxygen doubly linked to an atom of carbon, and in order that the values given may be used in calculating the molecular refractive power of organic compounds it must be further noticed that the value for the group $-\overset{\overset{\displaystyle O}{\|}}{C}-$ is $5+3{\cdot}4=8{\cdot}4$ and that for the group $-\overset{|}{C}=\overset{|}{C}-$ is $2\times 6{\cdot}15=12{\cdot}3$.

TABLE IV.

	r_a	r_A
C′	5·00	4·86
C″	6·15	5·86
C‴	5·95	5·76
O′	2·80	2·71
O″	3·40	3·29
H	1·30	1·29
Cl	9·80	9·53
Br	15·30	14·75
T	24·90	23·55
N′	5·80	5·35

With these data it is now easy to calculate the molecular refractive powers of the greater number of organic compounds, not only the parafines and their derivatives in which the carbon atoms are usually singly linked, but also the olefines, the acetylenes and the aromatic bodies, in which the complexity of the structure is increased by double or treble links. In the original papers such results are compared with the molecular refractive powers calculated by Landolt's formula from the index of refraction and density, measured with every refinement, and with materials of undoubted purity. In almost all cases the agreement is exceedingly close especially when the observations are reduced by Cauchy's formula so as to eliminate the effect of the irregular dispersive powers of the substances compared. We have not however room to reprint the numerous tables or to describe the details of the investigation which involve many incidental points of great interest. It must be sufficient to say that the papers show that the work has been done with all the care and refinements of which the methods used are capable, and limit ourselves to a description of one only of the important conclusions to which the investigations points.

It is obvious that, when a question in regard to molecular structure turns on the existence or absence of multiple bonds, the calculated molecular refractive power will not be the same in the two cases and then the index of refraction and the density of the substance may give us the means of testing our hypothesis. As is well known there has been a question in regard to the molecular structure of benzol, C_6H_6. According to the well known theory of Kekulé the six carbon atoms form a ring and are united by three single and three double bonds; but according to the theory of Ladenburg, the bonds in this structure are all single, each carbon atom being united with two of the other carbon atoms of the ring. The principles developed by Bruhl give him a new test of the theories in question since the molecular refractive power should be six units higher with the structure of Kekulé than with that of Ladenburg, and as the value deduced from the observed index of refraction and density of benzol gives a result which very closely agrees with the larger of the two values, Bruhl concludes that the generally received theory of Kekulé is "the only one which harmonizes with the physical as well as the chemical relations of the aromatic compounds."

J. P. COOKE.

8. *Chemical Energy and Electromotive force of different galvanic elements.*—THOMSEN reviews his earlier work upon this subject and makes a new and careful determination of the chemical energy and the electromotive force of a Daniells cell. According to his later measurements, the total devlopment of heat by galvanic means in all parts of the Daniells element amounts to 50292 units of heat during the time in which one molecule of copper sulphate ($CuSO_4$) is reduced. A calculation of the value of the energy of the chemical processes in the cell gives 50130 units. The difference between 50292 and 50130 is so small that Thomsen concludes that the total chemical energy of a Daniells cell is converted into electricity and the development of heat in the circuit is the equivalent of the chemical energy developed by the cell. Other forms of cells are then investigated from this point of view and the same conclusion is reached in the case of zinc-cadmium elements and chloride of silver elements, or in general wherever the metallic surface of the negative electrode is not changed by the electrolytic process.—*Ann. der Physik und Chemie*, No. 10, 1880, p. 246.

J. T.

9. *Spectra of the compound of Carbon with Hydrogen and Nitrogen.*—Professors LIVEING and DEWAR used in their experiments a DeMeritens dynamo-electric machine which produced the voltaic arc in the different gases they experimented upon. It was found that the indigo, violet and ultra violet bands characteristic of the flame of cyanogen are conspicous in the arc taken in an atmosphere of nitrogen, air, nitric oxide or ammonia, and disappear very nearly in a non-nitrogenous atmosphere of hydrogen, carbonic oxide, carbonic acid, or chlorine. These bands are seen in the flame of cyanogen and hydrocyanic acid, but are not seen in those of hydrocarbons, carbonic oxide, or carbon disulphide. The authors therefore conclude that they belong to cyanogen, and support this conclusion by reference to various facts. Their experiments on the spectrum of carbon are at variance with those of Lockyer on the same subject. They state that the evidence that carbon uncombined can take the state of vapor at the tempera-

ture of the electric arc is very imperfect; and they believe that any reasoning based upon the absence of nitrogen is imperfect, for it cannot be shown conclusivly that nitrogen has really been absent in the experiments hitherto conducted. They contend against the hypothesis that if cyanogen bands are present in the solar spectrum they are due to vapors of carbon uncombined in the upper cooler region of the chromosphere. It appears to them that nitrogen may be recognized in the solar atmosphere through cyanogen when free nitrogen might not be detected.—*Proc. R. S.*, xxx, pp. 152, 494. *Nature*, Oct. 28, 1880. J. T.

10. *On the behavior of gases under the influence of electrical discharges.*—Professor E. WIEDEMANN in a paper not yet concluded, describes his method of experimenting and gives some preliminary results. He arrives at a confirmation of fact previously stated by him: that a gas may be rendered luminous by electric discharges without any corresponding elevation of temperature.—*Ann. der Physik und Chemie*, No. 6, 1880. J. T.

11. *A theoretical and practical treatise on the manufacture of Sulphuric acid and Alkali;* by GEORG LUNGE. Vol. II. London: 1880.—Dr. Lunge's second volume quite sustains the character which the first so justly won, of being the most correct and exhaustive treatise yet published on the subject of which it treats. The first was confined to the manufacture of sulphuric acid—the starting point in almost every chemical industry. The second is occupied by that of carbonate, bicarbonate of soda and caustic soda. Every operation, as well as the plant for carrying it out, is described with minuteness and illustrated by drawings to scale.

This volume will excite less interest than the first in as much as the manufacture of sulphuric acid is very general, while that of alkali is in this country conducted by but few firms and by these on a very limited scale; yet a study of the technical and commercial bearing of this great industry is therefore the more necessary, in order to determine whether its exclusion from the list of American enterprises is due to remediable or irremediable causes. In Europe only at certain favored centers, where sulphur, coal, salt and limestone are cheap, can alkali be economically manufactured. If there be any such in this country not far removed from the centers of consumption, the alkali trade may take the place it occupies in Europe, and notably in Britain, as second only to the iron trade. Unless, however, this combination of materials occurs in one or more favorably situated localities, the Mersey, the Tyne and the Clyde must continue to supply with alkali our glass and soap makers. The problem yields in importance to none.

The mention of the above materials, used in the Leblanc process, is due to the fact that as yet none of the many substitutes proposed for it, cumbersome and wasteful as it is, have been successfully introduced. Our author reserves for a third volume a description and discussion of the ammonia process and of the manufacture of alkali from cryolite, as practiced exclusively in this country by the Pennsylvania Salt Co. But he gives full details of the plant, and manipulation for the method proposed by Hargreave for the manufacture of sulphate of soda direct from salt by the action of sulphurous acid,—thus reducing to one the double operation of first making sulphuric acid and then decomposing by it the salt. Although not generally adopted and far from perfected, it deserves to rank as the most important recent modification of the Leblanc process.

The operation may be expressed by the following equation: $SO_2+O+H_2O+2NaCl=Na_2SO_4+2HCl$. It is effected by drawing, by means of a Root exhauster, sulphurous acid gas, with 6 to 8 vols. of sulphurous acid, from ordinary pyrites burners, mixed with superheated steam through a series of connected cylinders, filled with salt. Complete decomposition is not effected in less than two to three weeks. Hence, owing to loss by radiation, the heat generated by the chemical action has not in practice been found —contrary to expectation—sufficient to maintain the contents of the cylinders at the requisite temperature of 400° to 500°. Therefore the fuel consumed in heating the cylinders, raising steam and preparing the salt, almost equals in some works that consumed in making sulphate in the old way.

In the appliances for converting the sulphate into carbonate no radical improvements have been made of late years, if we except the revolving black ash furnace. But the attention of manufacturers has been of necessity directed to condensing all deleterious escaping gases and rendering harmless all fluids, before discharging them into any water courses; for the several Alkali and River Pollution Acts of the British and other European parliaments define the amount of impurity which may be thrown into the air, or discharged as drainage. It has been found very easy to condense very perfectly the gases, but not so easy to deprive the liquors flowing from the vast accumulation of soda waste, that encumbers old works, of their offensive character. An economical reward has, however, followed the compulsory performance of this public duty; for the result at all works has been the recovery from the tank waste of 40–60 per cent of the sulphur originally used. The process most in favor is that of Mond, which consists like most others in oxidizing the insoluble CaS of the waste into soluble CaS_2O_3, and then separating the S from the solution by HCl. Mactear, at the St. Rollox works, treats the yellow liquors as they flow from the waste heaps with SO_2. But the most recent and thorough method, as described by our author, and one which, if practicable, will raise the Leblanc to the rank of a regenerative process, has been proposed by Schaffner and Helbig. By the aid of $MgCl_2$ they convert CaS into $CaCl_2$ and generate H_2S.

I. $CaS+MgCl_2+H_2O=CaCl_2+MgO+H_2S$.

II. The H_2S is drawn off and the S separated by SO_2,—the difficulty heretofore always experienced of collecting the extremely fleecy sulphur being overcome by bringing the gases into contact with such salts as calcium or magnesium chloride, when dense granular sulphur separates and none passes off as polythionic acids.

III. The $CaCl_2$ under the action of CO_2 restores $CaCO_3$—the reagent for carbonizing the $NaSO_4$ of another lot; and the Cl passes back to the manganese for use again.

$$MgO+CaCl_2+CO_2=MgCl_2+CaCO_3.$$

If this beautiful series of reactions can be carried out in practice the names of Schaffner and Helbig will deserve a place in the list of industrial chemists next to that of Leblanc himself. J. D., JR.

II. Geology and Natural History.

1. *Notes on alleged changes in the relative elevations of Land and Sea;* by Henry Mitchell, Assistant. Appendix No. 8 in the Report of the Coast and Geodetic Survey for 1877, Carlile P. Patterson, Superintendent.—The author alludes to the impression that the northeastern coast of the American Continent is so rapidly rising that the change of depth over rocky bars upon the coast of Maine has been noticeable within a generation of practical boatmen; and mentions Professor Shaler's estimate of the emergence in progress as probably over a foot in a century, and perhaps as much as three feet. The author of this memoir, who was assistant under Professor Bache in the work of establishing benches at all the tidal stations along the coast of Maine, gives as the result of his study of the subject, the following conclusions:

(1) That the attention of early explorers was attracted by the salt marshes, which broke the monotony of our otherwise then wooded country, and that these were then, as now, at ordinary high-water level.

(2) That rocks upon our coast, long notorious as dangerous to navigation, have not risen since they were first discovered.

In his statements ancient maps and documents are cited, and the conditions of the various rocks are considered in detail. The memoir concludes as follows:

"From the foregoing it has been seen that the study thus far extends from Wood's Hole, latitude 41° 31′, longitude 70° 39′, to Percé Rock, latitude 48° 30′, longitude 64° 13′, embracing 7° of latitude (420 nautical miles) and 6° 26′ of longitude (266 nautical miles). It would, of course, be quite unwarrantable to conclude that a parallelogram with these limits has remained unchanged, but a smaller district may be claimed as beyond dispute. If, confining ourselves to Champlain's points, we draw a line from Green Ledge to Annapolis, Nova Scotia, thence to Wells, in Maine, thence to Gloucester, thence to Mary Ann Rocks, thence to Harwich, Massachusetts, thence to point of beginning at Green Ledge, we inclose a district of 20,000 square miles. Within this district lie Trinity Rocks, and near it Harding's and Brazil, which have not changed during the past century; so that it is fair to conclude that no tilt in either direction has taken place in the Gulf of Maine. The arc of the meridian between Green Ledge and Percé Rock, measuring two hundred and seventy-one nautical miles, passes near the *Grand Pré* and across the meadows of the Cumberland Basin. It is to these two salt-marsh districts that Mr. Akins refers particularly in his letter already quoted, when he speaks of the ancient French and modern English dykes with the conclusion that no change of elevation can be alleged. So that we have really four stationary points in this arc.

I must, in closing, reiterate that to the eastward of this meridian, and especially in Newfoundland, great changes present themselves in the comparison of charts, the depths appearing to be at some points less and at other points greater now than formerly."

2. *Further discoveries of fossils in the Wappinger Valley or Barnegat limestone;* by Professor W. B. DWIGHT, of Vassar College, Poughkeepsie. (From a letter to J. D. Dana, dated Dec. 11, 1880.)—In extending my explorations in the Wappinger Valley limestone I discovered at Rochdale, east of Poughkeepsie, N. Y., on Oct. 28th, a limestone locality affording great numbers of Orthocerata and of other fossils, many of which are not reported as occurring in New York State. The Orthocerata present quite a variety of sizes and shapes; but all agree in showing the large number of septa so characteristic of formations below the Trenton and Black River. The lengths vary from $1\frac{1}{2}$ inches to 9 inches, the widths from $\frac{3}{8}$ to $1\frac{1}{2}$ inches; the septa vary from thirty to forty to the inch in some specimens, to eleven to an inch in others. These fossils are more or less scattered through a ledge for at least 1,500 feet, and at one point, for about fifty feet, they are so crowded that one can hardly be taken out without disturbing several others.

There are also here abundant specimens of discoidal gasteropods, some of which are an inch and a half in diameter; a large turreted gasteropod, probably Cyclonema, about three inches in length; and two small Atrypa-like brachiopods.

This formation is entirely different from the adjoining Trenton limestone, both in its lithological nature and in its fossils. It is, however, apparently identical in its physical characteristics with the adjacent formation which I have already assigned, on fossiliferous evidence, to the Calciferous, (this Journal, vol. xix, p. 50, Jan., 1880), and concerning which I see no reason to change my opinion. It appears, also, in addition to its own peculiar and striking fossils, to contain the characteristic fucoids and the other fossils of the adjacent Calciferous. It would be premature to offer any decided opinion as to the stratigraphical position of this remarkable rock before the fossils have been carefully studied; but I may say that while it reveals a wealth of cephalopodic life, of a character and abundance hitherto unknown in the United States in any formation to which this is likely to belong—i. e. below the Trenton and Black River strata,—it is at least very closely related to the Calciferous, and in its numerous Orthocerata is like the Calciferous and the Quebec groups of Canada. I am collecting and carefully examining the specimens, (of which I have already from 150 to 200,) with reference to giving full details and further results in a future paper.

3. *Volcanic Eruptions of Mauna Loa, Hawaii.*—A letter of November 9th to 12th, from the Rev. Titus Coan of Hilo, addressed to Prof. C. S. Lyman of New Haven, states that, on the 6th, vapors were seen toward the summit of Mauna Loa and evidence of a flow of lavas in progress toward Mauna Kea. On the 7th, according to the report of a person from Waimea who had ascended for a view of the region one of the spurs of Mauna Kea, all the elevated plain between Mauna Loa and Manna Kea was a sea of glowing lava, and from it a current was flowing off eastward toward Hilo. Mr. D. Hitchcock, who visited the region of lavas between the mountains, on the 9th, states that the stream was on the north side of the flow of 1855–56, had a length to the plain of about thirty miles, and was three-fourths of a mile wide at its terminus. Heavy clouds from the escaping vapors concealed the region of fires the most of the time from observers at Hilo. On the 10th, the eastward stream was distinguished by the brilliant light for a length of twenty miles, running southeasterly toward East Kau or Kilauea. On the 11th the fires were still active from the summit downward. The "fountain-head" had not been visited, but Mr. Coan judged that it was to the north of the summit crater near the point of eruption of 1843, which was about 13,000 feet above the sea-level; and he states that adding thirty miles for the length of the southeast branch, it makes a continuous line of flow of sixty miles.

The Commercial Advertiser of Honolulu for November 20th contains noties from which the following facts are taken. The eruption began on the evening of the 5th without any violent demonstrations or earthquake. The river of fire from the summit, as seen at night, was a continuous line of light. The whole front edge, about three-fourths of a mile wide, was intensely brilliant; and as it slowly advanced and rolled over the small trees and shrubs, bright flames would flash up and die out along its whole edge. Every now and then there was a report like that of cannon, made probably by the escape of steam from waters that were caught beneath. According to a describer who went within twenty feet of the eastern stream, then very sluggish, its broad extremity, along the whole front, was a bright-red mass of solidified lava, twelve to thirty feet in height, moving slowly along by breaking and bearing on the crusted covering; "it was one crash of rolling, sliding, tumbling, red-hot rock, no liquid rock being in sight; there were no explosions, but a tremendous roaring, like ten thousand blast furnaces all at work at once." Such a flow makes what are called on Hawaii *aa*, or clinker-fields. The rough blocks lie piled together in the wildest confusion, many as large as ordinary houses. They form only when the movement is slow. Fears were at first felt that the eastern stream would descend to Hilo.

4. *The Genesis of the Ores of Iron*, by J. S. NEWBERRY. (From the School of Mines Quarterly for Nov., 1880).—Iron-ore deposits, including those of the Archæan, are shown by Dr. Newberry to be of sedimentary origin, and their formation through the aid of organic acids is sustained. Speaking of the Archæan iron ores, he says: "That in some cases the ore has been profoundly modified, both in character and position, since its deposition, is undeniable; but to be asked to believe that the ore sheets are intrusive is a greater strain upon my credulity than it can endure."

The magnetite and hematite ores in southern Utah, which Prof. Newberry was the first to describe, are situated 300 miles south of Salt Lake City, in what is really the prolongation of the Wahsatch Mountains. He observes that near Iron Springs, the so-called "Big Blow out" is a projecting mass of magnetite iron ore, measuring probably 1000 feet by 500, rising in castellated crags 100 feet or more above its base. The "Blair Mine" is a ragged black crest of magnetite, 200 to 300 feet high. The ore of the region, which is half hematite, is in belts standing nearly vertical; it is often intersected by thin layers of quartz, or jasper, and occasionally by zones of crystals (2 to 3 inches long) of apatite. The containing rock is granite, of a finer kind than that of the Wahsatch axis; "some of the ore beds are interstratified with the granite, and are certainly, like it, metamorphosed sediments," as is well seen at the Blair-Mine. Prof. Newberry states that no eruptive iron ore exists in the Rocky Mountains, and that in the opinion of Prof. Otto Torell, Director of the Geological Survey of Sweden, the ores of Sweden are metamorphic and not eruptive.

5. *Descartes l'un des Créateurs de la Cosmologie et de la Géologie;* par M. DAUBRÉE. 27 pp. 4to. (Journal des Savants, March, April, 1880).—Prof. Daubrée, in this interesting memoir, cites from Descartes' remarkable work his descriptions and the illustrating figure, which show—especially the latter—that he had conceived the idea of mountain making, or the displacement of strata, through movements, contraction-like, beneath the earth's surface. He also points out that Descartes attributed the formation of mineral veins to emanations from below.

6. *Geological map of a portion of the Southern Interior of British Columbia*, by G. M. DAWSON. Montreal, July, 1880.—This colored map, about 21 inches square, shows the geological formations over a region directly north of the U. S. boundary between the meridians of 118° and 122°, Great Shuswap Lake being in the northeast corner. The Triassic covers large areas, but uncertainty remains as to their outline; the areas of the Cretaceous and Tertiary deposits are much smaller. Tertiary volcanic rocks cover a wide region.

7. *Application of Organic Acids to the examination of Minerals.—Second paper;* by H. CARRINGTON BOLTON, Ph.D.—This paper forms a continuation of those already published by Prof. Bolton upon this subject. It gives the results obtained by sub-

jecting a large number of minerals—upward of 100—to the action of citric acid, in some cases with the addition of a second reagent, as sodium nitrate, potassium iodide, etc. It is concluded that all carbonates and phosphates are decomposed by citric acid, some sulphides, and all the hydrous silicates with one or two exceptions. A series of tables are given at the end of the paper in which some ninety minerals are arranged according to their behavior with citric acid, with and without the addition of other reagents. The memoir gives proof of much patient labor, and the field is one in which little had been done previously.—*Annals N. Y. Acad. Sci.*, ii, No. I.

8. *Proceedings of the Academy of Natural Sciences of Philadelphia.*—For the convenience of those interested in Mineralogy and Geology, the papers of the Proceedings of this Academy in these departments for the years 1877–1879, have been issued as a separate pamphlet, and made Number 1 of a proposed series.

9. *Ctenophoræ*;* by Dr. C. CHUN. — This volume forms the first monograph of the Memoirs to be published under the auspices of the Zoological Station at Naples. As Dr. Dohrn informs us in the introduction, there are no less than twenty monographs now in preparation, all based upon the rich materials to be found in the Bay of Naples. The subjects of these monographs have been so far circumscribed that Dr. Dohrn hopes little by little to succeed in accomplishing the task of "sweeping before his own door," and giving us a complete history of the Fauna and Flora of the Gulf. If the succeeding monographs can be maintained to the high standard set for them by the first of these publications, they will form a series of faunistic biological monographs without a parallel, and present a model which few biologists can hope to excel. Dr. Dohrn has here shown far better than by any verbose report, the value to science of stations like the Zoological Station at Naples. A few such stations distributed along the shores of the Atlantic and Pacific, so selected as to bring faunal districts as dissimilar as possible, within easy reach of the investigator, and biology would be revolutionized. Our embryological and anatomical journals have been so flooded with disconnected papers upon all classes of invertebrates that only careful faunal monographic biological studies connecting the chaos of independent observations into a homogeneous whole, will drag us out of this sea of contradictions, and enable us to survey anew the field of biology, unencumbered by the drift-wood through which every worker has now to make his way. Biologists cannot be too grateful to Dr. Dohrn for his patience in waiting until he could publish a monograph comprehensive enough to cover not only the systematic work, but to include also the anatomy, the embryology, in fact the whole biology of the group understood in its broadest sense.

* Fauna u. Flora des Golfes von Neapel. Herausgegeben von der Zoologischen Station zu Neapel. I Monographie, Ctenophoræ, von Dr. Carl Chun, 4to, pp. xviii, 313, mit 18 Tafeln u. 22 Holzschnitten. Leipzig, 1880. (Wilhelm Engelmann.)

With the intense competition for priority which rapid publication has introduced into all biological work, it is most gratifying to see a student who, instead of rushing into print at the end of every three months, and inflicting on his brother naturalists his undigested notes of a season's work, sits down for four years of quiet investigation and then gives us the result, a masterly monograph, such as Dr. Chun has just published, upon Ctenophoræ. We trust the volume before us may not only bring into vogue again carefully prepared monographs, but that we may also find in them the same modesty and the same good temper which characterizes every page of this magnificent memoir. It is rare to find so gentle a critic and yet one who, combining original investigation of the first order with an exhaustive knowledge of the literature of his subject, is yet able and willing to place himself on the ground occupied by his predecessors, and judging them by the standard of the time at which they wrote—never extolling the progress of later days, at the expense of the pioneers.

It is not too much to say that the Revision of the Ctenophoræ, given by Dr. Chun in this faunistic monograph, makes this memoir by far the most valuable one ever published on the Ctenophoræ. There is hardly a point in the habits, in the anatomy, in the embryology, or in the systematic working up of the group, which has not been greatly advanced by the light thrown upon it by Dr. Chun. And while we may differ radically from him in regard to some of his views respecting the affinities of Ctenophoræ, their relationship to Echinoderms and Polyps, and the typical structure underlying them, we cannot fail to be struck with the original method of presenting these views, and the candor and fairness with which opposite opinions are discussed.

This memoir is remarkable for the great thoroughness with which all histological points are discussed, the neatness of the minute anatomy necessary to follow the complicated structures of Ctenophoræ, and the perseverance shown in tracing the post-embryonic stages of so many genera. This perhaps is the most valuable feature of this notable memoir. No family has been left in the dark, and the flood of light which these studies have thrown on the systematic relationship of the other Ctenophoræ is indeed wonderful. By far the most interesting page of this chapter is the complete development given us of Cestus. This genus theoretically promised to do more than any other towards unravelling the affinities of the Ctenophoræ, and Dr. Chun's investigations have fully justified these anticipations.

Excellent as we have found the text to be, it is difficult to speak with sufficiently high praise of the plates. To appreciate their value one should be familiar with Ctenophoræ, have watched them as the writer of this notice has done, day after day, and season after season, until their pictures can be called up with all the vividness of nature. A student familiar with Ctenophoræ, will recognize the truthfulness of these exquisite illustrations, in which every structural detail is sharp and firm, while nothing is lost in delicacy of texture or grace of motion; and even one who has never seen a living Ctenophore, may study their structure in these wonderful plates, superior as they are to the very best figures thus far published. Dr. Chun is evidently as good an artist as he is a biologist, and we cannot close without congratulating him most heartily on the publication of this model monograph.

A. AG.

10. *The Spiral Character of Cœlenterate Development.*—Professor JOHN YOUNG, in the number of the Annals and Magazine of Natural History for March, 1880, argues from the order of development of the septa and tentacles that the radiate forms of Cœlenterates arises from the shortening and crowding together of the successive septa either side of a line of bilateral symmetry, by which an apparent radiation around the mouth is produced.

11. DR. ELLIOTT COUES' *Third Installment of American Ornithological Bibliography*, making Art. xxvi and pages 521 to 1066 of vol. v of the Bulletin of the U. S. Geological and Geographical Survey of the Territories, F. V. Hayden, U. S. Geologist-in-charge. Department of the Interior.. Washington, September 30, 1880.—This bibliography, of over 500 closely printed pages, with the two preceding installments, "represent a nearly complete bibliography of Ornithology so far as America is concerned."

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Some incidental results from a series of analyses of air, made at Hudson, Ohio;* by EDWARD W. MORLEY.—The samples were taken daily, and at a regular hour. They were analyzed in duplicate. The greatest difference between the results of analyses of the same sample was ·016 per cent. The probable error of a single determination was less than ·003 per cent.

(1) The mean propertion of oxygen to the sum of oxygen and nitrogen for the first half of the year 1880 is as follows: January 20, ·951; February 20, ·935; March 20, ·949; April 20, ·950; May 20, ·949; June 20, 951; January to June 20, ·949.

(2) Uncertainties in callibration, errors of observation and manipulation, and variations in the quantity to be measured, make the probable error of the final mean less than ·002 per cent.

(3) Any given sample of air was as likely as not to differ from the mean of ·012 per cent.

(4) The probabilities are about ten to one that the differences between the means for any two months are within ·002 per cent of the truth.

(5) The largest proportion of nitrogen yet noticed was on December 29th, 1879, when three analyses of the same sample gave 21·045, 21·045, 21·044. The largest during the six months mentioned was March 9th: 21·001, 21·006.

(6) The lowest yet found was on February 26th, 1879, when, with another apparatus, there was found 20·45 and 20·50. The lowest during the six months was on February 14th, when one sample gave, 20·896 and 20·903; another sample gave 20·867.

2. *National Academy of Sciences.*—At the session of the National Academy in New York City, commencing November 17, the following papers were read:

On the basin of the Gulf of Mexico; J. E. HILGARD.

On the origin of the coral reefs of the Yucatan and Florida Banks; ALEXANDER AGASSIZ.

Observations on ice and icebergs in the polar regions; F. SCHWATKA.

The duration of the Arctic winter; F. SCHWATKA.

Mineralogical notes; BENJAMIN SILLIMAN.

The relationship of the Carboniferous Euphoberia to living and extinct Myriapods; SAMUEL H. SCUDDER.

On the ellipticity of the earth as deduced from pendulum experiments: C. S. PEIRCE.

An improvement in the Sprengel air-pump; O. N. ROOD.

The thermal balance; S. P. LANGLEY.

Measurement of radiant energy; S. P. LANGLEY.

Causes which determine the progressive movement of storms; ELIAS LOOMIS.

The antimony mines of Southern Utah; J. S. NEWBERRY.

The conglomerate ore deposits of the United States and Mexico; J. S. NEWBERRY.

On photographing the Nebula in Orion; HENRY DRAPER.

On condensers for currents of high potential; GEORGE F. BARKER.

Sigsbee's gravitating trap; ALEXANDER AGASSIZ.

Observations on ice and icebergs in the polar sea; Lieut. F. SCHWATKA, U. S. A.

The deposits of crystalline iron ores of Utah; J. S. NEWBERRY.

The origin of anthracite; T. STERRY HUNT.

On the star-list of Abul Hassan; C. H. F. PETERS.

Dimensions of the brain and spinal cord in some extinct reptiles; O. C. MARSH.

On the Mimoravidæ; E. D. COPE.

On the Miocene Canidæ; E. D. COPE.

On a new and general method in analysis; WOLCOTT GIBBS.

Note on the relations of the Oneonta and Montrose Sandstones with the sandstone of the Catskill Mountains; JAMES HALL.

3. *Annual Report of the Chief of Engineers to the Secretary of War, for the year* 1879. In three Parts, containing over 2400 pages 8vo.—Besides the special reports relating to forts, harbor and river surveys and improvements, and maps illustrating the same, there are the following: Report on the Contents of Troughton and Simms' Theodolite, No. 3, by Mr. R. S. WOODWARD, Assistant Engineer, (p. 1945); Report on the Errors of Certain Thermometers as to calibration, etc., by T. RUSSELL, (p. 1952); Report on Sand waves and Sediment observations in the Mississippi, by J. B. JOHNSON, (p. 1963); Annual Report of Capt. G. M. WHEELER, corps of Engineers, (pp. 1977–2313), and including the Reports of a geological party in Colorado and New Mexico from Spanish Peaks to the South, in 1878 and 1879, by Prof. J. J. STEVENSON, and an ornithological report on observations and collections made in portions of California, Nevada and Oregon, by Assistant H. W. HENSHAW.

The report of Captain Wheeler contains a long table of altitudes determined by the survey in Oregon, California, Nevada, New Mexico and Arizona.

The report includes also (pp. 2331 to 2343) a Chemical Report on the Pagosa Springs of Colorado by Dr. C. SMART, U. S. A., in whose waters sodium sulphate constitutes nearly two-thirds of the material in solution (2·263 to 3·042 grains per liter), and the gases are carbonic acid and hydrogen sulphide; and pp. 2371–2395 a report on the Mammals and Birds of the general region of the Big Horn River and Mountains of Montana Territory, by C. E. McChesney, Asst. Surgeon, U. S. A.

4. *Report on the Meteorology of Tokio, for the year* 1879; by Prof. T. C. MENDENHALL.—This report forms Part I of vol. iii of the Memoirs of the Science Department of the University of Tokio. It contains the usual meteorological observations, and its notable feature is the free use of graphical representation of most of the results. Its forty-one pages of letter-press, including tables, are accompanied by *twenty-seven* pages of charts showing curves of barometer and thermometer, prevailing winds, rain-fall, etc. It is published by the University and is handsomely printed at the Government Printing Office. C. G. R.

5. *United States Commission of Fish and Fisheries, Part VI; Report of the Commissioner,* Dr. SPENCER F. BAIRD, *for the year* 1878. lxiv and 988 pp. 8vo. Washington. 1880.—The prominent subjects of this large volume are the history and statistics of food-fishes of different coasts, rivers, lakes, etc.; their decrease and the modes of preventing it; their propagation in the waters of the United States; the quality of fishes, their value, products, economical uses; the planting of American waters with ova from foreign countries and the reverse. What has been done in these directions, or is doing, together with a statement of the objects of the Fish Commission and of the assistance it has received from the departments of the Government, is briefly brought out in an Introductory Chapter of lxiv pages; and then follows the appendix, of 974 pages, which consists of papers giving full details and descriptions on these and other topics. Among these papers there are the following in descriptive Natural History: On the marine Isopoda of New England and adjacent waters (some of which are parasitic on fishes), by OSCAR HARGER, illustrated by 13 plates; on the Pycnogonida of the same region, by E. B. WILSON, with 7 plates. Another of botanical interest, is, on the nature of the peculiar reddening of salted codfish during the summer season, by W. G. FARLOW, in which the author shows that the red color is owing to a very minute plant known to botanists by the name of *Clathrocystis roseo-persicina ;* that this plant is abundant on the marshes in the vicinity of Gloucester, and in the buildings where the fish are cured; that it exists in the salt imported from Cadiz, which salt is therefore to be avoided in the cure of the cod; and that the Trepani salt is pure from it or nearly so. Mr. Farlow describes also another minute plant from the red codfish of Gloucester, which he names *Sarcina? Morrhuæ.*

The volume, like its predecessors, bears ample testimony to the great value of the work of the Fish Commission, and to the able supervision and judicious management of the Commissioner, Professor Baird.

6. *Röntgen's Principles of Thermodynamics, with special applications to hot-air, gas and steam engines.* Translated, revised and enlarged by A. Jay DuBois. New York, 1880. John Wiley & Sons. 8vo, pp. xviii and 641.—The aim of the author and of the translator has been to furnish a work for the engineering profession and technical schools suited to the needs of beginners by the mode of treatment, and yet sufficiently wide in its scope and practical in its applications. Besides the extensive additions made by the translator himself there are given as an introduction to the whole subject two lectures of Verdet. The extent of the work is greater than is needed in the class room in order to serve as a book of reference. H. A. N.

7. *The American Naturalist.* — The American Entomologist, hitherto edited by Mr. C. V. Riley, has been united with the Naturalist, and the latter will hereafter have the able assistance of Mr. Riley in the Entomological department.

8. *The Kansas City Review of Science and Industry*, edited by T. S. Case, is a monthly "Record of progress in science, mechanic arts, and literature," and aims to be "an exponent of Western thought and a means of communication of Western discoveries and theories." The December number contains the proceedings of the Kansas Academy of Science, and, in a briefer form, those of the St. Louis Academy of Science. It is published at Kansas City, Missouri, in monthly numbers of 64 pages each, for $2.50 a year.

9. *Medals of the Royal Society.*—The Copley Medal has been given the present year to Prof. J. J. Sylvester (of the Johns Hopkins University); Royal Medals to Prof. Joseph Lister and Capt. Andrew Noble; the Rumford Medal to Dr. William Huggins; and the Davy Medal to Prof. Charles Friedel of Paris.

10. *A Physical Treatise on Electricity and Magnetism;* by J. E. H. Gordon, B.A. In ten volumes. New York, 1880. (D. Appleton & Co.).—A notice of this work will appear in another number.

OBITUARY.

Sir Benjamin C. Brodie, Bart., F.R.S., late Professor of Chemistry in the University of Oxford, died at Torquay on the 24th of November, in his sixty-fourth year.

J. Charles Almeida, the founder of the Société Française de Physique, and its Secretary, the author of a Traité de Physique, and formerly Professor of Physics in the Lyceum of Henry IV, died in November last.

Michel Chasles, the eminent French mathematician, died, on the 18th of November, at his home in Chartres. He was born November 15, 1793.

TRACKS OF AMERICAN STORMS ADVANCING WESTERLY.

TRACKS OF AMERICAN STORMS ADVANCING SOUTHEASTERLY

Am. J Sci. Vol XX.

TRACKS OF AMERICAN STORMS ADVANCING NORTHEASTERLY

Am. J. Sci. Vol. XX. Art. 1. 1881.

PLATE III.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AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. VIII.—*Notice of Julius Thomsen's Thermochemical Investigation of the Molecular Structure of the Hydrocarbon Compounds;** by JOSIAH P. COOKE.

THE value called in thermo-chemistry the heat of formation of a chemical compound is simply the sum of the calorific effects—both positive and negative—of the several processes, by which the compound may be formed from the elementary substances of which it consists. According to a fundamental theorem of thermotics this sum is always the same, by whatever series of processes the compound may be obtained, and may be regarded therefore as representing the amount of heat, which would be evolved by the direct union of the elementary substances, even when the given compound cannot be formed in that way. For convenience of calculation the results are usually stated not for the same weight of each compound, but for its equivalent or molecular weight. Thus when the heat of formation of sulphuric acid (H_2SO_4) is given as $193{,}000^c$ it is to be understood that 32 grams of solid sulphur, 64 grams of oxygen gas, and 2 grams of hydrogen gas (both gases taken in their ordinary state under the normal conditions of temperature and pressure), when united to form 98 grams of sulphuric acid, evolve sufficient heat to raise the temperature of 193,000 grams of water one degree. It must be noticed that our experiments only prove that in passing from the elementary substances to the ultimate product through the intermediate stages, which the production of sulphuric acid

* Berichte der deutsch. chem. Gesellschaft, xiii, 1880, pp. 1321, 1388, 1806.

involves, a certain amount of heat is lost on balancing the account. The further conclusion that the ultimate loss of heat is precisely the same as it would be if sulphuric acid could be made by the direct union of its elements, is an inference from the general theorem to which we have referred, and which may be stated thus:

Whenever a system of bodies undergoes chemical or physical changes and passes into another condition, whatever may have been the nature or succession of the changes the quantity of heat evolved or absorbed depends solely on the initial and final conditions of the system provided no effect has been produced on the bodies outside.

Hence when the initial and final conditions are the same, the total thermal effect is the same, however different the processes by which the result may be reached. These processes are physical as well as chemical. Thus in the production of sulphuric acid not only has a solid been rendered fluid but also two highly elastic gases have been condensed to the liquid state, changes, which, as is well known, must involve large calorific effects. Were it possible to eliminate the effects of such physical changes, we might hope to determine the amount of heat evolved in the chemical changes alone, and this would give us what we have so long sought, a measure of the forces which determine the union of the elementary atoms. We might then be able to find the amount of heat which would be evolved by the union of 32 grams of isolated sulphur atoms, 64 grams of isolated oxygen atoms, and 2 grams of isolated hydrogen atoms, to form 98 grams of isolated molecules of sulphuric acid. The comparison of such data would give us what we may appropriately call the thermal potentials of the isolated atoms in their several relations, and this would furnish a measure of the various bonds by which the atoms are held in combination, and afford a new and direct method of investigating molecular structures. We should thus obtain a certain criterion for determining the order and the nature of the bonds by which the atoms are united in any molecule. In a recent notice (this Journal, vol. xix, 264, April, 1880), we wrote: "The problem of finding what we have called the thermal potential of the atoms is not more remote than many problems which have been successfully solved in organic synthesis," and we have thus soon the pleasure of calling attention to a partial solution of the problem then stated.

As is well known, in the molecules $C \equiv C$; $HC \equiv CH$; $H_2C = CH_2$; $H_3C–CH_3$; $H_4C \mid CH_4$ (the first representing an assumed molecule of carbon in an aeriform condition, and the last representing two molecules of marsh gas) our present theories regard the two carbon atoms as united by four, three, two, one and no bonds respectively; and in the paper we are noticing Thomsen seeks to determine the thermal value of these several bonds which he represents by the symbols v_4, v_3, v_2 and v_1.

As a starting point for the investigation he has redetermined experimentally the heat of combustion of several of the hydrocarbons, namely Methan CH_4, Ethan C_2H_6, Propan C_3H_8, Propylen C_3H_6, and the values obtained, together with the corresponding values for Ethylene C_2H_4 and Acetylene C_2H_2, previously determined (Pogg. Ann., v. 148, 390), are united in the column under I in the following table. Under column II of the same table we have given the heat of formation of the same hydrocarbons assumed to be produced from amorphous carbon and hydrogen gas. As we already know (from the experiments of Favre and Silbermann and from previous experiments of Thomsen), the heat of combustion both of amorphous carbon and of hydrogen gas, namely,

$$(C, O_2)=96{,}960^c \qquad (H_2, O)=68{,}360^c$$

it is very easy to calculate the values in column II from those in column I; for by a well-known principle of thermo-chemistry the heat of formation of a hydrocarbon is equal to the difference between the heat of combustion of the compound and sum of the similar values for the charcoal and hydrogen gas from which it is assumed to be formed. In the case of CH_4,

$$20{,}150^c=96{,}960^c+2\times 68{,}360^c-213{,}530^c.$$

We here assume that the hydrocarbon used in our experiments has the volume it naturally would take under the normal pressure of the air, and hence the values of heat of formation in column II are said to be measured under constant pressure. But as the symbols of the several hydrocarbons represent equal volumes (the same volume as that of a molecule of hydrogen gas represented by H_2) it is evident that the amount of condensation attending the formation of these compounds differs very greatly. Thus if we leave out of view the comparatively insignificant volume of the solid charcoal, it is evident that, while in the formation of CH_4 two volumes are condensed to one, in the formation of C_3H_8 four volumes are condensed to one, and it is evident that if we wish to study the chemical action solely we must eliminate the effect of this mechanical cause of the evolution of heat.

Now it can be calculated from well-known data, that at a mean temperature of 20° C. 580^c are set free for every molecular volume lost by condensation. In the formation of CH_4 from $2H_2$ one molecular volume is lost, and hence by subtracting 580^c from $20{,}150^c$ we obtain the amount of heat which would have been evolved had the product occupied the same volume as the factors from which it was formed. In like manner the other values of column III have been calculated, and we thus obtain what may be called the heat of combination under constant volume.

TABLE I.

	I.	II.	III.
1. CH_4	213,530c	20,150c	19,570c
2. C_2H_6	373,330c	25,670c	24,510c
3. C_3H_8	533,500c	30,820c	29,950c
4. C_2H_4	334,800c	−4,160c	−4,740c
5. C_3H_6	495,200c	+760c	−400c
6. C_2H_2	310,570c	−48,290c	−48,290c

It may be noticed incidentally in connection with this table that the results confirm the previous conclusion of Favre and Silbermann, that the common difference of CH_2 between the members of a series of homologues corresponds in all cases to equal differences in the calorific power of their molecules. Thus from the above table we have

$$C_3H_8 - C_2H_6 = 160{,}170^c$$
$$C_2H_6 - CH_4 = 159{,}800^c$$
$$C_3H_6 - C_2H_4 = 160{,}400^c$$

and it is evident that the difference in question must be very closely $160{,}000^c$.

If, next, we compare the heat of formation under constant volume of all the hydrocarbon molecules which contain two atoms of carbon, we find between these values, also, a manifest relationship, and from this the remarkable conclusions of the paper we are noticing have been deduced.

TABLE II.

		Differences.
C_2	$= -a,$	
		$= 4r$
$C_2 + H_2$	$= -48{,}290^c$	
		$43{,}550 = 3r$
$C_2 + H_4$	$= -4{,}740^c$	
		$29{,}250 = 2r$
$C_2 + H_6$	$= +24{,}510^c$	
		$14{,}630 = r$
$2(C+H_4) = C_2 + H_8$	$= +39{,}140^c$	

Now just as $2CH_4$ is the limit of this series of molecules at one end, C_2 is evidently the limit of the series at the other end, and the symbol C_2 represents the theoretical molecule of carbon in the aeriform state occupying the unit of molecular volume, the two atoms of this molecule united by four bonds. Now if we represent the heat of formation of this molecule by $-a$, it will be seen that the relationship exhibited by the table gives us at once the means of calculating its value. But it is obvious that while the results given in the table are sufficiently accordant to exhibit their relationship, we should obtain quite different values for $-a$ by combining different results, and the only correct method is to bring all the determinations into the calculation, combining the several values according to the principle of least squares. This Thomsen has done, and deduced for the most probable values

$$a = 106{,}630^c. \qquad r = 14{,}573.$$

With these values it is now easy to calculate the following table:

TABLE III.

Symbol.	Heat of Formation.	Differences.
$C \equiv C$	$-a \quad = -106{,}630^c$	
		$4r = 58{,}292$
$HC \equiv CH$	$-a + 4r = -48{,}338^c$	
		$7r = 102{,}011$
$H_2C = CH_2$	$-a + 7r = -4{,}619^c$	
		$9r = 131{,}157$
$H_3C - CH_3$	$-a + 9r = 24{,}527^c$	
		$10r = 145{,}730$
$H_4C \mid CH_4$	$-a + 10r = 39{,}100^c$	

and by comparing these calculated values with the observed values of table II it will be seen how closely they satisfy the observations. In table III the value $-a$ is the heat of formation of the assumed product $C \equiv C$ from amorphous charcoal, and is the sum of two quantities, first the amount of heat absorbed in completely disassociating the atoms from the amorphous solid coal, and secondly the amount of heat that must be set free in the union of free carbon atoms in pairs by four bonds. If now we represent the first value by $-2d$ and the second as already proposed by v_4 we can evidently make the equation

$$-a = -2d + v_4 = -106{,}630^c. \tag{1}$$

If a hydrocarbon is formed from amorphous carbon and hydrogen gas, the process must involve in addition to the disassociation of the atoms of the coal a division of the molecules of hydrogen gas also, and then a union of the hydrogen atoms to the carbon atoms, and perhaps also a union of the carbon atoms by the bonds which remain open one, two or three, as the case may be. Let us represent now by $-hh$ the heat absorbed in the disassociation of the atoms of hydrogen gas, and by ch the heat evolved from the union of the carbon and hydrogen atoms, and by v_3 v_2 v_1 the thermal effect resulting from the union of the carbon atoms by three bonds, two bonds, or a single bond, respectively, and we can at once deduce the following equation which shows the elements of which the heat of formation of acetylene consists:

$$HC \equiv CH = (C_2, H_2) = -2d + v_3 + 2ch - hh. \tag{2}$$

It will be noticed that the symbols in lower case type are used to represent what we have called the thermal potentials of the atoms.

Assuming, as the facts of organic chemistry undoubtedly justify, that the thermal effect in the union of hydrogen and carbon atoms is always the same, and putting

$$2ch - hh = 2q^* \tag{3}$$

we can readily deduce for the several hydrocarbons we are studying the following equations:

TABLE IV.

For	$C \equiv C$	$-a = -2d + v_4.$
	$HC \equiv CH$	$-a + 4r = -2d + v_3 + 2q$
	$H_2C = CH_2$	$-a + 7r = -2d + v_2 + 4q$
	$H_3C - CH_3$	$-a + 9r = -2d + v_1 + 6q$
	$H_4C \mid CH_4$	$-a + 10r = -2d \ldots. + 8q$

and from the differences between the successive equations of this group we obtain the following simple relations between the quantities we are investigating:

$$v_4 - v_3 = 2q - 4r$$
$$v_3 - v_2 = 2q - 3r$$
$$v_2 - v_1 = 2q - 2r$$
$$v_1 = 2q - r$$

It will be seen that we have thus made a very near approach to the determination of the thermal value of the several bonds between the carbon atoms, but as in the last group the number of unknown quantities exceeds by one the number of separate equations (it must be remembered that r is known), we must look for some other relation to furnish an additional condition. We can find this, in part at least, in the thermal relations of the oxides of carbon.

The heat of formation of the oxides of carbon from amorphous carbon and oxygen gas, and also the heat of formation of carbonic dioxide from carbonic oxide and oxygen gas are given in the following table:

TABLE V.

	Heat of Formation Under constant pressure.	Under constant volume.
(C, O_2)	$96,960^c$	$96,960^c$
(CO, O)	$68,370^c$	$68,080^c$
(C, O)	$28,590^c$	$28,880^c$

The first of these values is the same as that used above, determined by Favre and Silbermann. The second has recently been re-determined by Thomsen. The third is not an experimental value, but deduced by simply subtracting the second from the first. As there is no condensation of gas volume when oxygen gas passes into carbonic dioxide, the heat of formation of carbonic dioxide under constant volume is the same as that under constant pressure. But when carbonic oxide gas unites with oxygen gas to form carbonic dioxide there is a condensation of one half a molecular volume, and hence in this case the value under constant volume is less than that under

* Notice that the quantity q is the result of two processes necessarily simultaneous, the breaking up of the hydrogen molecule and the union of the hydrogen and carbon atoms.

constant pressure by half 580^c (page 89). If now we analyze, after the principles applied to the hydrocarbons, the production of the oxides of carbon from amorphous carbon and oxygen gas we can readily deduce the following equations, the meaning of whose terms must be now evident:

$$2(C, O) = -2d - oo + 2co \qquad (4)$$

$$(C, O_2) = - d - oo + oco \qquad (5)$$

$$(C, O_2) - 2(C, O) = d - 2co + oco = 39{,}200^c. \text{ (Table V).} \qquad (6)$$

Here $-oo$ represents the heat absorbed in dividing the molecules of oxygen gas, co the heat evolved in the union of atoms of carbon each with one atom of oxygen and oco the heat evolved in the union of atoms of carbon each with two atoms of oxygen. Could we assume that in the molecule of carbonic dioxide $O{=}C{=}O$ the bonds were all of equal value we should necessarily have $oco = 2co$, and then from the last equation we should at once deduce

$$d = 39{,}200^c \qquad (7)$$

and this being known the values of v_1 v_2 v_3 and v_4 could at once be definitely calculated from the previous equations. But although the assumption we have made is highly probable, it cannot as yet be proved, and it is possible that

$$2co - oco = x \text{ (some unknown quantity),}$$

and in this case we should have

$$d = 39{,}200^c + x,$$

a value which is independent of all hypothesis.

Returning now to the equations of table IV and taking the numerical values of the left-hand member in each of these equations from table III, we can at once find by simple substitution the following values:

$$q = 14{,}867^c + \frac{x}{4} \qquad (8)$$

$$v_4 = C{\equiv}C = -\ 28{,}230^c + 2x \qquad (9)$$

$$v_3 = C{\equiv}C = +\ \ 688^c + \tfrac{3}{2}x \qquad (10)$$

$$v_2 = C{=}C = +\ 15{,}033^c + x \qquad (11)$$

$$v_1 = C{-}C = +\ 14{,}805^c + \tfrac{1}{2}x \qquad (12)$$

Then by subtracting we find the thermal values of the several bonds, which take the following simple forms:

For the first bond	$+\ 14{,}805^c + \frac{1}{2}x$	(13)
For the second bond	$+\ \ 228^c + \frac{1}{2}x$	(14)
For the third bond	$-\ 14{,}345^c + \frac{1}{2}x$	(15)
For the fourth bond	$-\ 28{,}918^c + \frac{1}{2}x$	(16)

Of course if the probable supposition made above—in regard to the constitution of the molecules of CO_2—is correct, then the terms containing x disappear from all these values.

Again, a very remarkable relation appears when we compare together, as in table VI, the values of r, q, v_1 and v_2.

TABLE VI.

$$r = 14{,}573^c$$
$$q = 14{,}687^c + \frac{x}{4} = r + \frac{x}{4}$$
$$v_1 = 14{,}805^c + \frac{x}{2} = r + \frac{x}{2}$$
$$v_2' = 15{,}033^c + x = r + x.$$

It seems highly probable that the numerical term is the same in all these values; and the fact that the same constant frequently appears as a factor in the data of thermo-chemistry renders this conclusion still more probable. Thus we find that the heat of formation of HCl, NO and H_2O (in the condition steam) all as aeriform products under constant pressure is as follows:

$$H_2 + Cl_2 = \quad 44{,}000^c = 3 \times 14{,}667^c$$
$$N_2 + O_2 = -43{,}150^c = 3 \times 14{,}383^c$$
$$H_2 + O = \quad 57{,}610^c = 4 \times 14{,}402^c$$

The constant we have represented by r has evidently then an important significance, and its most probable value is that deduced by the method of least squares from all the observations on the series of hydrocarbons containing two atoms of carbon, as shown by table III. If we take then $r=14{,}573$ as the true value and $q=r+\frac{x}{4}$, we can easily deduce a second value of d from the data given in the table on page 92. Since $39{,}100^c=-2d+8q$, we have by substituting the value of q, $d=38{,}742^c+x$. From the oxides of carbon we have $d=39{,}200^c+x$. The mean of these values, omitting the last two figures as insignificant, is $d=38{,}900^c+x$.

The following are, now, the most probable values of the chief constants used in this investigation:

TABLE VII.

$d = 38{,}900^c + x$	$r = 14{,}570^c$
$q = r + \frac{1}{4}x$	$co = 67{,}880^c$
$v_1 = r + \frac{1}{2}x$	$v_2 = r + x$
$v_3 = + \frac{3}{2}x$	$v_4 = -2r + 2x$

With these values we can calculate the heat of formation, under constant volume, of a hydrocarbon from amorphous carbon and hydrogen gas, by means of the equation

$$(C_n, H_{2m}) = -nd + 2mq + \Sigma v \tag{17}$$

in which the Σv is the sum of the calorific effects resulting from the union of the carbon atoms with each other. The results are independent of the unknown quantity x which is eliminated in reducing the equation. Since, as just stated the, unknown quantity x is always eliminated on solving the last equation we can put $r=q=v_1=v_2=14{,}570$ and $v_3=0$. If also we put $\Sigma v=x_1\ v_1+x_2\ v_2+x_3\ v_3$, ($x_1$, x_2, x_3 representing respectively the number of single, double and treble carbon bonds which occur in the molecule of the hydrocarbon in question), we can write equation (17) in the following more convenient form:

$$(C_n,\ H_{2m})=-n\times 38{,}900^c+(2m+x_1+x_2)\ 14{,}570^c \qquad (18)$$

This formula may be readily adapted to the various types of hydrocarbons (the paraffines, the olefines, the acetylenes, benzol, etc.), and by its aid we can calculate the heat of formation of different isomers according to their assumed structure, and then on comparing the calculated values with the direct results of experiment we may hope to obtain a new test of our theories of molecular structure.

In the series of paraffines the carbon atoms are all linked by single bonds, and no isomerism resulting from different relations of the carbon bonds is possible. Of course isomerism can result from differences in the grouping of the carbon atoms, but of this our thermo-chemical theory takes, as yet, no account. The general formula of a paraffine is $C_n\ H_{2n+2}$ and the number of single carbon bonds is $n-1$. We have then $2m=2n+2$; $x_1=n-1$; $x_2=0$. Making these substitutions in (18) we have

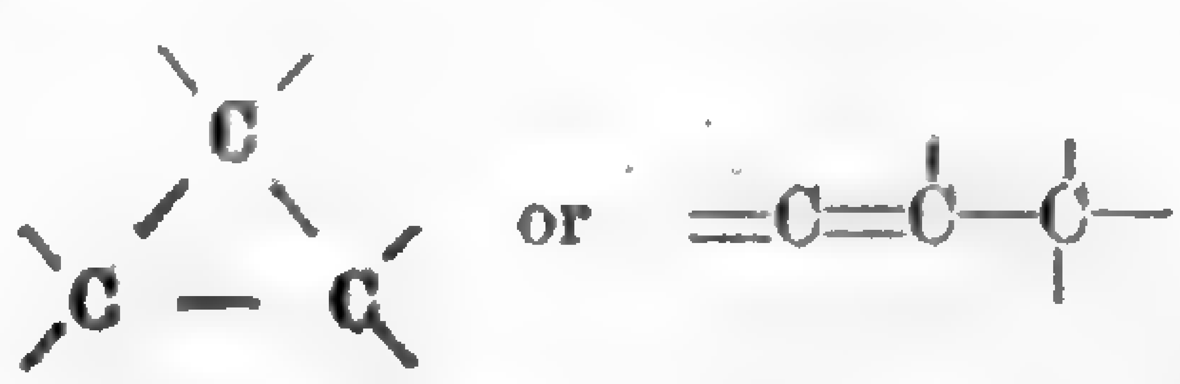
$$(C_n,\ H_{2n+2})=n\times 4810^c+14570^c \qquad (19)$$

and the calculated values of the heat of formation under constant volume for the first three members of the series is as follows. The observed values in the parallel column shows as close accordance as could be expected.

TABLE VIII.

	Calculated.	Observed.
$C\ H_4$	19,380^c	19,570^c
C_2H_6	24,190^c	24,510^c
C_3H_8	29,000^c	39,950^c

In the olefines, however, isomerism resulting from different relations of the carbon bonds is possible; thus in the case of C_3H_6 we may have

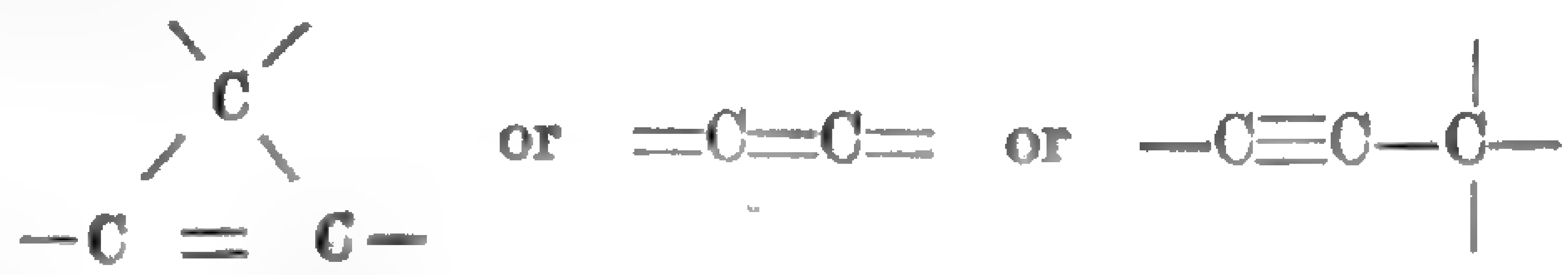


The general formula of an olefine being C_nH_{2n}, we have in the first case n single carbon bonds, and in the second case $n-2$ single bonds together with one double bond. Making the obvious substitutions in equation (18), we have for the heat of formation under constant volume

(1) $(C_n,\ H_{2n}) = n\times 4810^c$
(2) $(C_n,\ H_{2n}) = n\times 4810^c - 14{,}570^c$

For propylene $n = 3$, and the calculated values are $+14{,}430^c$ or -150^c. According to Thomsen's experiments the heat of formation of propylene prepared from isopropyliodide is -400^c, which would indicate that the generally received opinion in regard to the structure of this molecule is correct.

With the acetylenes we may have three distinct types of structure depending on the distribution of the carbon bonds. Thus for C_3H_4 either



The general symbol for an acetylene being $C_n\ H_{2n-2}$, we have in isomers of the first type $n-1$ single with one double bond; in isomers of second type $n-3$ single with two double bonds, and in isomers of the third type $n-2$ single with one treble bond. Making the substitutions as before, we obtain the following equations:

$$(1) \qquad (C_n, H_{2n} - 2) = n \,.\, 4810^c - 29140^c$$
$$(2) \qquad (C_n, H_{2n} - 2) = n \,.\, 4810^c - 43710^c$$
$$(3) \qquad (C_n, H_{2n} - 2) = n \,.\, 4810^c - 58280^c$$

and for allylene the three values are

$$-14710^c \qquad -29283^c \qquad -43856^c$$

A determination of the heat of combustion of allylene was made by Berthelot, and since the heat of formation under constant volume deduced from his experiment is $-38{,}320^c$, it is probable that the last of the three symbols above represents the ordinary type of structure and this again is in accordance with the generally received opinion. The discrepancy between theory and observation, however, is quite large, and Thomsen intends to make further experiments on this substance.

One feature of this investigation of Thomsen, which might be overlooked unless attention was called to it, may be appropriately noticed in this connection. Omitting the unknown quantity x, which indeed is probably zero, we have for the values of the carbon bonds,

$$v_1 = r \qquad v_2 = r \qquad v_3 = 0 \qquad v_4 = -2r$$

and $r = 14\,570^c$. Hence it follows that the same energy results whether two carbon atoms unite by one or by two bonds, and that when they unite by three bonds no energy whatever is set free. At first sight this result seems strange, for we should naturally expect that the larger the number of bonds of union, the greater would be the force required to separate these atoms and hence the greater the manifestation of energy when these atoms united. On the contrary this investigation shows that if two carbon atoms are united by two bonds it requires no energy to break one of the bonds if the other is left unimpaired, although it requires an energy measured by $14{,}770^c$ to break the last. While if the atoms are united by three bonds there is as strong a tendency to break away at the first bond as there is to hold together at the last bond.

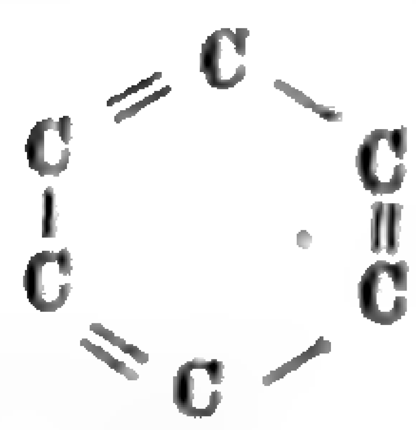
Strange, however, as these results may appear, they harmonize with the known chemical relations of the paraffines, olefines and acetylenes. The stability of a chemical compound is to a certain extent proportional to the amount of energy set free in its production; since in order to decompose it the same amount of energy must be expended. In the paraffines, where all the carbon atoms are united by single bonds, and all the other bonds closed by hydrogen atoms, the molecules can not be decomposed unless one at least of the bonds is broken, and each break, whether between *cc* or *hc*, implies an expenditure of energy represented by $14{,}570^c$. Here then is the explanation of the great stability of this class of hydrocarbons.

Passing next to the olefines we find a very different condition. In every molecule of these bodies two of the carbon atoms are united by a double bond, and one of the two can be broken without the expenditure of energy, so that atoms of chlorine or bromine have no work to do in order to unite at these points except to free themselves from their previous association. Hence arises the most familiar and characteristic chemical property of these substances.

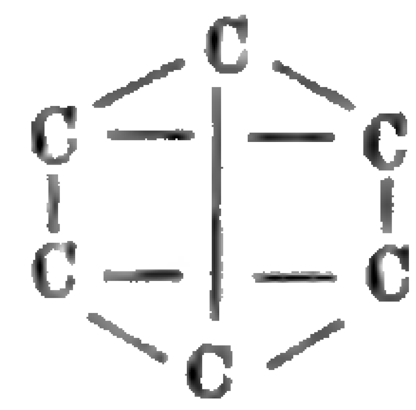
Lastly, in the acetylenes the same tendency is still more strongly marked; for in the molecules of these bodies two of the carbon atoms are united by a treble bond, and the parting of either one or of two of these bonds is attended with a development of energy which is added to that resulting from the normal attraction of the carbon atoms for other radicals.

But the molecular structure of none of the more complex hydrocarbons has been so fully studied as that of benzol (C_6H_6), and we therefore have naturally waited with great interest for the results of the application of the new method of investigation to this compound. In the last number of the Berichte der deutsch. chem. Gesellschaft (Oct. 25, 1880), the expected results are published. In the benzol molecule, six only of the twenty-four bonds, which belong to six carbon atoms, are closed by hydrogen atoms leaving eighteen bonds to unite with each other, or nine connecting bonds as they are usually represented. Now we can conceive of a number of different ways in which these bonds may be distributed; but there are only two schemes which will satisfy the well-known facts in regard to the three types of isomeric derivatives of benzol. These schemes are that of Kékulé represented in fig. 1, and that of Ladenburg in fig. 2.

1.



2.



In the first scheme there are three single and three double bonds; in the second scheme nine single bonds. Making now the obvious substitutions in equation (18), we obtain for the heat of formation under constant volumes either

$$-60{,}360^c \text{ or } -16{,}650^c,$$

and for the heat of formation under constant pressure

$$-59{,}200^c \text{ or } -15{,}490^c.$$

We can now easily calculate, by the method already described, the heat of combustion of benzol vapor and we shall obtain

$$846{,}040^c \text{ or } 802{,}330^c.$$

Finally, Thomsen has re-determined with great care the same value and finds as the mean of five experiments that the heat of combustion of the molecular weight of benzol (72 gr.) is 805,800^c. Hence he concludes:

"The six carbon atoms of benzol are united to each other by nine single bonds, and the previous assumption of a structure of benzol with three single and three double bonds is not supported by experiment."

Thomsen endeavors to prepare the way for the reception of this conclusion by emphasizing the statement that: "*The great resisting power of benzol militates against the presence of multiple bonds.*" But although it is true that chlorine or bromine act on benzol far more feebly than on ethylene or acetylene, nevertheless, under no great stress, benzol does yield addition products, and there can be no question that the original scheme of Kékulé harmonizes more chemical facts than the modification of this scheme proposed by Ladenburg. The new evidence is very important, but until its bearing has been more fully investigated it can not be regarded as conclusive. Indeed the interest of this investigation depends not so much on its results as on its method. It is a bold push beyond the beaten tracks of science, and although the first results of the venture must be accepted with caution, the skill displayed calls forth our admiration and the importance of the methods employed justifies this extended notice.

Art. IX.—*On a Determination of the Force of Gravity at the Summit of Fujiyama, Japan;* by T. C. Mendenhall.

An excursion to the summit of Fujiyama was made during the first ten days in August of the present year (1880), for the purpose of making a determination of the force of gravity at that point. In addition to four special students in physics from the Imperial University, the writer was accompanied by W. S. Chaplin, Esq., Professor of Civil Engineering, who determined the rate of the chronometer, and rendered much other valuable assistance. The preliminary experiments at the University in Tokio, as well as those upon the mountain, were mainly carried out, under the direction of the writer, by Messrs. Tanakadate and Tanaka, who had already gained much valuable experience in the determination of the force of gravity at Tokio.*

As stated in the previous paper, it was decided to make use of some form of the so-called "invariable" pendulum, and to compare a series of vibrations made at Tokio and at the top of the mountain. Owing to the difficulty of getting anything in the way of knife-edges made with sufficient accuracy in this country, nothing better could be done than to make use of a Kater's pendulum by Negretti and Zambra, after removing one of the knife-edges, the "tail-pieces" and all of the unnecessary parts. In the condition in which it was used, it consisted of a flat bar of brass 134 cm. long, 38 mm. wide and 4 mm. thick, with a knife-edge at a distance of about 15 cm. from one extremity. At nearly the lowest point was fixed the flat cylindrical weight, 10 cm. in diameter and 19 mm. thick, which was also of brass. On the short piece projecting above the knife-edge was an adjusting slide-piece which, as well as the cylindrical weight, was fixed in such a way that accidental movement was rendered impossible. In order to prevent any possibility of entire loss of results by means of the accidental injury of this pendulum, while being carried to and from the mountain, another of nearly the same vibrating period was prepared, the flat bar in this case being of well-seasoned wood, and the cylindrical weight being of somewhat different form. The knife-edge used was that which had been removed from the Kater's pendulum. During the month of July, both pendulums were vibrated in the Physical Laboratory of the University at Tokio in the same room and from the same pier referred to in the previous paper. Besides these two pendulums, the appliances consisted, in the main, of a Negus break-circuit chronometer, a chronograph and a portable transit instrument

* This Journal for August, 1880.

for rating the chronometer. Fortunately, all of the apparatus reached the top of the mountain in safety. The weather was exceptionally favorable during our stay, the nights being clear and the wind much less violent than is usual. The party occupied a small tent upon the summit of the mountain within a few feet of the edge of the crater, but it was evident that it could not be made a suitable place for carrying on the experiments. Fujiyama is a "holy mountain," and its ascent is accomplished yearly by thousands of pilgrims from all parts of Japan. This has resulted in the erection upon the summit of several small stone huts, which are used as temples. They are built of large and regularly-shaped pieces of lava, piled together so that the shrines within are perfectly protected from wind and weather. The priest in charge of one of these kindly permitted us to take possession of it during the few days of our stay, and it proved to be well adapted to our needs. In twenty-four hours after our arrival the pendulums were ready for work, and vibrations were continued during the greater portion of two days. Both pendulums were swung and the mode of recording the time was similar to that used in the previous determination at Tokio. The length of time in each series was, in general, thirty minutes. Temperature and barometric observations were made during the time of the experiments. Immediately after the pendulums were returned to Tokio they were again vibrated at the University, in order to discover if any change had taken place during their absence. With the results to be considered the brass pendulum alone is concerned. The two pendulums agree well with each other, but it is impossible to introduce any correction for the influence of moisture upon the wooden pendulum. Experiments made with it since the return from Fujiyama, under different degrees of humidity, show that such a correction would be necessary, so that it has not been introduced into the calculations, although it has served a useful purpose as a check. Many groups of vibrations were recorded both upon the mountain and at Tokio before and after the mountain work. Without quoting the individual results, it will be sufficient to remark that they agree among themselves slightly better than those given in the previous paper on the Tokio determination.

The vibrations at Tokio were all made under nearly the same conditions, and for convenience they were reduced to the common temperature of 23°·5 and barometer 30 inches. The time of vibration of the pendulum at Tokio, under these conditions, the mean of all the results, was:

$$t_1 = \cdot 999834 \text{ seconds.}$$

On the summit of the mountain the barometric pressure was tolerably constant at 19·5 inches and the temperature 8°·5, and to these conditions they were all reduced after being corrected for arc, chronometer rate, &c. Finally the mean of all is reduced to the Tokio conditions as to temperature and pressure. The coefficient of expansion of the bar has not been determined, but it has been assumed to be ·00000187 for 1° C. This is a commonly accepted coefficient for brass, and a comparison of the vibration periods of the pendulum, under different temperatures, indicates that it cannot be far from correct. The correction for difference of barometric height is the most difficult to determine. Were it possible to vibrate the pendulum at the same place under pressures widely differing, it might be determined experimentally. Lacking this, I was, fortunately, able to refer to a recent elaborate and exhaustive discussion of the whole subject, from an experimental as well as from a theoretical standpoint, by C. S. Peirce, Esq., of the U. S. Coast Survey.* In this valuable memoir Mr. Peirce gives a graphical representation of the periods of vibration of his pendulum, under various pressures, from 30 inches of mercury down to what is practically a vacuum. By interpolation the period for any pressure between these limits can be very closely ascertained, as also the correction in going from one pressure to another. There are important differences between the pendulum used by Mr. Peirce and that in use here, the principal one being the difference in shape of the cylindrical weights, and the fact that in our pendulum only one cylinder was carried. Nevertheless, a fair approximation to the correction may be taken from his curve showing the results with "heavy end down," and observing that the differences in the two pendulums are such as to make the correction for our pendulums considerably less than that of the Coast Survey. In this way, by considering these differences the correction used in the reduction was determined. After it had been established, I was fortunate in getting possession of the complete memoir of Mr. Bailey, published in 1832, in which his elaborate experiments to determine this correction are given in full. Among the many pendulums which he used was one "No. 22," which, in form and dimensions, resembles ours quite closely, and the results of his experiments with it confirm the accuracy of the assumption made. It will be remembered that, as all results are reduced to the Tokio conditions, the correction is to be made for only about one-third of an atmosphere, so that, although important, it is less so than if the reduction had been to a vacuum. It is thought, therefore, that the correction applied is not far wrong. The corrected time, then, appears to be as follows:

* Measurements of Gravity at Initial Stations in America and Europe. Appendix No. 15, U. S. Coast Survey. Report for 1876.

Time on Summit—temperature, 8°·5; barometer, 19·5 inches;

$$t_2 = 1{\cdot}000146$$

Correction for temperature to reduce to 23°·5 . . . . ·000140

Air correction . . . . . ·000050

Time reduced to Tokio conditions.

$$t_2 = 1{\cdot}000336$$

Assuming the value of the force of gravity at Tokio to be as previously determined,

$$g_1 = 9{\cdot}7984$$

it follows that on the summit of Fujiyama,

$$g_2 = 9{\cdot}7886$$

Mr. Peirce has introduced an important correction to the time of vibration of a pendulum which depends upon the flexure of the support. I have carefully examined the support used in these experiments, attached to the massive stone pier, as described in a previous paper, and I can find no perceptible flexure. No means of making a minute examination were at hand on the summit of the mountain, but from the nature of the mounting there I am convinced that no considerable amount of flexure was possible.

The question at once suggests itself, whether it is possible to make use of this result in a determination of the density of the earth. While many of the circumstances are extremely favorable to this end, many of the data are, unfortunately, quite uncertain. It was originally planned to undertake at the same time a complete trigonometrical survey of the mountain, in order to obtain the necessary data as accurately as possible. This, however, we were obliged to defer, but it is hoped that it may be made at some future time. The following is offered as, perhaps, the nearest solution of the problem possible under the circumstances.

Fujiyama is an extinct volcano, whose height is known to be 2·35 miles very closely. It is renowned for its almost perfect symmetry of form, and for the fact that it rises solitary and alone out of a plain of considerable extent. Thus there is not much to consider except the attraction of the mountain itself. To determine this is, of course, a matter of considerable difficulty, but it is believed that a result not far out of the way is reached by making the following assumptions. Without any great error the mountain may be assumed to be a cone. The summit angle of this cone has been obtained by making careful measurements upon a large number of photographs of the mountain, taken from many different points of view. The mean of many measurements, which do not differ greatly among themselves, gives for this angle 138°. Another point of vital importance is the mean density of the mountain. The rock, as far as can be discovered, is quite uniform in its composition throughout. It is a part of Japanese tradition, for it can hardly be called history, that the mountain was produced in a single night in the year B. C. 286. Many geologists are of opinion that it is mainly the result of a single eruption. A number of specimens from the surface have been examined, and it is found that when the air is retained in the pores the density is about 1·75, but when it is ground to a powder and the air excluded, it is 2·5. These facts were communicated to five geologists, at present employed in Japan, most of whom have considerable knowledge of the mountain from personal examination. They were requested to give an opinion as to what was the most probable mean density of the mountain. The mean of these results was 2·12, which is assumed to be correct in computing the result, and it also happens to be almost exactly the mean of the two densities given above. The time of vibration of the pendulum at the level of the sea at Tokio has been corrected for the difference of latitude between Tokio and Fujiyama, which is about 19′, by means of the well known formula. When this is done it becomes

$$t_3 = \cdot 999847$$

From these times of vibration the part of the attraction on the summit, which is due to the mountain itself, is easily computed, and then the attraction of the mountain in terms of the density of the earth. The mountain is assumed to be a cone, whose semi-vertical angle is 69° and density 2·12, and its attraction on a particle at its vertex is computed. Equating these results the density of the earth results as follows:

$$D = 5 \cdot 77$$

This result is somewhat greater than the generally accepted density, but when the uncertainty of some of the data is considered it must be regarded as remarkably lose.

It is believed that the density of the mountain is the most uncertain of all the factors, and it will be of interest to reverse the problem and, assuming the density of the earth to be 5·67, as determined by Baily, find, by combining this with the pendulum experiments, the density of the mountain. When this is done the result is:

$$d = 2 \cdot 08$$

It seems to me that these experiments establish, with considerable certainty, the fact that the mountain is, for some reason, deficient in attraction, which leads to many questions of great interest concerning the possible or probable structure of the mountain. It is possible, therefore, that these results may be of some value to geologists who are interested in the structure of volcanoes.

ART. X.—*Extract from a Report to* C. P. PATTERSON, *Supt. Coast and Geodetic Survey;* by W. H. DALL, Assistant in charge of schooner "Yukon," employed on the coast of Alaska.

ON the 11th of August, after a stormy and tedious passage, we arrived at Plover Bay, in Eastern Siberia, near Bering Strait. The longitude of this place has been independently determined from San Francisco and St. Petersburg, so that it afforded a convenient place for rating our chronometers before beginning work on our coast in the Arctic. We obtained good observations for time and a full series of magnetics.

The surroundings of the anchorage are barren and dreary, the rocky hills covered with material comminuted by the frost and presenting little vegetation, except a luxuriant growth of lichens. The people here are the Asiatic Eskimo, described by Nordenskjold, modern emigrants from America, few in number and deteriorated by use of alcohol obtained from illicit traders. They gave us no trouble, however, and the fine weather made our stay here quite pleasant. When we arrived, late at night, two canoes, containing the entire population, came out to meet us, it being the practice of the traders to give everybody a drink on their arrival "to facilitate trade." They asked for "lum" (rum) and were informed we had none. "No got lum! American schooner no got lum! (with rising indignation), Lie! Lum got!" was the exclamation of a linguist among them. However, much to their disgust, they were finally convinced we were not traders and departed, leaving us in peace.

On the 14th of August we sailed from Plover Bay to the Arctic, having light breezes and fine weather. On the 20th, we anchored behind Cape Lisburne, on the American shore in the Arctic, nearly 200 miles north of Bering Strait. The air was balmy, the sun warm and bright: no snow or ice visible on land or water, and the banks covered with flowers, among which daisies, monkshood and forget-me-nots were conspicuous. The natives were the most curious and annoying beggars we met during the voyage, and it was necessary to have a guard on hand to keep an eye on the instrument cases, etc., while observations were going on, lest they should be stolen. However, we lost nothing except our patience now and then, and obtained good observations for latitude, time, and a good series of magnetics.

The land hereabouts is high for the most part, and contains beds of good coal, belonging to the true Carboniferous period, with limestones containing many fossil corals and other Paleozoic remains. The revenue cutter "Corwin" coaled several times from these beds, which are near the beach, and reported the coal of good quality. It will prove of importance if steam whaleships come into general use in this region.

We sailed for Icy Cape the next day, but the wind being light, did not reach it until the 25th of August. That evening we proceeded, seeing several whaleships, and the following afternoon spoke the cutter, who reported ice near at hand, and that she did not think we could proceed much further with safety. We soon made the ice, which was about eleven miles off shore and nearly parallel with it, consisting of floating fragments, much soiled with mud and rising seldom more than ten feet above the water, forming a fringe around of solid fields of rather rough pack ice, extending beyond the range of vision from the masthead.

We spoke several of the whalers as we proceeded. All represented the ice as moving in toward the land. The night before it had moved in eighteen miles, there being a strong northerly wind. After passing Point Belcher and finding that off the Sea Horse Islands there was only a quarter of a mile of open water, we decided to anchor and await further developments. The weather was cloudy with heavy wet fog. That night the ice moved in three miles toward shore; the wind also strengthened; the weather showed no signs of improvement, and, rather than risk being grounded by the ice with only two months' provisions on board, I decided to take advantage of the favorable wind and return to the southward, where there was still much work to do. We reached nearly the latitude of Point Barrow, and were about fifty miles westward from it. The country in this vicinity was almost perfectly flat, and nothing like a hill or rise was visible anywhere.

The vegetation was quite dense on the land, but less profuse than at Cape Lisburne and with fewer flowers. Large lumps of coal lay on the beach, which had been pushed up by the ice from the bottom of the sea, but no bed rock could be seen, and the soil seemed to be chiefly a sort of red gravel. At a depth of two feet is a stratum of pure ice (not frozen soil) of unknown depth. This formation extends, with occasional gaps, north to Point Barrow and east to Return Reef, where the ice layer is about six feet above the level of the sea. It goes south at least as far as Icy Cape without any decided break, and is found in different localities as far south as Kotzebue Sound.

We sailed on the 28th of August from Point Belcher and entered Kotzebue Sound on the 30th. The next morning, August 31st, we anchored in Chamisso Harbor, Eschscholtz Bay, in which vicinity we remained four days. We were beset with natives from all quarters, eager to trade and much disappointed that we had nothing to sell. It was fortunate that no rumsellers had been in the vicinity, for the number of the natives was so great that they might easily have taken charge if they had been so disposed.

We obtained a first rate series of observations of all kinds on Chamisso Island. On the 2d of September, the weather being unsuitable for observations, I took the large boat and crew and crossed the bay toward Elephant Point, the site of the extraordinary ice formation, first observed by Kotzebue and afterward reported on by Beechey and Seemann.

We landed on a small, low point near some old huts, and proceeded along the beach about a mile, the banks being chiefly composed of volcanic breccia or a slaty gneissoid rock. They rose fifteen to fifty feet in height above the sea, rising inland to hilly slopes, without peaks and probably not attaining more than three or four hundred feet anywhere in the vicinity.

As we passed eastward along the beach, a change took place in the character of the banks. They became lower and the rise inland was less. From reddish volcanic rock they changed to a grayish clay, containing much vegetable matter, which, in some places, was in strata in the clay, and in others indiscriminately mixed with it. Near the beginning of these clay banks, where they were quite low, not rising over twenty feet above the shore, we noticed one layer of sphagnum (bog-moss) containing marl of fresh water shells, belonging to the genera *Pisidium*, *Valvata*, etc. This layer was about six inches thick. The clay was of a very tough consistency, and, though wet, did not stick to or yield much under the feet. The sea breaks against the foot of these banks and undermines them, causing them to fall down, and the rough irregular talus that results is mingled with turf and bushes from the surface above. A little farther on a perpendicular surface of ice was noticed in the face of the bank. It appeared to be solid and free from mixture of soil, except on the outside. The banks continued to increase slowly but regularly in height as we passed eastward. A little farther on another ice-face presented itself on a larger scale. This continues about two miles and a half to Elephant Point, where the high land turns abruptly to the south and west, and we followed it no farther. The point itself is boggy and low, and is continued from the foot of the high land, perhaps half a mile to the eastward, forming the northwest headland to a shallow bay of considerable extent.

To return to the "cliffs": these for a considerable distance were double; that is, there was an ice-face exposed near the beach with a small talus in front of it, and covered with a coating of soil two or three feet thick, on which luxuriant vegetation was growing. All this might be thirty feet in height.

On climbing to the brow of this bank, the rise from that brow proved to be broken, hummocky and full of crevices and holes; in fact, a second talus on a larger scale, ascending to the foot of a second ice-face, above which was a layer of soil one to three feet thick covered with herbage.

The brow of this second bluff we estimated at eighty feet or more above the sea. Thence the land rose slowly and gradually to a rounded ridge, reaching the height of three or four hundred feet only, at a distance of several miles from the sea, with its axis in a north-and-south direction, a low valley west from it, the shallow bay at Elephant Point east from it, and its northern end abutting in the cliffs above described on the southern shore of Eschscholtz Bay. There were no mountains or other high land about this ridge in any direction, all the surface around was lower than the ridge itself.

About half a mile from the sea, on the highest part of the ridge perhaps two hundred and fifty feet above high water mark, at a depth of a foot, we came to a solidly frozen stratum, consisting chiefly of bog moss and vegetable mould, but containing good-sized lumps of clear ice. There seemed no reason to doubt that an extension of the digging would have brought us to solid, clear ice, such as was visible at the face of the bluff below. That is to say, it appeared that the ridge itself, two miles wide and two hundred and fifty feet high, was chiefly composed of solid ice overlaid with clay and vegetable mould. It was noticeable that there was much less clay over the top of the upper ice-face than was visible over the lower one, or over the single face when there was but one and the land and bluff were low near the beach. There also seemed to be less vegetable matter. Near the beach six or eight feet of clay were observed in some places, without counting what might be considered as talus matter from further up the hillside. In one place only did we notice a little fine, reddish gravel, and nowhere in the talus or strata any stones.

The ice-face near the beach was not uniform. In many places it was covered with clay to the water's edge. In others, where the bank was less than ten feet high, the turf had bent without breaking after being undermined, and presented a mossy and herbaceous front, curving over quite to high water mark.

The ice in general had a semi-stratified appearance, as if it still retained the horizontal plane in which it originally congealed. The surface was always soiled by dirty water from the earth above. This dirt was, however, merely superficial. The outer inch or two of the ice seemed granular, like compacted hail, and was sometimes whitish. The inside was solid and transparent, or slightly yellow-tinged, like peat water, but never greenish or bluish like glacier ice. But in many places the ice presented the aspect of immense cakes or fragments, irregularly disposed, over which it appeared as if the clay, etc., had been deposited. Small pinnacles of ice ran up into the clay in some places, and, above, holes were seen in the face of the clay-bank, where it looked as if a detached fragment of ice had been and had been melted out, leaving its mould in the clay quite perfect.

In other places the ice was penetrated with deep holes, into which the clay and vegetable matter had been deposited in layers, and which (the ice melting away from around them) appeared as clay and muck cylinders on the ice-face. Large rounded holes or excavations of irregular form had evidently existed on the top of the ice before the clay, etc., had been deposited. These were usually filled with a finer-grained deposit of clay with less vegetable matter, and the layers were waved, as if the deposit had been affected by current action while going on.

In these places was noticed, especially, the most unexpected fact connected with the whole formation, namely, a strong, peculiar smell, as of rotting animal matter, burnt leather and stable manure combined. This odor was not confined to the spots above mentioned, and was not quite the same at all places, but had the same general character wherever it was noticed. A large part of the clay had no particular smell. At the places where the odor was strongest, it was observed to emanate particularly from darker, pasty spots in the clay (though permateing elsewhere), leading to the supposition that these might be remains of the soft parts of the mammoth and other animals, whose bones are daily washed out by the sea from the clay talus.

At or near these spots, where the odor was strongest, a rusty, red lichen, or lichen-like fungus, grew on the wet clay of the talus in extensive patches. Some of these, of the bad smelling deposit, and as many bones of the mammoth, fossil buffalo, etc., as we could carry were secured. These included a mammoth tusk, with both ends gone, but still five and a half feet long and six inches in diameter, which I shall forward to the office. Dwarf birches, alders, seven or eight feet high, with stems three inches in diameter, and a luxuriant growth of herbage, including numerous very toothsome berries, grew with the roots less than a foot from perpetual solid ice.

The formation of the surrounding country shows no high land or rocky hills, from which a glacier might have been derived and then covered with debris from their sides. The continuity of the mossy surface showed that the ice must be quite destitute of motion, and the circumstances appeared to point to one conclusion, that there is here a ridge of solid ice, rising several hundred feet above the sea, and higher than any of the land about it, and older than the mammoth and fossil horse: this ice taking upon itself the functions of a regular stratified rock. The formation, though visited before, has not hitherto been intelligibly described from a geological standpoint. Though many facts may remain to be investigated, and whatever be the conclusions as to its origin and mode of preservation, it certainly remains one of the most wonderful and puzzling geological phenomena in existence.

On the 3d of September we sailed from Chamisso Harbor for Bering Strait, arriving off East Cape of Asia about 6 A. M. of the 5th. Broken ice intervened between us and the shore, and the bight southward from the cape was packed full of ice. We could not approach nearer to the shore than four miles.

The wind was fresh but the opportunity seemed tolerably favorable, and I concluded to attempt making the hydrothermal section across Bering Strait at once, rather than risk the chance of a more favorable opportunity with its possible long delays. We therefore proceeded across the strait at its narrowest part, taking temperatures at short intervals on the surface and soundings with serial five-fathom temperatures every four miles, as nearly as we could determine at the time.

The shallow depth of water facilitated our work very much, as we were able to bring up several gallons of water in the bivalve water-buckets, from any depth, in a few seconds and test it with an unprotected thermometer, giving us much more accurate results than the Casella thermometers are capable of. We found the wind growing more and more severe, and were obliged to reef down during the latter part of the day, but succeeded in getting our last serial sounding, completing the section at a time when we should at any rate have had to cease work, so heavy was the sea produced by the wind against the tide. Finally, we were very glad to run for shelter to Port Clarence, which we reached the following morning quite early.

The diagrams* appended to this report will show the details of the work, and I may say here, that the general conclusion reached from these, with previous and subsequent observations in the strait, was as follows: The water is warmest toward the American side, and cools gradually toward the Asiatic side. The highest temperature is 48° F. and the lowest about 36° F. The uniform succession of the vertical curves, representing degrees of temperature, is somewhat interfered with by an eddy around the Diomede Islets in the middle of the strait, but is otherwise very regular.

* The diagram of hydrothermal section, showing surface temperatures and depth, is the only one that could be engraved in time for this issue.

The uniformity of the temperatures from top to bottom, does away with the idea of a sub-surface current from the Arctic Ocean, carrying cold water southward, a result I had expected, and confirmatory of my suspicions expressed in the Appendix to the Coast Pilot of Alaska, and of Onatzevich's observations on the Kamchatka coast.

Our current observations showed another conclusion to be probable, though a more thorough investigation will be required to place it beyond question, namely, that the northerly current through the strait and along the Arctic Ocean is chiefly dependent on the tide for its force and direction, and on the warming of the shallow waters of Norton Sound and the "Yukon" and vicinity, for its high temperature, which is greater than any of the Bering Sea water south of St. Lawrence Island. This would agree with the observations of explorers along the Siberian coasts and elsewhere, where large bodies of comparatively warm water, derived from large rivers, are poured out over shallow areas of a cold sea basin.

The direction of the current in the strait, when we were lying near the Diomedes, was reversed by the tide, and the vessel tailed in opposite directions during flood and ebb. The rate varied with the strength of the tide, and during our stay did not exceed three knots. The directions agreed with the trend of the land on either side of Cape Prince of Wales (along which the tide runs and would naturally gather its greatest velocity), and as a consequence diagonally across the strait.

Early in the morning of the 10th of September we arrived at the Diomedes, and were most fortunate, notwithstanding a very strong breeze was blowing, to be able to make a lee under the end of the Big Diomede, and a landing on the snow in a small gully, where observations could be taken. Had the wind varied half a point from its direction this could not have been done, and weeks might have passed without an opportunity.

These islands are granite domes, rising abruptly from the water, and their sides rendered perpendicular by the action of the sea. The water is bold to; there are no beaches. The weather has acted on the surface of the top of the islands so as to make a sort of broken table-land, the drainage from which has cut a few gullies in the granite bluffs. By digging into the rubbish and massing it below, the natives have obtained spaces sufficiently level to hold a few huts. There are two villages, one on each island. Fairway Rock, at no great distance, is uninhabited and almost inaccessible. Near our station was one hut—empty—and by climbing up the gully, by steps laboriously excavated in the crumbling granite, the natives were able to go over the top of the island to the village on the other side.

Surface Temperatures
Aug. & Sept. 1880.
By W.H.Dall Asst. U.S.C.& G. Survey
In charge of Schr. Yukon
Statute Miles
East Cape
ASIA
AMERICA
Diomede Islands
BERING STRAIT
Fairway Rock
Cape Prince of Wales
Edge of shore ice
A.B. Line of Hydrothermal Section.
Roman Numerals indicate serial Soundings.
Soundings in Fathoms.
66°
170°
169°
168°

Millions of birds afford a large item of subsistence, and seal, and later in the season some walrus, are taken by these natives, who act as middle-men in trading between Asia and America. A short but satisfactory set, each, of time, latitude, dip, intensity and azimuth was obtained, with angles determining the position of the adjacent island and the prominent features of the mainland on either side.

One of the most important results of the occupation of this station was the determination of the fact that the boundary line, as defined by the treaty, does pass between the two islands without touching either, as was assumed in that document, but which had been put in doubt by certain erroneous charts of the vicinity.

I may say that the decreasing easterly variation which we pointed out in 1873, was extremely marked in the northern stations occupied, some of the results showing five or six degrees less variation than is indicated on the latest charts. A thorough explication of the results must, of course, await the final revision of the computations.

Art. XI.—*Relation of Devonian Insects to later and existing types;* by Samuel H. Scudder.*

It only remains to sum up the results of this reëxamination of the Devonian insects, and especially to discuss their relation to later or now existing types. This may best be done by a separate consideration of the following points:—

1. There is nothing in the structure of these earliest known insects to interfere with a former conclusion† that *the general type of wing structure has remained unaltered from the earliest times.* Three of these six insects (Gerephemera, Homothetus and Xenoneura) have been shown to possess a very peculiar neuration, dissimilar from both Carboniferous and modern types. As will also be shown under the tenth head, the dissimilarity of structure of all the Devonian insects is much greater than would be anticipated; yet all the features of neuration can be brought into perfect harmony with the system laid down by Heer.

2. *These earliest insects were hexapods*, and as far as the record goes preceded in time both arachnids and myriapods. This is shown only by the wings, which in all known insects belong only to hexapods, and in the nature of things prove the earlier

* This summary of results is the conclusion of a memoir by Mr. Scudder on the Devonian Insects of New Brunswick, published in the Anniversary Memoirs of the Boston Society of Natural History, 1880.

† The Early types of Insects. Mem. Bost. Soc. Nat. Hist., iii, 21.

apparition of that group. This, however, is so improbable on any hypothesis, that we must conclude the record to be defective.

3. *They were all lower Heterometabola.* As wings are the only parts preserved, we cannot tell from the remains themselves whether they belong to sucking or to biting insects; for, as was shown in the essay already referred to, this point must be considered undetermined concerning many of the older insects until more complete remains are discovered.

They are all allied or belong to the Neuroptera, using the word in its widest sense. At least two of the genera (Platephemera and Gerephemera) must be considered as having a closer relationship to Pseudoneuroptera than to Neuroptera proper, and as having indeed no special affinity to the true Neuroptera other than is found in Palæodictyoptera. Two others (Lithentomum and Xenoneura), on the contrary, are plainly more nearly related to the true Neuroptera than to the Pseudoneuroptera, and also show no special affinity to true Neuroptera other than is found in Palæodictyoptera. A fifth (Homothetus), which has comparatively little in common with the Palæodictyoptera, is perhaps more nearly related to the true Neuroptera than to the Pseudoneuroptera, although its pseudoneuropterous characters are of a striking nature. Of the sixth (Dyscritus) the remains are far too imperfect to judge clearly, but the choice lies rather with the Pseudoneuroptera or with Homothetus. The Devonian insects are then about equally divided in structural features between Neuroptera proper and Pseudoneuroptera, and none exhibit any special orthopterous, hemipterous or coleopterous characteristics.

4. *Nearly all are synthetic types of a comparatively narrow range.* This has been stated in substance in the preceding paragraph, but may receive additional illustration here. Thus Platephemera may be looked upon as an Ephemerid with an odonate reticulation; Homothetus might be designated as a Sialid with an odonate structure of the main branch of the scapular vein; and under each of the species will be found detailed accounts of any combination of the characters which it possesses.

5. *Nearly all bear marks of affinity to the Carboniferous Palæodictyoptera*, either in the reticulated surface of the wing, its longitudinal neuration, or both. But besides this there are some, such as Gerephemera and Xenoneura, in which the resemblance is marked. Most of the species, however, even including the two mentioned, show palæodictyopterous characters only on what might be called the neuropterous side; and their divergence from the Carboniferous Palæodictyoptera is so great that they can scarcely be placed directly with the mass

of Palæozoic insects, where we find a very common type of wing structure, into which the neuration of Devonian insects only partially fits. For:

6. *On the other hand, they are often of more and not less complicated structure than most Palæodictyoptera.* This is true of the three genera mentioned above with peculiar neuration, but not necessarily of the others, and it is especially true when they are compared with the genus Dictyoneura and its immediate allies. There are other Palæodictyoptera in the Carboniferous period with more complicated neuration than Dictyoneura, but these three Devonian insects apparently surpass them, as well as very nearly all other Carboniferous insects. Futhermore:

7. With the exception of the general statement under the fifth head, *they bear little special relation to Carboniferous forms, having a distinct facies of their own.* This is very striking; it would certainly not be possible to collect six wings in one locality in the Carboniferous rocks, which would not prove, by their affinity with those already known, the Carboniferous age of the deposit. Yet we find in this Devonian locality not a single one of Palæoblattariæ or anything resembling them; and more than half the known insects of the Carboniferous period belong to that type. The next most prevailing Carboniferous type is Dictyoneura and its near allies, with their reticulated wings. Gerephemera only, of all the Devonian insects, shows any real and close affinity with them; and even here the details of the wing structure, as shown above, are very different. The apical half of the wing of Xenoneura (as I have *supposed* it to be formed) also bears a striking resemblance to the dictyoneuran wing; but the base, which is preserved, and where the more important features lie, is totally different. The only other wing which shows particular resemblance to any Carboniferous form (we must omit Dyscritus from this consideration, as being too imperfect to be of any value) is Platephemera, where we find a certain general resemblance to *Ephemerites Rückerti* Gein., and *Acridites priscus* Andr., but this is simply in the form of the wing and the general course of the nervules; when we examine the details of the neuration more closely we find it altogether different, and the reticulation of the wing polygonal and not quadrate as in the Carboniferous types.* In this respect indeed, Platephemera differs not only from all modern Ephemeridæ, but also from those of other geological periods.† Another prevailing Carboniferous type,

* Dr. H. B. Geinitz has kindly reëxamined *Ephemerites Rückerti* at my request, and states that the reticulation is in general tetragonal, but that at the extreme outer margin the cells appear in a few places to be elliptical five- or six-sided.

† The Dictyoneuræ and their allies, as may be inferred, are considered as belonging to the Palæodictyoptera, although their ephemeridan affinities are not disregarded.

the Termitina, is altogether absent from the Devonian. Half a dozen wings, therefore, from rocks known to be either Devonian or Carboniferous, would probably establish their age.

8. *The Devonian insects were of great size, had membranous wings, and were probably aquatic in early life.* The last statement is simply inferred from the fact that all the modern types most nearly allied to them are now aquatic. As to the first, some statements have already been made; their expanse of wing probably varied from 40 to 175 mm. and averaged 107 mm. Xenoneura was much smaller than any of the others, its expanse not exceeding four centimeters, while the probable expanse of all the rest was generally more than a decimeter, only Homothetus falling below this figure. Indeed if Xenoneura be omitted, the average expanse of wing was 121 mm., an expanse which might well be compared to that of the Æschnidæ, the largest, as a group, of living Odonata. There is no trace of coriaceous structure in any of the wings, nor in any are there thickened and approximate nervules—one stage of the approach to a coriaceous texture.

9. *Some of the Devonian insects are plainly precursors of existing forms, while others seem to have left no trace.* The best examples of the former are Platephemera, an aberrant form of an existing family; and Homothetus, which, while totally different in the combination of its characters from anything known among living or fossil insects, is the only Paleozoic insect possessing that peculiar arrangement of veins found at the base of the wings of the Odonata, typified by the arculus, a structure previously known only as early as the Jurassic. Examples of the latter are Gerephemera, which has a multiplicity of simple parallel veins, next the costal margin of the wing, such as no other insect, ancient or modern, is known to possess; and Xenoneura, where the relationship of the internomedian branches to each other and to the rest of the wing is altogether abnormal. If too, the concentric ridges, formerly interpreted by me as possibly representing a stridulating organ, should eventually be proved an actual part of the wing, we should have here a structure which has never since been repeated even in any modified form.

10. *They show a remarkable variety of structure, indicating an abundance of insect life at that epoch.* This is the more noticeable from their belonging to a single type of forms, as stated under the seventh head, where we have seen that their neuration does not accord with the commoner type of wing structure found in Paleozoic insects.* These six wings exhibit a diversity of neuration quite as great as is found among the hundred or more species of the Carboniferous epoch; in some, such as

* Cf. Mem. Bost. Soc. Nat. Hist., iii, 19, note 1.

Platephemera, the structure is very simple; in others, like Homothetus and Xenoneura, it is somewhat complicated; some of the wings, as Platephemera and Gerephemera, are reticulated; the others possess only transverse cross veins more or less distinct and direct. No two wings can be referred to the same family, unless Dyscritus belongs with Homothetus—a point which cannot be determined from the great imperfection of the former. This compels us to admit the strong probability of an abundant insect fauna at that epoch. Although many Paleozoic localities can boast a greater diversity of insect types if we look upon their general structure as developed in after ages, not one in the world has produced wings exhibiting in themselves a wider diversity of neuration; for the neuration of the Palæodictyoptera is not more essentially distinct from that of the Palæoblattariæ or of the ancient Termitina, than that of Platephemera or Gerephemera on the one hand is from that of Homothetus or Xenoneura on the other. Unconsciously, perhaps, we allow our knowledge of existing types and their past history to modify our appreciation of distinctions between ancient forms. For while we can plainly see in the Palæoblattariæ the progenitors of living insects of one order, and in other ancient types the ancestors of living representatives of another order; were we unfamiliar with the divergence of these orders in modern times, we should not think of separating ordinarily their ancestors of the Carboniferous epoch. It may easily be seen, then, how it is possible to find in these Devonian insects—all Neuroptera or neuropterous Palæodictyoptera—a diversity of wing structure greater than is found in the Carboniferous representatives of the modern Neuroptera, Orthoptera and Hemiptera.

11. *The Devonian insects also differ remarkably from all other known types, ancient or modern; and some of them appear to be even more complicated than their nearest living allies.* With the exception of Platephemera, not one of them can be referred to any family of insects previously known, living or fossil; and even Platephemera, as shown above, differs strikingly from all other members of the family in which it is placed, both in general neuration and in reticulation; to a greater degree even than the most abberrant genera of that family do from the normal type. This same genus is also more complicated in wing structure than its modern allies; the reticulation of the wing in certain structurally defined areas is polygonal and tolerably regular, instead of being simply quadrate; while the intercalated veins are all connected at their base, instead of being free. Xenoneura also, as compared with modern Sialina, shows what should perhaps be deemed a higher (or at least a later) type of structure, in the amalgamation of the ex-

ternomedian and scapular veins for a long distance from the base, and in the peculiar structure and lateral attachments of the internomedian veins: in the minuter and feebler cross venation, however, it has an opposite character.

12. *We appear, therefore, to be no nearer the beginning of things in the Devonian epoch, than in the Carboniferous,* so far as either greater unity or simplicity of structure is concerned ; and these earlier forms cannot be used to any better advantage than the Carboniferous types in support of any special theory of the origin of insects. All such theories have required some Zoæa, Leptus, Campodea, or other simple wingless form as the foundation point: and this ancestral form, according to Hæckel at least, must be looked for above the Silurian rocks. Yet we have in the Devonian no traces whatever of such forms, but on the contrary, as far down as the middle of this period, winged insects with rather highly differentiated structure, which, taken together, can be considered lower than the mass of the Upper Carboniferous insects, only by the absence of the very few Hemiptera and Coleoptera which the latter can boast. Remove those few insects from consideration (or simply leave out of mind their future development to very distinct types), and the Middle Devonian insects would not suffer in the comparison with those of the Upper Carboniferous, either in complication or in diversity of structure. Furthermore, they show no sort of approach toward either of the lower wingless forms, hypothetically looked upon as the ancestors of tracheate Articulata.

13. *Finally, while there are some forms which, to some degree, bear out expectations based on the general derivative hypothesis of structural development, there are quite as many which are altogether unexpected, and cannot be explained by that theory, without involving suppositions for which no facts can at present be adduced.* Palephemera and Gerephemera are unquestionably insects of a very low organization related to the existing may-flies, which are well known to be of inferior structure, as compared with other living insects; these may-flies are indeed among the most degraded of the sub-order to which they belong, itself one of the very lowest sub-orders. Dyscritus too may be of similar degradation, although its resemblance to Homothetus leaves it altogether uncertain. But no one of these exhibits any inferiority of structure when compared with its nearest allies in the later Carboniferous rocks, and they are all higher than some which might be named. While of the remaining species it can be confidently asserted that they are higher in structure than most of the Carboniferous types, and exhibit syntheses of character differing from theirs. It is quite as if we were on two distinct lines of descent when we study the Devonian and the Carboniferous insects; they have little in common, and

each its peculiar comprehensive types. Judging from this point of view, it would be impossible to say that the Devonian insects showed either a broader synthesis or a ruder type than the Carboniferous. This of course may be, and in all probability is, because our knowledge of Carboniferous insects is, in comparison, so much more extensive; but, judging simply by the facts at hand, it appears that the Carboniferous insects carry us back both to the more simple and to the more generalized forms. We have nothing in the Devonian so simple as Euephemerites, nothing so comprehensive as Eugereon, nothing at once so simple and comprehensive as Dictyoneura. On the derivative hypothesis, we must presume, from our present knowledge of Devonian insects, that the Palæodictyoptera of the Carboniferous are already, in that epoch, an old and persistent embryonic type (as the living Ephemeridæ may be considered to-day, on a narrower but more lengthened scale); that some other insects of Carboniferous times, together with most of those of the Devonian, descended from a common stock in the Lower Devonian or Silurian period; and that the union of these with the Palæodictyoptera was even further removed from us in time;—carrying back the origin of winged insects to a far remoter antiquity than has ever been ascribed to them; and necessitating a faith in the derivative hypothesis, which a study of the records preserved in the rocks could never alone afford; for no evidence can be adduced in its favor based only on such investigations. The profound voids in our knowledge of the earliest history of insects, to which allusion was made at the close of my paper on the Early Types of Insects, are thus shown to be even greater and more obscure than had been presumed. But I should hesitate to close this summary without expressing the conviction that some such earlier unknown comprehensive types as are indicated above did exist and should be sought.

ART. XII.—*On the Meteoric Iron of Lexington County, South Carolina;* by CHARLES UPHAM SHEPARD, Emeritus Professor of Natural History in Amherst College.

THE mass here described was sent in May last by the farmer on whose land it had been found (through the hands of the Hon. N. A. Meelze) to the State Commissioner of Agriculture, Col. A. P. Butler, for examination, and by the latter it was forwarded to Prof. C. U. Shepard, jr., professor of chemistry in the Medical College at Charleston. It was immediately reported upon as meteoric iron. The finder had supposed it to be a valuable ore, and that it indicated a mine upon his property. On learning its true character he relinquished the idea and was willing to allow Prof. Shepard to become its purchaser.

Its weight as first found was ten and a half pounds. Its figure was oblong or that of a cylinder with two flattened edges and somewhat compressed at the ends; on the whole, approaching most nearly to the shape of a very transverse fresh-water bivalve. Unlike many of the iron masses found in the soil, the surface of the present iron is nearly free from yellow hydrated peroxide of iron, being mostly enveloped with a black and brittle coating, which, though containing some turgite, is yet mostly formed of magnetite. The general surface is smooth, though presenting a few broad but shallow depressions. A series of amygdaloidal masses of troilite, the largest having the size of filberts, traverses the body near the end which has been sliced, and where they were so abundant as to constitute for a considerable space nearly one-third of the aggregate, while elsewhere they scarcely come into view, except in remote isolated amygdules. Where the scaly coating of magnetite is thin or wholly wanting a coarse crystalline structure appears, but without any very continuous lamination. The slicing is not difficult unless the saw encounters troilite or magnetite, the latter of which, associated with traces of graphitoid, envelopes the former and also exists elsewhere in the immediate vicinity of the amygdules, in a coarse net-work of veins. The existence of these seams occasionally aids in the separation of small fragments of the iron, between whose layers it seems to have insinuated itself and acted as a rupturing force. This circumstance seems worthy of notice here, as one of the causes of the disintegration and detonation of meteorites while traversing our atmosphere.

The most interesting feature by far, of the Lexington iron, is that of its remarkable analogy in structure and composition with the Bohumilitz iron, found in 1829, and now preserved in the Bohemian National Museum of Prague, of which a description is given by Dr. Otto Buchner in his catalogue of meteoric collections, page 158,* and still further in the memoir on meteorites, of Prof. Gustave Rose, in the transactions of the Royal Academy of Berlin, 1863.†

The resemblance of the etched surfaces of these irons is so strong that they might very easily be confounded together. They are the only two irons which strikingly give the *moiré*

* Die Meteoriten in Sammlungen, ihre Geschichte, mineralogische und chemische Beschaffenheit, von Dr. Otto Buchner. Leipsic, 1863.

† Beschreibung und Eintheilung der Meteoriten auf grund der Sammlung im mineralogischen Museum zu Berlin, von Gustave Rose, aus den Abhandlungen der Königl. Akadamie der Wissenschaften zu Berlin, 1863, mit vier Kupfertafeln. Berlin, 1864.

métallique luster. The chief difference between the two consists in the thickness of the crystalline bars, which in the Lexington iron is nearly double that in the Bohumilitz. In both, their walls, or bounding sides, are alike broadly undulatory or wavy; and the included spaces are filled with closely crowded points of rhabdite (Rose) and extremely minute lines of tænite (Reichenbach), crossing each other at all angles from 90 to 150°, for the distinct observation of which, however, a lens is requisite. Instead of the usually bright edges of the tænite layers, as they occur within the bars, one sees only bright furrows or channels,—the rhabdite constituting the elevated portions of the surface, evincing its greater passivity under the action of the acid in the process of etching. Indeed, the tænite laminæ, including the bars, have, from the same cause, been similarly depressed below the general surface, though not to such a degree as to conceal their glittering edges. Whether the degree of corrosion in these different constituents of the iron is referable to a difference in their chemical composition, or is simply dependent upon a diversity of crystalline structure, it is impossible to decide. It should here be added that in passivity it far surpasses any iron hitherto discovered. Schreibersite occurs in small quantity along with the graphitoid and magnetite that form enveloping wrappers around the amygdules of troilite; also in short veins and gashes that may be detected here and there on broad polished surfaces of the iron.

The Lexington iron shows no signs of chemical alteration by exposure to the air, in which respect, also, it agrees with that from Bohumilitz.

The specific gravity of the entire mass was 7, that of homogeneous fragments, 7·405. Specific gravity of troilite, 4·77.

The analysis was made by Prof. C. U. Shepard Jr., from cuttings obtained in the division of the iron in such a way as not to include portions of the pyritic nodules. The following result was found:

Iron (with traces of manganese)	92·416
Nickel	6·077
Cobalt	0·927
Insoluble matters	0·264
	99·684

With traces of tin and phosphorus.

New Haven, Nov. 17, 1880.

ART. XIII.—*An attempt to calculate approximately the date of the Glacial era in Eastern North America, from the depth of sediment in one of the bowl-shaped depressions abounding in the Moraines and Kames of New England;* by G. FREDERICK WRIGHT.

[Read at the meeting of the American Association for the Advancement of Science, in Boston, Aug., 1880.]

FOLLOWING the suggestions of Mr. Clarence King, made to the writer four years since,* Mr. Warren Upham traced a terminal moraine of the Continental ice sheet, through Cape Cod from east to west, connecting by the Elizabeth Islands with the back bone of Long Island at Montauk Point, and continuing to Brooklyn, N. Y. From this point across Staten Island and through New Jersey to Belvidere, Professors Cook and Smock have explored it.†

Professor Geo. H. Stone, Mr. Upham and myself have explored and extensively mapped the "Kames" or "Eskers" of New England, which prove to be accumulations of gravel marking the course of the streams which, toward the close of the Glacial period, poured southward toward the sea, independent in large degree of the present water-courses.‡ A striking feature of both the terminal moraine and the kames is the numerous bowl-shaped depressions occurring in them, which Dr. Edward Hitchcock § described as "mere holes, not unfrequently occupied by water," but which could not have been formed by running water. In Wisconsin these are called kettle holes, from their resemblance to a potash kettle, and were first described and correctly explained by Col. Charles Whittlesey of Cleveland, O.‖ Professors N. H. Winchell and Chamberlin have since been industriously marking their extent as they occur in the so-called Kettle Range in Wisconsin. The most satisfactory explanation of these "holes," in my view, is that they mark places where masses of ice were buried in the debris of sand and gravel brought down by the streams of the decaying glacier, and where, upon the melting of the buried ice, a cone-shaped depression would appear with sides as steeply inclined as the nature of the soil would permit. At any rate there can

* See Proceedings of the Boston Society of Natural History, vol. xix, pp. 60–63.

† See Annual Reports of the Geological Survey of New Jersey for 1877 and 1878.

‡ For the observations upon which these statements are based, see Index of Geol. Report of N. H., vol. iii, under "Kames," communications of the author in Proceedings of Bost. Soc. Nat. Hist., vol. xix, pp. 47–63, and xx, pp. 210–220, also a paper read by Professor Stone at the American Association for the Advancement of Science in 1880.

§ See Transactions of Am. Assoc. of Geol. and Nat. for 1841 and 1842, p. 191.

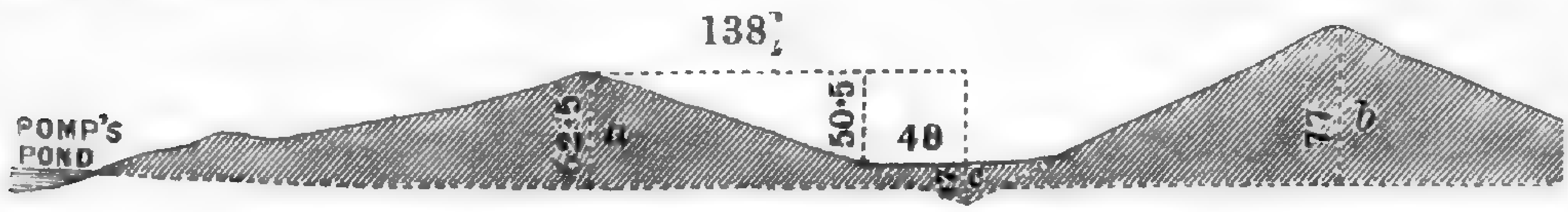
‖ See the Smithsonian Contributions to Knowledge for 1866.

be no question that they were formed about the close of the Glacial period.

It occurred to the writer, some years ago, that these holes might be made to do service in estimating the date of the Glacial era. The results are not so definite as could be wished and from the nature of the case perhaps investigations in this line can never be wholly satisfactory. Still, where every attempt at chronological accuracy has been unsatisfactory, this may not appear wholly useless.

The depressions of which we speak are of all shapes and sizes, from symmetrical "kettle holes" to ponds and lakes of no mean dimensions. It is evident that they cannot always exist, for they are wearing down at the top and filling up at the bottom. For the same reason we know they cannot always have been in existence. As typical of numberless others which appear in the kames I present facts concerning one near Pomp's Pond in Andover, Mass.

Pomp's Pond is one of the moraine basins to which we have referred, and is about a quarter of a mile in diameter and but slightly above the level of the Shawshin River into which it empties. Upon its north side is an accumulation of gravel and sand with pebbles intermingled, in which there are several of the smaller characteristic bowl-shaped depressions of which we have spoken. Their appearance is much like that of volcanic craters. You ascend a sharp declivity from every side to a rim of gravel and then descend as rapidly into the bowl-shaped, or crater-like, depression. A section carried across will present the idea.



Section of "Kettle Hole."

From the level of the pond, and two or three rods from the edge, you begin to ascend at an average rate of about one foot in three till the south side of the rim is reached at a height of $52\frac{3}{10}$ feet above the pond. (This rim is not, however, of a uniform height. On the east side it rises into a pyramid $77\frac{7}{10}$ feet high). Then descending $50\frac{5}{10}$ feet vertically you are carried 138 feet horizontally, reaching at that point the edge of a circular mass of peat which is 96 feet in diameter. From the opposite side, the ascent of the northern rim begins and you descend from its top to the valley, repeating almost exactly the first ascent and descent from the pond. The distance from rim to rim, or the diameter, is 380 feet.

Thus it is evident that since the first formation of this crater-like depression no material can have reached the bottom except from three sources: 1st, the wash from the sides; 2d, the decay of vegetation which grew within the circumference of the rim; 3d, the dust brought by the winds. It is equally evident that what is once in cannot get out.

Now, from the angle of the declivity the original depth of the depression can be approximately estimated. If the angle be still the same as at first, the first three terms of the proportion would be 138 : 50·5 : : 48 : 17·5, making the original depth below the present surface of the peat a trifle over 17 5 feet. If, however, we suppose the original slant to have been steeper and the rim higher we can still see that there must have been a limit to the depth. Suppose the rim to have been one-third higher and the slant one-third steeper we then would have in round numbers the proportion 138 : 68 : : 48 : $23\frac{15}{23}$, making the original depth of the depression nearly 24 feet below the present surface of the peat. From the nature of the material it is impossible that the depression should originally have much exceeded that amount.

Accepting this conclusion, the problem is to determine the time it would require the agencies mentioned above to fill the bottom of this bowl to a depth of twenty-four feet—a cone ninety-six feet in diameter at the base and twenty-four feet to the apex—which would be equal to a depth of only *eight* feet over the present surface.

Let us apply some of the estimates of the date of this period. Mr. J. Geikie, following the lead of Mr. Croll and others who look to astronomical data alone, supposes that the so-called Glacial period, whose marks we now study in these low latitudes, synchronized with the last period of high eccentricity of the earth's orbit, which closed about 80,000 years ago and whose maximum influence must have been exerted about 200,000 or 210,000 years since. But, once in 21,000 years, the astronomical conditions dependent upon the precession of the equinoxes favorable for a glaciation of the northern latitudes, occur, though owing to the present low eccentricity of the earth's orbit this influence is now at its minimum.

The question arising in connection with the crater-like depressions I have described is: Could this have stood with so little change for 80,000 years? or even for 40,000 years, as C. H. Hitchcock supposes.* Is not the supposition of 10,000 sufficiently extravagant? If the close of the great glacial period be so far back as Mr. Croll and Mr. Geikie estimate, we must believe that detritus would accumulate, in the situation above described, over a surface of the area of the present peat bog only at the rate of one inch in 1,000 years. While, if we put the close of this period back 10,000, the rate of accumula-

* See Geology of New Hampshire, vol. iii, p. 327.

tion would seem to be as slow as our imagination can well comprehend, viz: one inch in 100 years. The slowest rate which Boucher de Perthes calculated for the accumulation of peat over Roman pottery in the valley of the Somme was three centimeters, or a little over an inch, in a century.

These considerations have led me to look with increasing distrust upon the astronomical calculations which are made concerning the Glacial period, unless we may suppose that the moraines of which we have spoken mark the limit reached at the last semi-revolution of the earth's equinoxes about 10,000 years ago. If we are to look for marks of glaciation in the earlier and more extreme period of the eccentricity of the earth's orbit we should go farther south. The glacial detritus in California, where Prof. Whitney has found human remains, may belong to that earlier period. But it is evident that the glacial phenomena of New England are comparatively recent in their origin.

ART. XIV.—*A Remarkable Nugget of Platinum;* by PETER COLLIER, of Washington, D. C.

SEVERAL years ago I came into possession of a nugget of platinum, said to have been found upon land adjacent to the village of Plattsburgh, New York. Upon examination, the nugget was found to be composed entirely of native platinum and chromite disseminated through it. This chromite was black and of a somewhat resinous luster. The dimensions of the nugget were: length 4 cm., width 3 cm., thickness $2\frac{1}{4}$ cm. Its weight was 104·4 grams. The specific gravity of the entire nugget was 10·446, and an average of three determinations with a pycnometer of small fragments of the native platinum gave 17·35 as their specific gravity.

This indicates the composition of the nugget by weight to be about as follows: chromite 54 per cent, native platinum 46 per cent. The nugget was found to be slightly attracted by the magnet, a fragment weighing ·09 gram being raised by the magnet. The metallic portion, separated as completely as possible from adhering chromite, was dissolved in aqua regia, leaving a slight residue, which was mainly chromite and sand, of only ·74 per cent. The chromite was decomposed by fusion with bisulphate of potassium. Its composition is given as follows:

Cr_2O_3	54·944
FeO	31·567
Al_2O_3	5·690
SiO_2	3·731
CaO	3·405
MgO	·941
	100·278

There appeared in the interstices of the mass a little earth which probably accounts for the above results of analysis. By deducting these impurities the above analysis would be:

Cr_2O_3	63·511
FeO	36·489
	100·000

An analysis of the platinum gave as follows:

Platinum	82·814
Iron	11·040
Palladium	3·105
Iridium	·627
Rhodium	·286
Copper	·397
Alumina	1·953
Lime	·069
Magnesia	·030
	100·321

Owing to the small quantity of the mineral taken for analysis, 1·45 grams, and the difficulty in separation, the above analysis is perhaps not rigidly exact, and in fact the presence of osmium was unmistakable, although its amount was undetermined. The above analysis, however, shows conclusively that the specimen is a genuine nugget of native platinum; and upon an investigation of the person who found the same, it seems established beyond question that his statement is correct, since the mode of its occurrence and the locality is such as to render the statement quite credible.

Several other specimens were said to have been found at the time when this was discovered, but owing to their real value being unknown they were mislaid or lost. A personal examination of the locality shows it to be in a drift deposit which is of considerable extent. Adjacent rocks exposed upon the surface show well-defined glacial scratches, and the bowlders constituting this deposit are mainly from rock not present in place in that immediate locality. The occurrence of the platinum metals in the St. Lawrence valley has long been known, and the presence of extensive deposits of chromite and its mineral-associate, serpentine, in the same general locality is well established, but so far as I can learn this nugget appears to be remarkable not only for its size, but also as an indication of the probable presence of this metal in a locality hitherto unsuspected.

ART. XV.—*Notice of a new Genus and Species of Air-breathing Mollusk from the Coal-measures of Ohio, and Observations on* DAWSONELLA; by R. P. WHITFIELD.

IN the excellent and interesting article entitled "Revision of the Land Snails of the Paleozoic era, with descriptions of new species," by J. W. Dawson, in the November number of this Journal, the author gives a summary of the knowledge possessed up to that time of the shells of this group of mollusks occurring in these formations. The recognition and description of what is supposed to be a similar form from the Devonian formations of New Brunswick adds a feature of great interest to the knowledge already possessed.

At the time the above mentioned article appeared, I was at work on a new form, the representative of a new genus of the Pupidæ, from the Coal-measures of Ohio, in connection with the preparation of material for the next volume of the Paleontology of that State, and had commenced an examination of the other species, for which purpose I wrote to Professor Dawson to obtain specimens of *P. vetusta;* when he called my attention to the article above mentioned, where I found the work already so admirably done for me.

The form from Ohio is so entirely distinct from any and all of those previously described, although, like them, of minute size, that I have concluded to call immediate attention to it.

The general form of the shell is similar to that of the group of the Pupidæ usually referred to the genus *Vertigo;* minute shells with a nearly vertical aperture, armed with several projecting tooth-like points within its cavity. The shell in question presents these same features with the additional character of a small, nearly circular notch in the peristome, near the upper end of the outer lip, very closely resembling the minute pore-like notch occurring near the upper angle of the aperture in the genus *Pupina* Vignard; or that seen in *Anaulus* Pfeiffer. This latter feature is not present, so far as I am aware, in any genus of inoperculated pulmoniferous shells; at least not in the same degree nor with the same apparent purpose that it occurs in the operculated genera above mentioned. Moreover the last whorl is contracted or flattened on the back in a very similar manner to that of Pupina. It would therefore almost seem that in this little shell of this early age is foreshadowed features of both of these great groups of a later time. The projecting teeth within the aperture as hereafter described would preclude the possibility of an operculum. Taking into consideration these anomalous features I have considered it entitled to rank as the type of a distinct genus, and propose the name *Anthracopupa*, with the following characters.

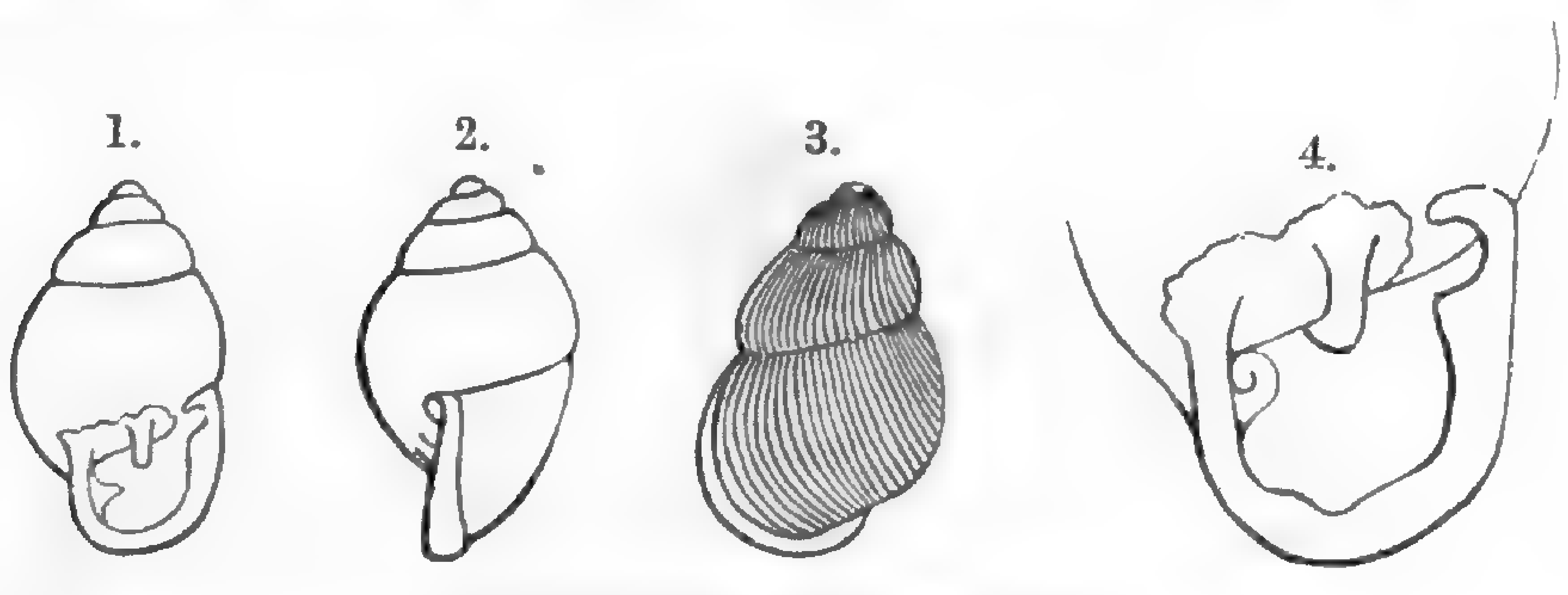
ANTHRACOPUPA, new genus.

Shell minute, pupaform, with few volutions, the last one unsymmetrical; axis imperforate; aperture large, nearly vertical; peristome thickened, united above by a thin callus on which may occur one or more palatal teeth; other tooth-like projections occur on the inner margin of the lip, and a small, nearly circular notch, resembling that in *Pupina*, deeply indents the inner edge of the outer limb near its junction with the body whorl. Surface of the shell marked by fine, nearly vertical lines. Type *A. Ohioensis.*

ANTHRACOPUPA OHIOENSIS, n. sp.

Shell small and robust, having a length of about three and one-third mm. with a transverse diameter of about two mm. and consisting of about four volutions, the last one extremely ventricose except on the outer half, where it is obliquely flattened and contracted, and, with the aperture, forms about three-fourths of the entire length of the shell. Aperture large, longer than wide, and broadly rounded at the base; lip

1. 2. 3. 4.



Anthracopupa Ohioensis Whitf.

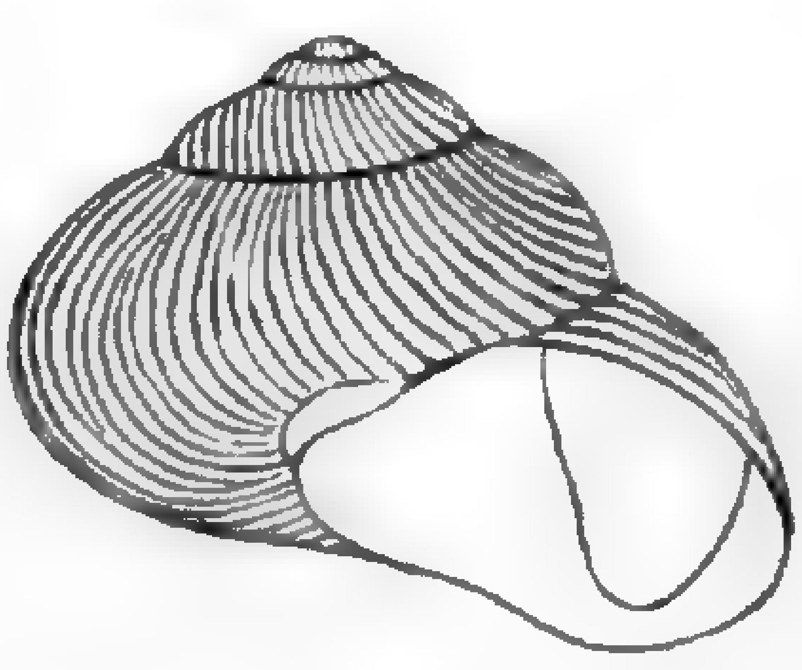
Fig. 1, view of the aperture; 2, lateral view to show the thickened lip; 3, back view, showing lip and striæ; 4, aperture more enlarged. Figs. 1–3 enlarged six times.

thickened, rounded within and forming a flattened, thickened rim on the outside, particularly on the lower part. Labial notch situated very near the upper extremity of the lip, regular in shape, and forming nearly two-thirds of a circle. A single tooth-like ridge of moderate size extends inward from the lip at about the middle of the columellar side, and another of greater size projects nearly vertically from the middle of the callus which coats the body of the volution within the aperture. Umbilical chink small. Surface of the shell marked by fine, nearly vertical, even striæ or lines. Apex apparently mamillated.

Formation and locality.—In the higher beds of the Coal-measures, near Marietta, Ohio.

In making the studies of the afore-mentioned shell, I obtained from John Collette, Esq., State Geologist of Indiana, specimens of *Pupa Vermilionensis* and *Dawsonella Meeki* Bradley. I find that the latter shell has the aperture much contracted by the thickening of the lip on the inside, and against the body volution by a thickened callus coating the volution and almost concealing the umbilicus, while it straightens that margin of the aperture. These features contract the aperture to a very small part of what it must have been before the callosity was formed, while the surface of the callus is slightly concave from side to side, over the distance between the umbilicus and the margin of the aperture. The form of this callus, especially when taken in connection with the thickening of the inside of the lip, has so much resemblance to the corresponding parts of Helicina, that I cannot but come to the conclusion that Dawsonella was an operculated shell, although in the rock in which they are found I have sought in vain for anything resembling an operculum. In the article quoted above, the author shows the extent of this callus in his figure 13 on page 412, and it is well shown in the accompanying outlines.

5.



6.

Dawsonella Meeki Bradley.

Figs. 5 and 6, profile and basal view of *Dawsonella Meeki* Brad., to show the form of aperture and callus resembling that of Helicina.

Pupa vetusta and *Pupa Vermilionensis* are both accompanied in the material in which they are found, by small helicoid shells, which have been described under the generic name *Dawsonella.* The present species is not known to have any such associate; but on the other hand, like the first specimen of *P. vetusta* found, is accompanied in one of the layers in which it occurs, by immense numbers of what appears to be a species of Spirorbis, which is so abundant that a small hand specimen from which two of the *Anthracopupas* were taken, seems to be nearly half composed of it. The form of these Annelid shells is that common in most species of the genus. They have a diameter of nearly one line, and although now packed together in the shale promiscuously, one surface is generally more or less flattened as if through attachment to some foreign body ; and they have, I presume, been attached to marine plants from which they have fallen, as they were decomposed, and have thus been amassed on the muddy bottom. This species I propose to designate by the following name; and illustrations of it will be given in the Paleontology of Ohio, vol. iii.

SPIRORBIS ANTHRACOSIA, n. sp.

Shell minute, planorbiform, composed of from one to two and a half volutions, tube slender, and very gradually increasing in diameter, marked by very fine, irregular, encircling striæ, which are often gathered into little knots or points near the border of the open umbilicus. Lower side of the shell more or less flattened as if for attachment to some foreign substance. Diameter seldom exceeding one line, generally less.

Formation and locality.—In the higher strata of the Coal-measures, near Marietta, Ohio; associated with *Anthracopupa Ohioensis.*

ART. XVI.—*Hiddenite, an Emerald-green variety of Spodumene;* by J. LAWRENCE SMITH, of Louisville, Ky.

THE new variety of spodumene described in this paper was discovered about five years since on the farm of Mr. Warren, in Alexander County, North Carolina, one of the western counties of the State, which counties have furnished within a few years so many interesting minerals, including the samarskite. Shortly after its discovery some crystals came into the hands of Mr. Stephenson of Statesville, the best of which he sent to Mr. N. Spang of Pittsburgh. Subsequently he showed others of them to Mr. W. E. Hidden, a very enterprising collector of the minerals of this region, and from him I obtained all the specimens examined, as well as my information in regard to their mode of occurrence. The crystals were first found very sparingly, and loose in the soil, but Mr. Hidden, having leased the locality and carried on a systematic exploration, has discovered the mineral *in situ*, and obtained many fine crystals.

Up to the time when my attention was called to the mineral it was considered *diopside*, a reasonable conclusion considering the imperfect character of the crystals that had been found. A blowpipe test, and a determination of its specific gravity showed me that it was not diopside, but an unusual variety of spodumene.

Mode of occurrence.—In the absence of any drift formation in this region it is evident that all the minerals found here detached and loose in the soil—as most of them are—were furnished by the rocks beneath. The soil has been formed by the decomposition of these rocks, and surface washings have caused only small displacement of the mineral from its original locality. The rocks are metamorphic and are mostly gneiss and mica schist.

The vein bearing the spodumene crystals runs almost due east-and-west across the bedding, and dips at an angle of 70°. It is only a few inches wide and two feet in lateral extension, being in fact a kind of chimney. There are other similar veins in the vicinity, but it is only in this one that the crystals have yet been found. The walls of this contracted vein contain crystals of quartz, mica, rutile, beryl and orthoclase. The beryls are very fine, and may yet be found sufficiently colored to be valuable as gems. The vein does not come to the surface but commences about eight feet below it, as a narrow seam of hard kaolin, and in this kaolin lies the spodumene; the vein so far as yet explored having undergone alteration. One end of the crystals is almost invariably broken; but they are sometimes imbedded in quartz crystals and are perfect in form; others occur attached to the sides of the quartz. The vein has been worked to a depth of twenty-three feet, without any material change in its character.

Color.—The mineral, which is always transparent, ranges in color from colorless (very rare) to a deep emerald green; sometimes the entire fragment has a uniform green color, but generally it is more intense at one of the extremities.

Crystallization.—The crystals are very frequently twins, rarely *fourlings*. They are often terminated at one extremity, but the planes are dull and curved, so that good measurements cannot be made. Sometimes single crystals are terminated by the planes $2\text{-}\grave{\imath}$ only, but the planes $\dot{2}$, $2\text{-}\grave{\imath}$ and $O^{\cdot}$ are common. The prisms $i\text{-}i$, I and $i\text{-}\bar{2}$ are common and deeply striated. The crystal which is supposed to be a fourling has two sharp projecting edges in the termination, crossing each other. The largest crystal yet found is $2\frac{1}{4}$ inches in length but very thin; the average size is about half an inch long by three-sixteenths thick.

Professor E. S. Dana has kindly furnished me with additional observations, made on some imperfect crystals, which I add here. "The crystals occur in slender prismatic forms, showing in the prismatic zone the two pinacoid planes, also $i\text{-}\frac{3}{2}$, I, $i\text{-}2^{\grave{}}$, $i\text{-}3^{\grave{}}$; in this zone the crystals are deeply striated, and are flattened in the direction of the inclined lateral axis. The terminal planes are uniformly rough and uneven, so much so that no satisfactory determination of their symbols can be made; they often form an edge, as the continuation of the front prismatic edge and this is rounded over the whole top of the crystal. Some of the crystals are twins with the orthopinacoid as the composition-face. An interesting feature of the crystals is the occurrence of *depressions* in the prismatic planes *I*, both the natural planes and those due to cleavage. These figures are shaped something like a sharp wedge; they are inclined at a small angle to the front prismatic edge and in an inverted position to that behind. In the twin crystals, however, they point upward both in the front and behind, in consequence of the inverted position of the other half of the crystal. Great numbers of these figures are sometimes seen, occasionally very minute and much crowded together. The prismatic cleavage is remarkably perfect, yielding surfaces of the highest luster."

The hardness across the crystal is equal to that of the emerald and on the prismatic faces from 6·5 to 7. The specific gravity, as taken from various good specimens, varies from 3·152 to 3·189.

Its behavior before the blowpipe is the same as that of other forms of spodumene. When heated to redness in the flame but not fused, it loses its color, but on cooling regains it—a reaction analogous to that afforded by the emerald. I have as yet in vain sought for the cause of the color. I have employed all the necessary care in examining for chromium, but have found no indication of its presence. In an examination made for vanadium, the result of an experiment with two grams of green material was lost. This behavior in the flame—losing its color, and recovering it again on cooling—belongs as well to chromium as to vanadium.

Composition.—A careful analysis yielded me the following results:

Silica	64·35
Alumina	28·10
Ferric oxide	0·25
Lithia	7·05
Soda	0·50
Loss by heat	0·15
	100·40

The specimen analyzed was of the paler variety. There is a trace of potash in the soda.

The crystals when cut and polished resemble the emerald in luster, though the color is not so intense as in the finest variety of the latter gem. There is reason to hope that further explorations may bring to light crystals of a size and beauty that will make them valuable as gems, and for this reason I have thought it proper to give this variety of spodumene a distinct name. I therefore propose the name of *Hiddenite*, after the indefatigable mineral explorer who has directed our attention to it.

ART. XVII.—*Remarks on the Genus Obolella;* by S. W. FORD.

THE genus *Obolella* was founded by Mr. Billings, in 1861, upon three small Linguloid species, namely *O. chromatica* from the north shore of the Straits of Belle Isle, *O. crassa* from Troy, N. Y., and *O. polita* from the Potsdam sandstone of Wisconsin, —*O. chromatica* being selected as the type. Although at that time the structure of these shells was very imperfectly known, enough had yet been seen, as Mr. Billings informs us, to convince him that the genus was a new one; but it was not until ten years afterward (Canadian Naturalist, December, 1871), that the number of muscular impressions characterizing it was correctly given. In a subsequent paper,* Mr. Billings contributed still further to our knowledge of the genus by his account of the structure of *O. chromatica*, and I hope, in the present article, to offer some additional facts bearing in the same direction, derived mainly from the study of another species, the *O. crassa.* The principal facts with regard to the structure of this species may be stated as follows:

The shell of *Obolella crassa* is suborbicular, with the beak of either valve extending slightly beyond the peripheral contour.

Obolella crassa Hall, sp.

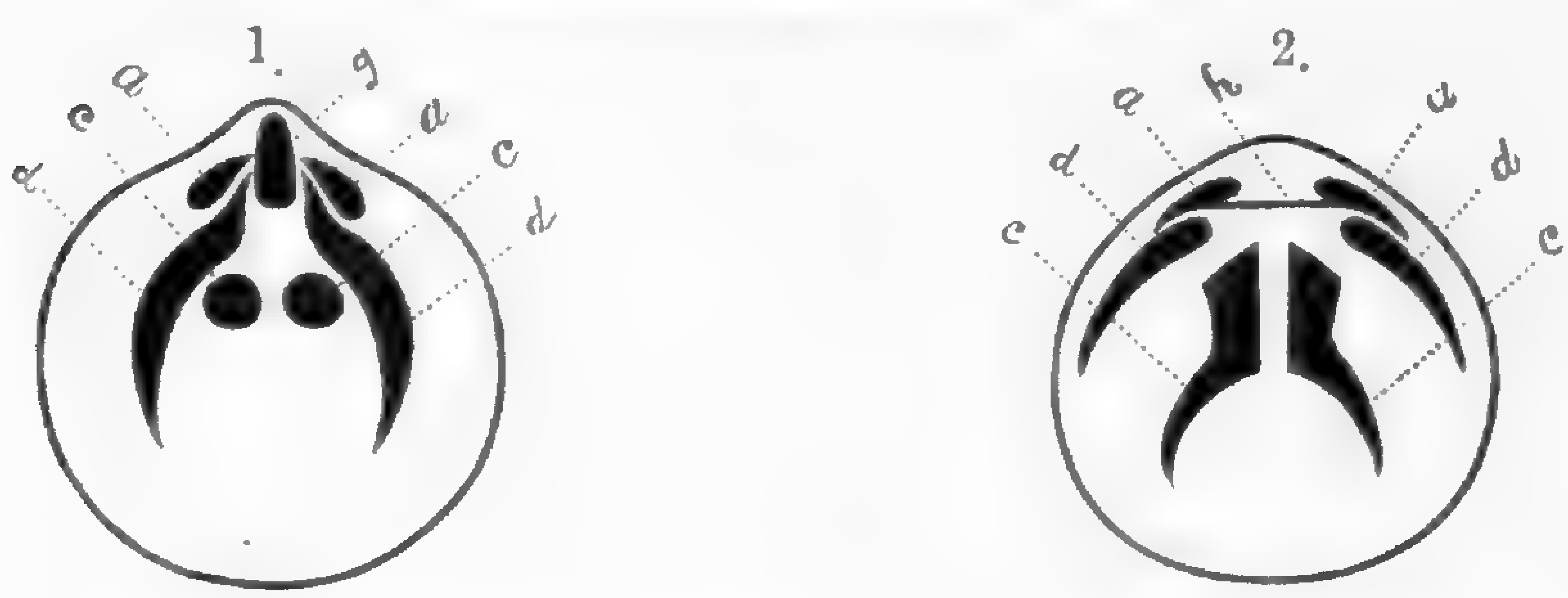


Fig. 1.—Diagram of the interior of the ventral valve of *O. crassa*, enlarged two diameters. Fig. 2.—Diagram of the interior of the dorsal valve, enlarged to the same degree. The specimens are from the original locality of the species, Troy, N. Y.

As a rule, the beak of the dorsal valve is curved downward so as to almost touch the short, indistinct hinge-line, while that of the ventral valve is less depressed and slightly more projecting; and these are the only features by which the two valves may be externally distinguished. The majority of the specimens of the ventral valve have an extremely shallow depression running from the beak to the anterior margin along the median line; but I have found that even this is not distinctive, inasmuch as some of the dorsal valves exhibit it. The specimens

* This Journal for March, 1876.

in my possession vary in length and breadth from one and one-half to six lines, the two diameters being generally nearly equal. The surface of both valves, when perfect, is both radiately and concentrically striated. The shell is thick and solid, showing no tendency to break up into successive laminæ on weathering. I have had portions of it ground and polished for microscopic examination, but am unable to make out any definite structure.

In the interior of the ventral valve, there are two small, ovate muscular scars, situated close to the beak, one on either side of the pedicle groove *g;* and immediately in advance of these a pair of large, elongate, curved scars, which sometimes extend forward into the anterior fourth of shell. Between these latter, and somewhat above the mid-length of the valve, there are two small subcircular impressions. All of these scars are, in well preserved specimens, deeply impressed, and, taken together, constitute a conspicuous and beautiful system. There is usually a distinct ridge running along the middle of the large lateral impressions, dividing them at bottom into two portions; and in some cases its wider, upper portion, is minutely pustulose. The rostral portion of the valve is often much thickened, the several scars bounding the elevation. The interior surface of the forward portion of the valve is marked by fine radiating striæ.

The dorsal valve possesses a small though distinct area, which is divided into two equal portions by a feeble longitudinal ridge. The slender cardinal line is delicately notched in the middle, and has immediately in advance of it a deep transverse groove (fig. 2, *h*). On either side of the longitudinal ridge referred to, there is a small, ovate, cardinal muscular scar. These scars have their apices directed downward and outward, their upper portions cutting across the extremities of and limiting the cardinal line. Directly in front of the cardinals there are two larger impressions of similar shape and direction, the laterals, which extend forward to the mid-length of the shell. These two pairs of impressions are frequently connected with each other, by the cardinals passing down into the laterals; but, as will be seen, they are not so connected in the specimen figured, which has been selected in order to illustrate more clearly their essential independence. In the central portion of the valve there is a pair of still larger impressions (*c c*), having their upper portions parallel, and their lower, falcate parts, widely diverging. Between their parallel portions there is a low mesial ridge, which dies out before reaching the hinge-line. The falciform portions of these scars are, in general, very faintly impressed, and might readily escape observation. The interior surface is usually smooth.

If we compare the interior of *O. crassa* with that of *O. chromatica*, illustrations of which are herewith introduced (figs. 3 and 4), we shall find that, while there are some notable differences, the plan in each is the same. The principal differences

3. 4. 5.

Fig. 3.—Plan of the interior of the ventral valve of *O. chromatica* as made out by Mr. Billings; Fig. 4.—Ditto of the dorsal. Fig. 5.—Plan of the interior of the ventral valve of *O. gemma* Billings. The notation is the same for all of the figures: *aa*, cardinal, *cc*, central and *dd*, lateral impressions; *g*, the groove in the area; *i*, pit in which the groove terminates.

are (1) that the cardinals of the ventral valve of *O. crassa* have their apices directed inward instead of outward as in *O. chromatica*; (2) that the central scars are not here connected with the laterals; and (3) that the central impressions of the dorsal valve of this species have, as compared with the corresponding impressions of the dorsal valve of *O. chromatica*, an extraordinary development. The upper portions of these scars are, in general, all that can be readily discerned; and, were it not for the fact that the central pair in fig. 4 are situated so far forward, I should be disposed to consider them but parts of larger impressions. But notwithstanding this objection, it is possible that better preserved specimens will show them to have possessed divaricating forward extensions. In fig. 5, we have a form departing still more widely from the type, but the plan of structure, as shown by Mr. Billings, is fundamentally the same.

In his paper on the structure of *Obolella chromatica* already referred to, Mr. Billings includes in his genus, *O. chromatica*, *O. crassa*, *O. polita*, *O. gemma* and *O. nana*; at the same time remarking that, although a number of other species have been referred to it, they are all more or less doubtful. The structural details of *O. polita* and *O. nana* have not yet been worked out as completely as could be desired, but it is evident that we have here a natural group, and one remarkable for its clearness of definition. It is, further, tolerably evident that such forms as *O. desiderata* Billings, from the Quebec group of Canada, and *O. sagittalis* Salter, from the Menevian group of Wales do not belong to it; neither of them possessing, so far as known, the characteristic muscular markings of *Obolella*, and *O. sagittalis* lacking, in addition (as shown by the figures of both Mr. Davidson* and G. Linnarsson†), not only an area but a pedicle groove. These differences, to my mind, render it highly probable that *O. sagittalis* will yet be found to constitute a new genus; and if the ventral valve should ultimately prove to possess an area, then the small Brachiopod described by Barrande and Verneuil from the Spanish Primordial‡ may possibly represent it. Unlike *Obolella*, the apex of the ventral valve in both of these species, is occasionally minutely perforated. The interior of the Spanish species is unknown, but its external aspect, apart from the perforation mentioned, is closely like that of an *Obolella*.

At present the genus *Obolella* appears to be restricted to the American Primordial, and to that portion of it which is regarded as higher in position than the *Paradoxides* beds. This horizon presents, under its life aspects, a number of features of unusual interest, some of which I purpose, hereafter, to make the subject of critical review.

I have presented the foregoing observations at this time, partly for the purpose of directing the attention of paleontological workers still more strongly to the interesting genus under notice; and partly in the hope that they may possibly contribute something looking toward a better understanding of the foreign species spoken of, both of which occur low down in the Primordial Zone.

December 10th, 1880.

ART. XVIII.—*The Millstone Grit in England and Pennsylvania*; by H. MARTYN CHANCE.

A LATELY published report on the "Geology of the Yorkshire Coalfield," by Professor A. H. Green and his associates, contains a description of the Millstone Grit which is of more than passing interest to those familiar with this formation in Pennsylvania and Ohio.

A survey of the Conglomerate, No. XII (Millstone grit), made in 1875 along the Beaver and Shenango valleys, led me to conclude that that rock in Western Pennsylvania is a composite series of sandstones and conglomerates separated by shales and slates with interbedded coals, limestones, iron ores and fire clays, with a total thickness of 250–325 feet (Report V,

* Monograph of British Silurian Brachiopoda, p. 339, pl. 50, figs. 1–14, (1871).

† On the Brachiopoda of the Paradoxides beds of Sweden, p. 19, pl. iii, figs. 36–41, (1876). Idem, "Om Faunan i kalken med Conocoryphe Exsulans," p. 27, pl. iii, figs. 45–49, (1879).

‡ Bull. Soc. Geol. Fr., vol. xviii, p. 536, pl. VIII, figs. 5*a*–*e*.

Geol. Survey of Pa., 1879). The same conclusion was simultaneously reached by Mr. Carll in the oil regions (Reports I and III) and afterwards by Professor White in his reports on the Ohio line counties (Q, QQ, QQQ); and it now appears that Professor Green and his colleagues were at the same time working out a strikingly similar structure in this rock in the Yorkshire district. The nomenclature first adopted by these geologists is compared in the following table with that adopted by Professor White and myself:

Yorkshire.	Pennsylvania.
"Rough Rock."	Homewood Sandstone.
Shales (sporadic coals).	Mercer coal group.
"Second Grit."	Connoquenessing Upper Sandstone.
Shales (coal).	Quakertown coal.
"Third Grit."	Connoquenessing Lower Sandstone.
Shales (coal).	Sharon coal.
"Kinder Scout Grit."	Sharon (or "Ohio") Conglomerate.

Over large areas this nomenclature is easily and naturally applicable to all vertical sections in both Yorkshire and Western Pennsylvania, but at some localities the English "Second" and "Third" grits and the Connoquenessing sandstones are represented by one or by several (four or five) rocks, and it was therefore found necessary to generalize the Yorkshire scheme by including these in one subdivision under the name "Middle Grits," thus: (Geol. of Yorkshire, p. 32).

Millstone Grit
- "Rough Rock or Topmost Grit.
- Shales.
- Middle Grits.—A group of sandstones and shales, variable in number, thickness and character.
- Shales.
- Kinder Scout or Lowest Grits."

In Western Pennsylvania a precisely similar generalization has been resorted to (Report V, pp. 188 and 223), thus:

Conglomerate, No. XII
- Homewood Sandstone.
- Mercer Group,—coals, etc.
- Connoquenessing Group,—sandstones.
- Sharon Group.
- "Ohio" or Sharon Conglomerate.

The Homewood Sandstone is a hard, massive conglomeritic rock; the Rough Rock is also of this type and is used as a key-rock just as the former has been used in Pennsylvania. The Kinder Scout Grit is hard, massive, coarse and often conglomeritic, and is also used as a key-rock; while in Pennsylvania the Sharon Conglomerate (or Olean, Garland or Meadville rock) has likewise been a most valuable guide. It is usually hard and massive and often a true conglomerate. When capping the hilltops it forms prominent "rock cities."

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On an Improved Process for preparing Potassium Iodide from Seaweed.*—Allary and Pellieux have devised an improved process for extracting potassium iodide from the ashes of seaweed. The mother liquors, obtained in the preparation of potassium chloride and sulphate from these ashes, are evaporated to dryness in a special air furnace and then carefully roasted in a current of air, to complete desulphurization. The residue is extracted with cold water and the solution is again evaporated to dryness. A white saline residue is obtained containing 50 per cent of iodides. This is pulverized, introduced into a digestor and treated with hot alcohol whereby the iodides are extracted and accumulate in the aqueous lower layers. The alcohol is then distilled off and the solution obtained contains a mixture of two-thirds sodium and one-third potassium iodide. To this is added the necessary quantity of potassium carbonate, in saturated solution, and a current of carbon dioxide gas is passed through the whole. Hydro-sodium carbonate crystallizes out and potassium iodide remains in solution. After exact neutralization of the small remaining quantity of the carbonate by hydrochloric acid, the potassium iodide is crystallized out. For special purposes, it is extracted by alcohol and recrystallized.—*Bull. Soc. Ch.*, II, xxxiv, 627, Dec., 1880. G. F. B.

2. *On the Volumes of certain Elements at their Boiling Points.*—Ramsay has determined the volumes of sodium and bromine at the boiling point, and in connection with Masson, of phosphorus also. The method used for bromine and phosphorus was that previously employed for sulphur.* A glass bulb of known capacity was filled with the liquid substance and placed in a vessel in which more of this substance was boiled. After allowing time for the temperature of the bulb and vapor to become uniform, the bulb was withdrawn and allowed to cool. The weight of substance that it contained was evidently that required to fill the bulb at the boiling point; i. e. to occupy a known volume. Hence the ebullition-volume could be easily calculated. Four determinations made in this manner gave for the specific weight of bromine 2·9503, 2·9474, 2·9483 and 2·9471; for its specific volume 0·3390, 0·3393, 0·3392 and 0·3393; and for its atomic volume 27·12, 27·14, 27·13 and 27·15. Or as a mean, sp. wt. 2·9483, sp. vol. 0·3392, and at. vol. 27·135. The phosphorus was fused in a wide tube in a current of CO_2, and the bulb filled by suction. The phosphorus was boiled on a sand bath, the bulb remaining in the vapor until liquid phosphorus ceased to issue from it. It was then withdrawn and weighed. The mean results were: sp. wt. 1·4850; sp. vol. 0·6734; and atomic volume 20·91 with a proba-

* J. Chem. Soc., xxxv, 463, July, 1879.

ble error of $\pm 0{\cdot}3987$. For sodium, the apparatus was made of iron, though essentially similar in form. After the bulb was filled with liquid sodium it was hung in an iron pot containing 20 grams of this metal, a tight cover having a small opening was fastened on and the whole was heated on a charcoal fire. After boiling for ten minutes, the cover was removed and the bulb plunged into paraffin oil. After cooling it was cleaned and weighed. The sp. wt. thus obtained was 0·7414; sp. vol. 1·3490; at. vol. 31·0. Ramsay calls attention to the fact that bromine and all the halogens probably have but one atomic volume, either when free or in combination. (For free bromine this is 27·135 and for combined bromine 28·1.) Sulphur, like oxygen, has two atomic volumes in combination, 22·6 and 28·6, its atomic volume when free being 21·6. As to phosphorus, since nitrogen has three atomic volumes, one in amines, one in cyanides and nitriles and one in the nitryl group, it is probable that this element has more than one when in combination. Hitherto its atomic volume in combination has been given as 25·3; free as above given it is 20·9. If the oxy- or sulpho-chloride be written with quinquivalent phosphorus $PXCl_3$ or $X{=}PCl_3$ in which X represents a sulphur or an oxygen atom, these atoms are saturating and the atomic volume of the phosphorus in these compounds calculated on this supposition is 20·7. This value agrees with that of free phosphorus. Hence in combination phosphorus has an at. vol. of 20·7 when a pentad and of 25·3 when a triad.—*Ber. Berl. Chem. Ges.*, xiii, 2145, 2146, 2147, Dec. 1880. G. F. B.

3. *On Vanadium Sulphides.*—KAY, under Roscoe's direction, has examined the compounds formed by vanadium and sulphur, particularly those which were described by Berzelius in 1831. He finds that three sulphides exist, having the formulas respectively, of V_2S_2, V_2S_3 and V_2S_5. Vanadium disulphide is formed by passing perfectly pure and dry hydrogen over the trisulphide heated to intense redness. Vanadium trisulphide is formed (1) by passing H_2S over the trioxide at a red heat; (2) by the action of H_2S on any chloride or oxychloride of vanadium heated to redness; (3) by acting on the pentoxide by CS_2 vapor at high temperatures; the latter being the most convenient. Vanadium pentasulphide is formed by heating the trisulphide to about 400° with one-third its weight of sulphur in a long narrow tube. The author finds that Berzelius's products obtained by precipitation were oxycompounds but not of definite composition; but that the sulphide prepared by him in the dry way was the true trisulphide.—*J. Ch. Soc.*, xxxvii, 728, Dec. 1880. G. F. B.

4. *On the Hydrocarbons of American Petroleum.*—BEILSTEIN and KURBATOW, in their research upon the petroleum of the Caucasus,* regarded the facility with which this petroleum was attacked by nitric acid as a proof of the absence of the hydrocarbons C_nH_{2n+2}. To test this conclusion further, and to ascertain exactly the resistance to the action of nitric acid offered by

* This Journal, III, xxi, 67, Jan., 1881.

this series, a portion of heptane, distilling at 95°–100° and of sp. gr. 0·7192 at 15·5°, was prepared from American ligroin. It gave on analysis C 84·3, H 15·4; C_7H_{16} requiring C 84, H 16 per cent. One part of this heptane was heated with four parts of nitric acid (sp. gr. 1·38) so long as red fumes were evolved. From the oily layer above the acid, unattacked heptane was isolated, boiling at 98·5°–99·5°, of sp. gr. 0·6967 at 19°, and yielding on analysis C 84·2, H 15·9. Further action of the nitric acid upon this body was scarcely detectable. These results showed that beside the series C_nH_{2n+2} American ligroin contained hydrocarbons poorer in hydrogen, which the nitric acid removed leaving the heptane pure. The suggestion that these hydrocarbons were the addition-products of the benzene series, as in the Caucasian petroleum, led to an examination; and from some ligroin of boiling point 115°–120° a small quantity of trinitroisoxylene was obtained by the action of nitrosulphuric acid; thus proving the presence of these bodies. In purifying a considerable quantity of crude American heptane by the nitric acid method, there was obtained on subsequent fractioning a product of much higher boiling point which proved to contain nitrogen. It boiled at 195°–200° (after treatment with stannous chloride 193°–197°) and had a gravity of 0·9369 at 19°. On analysis it gave the formula $C_7H_{15}NO_2$. Hence the nitro-product of the American petroleum belongs to the marsh gas series, while that of Caucasian is derived from the ethylene series $C_6H_{11}NO_2$.—*Ber. Berl. Chem. Ges.*, xiii, 2028, Nov. 1880. G. F. B.

5. *On Inulin.*—KILIANI has published a research upon inulin as an inaugural dissertation at Munich. The following are the conclusions of his paper: Inulin stands in the most intimate chemical relation to levulose. It appears to be the anhydride of this body and passes into it with such facility, that in all reactions which require a long warming with water or need the presence of dilute acids, the inulin is replaced by levulose. By nearly all reactions therefore these bodies yield the same products. Inulin is distinguished sharply from levulose, in consequence of a property possessed by the latter in common with the simple sugars, of reducing the copper test and of fermenting under the action of yeast. Inulin neither reduces Fehling's test nor undergoes fermentation. Moreover it does not form hydrogen addition products. Its hydrate, levulose, differs from dextrose in its oxidation-products; the latter affording when oxidized with nitric acid or bromine and water, compounds which contain six carbon-atoms, saccharic (perhaps gluconic) acid; while levulose similarly treated affords bodies with a less content of carbon; glycolic and oxalic acids. This the author explains by supposing dextrose to be the aldehyde of mannite and levulose its ketone. Oxidation of both dextrose and levulose with silver oxide gives glycolic acid; but gluconic acid is probably first formed and then oxidized to glycolic and carbonic acids.—*Liebig's Ann.*, ccv, 145, Nov. 1880. G. F. B.

6. *On Saccharin and Saccharinic Acid.*—SCHEIBLER has examined carefully the new glucose derivative discovered by Peligot and called saccharin, to which he assigned the formula $C_{12}H_{22}O_{11}$. For its preparation dextrose or levulose or a mixture of both may be used. The best material is the solid starch-sugar of commerce. A kilogram was dissolved in 7 or 8 liters of water, the solution heated to boiling and freshly prepared and still warm slacked lime added in large excess. The boiling is continued so long as lime salts separate. It is then cooled, the liquid drawn off with a siphon, freed from excess of lime by carbon dioxide gas, and from combined lime by addition of an equivalent quantity of oxalic acid. The filtrate from this is evaporated to a thick syrup and allowed to crystallize. This may take days, and is hastened by adding a crystal from a previous operation. It is freed from the adhering mother liquor and re-crystallized. Its properties confirmed those given by Peligot; but its analysis gave numbers leading to the formula $C_6H_{10}O_5$; carbon 44·26, H 6·32. The author shows that when saccharin is boiled with freshly precipitated calcium carbonate the latter is dissolved with evolution of CO_2, and calcium saccharinate is formed. If, however, the calcium be separated by oxalic acid, saccharinic acid itself is not obtained but splits at once into saccharin and water. To this body saccharin, therefore, Scheibler assigns the structural formula

$$CH_2(OH)-CH(OH)-CH(OH)-\underbrace{CH-CH_2-CO}_{O}$$

The saccharinates are remarkably soluble in water and are uncrystallizable, except those of potassium and ammonium. Optically, saccharin is dextrorotatory, $[\alpha]_D=+93·8$. But the saccharinates are lævorotatory, the calcium salt giving $[\alpha]_D=-5·7$ and the sodium salt $[\alpha]_D=-17·2$. Further researches are in progress.—*Ber. Berl. Chem. Ges.*, xiii, 2212, Dec. 1880. G. F. B.

7. *On the Synthesis of Tropic Acid.*—LADENBURG and RÜGHEIMER have succeeded in effecting the synthesis of tropic acid. By the action of phosphoric chloride upon acetophenone, dichlorethylbenzene was prepared by the reaction:

$$C_6H_5COCH_3+PCl_5=C_6H_5CCl_2CH_3+POCl_3.$$

20 grams of this was put into a solution of 16 grams KCy in 160 grams 50 pr. ct. alcohol and allowed to stand 48 hours. After heating, neutralizing with barium hydrate and filtering, the solution was acidulated, filtered and agitated with ether. This left on evaporation ethyl-atro-lactic acid, which treated with hydrochloric acid gave atropic acid, readily converted into tropic acid.—*Ber. Berl. Chem. Ges.*, xiii, 2041, Nov. 1880. G. F. B.

8. *Experimental Researches upon the magnetic rototory Polarization of Gases.*—M. HENRI BECQUEREL carefully describes his apparatus and the means taken to eliminate all causes of error in his difficult determinations. A copper tube 0·122^m in diameter and 3·27^m in length enclosed the gases and this was made the

core of an electro-magnet. By means of mirrors at each end of the tube a ray from a lime light was made to traverse many times by successive reflections the column of air or gas. The principal causes of error arising from the heating of the gas by the strong current traversing the electro-magnet and from the polarization of the glass plates at the ends of the tube were carefully eliminated. The author concludes that the magnetic rotatory powers of bodies are intimately connected with their indices of refraction n, and the variations of the function $n^2(n^2-1)$ are of the same order of magnitude as those of the magnetic rotations of the same bodies in the solid, liquid or gaseous states. The following conclusions are drawn from the investigation.

(1) Bodies in the gaseous state, as well as solid substances and liquids, have the property of deviating the plane of polarization when submitted to magnetic influence.

(2) The magnetic rotations of the plane of polarization of rays of different wave lengths traversing the same gas (oxygen excepted) are generally inversely as the squares of the length of wave of the luminous rays which are considered.

(3) The magnetic rotatory power of gases can be compared to that of liquid sulphide of carbon, and consequently to those of other solid and liquid bodies. A remarkable relation appears to exist between the magnetic rotatory power of gases and their indices of refraction.

(4) Oxygen presents an anomaly which is apparently connected with the exceptional magnetic properties of this gas.—*Annales de Chimie et de Physique*, Nov., 1880, p. 289. J. T.

9. *The influence of Gases and Steam upon the Optical properties of reflecting surfaces.*—It is well known that gases and steam can alter the physical condition of the surfaces of solid bodies even if they do not act chemically upon these surfaces. Herr Glan after careful experiments decides that if the gases do not act chemically upon the substances of the reflecting surfaces and are not condensed in a quantity apparent to the eye, no change of phase takes place in reflection.—*Ann. der Physik und Chemie*, Nov. 11, 1880. J. T.

10. *A Physical Treatise on Electricity and Magnetism;* by J. E. H. Gordon, B.A., Cambridge. 8vo. (D. Appleton & Co., N. Y.) —The treatise of Mr. Gordon is beautifully illustrated with cuts of Sir William Thomson's Electrometers which the student will not find elsewhere. There are also many engravings of other electrical apparatus which one is tempted to criticize as too elaborate; a diagram would have answered in many cases better than the finely finished perspective views, and there would have been more room for solid information. A full page, for instance, is given to an illustration of Mr. Spottiswode's gigantic induction coil, which cut it seems to us is chiefly useful in showing the assistant in the act of discharging the coil. This method of illustrating treatises on science is too much in the manner of the instrument makers' catalogues.

The chapter on inductive capacity is very ample and the student will be repaid by its perusal. The treatise also contains a full account of the late experiments of de la Rue, and of Crookes on electrical discharges in rarefied gases, also of the experiments of Dr. Kerr and others on the magnetic polarization of light. The author evidently desired to do for the physical side of electricity and magnetism what Maxwell has done for the mathematical side of the science. The careful reader of Maxwell's treatise, even if he is not a mathematician, will gain a very good knowledge of the physical side of the subject. Still there are those who are deterred from reading Maxwell on account of the formidable array of mathematical formulas, and to such readers the treatise of Mr. Gordon cannot fail to be very acceptable. J. T.

11. *On the Space protected by a Lightning-Conductor;* by WILLIAM HENRY PREECE.*—Any portion of non-conducting space disturbed by electricity is called an electric field. At every point of this field, if a small electrified body were placed there, there would be a certain resultant force experienced by it dependent upon the distribution of electricity producing the field. When we know the strength and direction of this resultant force, we know all the properties of the field, and we can express them numerically or delineate them graphically. Faraday (Exp. Res., § 3122 *et seq.*) showed how the distribution of the forces in any electric field can be graphically depicted by drawing lines (which he called *lines of force*) whose direction at every point coincides with the direction of the resultant force at that point; and Clerk-Maxwell (Camb. Phil. Trans., 1857) showed how the magnitude of the forces can be indicated by the way in which the lines of force are drawn. The magnitude of the resultant force at any point of the field is a function of the potential at that point; and this potential is measured by the work done in producing the field. The potential at any point is, in fact, measured by the work done in moving a unit of electricity from the point to an infinite distance. Indeed the resultant force at any point is directly proportional to the rate of fall of potential per unit length along the line of force passing through that point. If there be no fall of potential there can be no resultant force; hence if we take any surface in the field such that the potential is the same at every point of the surface, we have what is called an *equipotential surface.* The difference of potential between any two points is called an electromotive force. The lines of force are necessarily perpendicular to the surface. When the lines of force and the equipotential surfaces are straight, parallel, and equi-distant, we have a *uniform field.* The intensity of the field is shown by the number of lines passing through unit area, and the rate of variation of potential by the number of equipotential surfaces cutting unit length of each line of force. Hence the distances separating the equipotential surfaces are a measure of the electromotive force

* From the Philosophical Magazine for December, 1880.

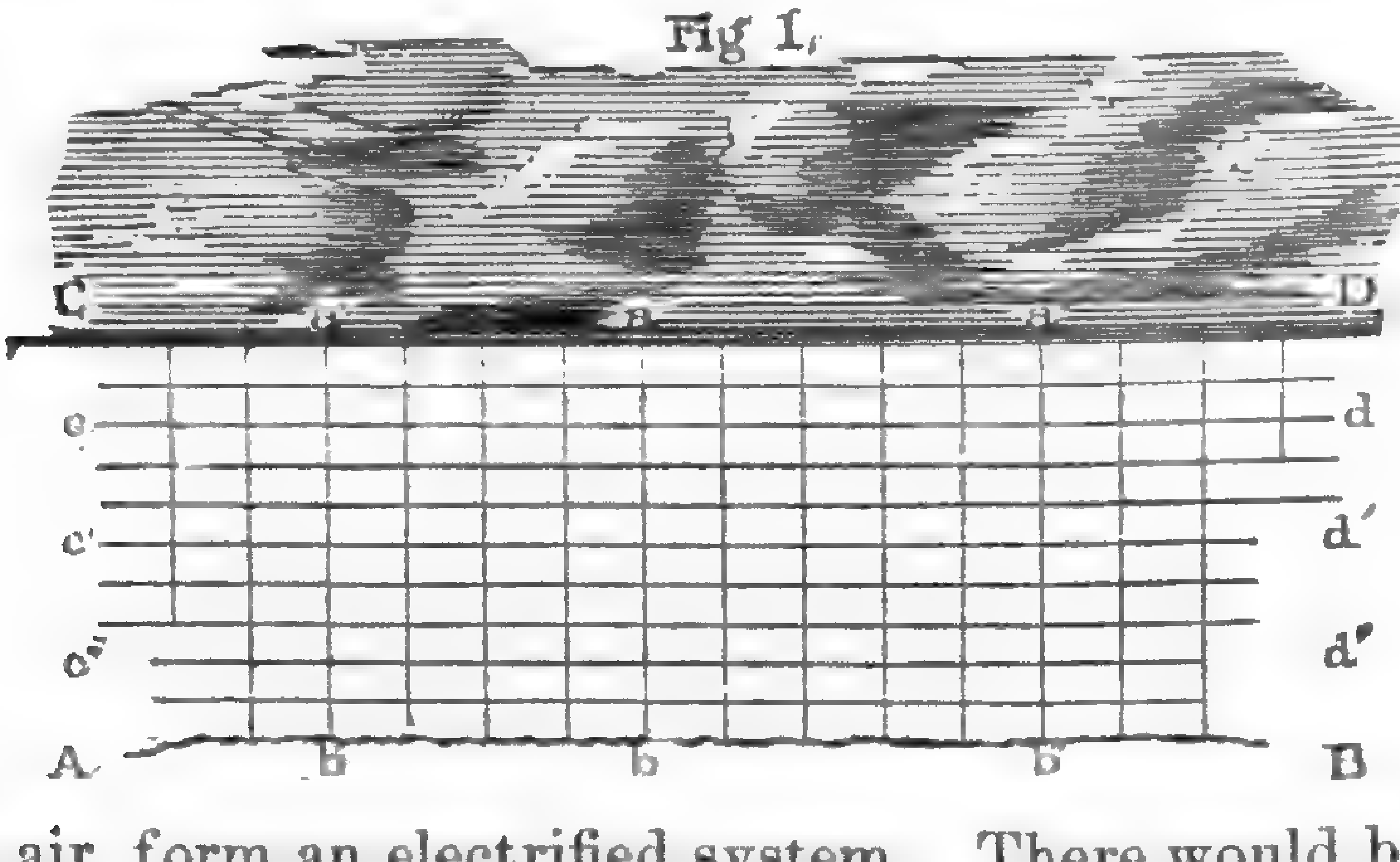
present. Thus an electric field can be mapped or plotted out so that its properties can be indicated graphically.

The air in an electric field is in a state of tension or strain; and this strain increases along the lines of force with the electromotive force producing it until a limit is reached, when a rent or split occurs in the air along the line of least resistance—which is disruptive discharge, or lightning.

Since the resistance which the air or any other dielectric opposes to this breaking strain is thus limited, there must be a certain rate of fall of potential per unit length which corresponds to this resistance. It follows, therefore, that the number of equipotential surfaces per unit length can represent this limit, or rather the stress which leads to disruptive discharge. Hence we can represent this limit by a length. We can produce disruptive discharge either by approaching the electrified surfaces producing the electric field near to each other, or by increasing the quantity of electricity present upon them; for in each case we should increase the electromotive force and close up, as it were, the equipotential surfaces beyond the limit of resistance. Of course this limit of resistance varies with every dielectric; but we are now dealing only with air at ordinary pressures. It appears from the experiments of Drs. Warren De La Rue and Hugo Müller that the electromotive force determining disruptive discharge in air is about 40,000 volts per centimeter, except for very thin layers of air.

If we take into consideration a flat portion of the earth's surface, A B (fig. 1), and assume a highly charged thunder-cloud, C D, floating at some finite distance above it, they would, together

Fig 1.



with the air, form an electrified system. There would be an electric field; and if we take a small portion of this system, it would be uniform. The lines $a\,b$, $a'\,b'$ . . . would be lines of force; and cd, $c'\,d'$, $c''\,d''$ . . . would be equipotential planes.

If the cloud gradually approached the earth's surface (fig. 2), the field would become more intense, the equipotential surfaces would gradually close up, the tension of the air would increase until at last the limit of resistance of the air $e\,f$ would be reached; disruptive discharge would take place, with its attendant thunder and lightning. We can let the line *e f* represent the limit of resistance of the air if the field be drawn to scale; and we can thus trace the conditions that determine disruptive discharge.

Fig. 2.

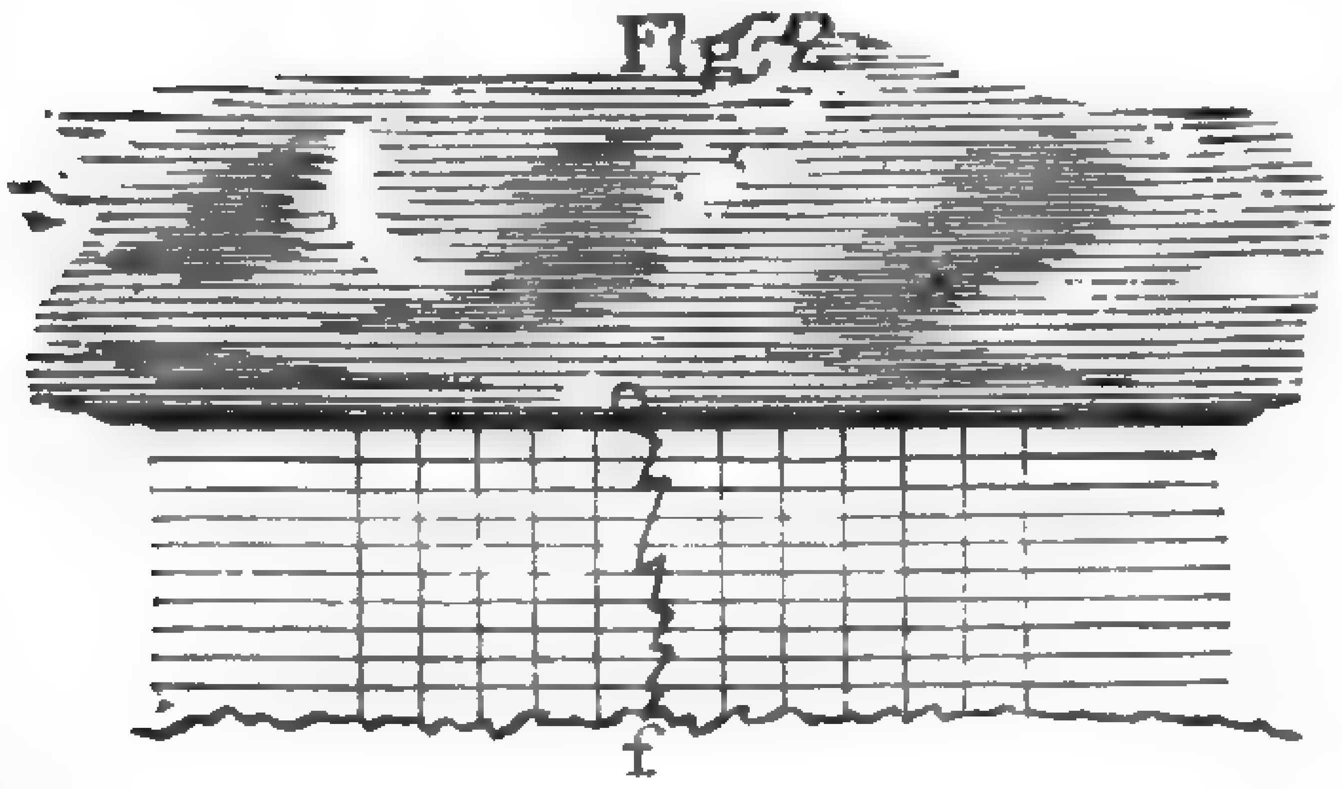
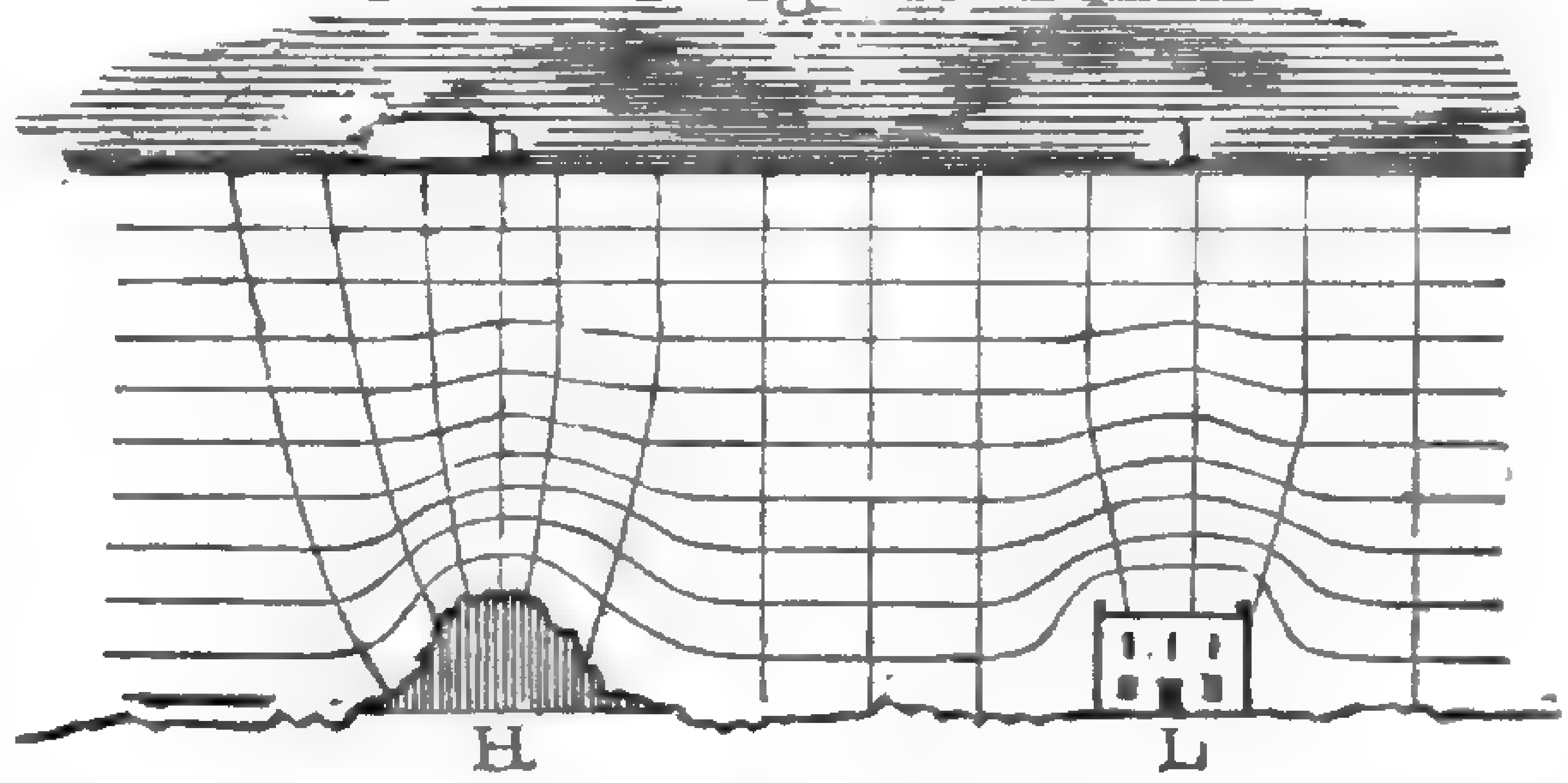


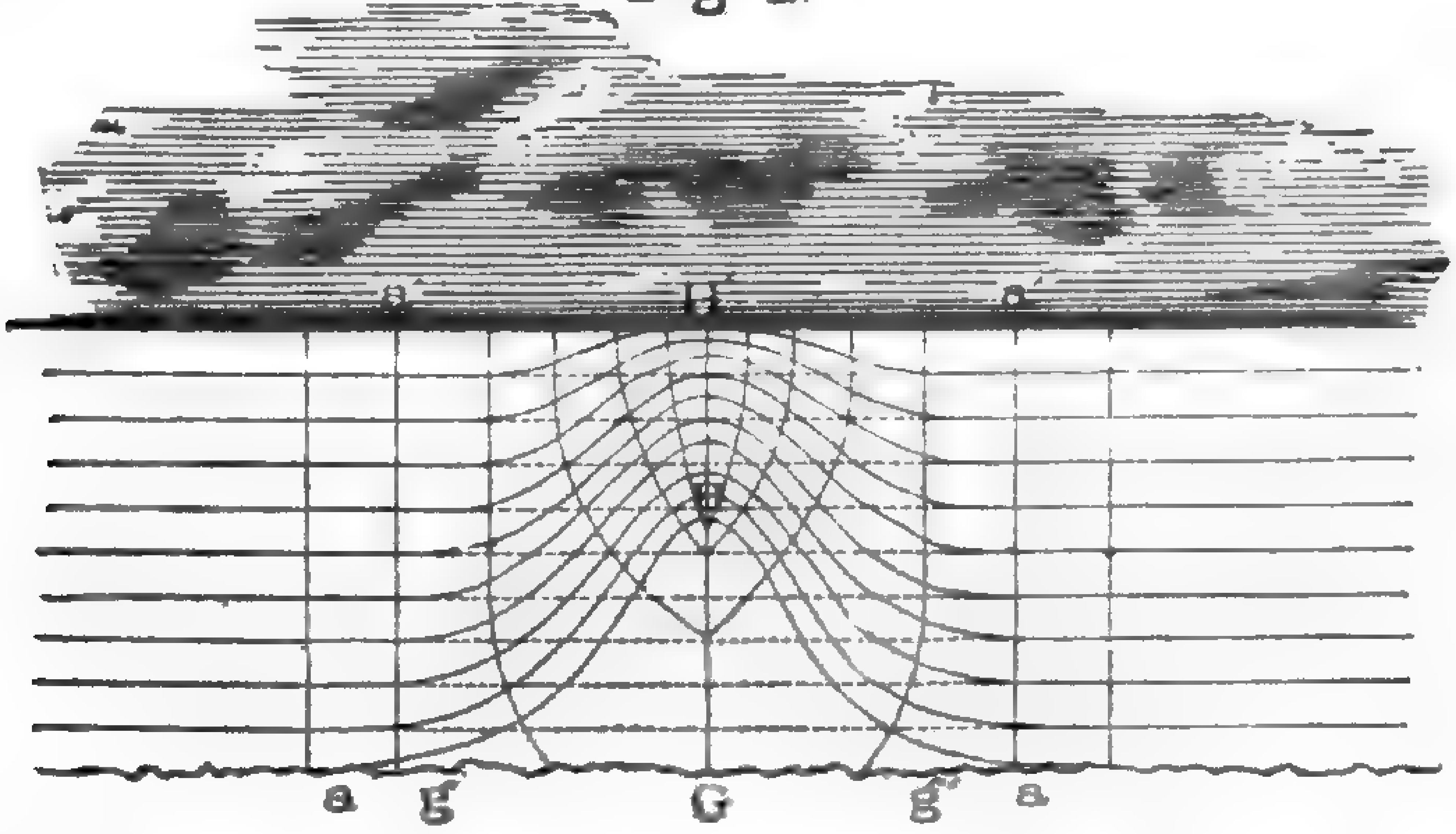
Fig. 3.



If the earth-surface be not flat but have a hill or a building, as H or L, upon it, then the lines of force and the equipotential planes will be distorted, as shown in fig. 3. If the hill or building be so high as to make the distance H *h* or L *l* equal to *e f* (fig. 2), then we shall again have disruptive discharge.

If instead of a hill or building we erect a solid rod of metal, G H, then the field will be distorted as shown in fig. 4. Now it is quite evident that whatever be the relative distance of the cloud

Fig. 4.

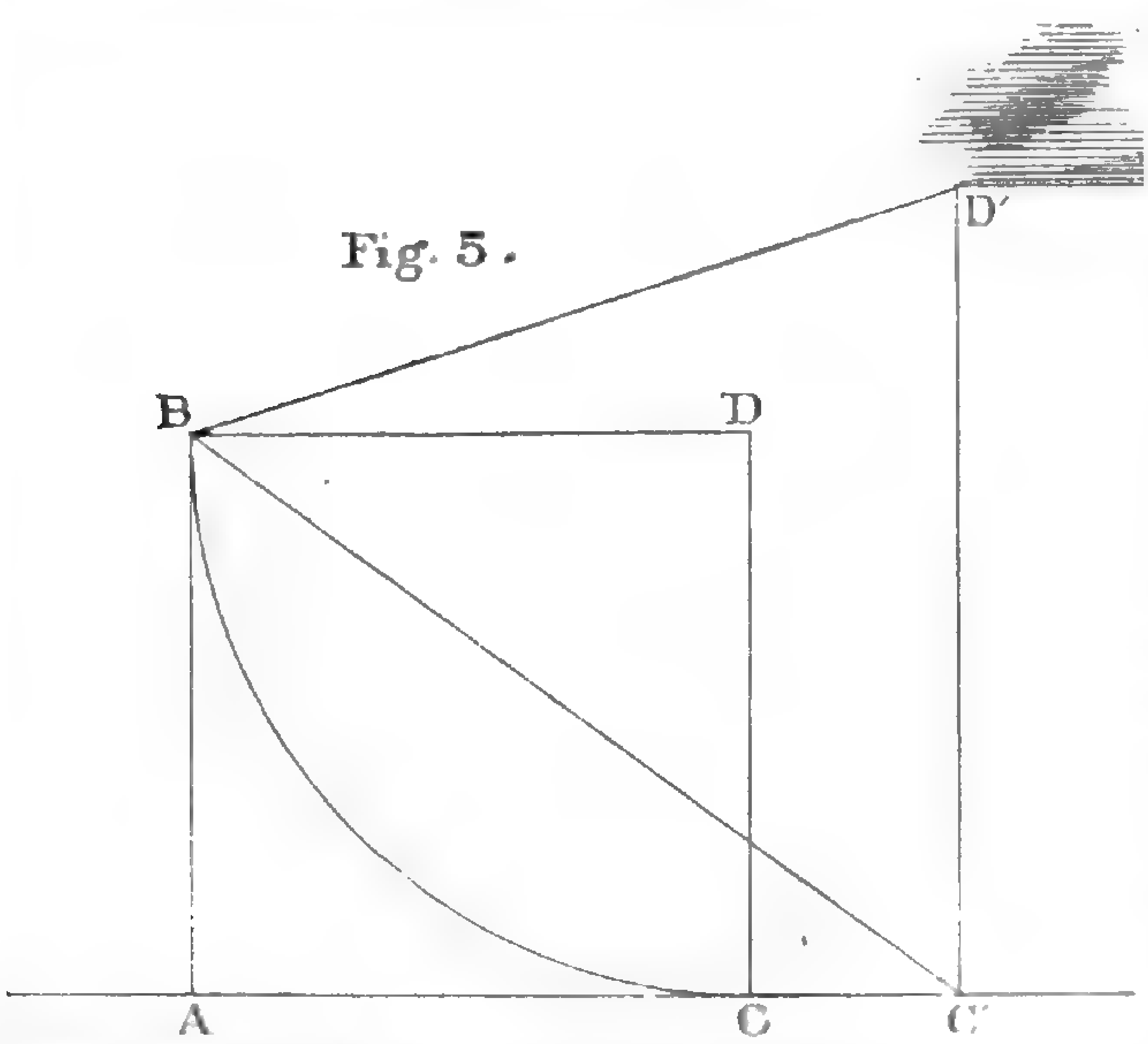


and earth, or whatever be the motion of the cloud, there must be a space *g g'* along which the lines of force must be longer than *a' a* or H H'; and hence there must be a circle described around G as a center which is less subject to disruptive discharge than the space outside the circle; and hence this area may be said to be protected by the rod G H. The same reasoning applies to each equipotential plane; and as each circle diminishes in radius as we ascend, it follows that the rod virtually protects a cone of space whose height is the rod, and whose base is the circle described by the radius G *a*. It is important to find out what this radius is.

Let us assume that a thunder-cloud is approaching the rod A B (fig. 5) from above, and that it has reached a point D' where the distance D' B is equal to the perpendicular height D' C'. It is evident that, if the potential at D be increased until the striking-distance be attained, the line of discharge will be along D' C or

D′ B, and that the length A C′ is under protection. Now the nearer the point D′ is to D the shorter will be the length A C′ under protection; but the minimum length will be A C, since the cloud would never descend lower than the perpendicular distance D C.

Fig. 5.



Supposing, however, that the cloud had actually descended to D when the discharge took place. Then the latter would strike to the nearest point; and any point within the circumference of the portion of the circle B C (whose radius is D B) would be at a less distance from D than either the point B or the point C.

Hence a lightning-rod protects a conic space whose height is the length of the rod, whose base is a circle having its radius equal to the height of the rod, and whose side is the quadrant of a circle whose radius is equal to the height of the rod.

I have carefully examined every record of accident that was available, and I have not yet found one case where damage was inflicted inside this cone when the building was properly protected. There are many cases where the pinnacles of the same turret of a church have been struck where one has had a rod attached to it; but it is clear that the other pinnacles were outside the cone; and therefore, for protection, each pinnacle should have had its own rod. It is evident also that every prominent point of a building should have its rod, and that the higher the rod the greater is the space protected.

12. *A theoretical and practical Treatise on the Manufacture of Sulphuric Acid and Alkali, with the collateral branches;* by George Lunge, Ph.D., F.C.S. Vol. III, 422 pp. 8vo. London, 1880 (J. Van Voorst).—The preceding volumes of this very valuable work have been noticed in full in this Journal (vol. xix, 230, and xxi, 70). The early part of the third and concluding volume contains the closing chapters on the soda industry, including a description of the ammonia process, the manufacture of soda from cryolite, and a statement of the applications of soda, with statistics. The two hundred pages following are devoted to bleaching-powder and chlorate of potash; the manufacture of chlorine by different methods, and of bleaching-powders, with other related subjects, are ably and fully treated. The volume closes with one appendix, giving estimates as to the cost of erecting an alkali-works, and a second in which much valuable matter supplementary to the body of the work is included.

II. Geology and Natural History.

1. *The Lava-fields of Northwestern Europe;* by Archibald Geikie, Director of the Geological Survey of Scotland. (Nature, Nov. 4, 1880).—In this paper the purpose of the author is to illustrate the fact that the greatest of igneous eruptions have taken place without the intervention of volcanic vents, and then to show that the lava-fields of northwestern Europe are examples to a large extent of such non-volcanic ejections.

Professor Geikie first observes that the volcanoes of the Mediterranean basin have given to science, as well as the popular mind the prevalent idea as to the features of igneous action—so that "even among those who have specially devoted themselves to the study of volcanoes there has been a tacit assumption * * * that where volcanic outbreaks have occurred it has been from local vents, like those of Etna, the Æolian Islands, the Phlegræan fields, or the Greek Archipelago;" and now, the statement that "the type of volcanic cones and craters has not been, in every geological age, and all over the earth's surface, the prevalent one, that on the contrary * * * it belongs perhaps to a feebler or waning degree of volcanic excitement," "would be received by most European geologists with incredulity if not with some more pronounced form of dissent." When Richthofen published, some twelve years since, about vast areas of lava on the Pacific slope of North America made without the aid of cones and craters, Scrope, in his "Considerations on Volcanoes," "ridiculed what he regarded as 'fanciful ideas' and 'untenable distinctions,' which it was 'a miserable thing' to find taught in mining schools abroad." Professor Geikie speaks of his acceptance at first of his teacher's views; but of his finding, afterward, as he studied the facts connected with the erupted masses of Great Britain, that in truth little light was thrown upon the subject by the modern volcano. There were multitudes of dikes of basalt over a region of 100,000 square miles, from Yorkshire to Orkney and from Donegal to the mouth of the Tay, spreading into basaltic plateaux to the westward in Antrim, Skye, northeastern Ireland and elsewhere, having in some places a thickness of 3000 feet, the origin of whose horizontal or nearly horizontal beds without interstratified tufas he says he attempted again and again to explain, but in vain; and, he adds, "Nor so long as the incubus of 'cones and craters' lies upon one's mind does the question admit of an answer."

The author next recounts the facts which he had himself observed in Western America, and states that these first enabled him to understand Richthofen's descriptions and the basalt-sheets of his own country. From his paragraphs we take the following:

"Never shall I forget an afternoon in the autumn of last year upon the great Snake River lava desert of Idaho. It was the last day of a journey of several hundred miles through the volcanic region of the Yellowstone and Madison. We had been riding for two days over fields of basalt, level as lake bottoms, among the valleys, and on the morning of the last day, after an interview with an armed party of Indians (it was only a few days before the disastrous expedition of Major Thornburgh, and the surrounding tribes were said to be already in a ferment), we emerged from the mountains upon the great sea of black lava which seems to stretch illimitably westward. With minds keenly excited by the incidents of the journey, we rode for hours by the side of that apparently boundless plain. Here and there a trachytic spur projected from the hills, succeeded now and then by a valley up which the black flood of lava would stretch away into the high grounds. It was as if the great plain had been filled with molten rock which had kept its level and wound in and out along the bays and promontories of the mountain-slopes as a sheet of water would have done." * * *

"Riding hour after hour among these arid wastes, I became convinced that all volcanic phenomena are not to be explained by the ordinary conception of volcanoes, but that there is another and grander type of volcanic action, where, instead of issuing from separate vents and piling up cones of lava and ashes around them, the molten rock has risen in fissures, sometimes accompanied by the discharge of little or no fragmentary material, and has welled forth so as to flood the lower ground with successive horizontal sheets of basalt. Recent renewed examination of the basalt-plateaux and associated dykes in the west of Scotland has assured me that this view of their origin and connection, which first suggested itself to my mind on the lava-plains of Idaho, furnishes the true key to their history." * * *

"No more stupendous series of volcanic phenomena has yet been discovered in any part of the globe than those of northwestern Europe. We are first presented with the fact that the crust of the earth over an area which in the British Islands alone amounted to probably not less than 100,000 square miles, but which was only part of the far more extensive region that included the Faroe Islands and Iceland, was rent by innumerable fissures in a prevalent east-and-west or southeast-and-northwest direction. These fissures, whether due to sudden shocks or slow disruption, were produced with such irresistible force as to preserve their linear character and parallelism through rocks of the most diverse nature, and even across old dislocations having a throw of many thousand feet. Yet so steadily and equably did the fissuring proceed over this enormous area, that comparatively seldom was there any vertical displacement of the sides. We rarely meet with a fissure which has been made a true fault with an upthrow and downthrow side."

The paper gives further details respecting these British ejections, and alludes also to the great basaltic plateaux of Abyssinia and of the Deccan in India; and in the course of his concluding remarks Professor Geikie observes, "I believe that the most stupendous outpourings of lava in geological history have been effected not by the familiar type of conical volcano, but by these less known fissure eruptions."

2. *Volumes of solid and liquid Cast Iron, with reference to the theories of Volcanic action.*—Under the above title Mr. J. B. HANNAY presents, in the Proceedings of the Philosophical Society of Glasgow for January, 1880, the results of experiments on cast iron. He first refers to the view of Messrs. Nasmyth and Carpenter, in their work on the Moon, that fusible substances, with few exceptions, are specifically heavier in their molten state than in the solid, and that, consequently, they expand on becoming solid, which view they sustain by referring to a fact recognized by iron founders, that a mass of solid cast iron dropped into molten iron of the same precise kind will float on it; and whence they draw the conclusions that solidification beneath the earth's crust is a cause of fissuring of the crust, and thus of opening volcanoes; and that the cooling of the same after solidification produces shrinkage, and consequently a wrinkling, or alternate ridges and depressions, over the surface. Mr. Hannay states that in his experiments, spheres of iron three to six inches in diameter were dropped into a bath of the same metal four feet wide and two feet deep. In one of them the sphere sank at first to the bottom, where it could be found by raking the pot; in fifty seconds it came to the surface, having a dull-red temperature; as the temperature increased it floated higher and higher, until it began to melt, when it remained constant but diminished in height, of course, as the sphere melted away. Another trial gave the same results, and the value was found to be constant. In other experiments the balls were fished out when at their maximum temperature; and they showed, by the "tide-mark" left, the exact depth of submergence, and also the relation between the volumes or densities of liquid and solid metal. The result reached is, that, on an average, cast iron expands 5·62 per cent of its volume on solidification. The various experiments proved that the iron *just* floats when at a red heat, which is estimated at 750° to 800°. The linear expansion of a bar of iron up to that temperature was ascertained to be, from four experiments, ·000055, ·000070, ·000050 and ·000065, giving a mean of ·000060 per degree Centigrade. The density of the iron used was 7·214, which decreased to 6·883 at about 800°, and this was the density of the liquid; but as the sphere floated with 5·62 per cent of its volume above the liquid, the density of the solid at its fusing point must have been reduced to at least 6·535. The expression *at least* is used because the iron in the experiments had to be above the fusing point to prevent its freezing while these were in progress, whence the result is under the truth. The facts are shown by Mr. Hannay to set aside the experiments of Mr. Mallet.

In the same volume of Proceedings, Dr. Henry Muirhead gives an account of experiments on the same point by Mr. Joseph Whitby and Mr. T. Wrightson. Mr. Wrightson's earliest experiments are published in the British Association Report for 1879, p. 506. Later results, from a much larger number of experiments on metals, are given in a paper in the "Journal of the

Iron and Steel Institute," No. 11, for 1879. Mr. Wrightson concludes that, in passing from the solid to the liquid state, the density of the iron is greatest when cold, least when in the plastic state, and that when liquid it is between the two extremes but much nearer the solid than the plastic density. Dr. Muirhead concludes that the results are not favorable to Sir Wm. Thomson's (or Hopkins's) hypothesis, that while the earth was passing from a liquid to a solid state, cooled fragments of the earth's crust would have descended deeply toward the earth's interior, and built up a sort of irregular interior framework to support the at last successfully forming crust.*

Mr. Hannay observes that slags and even molten granite show the same phenomenon—the solid floating on the liquid; that from experiments he has made at blast furnaces on the Clyde, he has invariably found this to be the result, though he has not yet had an opportunity for making measurements.

3. *Climate of Siberia in the Era of the Mammoth.*—An excellent paper by HENRY H. HOWORTH, in the Geological Magazine for December, discusses the question as to the climate the ancient Mammoth and Rhinoceros had in Siberia. In earlier papers the author had presented the facts as to the distribution of these animals in that region; that the bones are few in Central Siberia, but increase in numbers toward and along the Arctic shores, the quantity being stated to be so great in the Bear Islands and the islands of New Siberia that "the ground is largely composed of the bones of Mammoths and the associated animals." In the last paper the author speaks of the unfitness of Northern Siberia for such life, the barren, frozen ground, even the most favored spots growing stunted willow bushes as almost the only vegetation, and green for not over two months in the year; and the vicinity of the Arctic coast where Mammoth bones abound, as a bare waste without trees or shrubs of any kind. He next shows, from the remains of plants associated with the bones in the beds containing them, as reported by investigators, that the flora of this same Northern Siberia in the Mammoth era contained species of *Picea*, *Abies*, *Larix* among Conifers, species of *Betula* (birch), *Salix* (willow), an *Alnaster* and *Ephedra*—plants now thriving in Southern Siberia; and the waters or land, as the fresh-water clays have in some places shown species of *Helix*, *Planorbis*, *Valvata*, *Limnæa*, *Cyclas*, *Anodonta*. Further, the deposits of trunks and branches of large trees (little altered) are very extensive, especially in the northern regions where the bones most abound, far beyond the reach of living trees of any size. In view of the facts, which are given with much interesting detail, the author concludes that the North Siberian climate in the era of the Mammoth was far more temperate than now; that the vegetation was much like that of Southern Siberia, the larch, willow and Alnaster being the prevailing trees; that probably Lithuania "where the Bison now survives, and where so many of the other contemporaries of the Mammoth still live, pre-

* Rep. Brit. Assoc. for 1876, Part II, p. 8.

sents to us a not unfaithful picture of what Northern Siberia must have been like from the Urals to Behring's Straits."

4. *The Climatic Changes of later Geological times: a discussion based on observations made in the Cordilleras of North America;* by J. D. Whitney. Memoirs of the Museum of Comparative Zoology at Harvard College. Vol. VII, No. 2. Part I. 120 pp. 4to. Cambridge, 1880.—This volume commences with a chapter on the glacial and surface geology of the Pacific Coast. It discusses the action of glaciers, argues that they cannot make lake basins, except through the inclosures its moraines may have formed, and attributes the erosion of glacier valleys chiefly to the running water. The glacial phenomena of the Sierra Nevada are described, and from these pages we cite a few of the facts. They are confined mostly to a belt three to four degrees wide, north of latitude 36°; but owing to declining height northward, they are less extensive north of the Tuolumne (37° 30′) than to the south. Along three rivers, the King's, the San Joaquin and the Tuolumne, the glacial masses were of great extent. That of the first had a length of fifty miles, and an area of 300 square miles. The glacial scratches are all over the region down to an altitude (as observed by Professor Brewer) of 4,000 feet, and nowhere below this. On the Joaquin, the glacier on the South Fork had a length of fifty miles, a depth, in some parts, of 1,500 feet, and a width in places of eight to nine miles. In the Tuolumne glacier region, the ice of the plateau region, 9,000 feet in elevation between the summit peaks, (Cathedral Peak, Mount Conness, Mount Dana and Mount Lyell), was over 1,000 feet thick. Below Soda Springs is the Cañon of the Tuolumne, having precipitous walls of rock 1,000 to 1,500 feet high, scored well by the glacier; but, as Professor Whitney holds, this gorge could not have been glacier made. The ice-marks reach down to about 3,650 feet above the sea-level. The glacier of the Merced is next described, and strong arguments are urged against the view that the Yosemite was made by glacier erosion. It is stated that the glacier of the Merced could not have extended as far as the Yosemite, and, consequently, the ice never entered that valley. Its walls bear no glacier-made markings. The glacial appearances of localities farther north are also treated of with many interesting details. In no part of the Sierra Nevada are they met with below a level of 2,000 feet above the sea.

The author also reviews the facts observed in the Rocky Mountains and to the north; and from the whole finds his former conclusion sustained, that no *northern* drift exists in any part of Western North America—not even in British Columbia; and he adds that Mr. Dall has reported the same to be true of Alaska.

"The desiccation of later geological times" is the subject of the closing chapter of the work. The facts are mentioned with regard to the former wide limits of existing lakes between the Sierra Nevada and the Front Range of the Rocky Mountains, and of many others now dried up, and others from other regions on the western part of the continent; and the conclusion is reached that the cause of the great desiccation was climatological, and not a consequence of change of level.

5. *Six Lectures on Physical Geography;* by the Rev. SAMUEL HAUGHTON, F.R.S., M.D. Dubl. and D.C.L. Oxon.; Fellow of Trinity College, and Professor of Geology in the University of Dublin. 386 pp. 8vo. Dublin, 1880. (Longmans, Green & Co., London.)—Professor Haughton's mathematical studies connected with certain points in physical geography have been of much service to geology. The lectures here published with their appended notes bring out some of these points, as well as many generally accepted views, and discuss a few others of like geological interest. Even if the results are in some cases unsatisfying, owing to the use of insufficient data, the work is an important contribution to the science of terrestrial physics.

The *first* lecture presents some recent views as to "the past history and future prospects of the earth," involved in the assumed truth of the nebular hypothesis, and the recent inference of astronomers that the earth's day is slowly shortening.

The *second* treats of "continents and oceans, volcanoes and mountains." The heights of continents and depths of oceans are briefly reviewed, and a few general deductions brought out as to *axes* (following the meridians) *of elevation*, corresponding one to each continent, and *of depression*, one to each ocean, which axes are regarded as indicating the courses of the original wrinkles in the contracting globe. No note is taken, however, of the structure, age, true directions, or other details with respect to actual mountain ranges, or of the general courses of the earth's structure-lines.

The great east-and-west range of high land of Europasia, from the Pyrenees to the Himalayas, is spoken of as the most modern of mountain chains. But the Rocky Mountains also were raised 8,000 to 12,000 feet during the progress of the Tertiary (especially the Miocene and Pliocene), and the Andes in part to a greater height. The vast extent of these movements over the earth's continental surfaces during the Tertiary, when other large regions experienced little or no change of level is not considered. It is a good subject for contemplation and study by all physicists interested in terrestrial dynamics and the condition of the earth's interior.

Lecture III considers "the laws of climate and atmospheric and oceanic circulation." Heat from the earth's interior, and that from a cooling sun are here made the prominent sources of the earth's early climates. But the author returns to the subject in a note to the sixth lecture, many pages in length, in which he applies to the case of the earth's surface Rossetti's law of cooling. Professor Haughton, by this method, calculates the rate of cooling on the supposition that the source of heat is, *first*, sun-heat alone; *second*, earth-heat alone; and, *third*, variations in the thermal conditions of the earth's atmosphere; the other conditions in each of these cases being supposed to be as they now are. The final "probable" conclusions thence reached are: that "the chief factor in changes of geological climate appears to have been the slow secular cooling of the sun;" that since life began on the globe, the earth's interior heat can not be regarded as "the sole and immediate cause of change of climate;" that the carbonic acid and moisture of the atmosphere have added to the warmth of past climates, the former chiefly during Paleozoic and earlier times.

He adds that the cold and precipitation of the Glacial era "was probably due to atmospheric changes caused by a temporarily diminished rate of heat-radiation from the sun."

The laws of modern climate also are discussed in the closing part of the third lecture, its main sources being made as usually understood, the sun's heat and aerial and oceanic circulation. In a note he introduces his calculations with regard to the total annual heat received at each point of the earth's surface, and on the amount of the loss of that heat caused by radiation into space; in which he finds that the whole amount of the sun's heat received is equivalent to that required to melt a layer of ice over the whole globe 80·5 feet thick, and that the part lost by radiation is equivalent to 28·5 feet of ice in thickness, leaving 51·5 feet, or more than 5-8ths of the whole, to be accounted for not as heat but as work.

The author, further, arrives at a parallel relation between the lengths of the geological ages as measured by the maximum thickness of sedimentary deposits, and by the rate of progress in its cooling climate. But, in the calculation, the Cambrian or Primordial era (in which Trilobites, Brachiopods and Worms were already in the seas) is united to the Azoic (Archæan), and thus it is made to antedate the epoch (of which he makes special use) when a mean Arctic temperature of 122° F. (that of the coagulation of albumen) was reached by the earth.

Moreover the calculations make the time between the era of the Miocene, with an Arctic mean temperature of 48° F., and the present to be longer than the preceding part of the Tertiary and all of Mesozoic time after the Triassic united (p. 93); or (as stated on p. 358, from other calculations) 41·7 per cent of the whole time of the possible existence of life on the globe at lat. 80° N.; a result widely at variance with the thickness of the sedimentary deposits of the eras, and also with the relative amount of physical and biological progress in the course of them. The idea of the extreme uniformitarian Professor Haughton rightly opposes, since it appears to have no sufficient support in geological facts. But that of regular gradation in declining temperature is in equal disagreement with the records. This is admitted by him for the Glacial era, whose cold is explained on the assumption of a temporarily lessened heat-radiation from the sun; and if this exception exists, there may have been, and probably were, many maxima and minima in the course of the progress.

It is probable, from recent discoveries, that the Arctic flora, referred to the Miocene by Heer, was actually Eocene; and if so, Professor Haughton's conclusion as to the length of after time would be more reasonable. But so many doubts invest the subject of geological time and rate of cooling that it would be premature to call any conclusion reasonable.

The remainder of the volume is occupied by Lectures IV and V, on the rivers and lakes of Europasia, Africa and America, in which the amount of water-discharge and detritus-transportation of a number of large rivers is estimated, and some conclusions deduced; and Lecture VI, on the Geographical Distribution of Animals and Plants, which treats also of the relations of species to climates with reference to geological questions, and assumes the existence of a once large and flourishing Antarctic Continent to help in explaining the origin of the resemblances which exist between the faunas of South America, Africa and Australia.

Many other topics, besides these here mentioned come under consideration in Professor Haughton's volume, making it a work of wide interest.

6. *Address by* H. C. SORBY, F.R.S., *President of the Geological Society of London, at the Anniversary meeting in February*, 1880. 60 pp. 8vo.—Mr. Sorby's presidential address is one of the most important of recent contributions to geological science. The author gives the result of a large amount of microscopic investigation into the condition and structure of the grains of non-calcareous stratified rocks, carried on in order to study out the true history or mode of origin of the rocks; and the rocks which are considered embrace fragmental rocks, from loose sand beds to consolidated sand-rocks and shales, metamorphic rocks, and slates as the passage way between the metamorphic and the preceding. The methods of distinguishing microscopically some of the more common minerals in slices and in sand, by the aid of polarized light, are also considered and elucidated by means of new researches. The development also of lamination, slaty structure and foliation, is among the subjects of investigation and receives new light. All the various topics are brought out in a brief way, and nothing short of the explanations given in the paper are sufficient to do them justice.

The following are a few of the results presented. From a study of sands from various sources the conclusion is arrived at that, excepting those which have been made by wind transportation, they generally bear little evidence of attrition, and often none. Even those of beaches, of river terraces, of the millstone grit of the coal-measures, and of most sand deposits, are often sharp-angled. Again, he shows that in what has been called crystallized sand or sandstone, the little quartz crystals which constitute it have sometimes been made by the deposition of silica about the grains; and that this is ordinarily, if not always, the mode of origin of a rock, whether friable or not, consisting of an aggregation of small or minute crystals of quartz. He instances the Devonian

Old Red Sandstone of Cockburnspath as affording examples, and mentions his finding them in deposits up to the Oölite. In remarks on the dependence of amount of wear on weight, Mr. Sorby observes that a grain one-tenth of an inch in diameter would probably be worn as much in drifting a mile as one one-thousandth of an inch in drifting 100 miles.

The lamination or fissile structure of shale, parallel with the bedding, he observes may be a result of mere pressure, the water of the original mud being thus squeezed out, and the thickness greatly reduced. In the case of slates from North Wales and other localities, he has found, by slicing and optical investigation, that they consist chiefly of microscopic scales which so closely resemble mica optically and in other ways, that they may be pronounced with good reason as of this species; and, since the scales lie mostly in the plane of bedding, a well cleaved slate of this type depolarizes like a uniaxial crystal having the principal axis perpendicular to the cleavage. When the mica scales conform thus in position to the plane of bedding in a slate, the author holds that they are probably of fragmental origin; since he has found in other slates in which the mica was "formed *in situ*, that the crystals of mica are not stratified but lie at all possible azimuths, and moreover are collected about special centers."

As an inference from the study of slates and other rocks, he says: "It appears to me that the development or absence of certain minerals in metamorphic rocks depended as much on the original nature of the material as on any mere difference of the temperature to which the rocks have been exposed; so that lower lying rocks might very well be less altered than those above them, even though probably at one time exposed to a higher temperature invading them from below."

Mr. Sorby has found that a gradual and perfect passage often exists "between an almost normal slate and what is practically a true mica schist," the only essential difference being in the difference in size of the crystals. Some fine-grained mica schists are further proved to be a result of the metamorphism of detrital beds by their containing isolated worn grains of quartz with the mica scales wrapped around them, and occasional grains of feldspar.

The proof that "the schists of the central Highlands of Scotland were originally slates" is worked out microscopically with great care, and the very probable conclusion is reached that "taking into consideration the character of both the feldspathic and quartzose grains," the material was to a considerable extent derived from a granite of a type very unlike that of Cornwall, but in some respects analogous to that of Aberdeen, though differing from it in being more like a quartz felsite."

These are a few of the deductions, in the Address, arrived at from the study of the least promising of all rock-formations—sand-beds and slates.

7. *Geological Survey of Pennsylvania.*—Great progress has been made toward the completion of the geological survey of

Pennsylvania, under its able director, Professor J. Peter Lesley. As recently announced by the Commissioner, forty-two counties of the State have been surveyed in full, eighteen surveyed in part, and only six remain untouched. The unfinished portion includes the eastern counties and some of the central. The publication of the results has gone forward as the work has advanced, and already eighteen reports on the geology of the several counties have been issued, besides sixteen special reports, and half as many more are in course of preparation. The field, and eminently that of Western and Central Pennsylvania, is one of vast mineral wealth, unexceeded in fact by any equal area on the continent, its coal, mineral oil and iron, yielding an annual income of 200 millions of dollars; and these are not the only valuable mineral products. And the surveys have had especial reference to all those points in the geological structure of the regions which should give more certainty to exploration and its results. They have been thorough geologically; and this means that they have gone to the bottom, so far as possible, both as regards scientific and economical questions, thoroughness comprising both classes of results. The yield of the three products just mentioned is so large, that any increase in the facilities or certainties of exploration, made by such a survey, even if producing a gain of only one per cent, is a vast increase in the aggregate amount of proceeds—sufficient to pay a hundred times over the whole cost of the survey.

Several of the reports have especially an economical bearing. A third report on the oil regions, by Mr. Carll, is the result of the last year's work, and will soon appear. Another, now in the press, treats of the waste in anthracite mining; it was prepared in response to a call from the legislature. The work on the area of the bituminous coal fields, being for the most part finished, the anthracite coal fields are now under careful study, and maps are in preparation showing not only the surface distribution but also the underground, at different depths, and the actual forms and extent as far as is possible, of the subterranean sheets of coal—work in which the geologists have great aid from the mining engineers. About twenty square miles, including the Wyoming region, were surveyed the past season, under Mr. Ashburner. The investigations seek to determine the actual thickness and course of the great mammoth vein, besides others, so that tunneling may be more certain in its results and safer from disaster. Besides maps, the work will include the making of a plaster model showing to the eye just how the great mammoth coal vein would look with all its flexures and irregularities, if the covering rock were lifted off—a method of exhibition first used many years since by Professor Lesley. Such investigations, besides aiding the miner, give a closely approximate idea of the amount of coal.

In a scientific way, also, the reports have great value. The "Keystone State" is eminently such geologically; and its survey is solving several problems for the country, besides giving us our best knowledge of its Coal-era vegetation.

The report of the Commissioner states that only three years more of work are needed to complete the survey; and it has been said rightly, that if continued and finished as proposed, it will be one of the most complete works of the kind ever accomplished, and will be worth to the State and its citizens many times its comparatively trifling cost.

The report of Mr. Ashburner on McKean County, including the Bradford oil-region, has been recently issued, and will be noticed in another number of this Journal.

8. *The Quaternary after the Era of the cave-animals in Europe.*—M. TARDY, in a paper in the Bulletin of the Geological Society of France for April 7, 1879, states that a bed of gravel, sands and clays, called *red diluvium* ("diluviums rouges"), occurs over a large part of France and the adjoining countries, covering the lœss and other deposits containing remains of the Cave-animals, Mammoth and in many places human remains or relics. It occurs near Paris and from there extends south. M. Hébert describes it about Bordeaux; and Casiano de Prado states that it overlies the stratified diluvium which contains bones of the *Elephas primigenius* and rolled pebbles, near Madrid, extending over the plateau of New Castille. Near Madrid it has an elevation of 660 meters; on the Col de l'Eremo, near Turin, 600 meters, and in France between Puy and Mende and between Mende and Saint-Flour, at a height of 800 meters. The fragments of the gravel are for the most part angular, and the beds show little stratification. The age to which this "red alluvium" is referred by Tardy is between the era of the mammoth and cave-animals (the equivalent of the Champlain period) and that of the neolithic beds or domesticated animals of Europe (or that of the early part of the modern period).

9. *River Channels filled with basalt and afterward cut out anew and deepened.*—Professor JOHN J. STEVENSON has described (Proc. Am. Phil. Soc., Aug., 1880) cases of re-eroded channel-ways on the Canadian and Mora Rivers, near Fort Union, in New Mexico. The original cañons of these rivers were cuts a thousand feet deep or so in the Dakota sandstone. At the mouth of the Mora (where the stream unites with the Canadian), the depth of the cañon before the inflow of basalt was 860 feet; the basalt filled up 470 feet of this depth; the waters, renewing the erosion process, cut a narrow way through the basalt, and below it to a depth of 230 feet. The cañon is now 1090 feet deep; but at a level 620 feet above the botton it is narrowed by a wide terrace, that of the top of the basalt. Mr. Stevenson's paper contains a section of the two streams two miles above their junction, showing similar features in the two as to the depth of the basalt and that of the new narrow channel cut through it into the subjacent sandstone. In other parts of the streams, the new channel follows the margin of the basalt. The basalt is that of a volcano seven miles east of Fort Union in the southern extremity of the Turkey Mountains. Entering the Mora cañon, the liquid rock flowed

onward to its mouth and, then, nearly three miles *up* the Canadian cañon. How far *down* this river was not ascertained.

The enormous extent of the erosion over the plains which preceded the time of the eruption of this basalt, the author attributes to an era of unusual precipitation that had then passed by.

10. *On the occurrence of* Proëtus longicaudus *Hall ;* by H. S. Williams. (Communicated.)—The only specimen of this Trilobite of which published notice has been taken is, so far as I can ascertain, the one described by Professor Hall in the fifteenth Regents' Report, New York, 1862, p. 108–109, figs. 7, 8 and 9, Plate 10. The same specimen is figured in the "Illustration of Devonian Fossils," 1876, Plate xx, figs. 32–34, and the same notice is given of the specimen, so that we take for granted that in 1876 Professor Hall had seen only this specimen. The original specimen is said to have come from "far northeast of Des Moines, Iowa," and is regarded as from Hamilton rocks by Hall.

I have recently examined two more specimens of the same species, one a pygidium about the size of Hall's specimen, and the other a complete and nearly perfect specimen, but only about a third as large, folded up, and the pygidium protruding beyond the anterior margin of the glabella, as in the original specimen. They agree well with Hall's description and figure. The "nine" dorsal segments, the "twenty annulations on the axis of the pygidium," and the other details of the description are well carried out. Only about twenty of the annulations on the axis could be counted in the larger specimen, but there was still room for two or three more, which would be expected to appear in a larger specimen, or a perfect one. In the smaller specimen, they were too indistinct to count beyond fifteen or sixteen, but the proportion of those seen and their relations to the length of the axis leave little doubt of the perfect identity of these with the original form as described.

The specimens were sent for examination by Edwin Walters, Principal of the Madison Public Schools, Madison, Kansas. He writes that they were found in a blue limestone near Madison, Greenwood County, Kansas, and he describes the locality as "on the border of the Upper Carboniferous, the Permian and Cretaceous with an occasional indication of a Jurassic Age." From the reports of the Geology of Kansas it seems impossible to consider this locality as any lower than the Carboniferous, and if we regard it as Carboniferous the occurrence of the species here would not be inconsistent with the fact of the same species being found northeast of DesMoines, Iowa, where Carboniferous strata crop out, if one does not go too far into the corner of the State. Still, from what we know of the two localities, the Kansas rocks are more recent than those of northeastern Iowa.

Mr. Walters promises to make further examination, and a few associated fossils will fix with greater accuracy the horizon of this species. It certainly is one of the later representatives of its race, and may prove to be the last one known.

Cornell University, Ithaca, December, 1880.

11. *The Northern Sahara.*—Mr. G. Rolland has a paper on the Geology and Hydrology of the Northern Sahara (south of Algiers and Tunis between Biskra and El Goleah, 350 miles) in the Annales des Mines, 7th ser., xviii, 152, 1880. He describes the country as rocky, and states that Cretaceous strata, consisting of hard limestone, often dolomitic, constitute, in nearly horizontal beds, high plateaus, and are overlaid by the Quaternary. The Cretaceous formations recognized by the fossils, as near El Goleah and Mechgarden, are the Cenomanian and Turonian. The Quaternary deposits are coarse, but regularly stratified, and are of fresh-water origin. There are in places saline lagoons which were formerly more extensive, and this fact accounts, as M. Tournoüer has shown, for the occurrence of *Cardium edule* as a common shell along with fresh-water species.

12. *Arctic Coal.*—The mineral coal of Grinnell Land, near the winter quarters of H. M. S. Discovery, lat. 81° 43′ N. and long. 64° 4′ W., from beds whose overlying shales contain plants referred to the Miocene, afforded Mr. R. J. Moss (Proc. R. Dublin Soc., May, 1878), on analysis, Carbon 75·49, hydrogen 5·60, oxygen and nitrogen 9·89, sulphur (including 0·36 of S from pyrite) 0·52, ash 6·49, water 2·01=100. The composition is like that of much Carboniferous bituminous coal, which it resembles closely in luster. Sp. gr. = 1·3. The coal cakes when heated and affords 61 per cent of a coherent coke.

13. *The Claiborne Group and its remarkable fossils;* by Professor P. H. Mell, Jr., Auburn, Alabama. 10 pp. 8vo, 1880. (Trans. Amer. Inst. of Mining Engineers.)—The author of this paper can not be a geologist. In a section on page 5, stated to be "after Tuomey," he has the "Drift" put in, conformably, between the Coal-measures and the Cretaceous, which is certainly not after Tuomey; and the text referring to "the accompanying sketch" shows a like misapprehension of the facts. He says that there is only one locality of Zeuglodon remains in Alabama and devotes a paragraph to the explanation of this limited distribution, when it is not a fact. Again, speaking of the Tertiary, he remarks that "several strata displayed at Claiborne which contain but few fossils must have been deposited in a short space of time by the *great influx of ice-bearing sediment.*" Thus the Tertiary, as well as the Cretaceous, is badly mixed up with the Drift.

14. *Paleontology of Austria-Hungary.*—A new periodical in 4to, bearing the title "Beiträge zur Palaeontologie von Oesterreich-Ungarn," has been recently commenced under the editorship of E. v. Mojsisovics and M. Neumayr. The prospectus (dated May, 1880) states that about 200 pages and 30 plates are to be issued yearly, and that the annual subscription will be $10. All the prominent paleontologists of the Austrian empire have pledged their coöperation. Subscriptions should be sent to Mr. Alfred Hölder, 1 Rothenthurmstrasse, Vienna.

15. *A crystallized Mineral made from bricks at Blaenavon in Monmouthshire.*—J. Emerson Reynolds reports (Proc. R. Dub-

lin Soc., May, 1879), that in the oven of a Bessemer converter which was lined with ordinary siliceous fire-bricks, basic bricks were piled on the floor in contact with this lining; and that, after reaching an intense white heat, the pile or stack of basic brick subsided and (as was afterward discovered) its lower layers actually passed through the flooring leaving sharply cut outlines of their angles in the siliceous bricks. The refractory basic brick were made from an aluminous magnesian limestone. The resulting fused mass was partly in semi-transparent crystals of long prismatic form, either colorless or greenish, with sp. gr. = 2·934; and they afforded on analysis the formula of a lime-and-magnesia pyroxene—the results obtained being Silica 55·35, lime 23·24, magnesia 16·20, alumina and iron-sesquioxide 4·20, water, loss, etc. 1·01 = 100, corresponding, if the alumina and iron are set aside as impurity, to $(\frac{1}{2}Mg+\frac{1}{2}Ca)SiO_3$.

16. *Fossil Sponge-spicules from a clay bed in the Carboniferous strata near Sligo, Scotland;* by Professor H. J. CARTER (Ann. Mag. Nat. Hist., V, xxxiii, 209).—Of the spicules here described, the most common is a sexradiate stellate kind, with 6 to 24 rays, according to the subdivisions of the arms, and having each ray spiriform—named by Carter *Holasterella Wrightii;* the other kinds are the hexactinellid, lithistid, and a sausage-shaped kind, like that of some of the *Renieræ* of the present day. *Holasterella conferta* has been found in a similar clay near Glasgow. Mr. Carter observes that "not only are the sponge-spicules, and the minute fossils of the Carboniferous limestone which accompany them, silicified and pitted on the surface with the same kind of rhomboidal excavations, but the "chert" to which Mr. Wright has alluded appears to be a solid pseudomorph of the limestone; for its pumice-like worm-eaten character occurring here and there, from partial absorption or decomposition of the material, presents a skeletal rhomboidal structure; while the same kind of rhomboidal excavations characterize the surface of the weather-worn *calcareous* fossils in the *pure Devonian limestone* of this neighborhood; by which I am led to infer that, in the first place, the sponge-spicules become partially or wholly calcified among *calcareous* material, else why should they now present rhomboidal excavations on their surface? that subsequently the siliceous element, being liberated, replaced the calcareous material so as to form the "chert;" and, thirdly, that the rhomboidal excavations on the surface of the spicules and the partial absorption of the spicules themselves, leaving nothing but their moulds, arises from the changes which the siliceous element itself is now undergoing—that is, becoming decomposed and removed, or passing from an amorphous state into clear quartz prisms."

17. *Glaciation of the Shetland Isles and the Orkneys.*—This subject has been well studied by Messrs. B. N. Peach and J. Horne. A paper by them on the Shetland Isles, published in the Quarterly Journal of the Geological Society for 1879, is referred to on page 72 of the last volume of this Journal; and another, on

the Orkney Islands, has since appeared in the Quarterly Journal for 1880 (pp. 648–663). In the former it was shown, from the striated surfaces and other evidence, that the region of the Shetland Isles had been glaciated by Scandinavian ice; and in the latter also the agency of the Scandinavian ice-movement is recognized; and the course of movement in both regions was mostly between W.N.W. and N.N.W. But while the Scandinavian glacier-mass was concerned in the great movement over both regions, in the case of the Orkneys, which are near Northern Scotland, the ice glaciating them came mainly, if not wholly, from Northeastern Scotland. This is apparent from the fragments of Scottish rocks, some of them fossiliferous, in the Orkney drift. The glacier of Northern Scotland descended northeastward over the west part of the North Sea, and there joined the great Scandinavian mass moving northwestward, in the direction of least resistance. The authors state that there is no evidence of marine drift deposits on the islands; and the absence of marine shells from the bowlder-clay is thought to "probably indicate that a portion of the present sea-floor round Shetland formed dry land during the climax of glacial cold." The facts are stated to confirm the views advocated by Dr. Croll more than ten years since. Two maps illustrate the recent article, one showing the striations of the Orkneys, and the other, the "probable path of the ice," from Scandinavia and Scotland over the islands named, and beyond to the margin of the deep-water trough of the ocean.

18. *Queensland Geology.* Report on the Geology and Mineral Resources of the district between Charters Towers Goldfields and the Coast; by R. L. Jack, F.G.S., Geological Surveyor Northern Queensland. Brisbane, 1879.

19. *Mineral discoveries in Alexander County, North Carolina.*—Mr. W. E. Hidden, who has been engaged for some time past in active mineral exploration in Western North Carolina, gives the following notes in regard to minerals found in Alexander County.—Beryl occurs in green, yellow, bluish and sometimes colorless crystals. The crystals are well terminated and often highly modified, resembling those from Siberia; they are generally implanted in cavities. A few fine crystals of a light chrome-green have been found loose in the soil on the Warren plantation. Spodumene is found on the Warren and Lyon plantations in small transparent crystals of a beautiful green color, associated with rutile, beryl, orthoclase and pyrite in a narrow vein. This variety of spodumene has been called Hiddenite by Dr. Smith (see p. 128). Rutile is found in brilliant crystals, often geniculated, transparent and of a beautiful deep red color. The best from Milholland's mill and R. Johnson's. Monazite in small splendent crystals occurs with rutile at Milholland's mill. Quartz occurs at many localities and in great variety of form and color, some of the crystals very beautiful. They are often highly complex, and rank with the most interesting of those from Switzerland. Many of the crystals enclose other minerals, such as chlorite, asbestus,

rutile, tourmaline, spodumene, and siderite. Other crystals contain fluid cavities. ORTHOCLASE occurs in large well-formed crystals (one weighed 40 lbs.) on the Price and Keever lands in a coarse granitic vein, associated with beryl, tourmaline, columbite, autunite, mica. TOURMALINE in fine brown-black crystals are found in the Price mine, also brilliant black crystals at B. Lyon's. In addition to the minerals already named, graphite, sphene, magnetite also occur in the county.

20. *Analysis of Jarosite from the Vulture mine, Arizona;* by S.F.PENFIELD. (Communicated).—The occurrence of jarosite with gold in the Vulture mine, Arizona, has been mentioned by Prof. B. Silliman (this Journal, xviii, 73, 1879). The variety analyzed is found in minute transparent crystals of a brownish-yellow color. It forms a frosted coating on cellular quartz, giving to the specimen a somewhat rusty look; under the microscope, however, the coating is resolved into distinct individual crystals, delicately grouped together. The crystals are tabular in habit, being a combination of the basal and rhombohedral planes; the angle of $O \wedge R$ was measured approximately and the result agreed with that already accepted ($124\frac{1}{2}°$).

The mineral is slightly soluble in water, the solution giving a reaction for sulphuric acid but not for iron. An analysis on material free from impurity except a little quartz, gave:—

	SO_3	Fe_2O_3	K_2O	Na_2O	H_2O	Quartz.
Sp. gravity=3·09.	30·42	48·27	8·53	0·28	12·91	1·08=101·49

The calculated ratio for $SO_3 : Fe_2O_3 : K_2O(Na_2O) : H_2O = 4 : 3·18 : 0·99 : 7·55$.

The water determination is probably slightly in error; if the amount be determined by difference (=11·42), the result differs but little from the ratio required by the formula $K_2SO_4 + Fe_2S_3O_{12} + 2H_6Fe_2O_6$.

21. *Jarosite from Colorado.*—Dr. G. A. KÖNIG has recently described jarosite from the Iron Arrow Mine, Chaffee Co., Colorado. It occurs in seams and cavities in a siliceous turgite and hematite. It is found in minute brilliant crystals (*R* with *O*) isolated, also in groups and in crystalline crusts. The crystals are transparent, varying in color from a light amber-yellow to dark brown; the luster on the faces is adamantine, on the fracture resinous. Specific gravity =3·144. An analysis afforded

SO_3	Fe_2O_3	K_2O	Na_2O	H_2O	SiO_2	
28·57	51·10	7·13	0·84	10·56	2·40	=100·80

Rejecting the silica as an impurity, also 8·7 p. c. turgite ($Fe_4H_2O_7$), the remainder is found to correspond to 89·6 p. c. of jarosite ($K_2Fe_6S_4O_{22} + 6aq = K_2SO_4 + Fe_2S_3O_{12} + 2H_6Fe_2O_6$) with ·4 p. c. water in excess.—*Proc. Acad. Nat. Sci. Philad.*, 1880, p. 331.

22. *Octahedrite from Burke County, North Carolina;* by W. E. HIDDEN (from a letter dated Stony Point, N. C., Dec. 17, 1880). —This rare mineral was found by the writer in the auriferous gravels of Brindletown in the summer of 1879. Subsequent search in the vicinity has proved its distribution through all the

gold placers of the surrounding country. Its best locality is on the northern slope of the Pilot Mountain, especially at the mine of Capt. J. C. Mills.

The crystals are commonly tabular in form, consisting of the planes 1 and *O*, though crystals have also been observed of the common octahedral habit. Some few were highly modified. The planes are as a rule splendent excepting the basal plane which is dull and striated parallel to 1 and 1-*i*. The prismatic (*I*) cleavage can often be seen. The crystals are well preserved and unusually large, some measuring one-third of an inch across; they average a line in thickness. Color from greenish-yellow to black. Some few are quite *colorless* and *transparent* and would admit of polariscopic examination. In only one case were they found implanted and that was on quartz. They occur loose in the gravel, having been derived from the disintegration of the local schists. The accompanying minerals are monazite, xenotime, fergusonite, samarskite, zircon, brookite and thirty-five other distinct mineral species.

23. *On Urano-thorite.*—Professor PETER COLLIER has described a mineral from the Champlain iron region (exact locality unknown), which is closely related to thorite (orangite), but differs in containing considerably more uranium. It has a dark red-brown color, a resinous or sub-vitreous luster, yellow-brown streak and sub-conchoidal fracture. Hardness about 5; specific gravity =4·126. It is infusible before the blowpipe. An analysis yielded:—

SiO_2	ThO_2	U_2O_3	Fe_2O_3	Al_2O_3	PbO	CaO	MgO	Na_2O	H_2O
19·38	52·07	9·96	4·01	0·33	0·40	2·34	0·04	0·11	11·31=99·95

The name given to the mineral has reference to the large amount of uranium present; thorite contains 1·6 p. c., according to Berzelius.—*Journal Amer. Chem. Soc.*, vol. ii.

24. *Mineralojia* por IGNACIO DOMEYKO, Profesor de Quimica i Mineralojia en la Universidad de Santiago de Chile. Third edition. 762 pp. with 6 plates. Santiago, 1879.—The preceding edition (2d) of the valuable Mineralogy of Prof. Domeyko was issued in 1860. Since that time he has published five Appendixes to this work, in addition to numerous articles printed in different scientific journals. It is consequently a great convenience to mineralogists to have this new edition, in which the large number of new facts, due mostly to labors of the author himself, are incorporated. The minerals of Chili and the neighboring republics are in many cases of peculiar interest, and for our knowledge of them we are indebted almost entirely to Professor Domeyko, whose unwearying and most successful activity in investigation, far removed as he is from the scientific centers of the world, is worthy of high praise.

25. *Las Especies Minerales de la Republica Argentina* por el Dr. D. LUIS BRACKEBUSCH. 117 pp. 8vo. Buenos Aires, 1879. —Dr. Brackebusch has rendered an important service to science in publishing in compact form a description of the minerals of the

Argentine Republic. Under each name is given a description of the species, and a full list of localities with the associated minerals at each. The fact that much of the matter has either not been published before, or, if at all, in periodicals not generally accessible, makes the book a valuable one to all interested in mineralogy, and gives it more than a local interest.

26. *Zoology for High Schools and Colleges;* by A. S. PACKARD, JR. Second edition, revised. New York: Henry Holt & Co. 1880.—In this edition, many improvements have been introduced, and some errors contained in the first edition have been corrected. The objectionable figures of the brains of fishes and of the anatomy of the cat have been replaced by new and better figures, drawn by Dr. C. S. Minot. The total number of cuts is 475, most of which fairly represent the objects for which they were intended, but there are still remaining some that were very badly engraved and others that were evidently badly drawn, and which might well have shared the fate of those that have been discarded. V.

III. ASTRONOMY.

1. *On the Figure of the Planet Mars and its accordance with the hypothesis of the former fluidity of the planet;* by Professor HENNESSY, (C. Rend., June, 1880).—Professor Hennessy here gives a calculation of the polar depression in Mars, supposing it to have been a result of rotation during a condition of fluidity. Assuming that the mass is distributed in spheroids of equal density, the density increasing from the surface to the center, and that the ellipticity depends on this law and the period of rotation of the planet, he arrives at the value

$$e = \frac{1}{227{\cdot}61}$$

which he says is very near the result obtained in the careful observations of Professor C. A. Young,* namely,

$$e = \frac{1}{219}.$$

Professor Hennessy also calculates the polar depression supposing it to be a result of erosion by a liquid moving over the surface of the planet, and obtains

$$e' = \frac{1}{179{\cdot}24},$$

which he observes is sensibly larger than the results of the best measurements. He states, therefore, that Young's result much better accords with the hypothesis of the former fluidity of the planet than with that of a shaping by erosion; and that this corresponds with the parallel fact as regards the earth.

* This Journal, xviii, 206, March, 1880.

IV. Miscellaneous Scientific Intelligence.

1. *Ocean temperatures in the Arctic—Observations taken on the S. S. Gulnare, by* O. T. Sherman.—The following observations were taken on the Arctic S. S. Gulnare, during the summer of 1880. A Miller-Cassella thermometer was employed; its scale errors, carefully obtained, have in each case been applied. The steamer, at the time of making the observations, lay becalmed. If we refer to the older maps we see that on some the warm waters which render the west coast of Greenland habitable are connected with the Arctic current which renders the east coast barren. On others the warm current is shown at once as a branch of the Gulf Stream. On the newer German maps the currents are shown overlapping in about latitude 61° N. The following table serves to give confirmation to this latter representation, and also indicates the limits and depth.

Table I.—*Deep Sea Temperatures.*

Depth in fathoms.	Lat. 60° 6′ N. Long. 56° 36′ W.	Lat. 57° 33′ N. Long. 55° 15′ W.
0	41°·9 F.	45°·0 F.
10	41·8	----
20	40·0	----
30	----	45·0
60	39·0	40·0
90	----	39·0
110	38·8	----
150	38·2	40·0
270	40·8	----
300	40·8	----

The sudden rise in temperature at the lowest depths naturally caused some surprise to the observer, and was therefore measured three times. These observations may also in part explain the bend in the curve representing the limit of ice.

Phenomena of some rarity in the surface temperatures and densities were also observed by us. When passing in front of a glacier outlet, or across the track of the ice pack, we suddenly entered a body of water much colder and fresher than that surrounding it. The ice in each case readily suggested an explanation. Our interest was more excited at the depth of the freshened water, for the engineer found independently the same changes of density in the water he took into the boiler about ten feet below the surface. On one occasion we had to sink a thermometer ten fathoms before obtaining indications of a rise in temperature.

It is true that the outcropping of the Arctic current would give similar phenomena, but to one on the spot the change was always seen to be connected with the melting of the ice.

TABLE II.—August 4, 1880.

Position.	Hour.	Surface Temperature.	Density Hydrometer, scale reading.	Remarks
	5	44·°0	4°·0=1·027316	
	6	46·0	4·0=1·027383	
	7	46·0	4·0=1·027383	
	8	35·5	2·5=1·016492	A deep-sea thermometer sank 10 fathoms, read 40°·0.
	9	36·0	2·8=1·018644	
	--	----	------------	
Cape Desolation sighted abeam,	10	39·5	3·0=1·020064	
	11	36·0	2·8=1·018644	
	12	36·0	3·2=1·021521	
	1	37·0	2·8=1·018527	
	2	42·0	2·8=1·018652	
	3	42·0	3·0=1·020091	
	4	43·0	3·0=1·020107	
		August 5, 1880.		
	2	44·°	3·0=1·020122	
Latitude 61° 27′,	3	44·	3·0=1·020122	
	4	36·	2·5=1·016486	Opposite glacier, about 30 miles off shore.
	5	37·	3·0=1·020068	
	7	37·8	2·8=1·018508	
Lat. 63° N., long. 51°,		Aug. 6, 1880.		
	4	38·0	4·0=1·027246	
	5	37·5	4·0=1·027240	
	6	38·0	4·0=1·027246	

2. *International Exposition of Electricity, under the patronage of the French Government at Paris, in* 1881.—An International Exposition for the conference of electricians and the exhibition of all kinds of electrical apparatus, practical and theoretical, will be opened at Paris on the 1st of August next, and closed on the 15th of November. The exposition is put under the department of the Minister of the Post Office and Telegraphy, M. AD. COCHERY, and under the special superintendence of M. GEORGES BERGER as Commissary General. The *Palais des Champs Elysées* is assigned for the exhibition. Announcements as to the apparatus and materials to be put on exhibition by individuals, and as to the space desired, should be made to the Commissary General by the 31st of March, who will send forms for their admission on being applied to, and special labels for packages, and will notify contributors by the 15th of May with respect to the space allotted them. Packages will be received at the grounds of the Palais des Champs Elysées on and after July 1st. They should be addressed *Commissaire Général de l'Exposition internationale d'Electricité, au Palais des Champs Elysées, porte No. IV.* No charge will be made for the space given. Motive power will be furnished at a low price to such as desire it, but without charge for all necessary experiments. The articles for exhibition will comprise:

Apparatus for the production and transmission of electricity. Native and artificial magnets and magnetic needles. Apparatus for the study of electricity.

Apparatus for its various applications; for telegraphy and the transmission of sound; for the production of heat; for illumination and uses in light-houses and signals; for mines, railroads and navigation; for military purposes; for the fine arts; in galvanoplasty, electro-chemistry and the chemical arts; for the production and transmission of motive power; in horology; in medicine and surgery; in astronomy, meteorology and geodesy; in agriculture; for registering purposes; for working various kinds of industrial machines, and for domestic uses.

Lightning rods. Collections of apparatus illustrating the history of the subject and its applications from the earliest times. Collections of books and memoirs pertaining to the science and to electrical industry.

In connection with the exposition, an International Congress of Electricians will be opened on the 15th of September, under the presidency of Minister AD. COCHERY.

3. *A History of the Jetties at the Mouth of the Mississippi River;* by E. L. CORTHELL, C.E., Chief Assistant and resident Engineer during their construction. 383 pp. 8vo, with numerous plates and maps. New York: 1880. (John Wiley & Sons).—This volume gives a detailed history of the construction of the Mississippi jetties by Mr. James B. Eads, from the time when this plan was first proposed until its final completion. The account is written in popular style, and will be read with interest even by those who have no knowledge of the scientific problems involved in the work. The excellence of the scheme as a whole has been proved by the success finally attained, and the perseverance and enterprise with which it was carried forward in the face of discouragements and difficulties of all kinds are deserving of high commendation. The position of Mr. Corthell as chief assistant and resident engineer has given him a minute and personal knowledge of the many details in the progress of construction of the jetties, and much of the interest of the book is due to this fact. Numerous charts and plates show among other things the successive steps in progress of the work, and the corresponding results attained in the deepening of the river channel. A portrait of Mr. Eads, to whom the success of the plan is most of all due, forms a frontispiece to the volume.

OBITUARY.

An announcement of the death of M. CHASLES appeared in the January number of this Journal. It occurred on the 18th of December last, in his 88th year, he having been born on the 15th of November, 1793. It is nearly seventy years since the first publication of the distinguished geometer appeared in Hachette's Correspondence; and his scientific activity has continued into the last year of his long life.

The larger works of M. Chasles are five in number: *Aperçu Historique sur l'Origine et le Développement des Méthodes en Géométrie*, *Traité de Géométrie Supérieure*, *Traité des Sections Coniques*, *Les trois livres des Porismes d'Euclid*, and *Rapport sur* *le Progrès de la Géométrie en France.* Besides these, however, there are between two and three hundred of his memoirs in the Academic publications and scientific journals.

His demonstrations were remarkable for their neatness and perfection of form. In geometry this quality is all important. Shortly after his appointment as Professor of Higher Geometry in the Faculty of Sciences at Paris, he published his *Traité de Géométrie Supérieure.* This was some years later followed by his *Traité des Sections Coniques.* In these volumes, as well as in his memoirs, M. Chasles uses in his demonstrations, three conceptions in addition to those of Euclid, *the anharmonic function of four points, homographic divisions,* and *involution of six points.* By these conceptions he introduces many of the advantages of analytic geometry into what will probably still be regarded as synthetic geometry. If asked what is the real addition thus made to Euclid we might answer: 1st, the conception of plus and minus segments of lines, and, 2d, the use implicitly of the relations of the roots and coefficients of the equation of the second degree. That is, he added to synthetic geometry the resources of the algebra of simple and quadratic equations. With the skill of a master he wrought into formal and logical connection the theorems that have enriched geometry in these later years, adding everywhere new propositions and new chapters of his own to the science.

Rarely has there lived a man more steadfast in his devotion to one object through life, more simple in character and aims, more charming in social intercourse, more honored and beloved by all who had the good fortune to know him. H. A. N.

First Annual Report of the Department of Statistics and Geology of the State of Indiana. 514 pp. 8vo, Indianapolis, 1879. Devoted to State Statistics, Agricultural, Social, Vital, etc.

Annual Report of the Curator of the Museum of Comparative Zoology at Harvard College to the President and Fellows of Harvard College for 1879–80.

Thirty-fifth Annual Report of the Director of the Astronomical Observatory of Harvard College; presented to the Visiting Committee, December 6, 1880, by Edward C. Pickering.

James Smithson and his Bequest, by William J. Rhees. 159 pp. 8vo, Washington, 1880. (Smithsonian Miscellaneous Collections, 330). This volume contains a sketch of the life of James Smithson, a list of his writings, notices of his death and tributes to his memory; it also gives a statement in regard to the founding of the Smithsonian Institution by his bequest.

Introduction to the Study of Indian Languages with words, phrases and sentences, to be collected by J. W. Powell. 4to, with several charts. Washington, 1880. This volume is intended to aid those engaged in collecting linguistic and ethnographic facts from the Indian tribes. After a chapter on the alphabet, and another of "hints and explanations," occupying together about 76 pages, there are 150 pages of schedules, for use in taking notes, containing, in a marginal column, lists of objects and sentences, with broad blank columns for the corresponding Indian terms and additional remarks.

APPENDIX.

ART. XIX.—*Principal Characters of American Jurassic Dinosaurs;* by O. C. MARSH. Part IV. *Spinal Cord, Pelvis, and Limbs of Stegosaurus.* With three Plates.

IN a previous article,* the writer brought together the more important facts then known in regard to the *Stegosauria*, one of the most singular groups of extinct reptiles hitherto discovered. In the present communication some additional characters of these animals are recorded, even more remarkable than those previously brought to light.

THE BRAIN AND SPINAL CORD.

In the article cited above the brain-cast of *Stegosaurus ungulatus* was described and figured, and it was shown that this reptile had the smallest brain of any known land vertebrate. The general form and comparative size of the brain in this reptile is represented in Plate VI, figures 1 and 2.

During a subsequent investigation of another individual of the same genus, the writer found a very large chamber in the sacrum, formed by an enlargement of the spinal canal. This chamber was ovate in form, and strongly resembled the brain case in the skull, although very much larger, being at least ten times the size of the cavity which contained the brain. This remarkable feature led to the examination of the sacra of several other individuals of *Stegosaurus*, and it was found that all had a similar large chamber in the same position. The form and proportions of this cavity are indicated in Plate VI, figures 3 and 4, which represent a cast of the entire neural canal enclosed in the sacrum. The large vaulted chamber, it will be observed, is mainly contained in the first and second sacral vertebræ, although the canal is considerably enlarged behind this cavity. The sections represented in figure 5 are in each case made where the transverse diameters are greatest.

* This Journal, vol. xix, p. 253, March, 1880.

The remarkable feature about this posterior brain-case, if so it may be called, is its size, in comparison with that of the true brain of the animal, and in this respect it is entirely without a parallel. A perceptible swelling in the spinal cord of various recent animals has indeed been observed in the pectoral and pelvic regions, where the nerves are given off for the anterior and posterior limbs; and in extinct forms some very noticeable cases are recorded, especially in Dinosaurs, but nothing that approaches the sacral enlargement in *Stegosaurus* has hitherto been known. The explanation may doubtless in part be found in the great development of the posterior limbs in this genus; but in some allied forms, *Camptonotus* for example, where the disproportion between the fore and hind limbs is nearly as marked, the sacral enlargement of the spinal cord is not one-fourth as great as in *Stegosaurus.*

It is an interesting fact then in young individuals of *Stegosaurus* the sacral cavity is proportionately larger than in adults, which corresponds to a well known law of brain growth.

The physiological effects of a posterior nervous center, so many times larger than the brain itself is a suggestive subject, which need not here be discussed. It is evident, however, that in an animal so endowed, the posterior part was dominant.*

The Pelvic Arch.

The true sacrum of *Stegosaurus* is composed of four well coössified vertebræ. In fully adult animals the pelvic arch may be strengthened by the addition of one or more lumbar vertebræ, as in the specimen figured in Plate VII, where two are firmly consolidated with the sacrum. The centra of the sacral vertebræ are solid, like the others in the column. Their neural arches are especially massive, and the spines have high and expanded summits. The transverse processes of the sacral vertebræ are stout vertical plates, which curve downward below, and unite to meet the ilia. Each vertebra supports its own process, although there is a tendency to overlap in front. There is a gradual increase in size from the first to the last sacral vertebra, and the first caudal is larger than the last sacral.

The ilium in *Stegosaurus* is a very peculiar bone, unlike any hitherto known in the Reptiles. Its most prominent feature is its great anterior extension in front of the acetabulum. Another striking character is seen in its superior crest, which curves inward, and firmly unites with the neural arches of the sacrum, thus roofing over the cavities between the transverse processes. The acetabular portion of the ilium is large and

* The main facts here presented were communicated to the National Academy of Sciences, in a paper read at the New York meeting in November last.

shallow (Plate VII, figure 1, *ac.*) The face for union with the ischium is large and rugose, but that for the pubis is much less distinct. The post-acetabular part of the ilium is very short, scarcely one-third as long as the anterior projection.

The ischium of *Stegosaurus ungulatus* was figured and described in the communication already cited. It is short and robust, and has a prominent elevation on the upper margin of the shaft (Plate VIII, figure 2). Its larger articular face meets a post-acetabular process of the ilium, and a smaller articulation joins the pubis. The shaft of the ischium is twisted so that it resembles somewhat the corresponding bone of *Morosaurus.*

The pubic element of the pelvis of *Stegosaurus ungulatus* is in general form somewhat like that of *Camptonotus.* The true pubis consists of a strong spatulate process, projecting forward nearly horizontally. (Plate VIII, figure 2, *p.*) Its proximal end articulates with the pre-acetabular process of the ilium. The post-pubic branch extends backward and downward, nearly to the end of the ischium. The two bones fit closely together in this region. The usual pubic foramen is in this species replaced by a notch, opening into the acetabular cavity. In a smaller undescribed species, which may be called *Stegosaurus affinis*, the post-pubic bone is slender and more rod-like, not flattened, as in the specimen here figured.

The Hind Limb.

The large bones of the leg of *Stegosaurus ungulatus* have already been figured, and their main characters described. The femur is remarkably long, and without a third trochanter. The tibia, on the other hand, is very short. When the animal stood at rest, these two bones of the leg were nearly in the same line, as shown in Plate VIII, figure 2. The fibula is slender, and has its larger end below.

The astragalus is firmly coössified with the tibia, and the calcaneum is also united, but less securely. There are three bones in the distal row of tarsals. (Plate VIII, figure 2.) The one on the inner side is massive, and semi-circular in transverse outline. The median tarsal is still larger, while the outer one is quite small. There are five well developed metatarsals, which are of moderate length, and robust proportions. The first digit is terminated by a strong, broad, ungual phalanx, the largest of the series. The second, third and fourth digits also have similar phalanges of smaller size. The outer digit has only a tubercle at its extremity. The number of phalanges in the fourth and fifth digits has not been exactly determined, but they were less than the usual number.

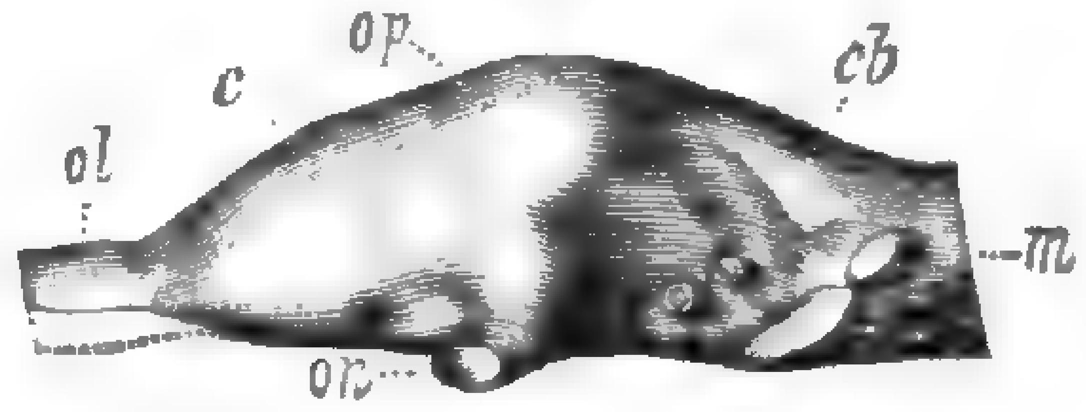
The Fore Limb.

The principal bones in the scapular arch and fore leg of *Stegosaurus* were described and figured in the article already cited. In Plate VIII, figure 1, these are brought together, and the fore foot added in its natural position. The humerus and bones of the fore arm show clearly that this limb, although very small in proportion to the hind leg, was very powerful, and as it admitted of considerable rotation, it was doubtless used mainly for other purposes than locomotion. The foot here represented was found by the writer, with the bones nearly in the position indicated. There are only three carpal bones in the proximal series, and in this foot the distal segment of the carpus remained unossified. There are five digits, the fifth being the smallest.

The great disproportion in size between the fore and hind limbs, as well as the structure of the principal joints in each, show plainly that *Stegosaurus* walked mainly as a biped. The massive posterior limbs, and the huge tail doubtless formed a tripod on which the animal rested at times, while the fore limbs were used for prehension, or defense. The heavy dermal plates and powerful spines probably rendered the latter an easy task.

Yale College, New Haven, Jan. 24th, 1881.

1.



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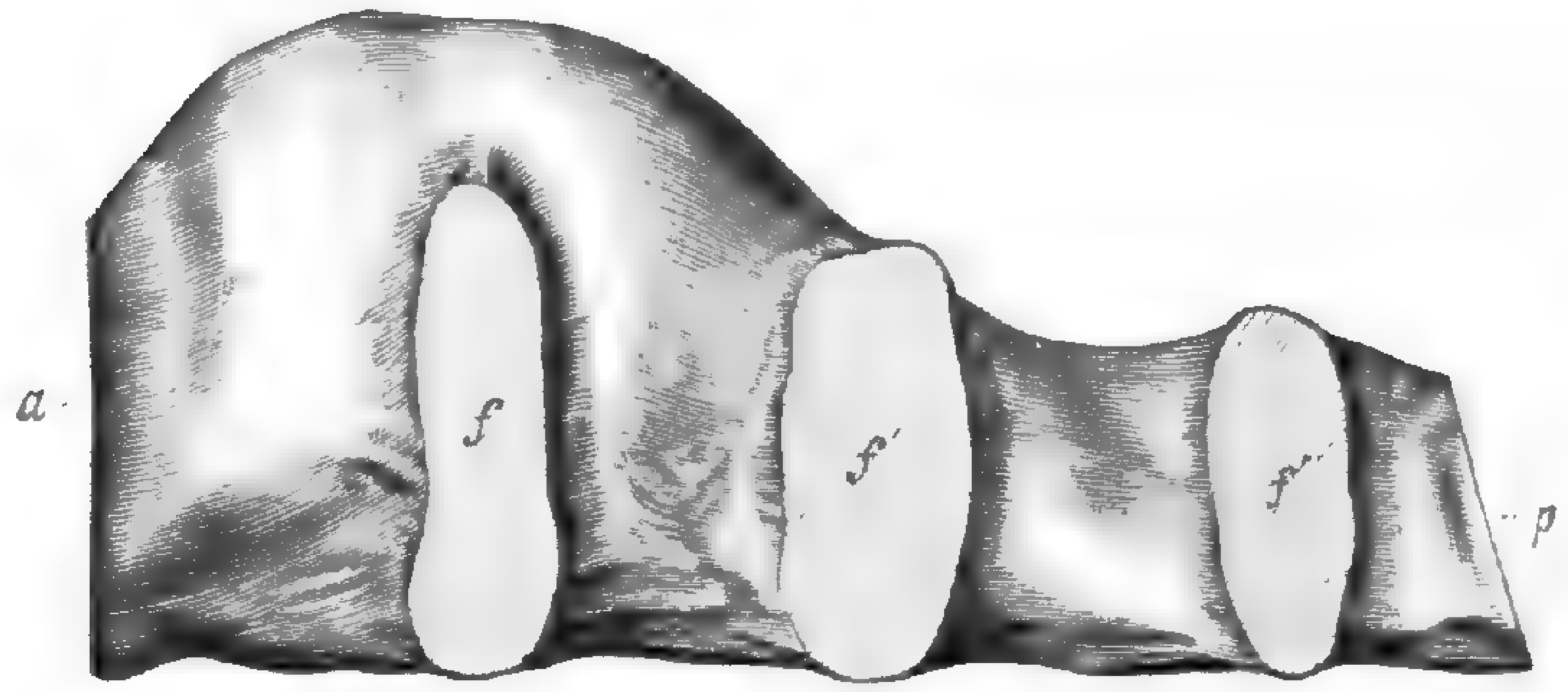

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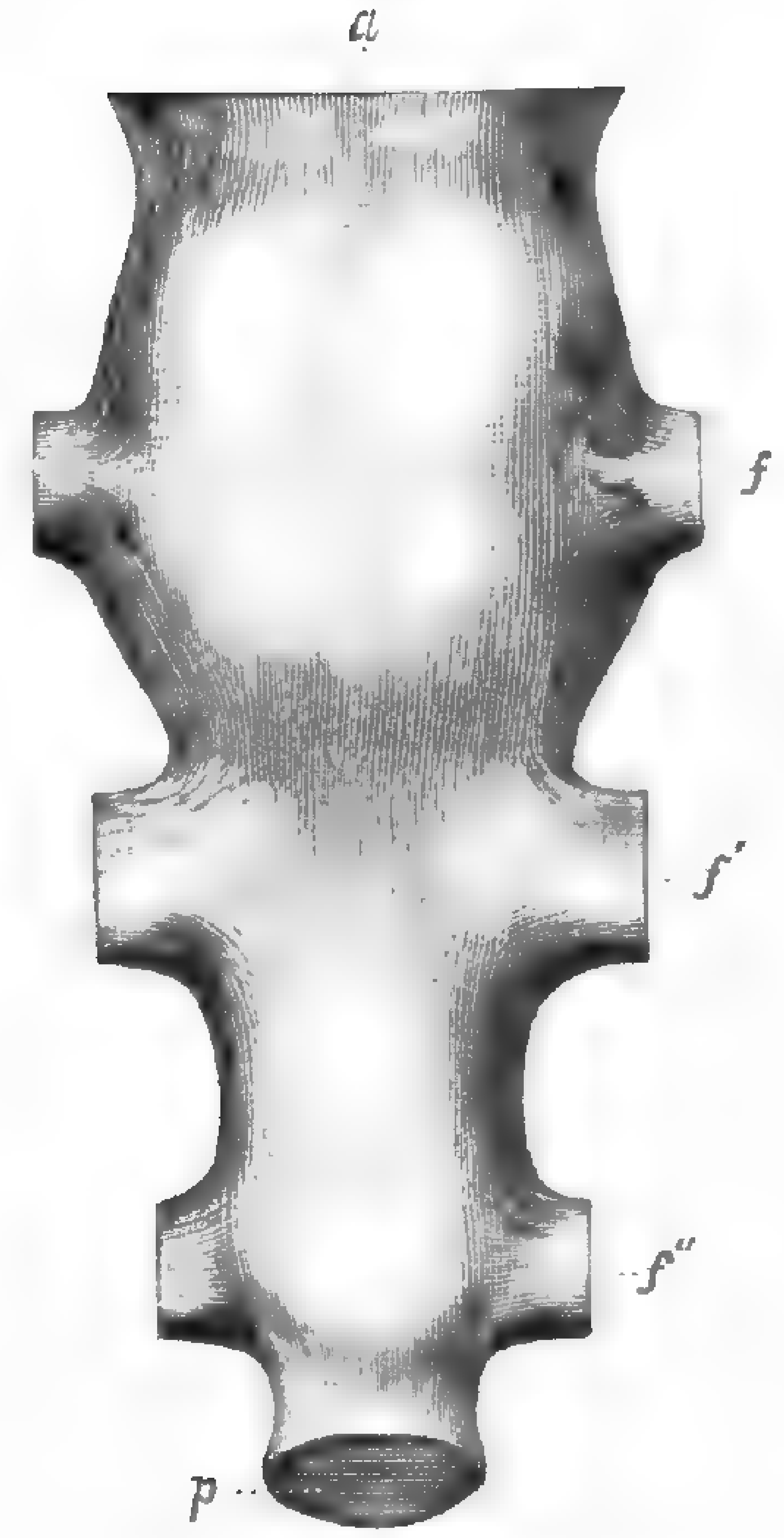

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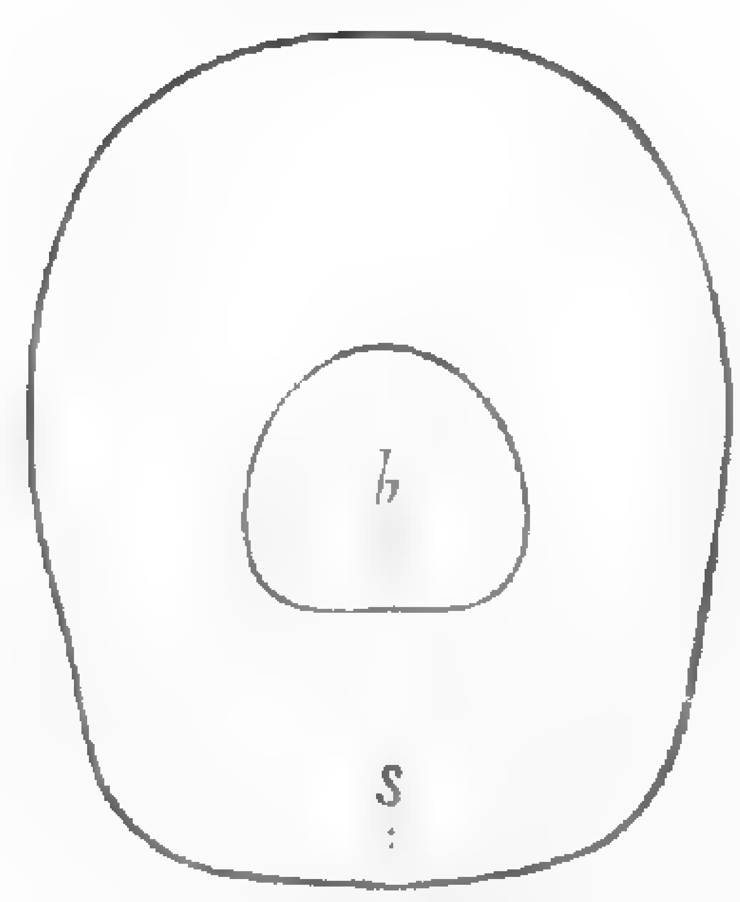

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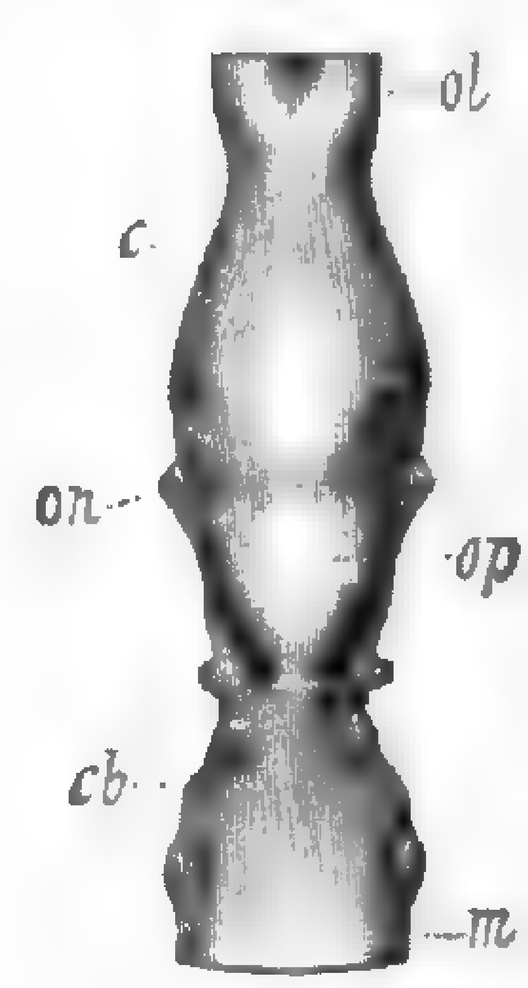

Figure 1.—Brain-cast of *Stegosaurus ungulatus*, Marsh, side view; *ol*, olfactory lobes; *c*, cerebral hemispheres; *op*, optic lobes; *on*, optic nerve; *cb*, cerebellum; *m*, medulla.

Figure 2.—Same brain-cast, seen from above.

Figure 3.—Cast of neural cavity in sacrum of *Stegosaurus ungulatus;* side view; *a*, anterior end; *f*, foramen between first and second vertebræ; *f'*, same between second and third vertebræ; *f''*, same between third and last vertebræ; *p*, exit of neural canal in last sacral vertebra.

Figure 4.—Same cast, seen from above.

Figure 5.—Outlines representing transverse sections through same brain, and sacral cavity; *b*, brain; *s*, sacral cavity.

All the figures are one-fourth natural size.

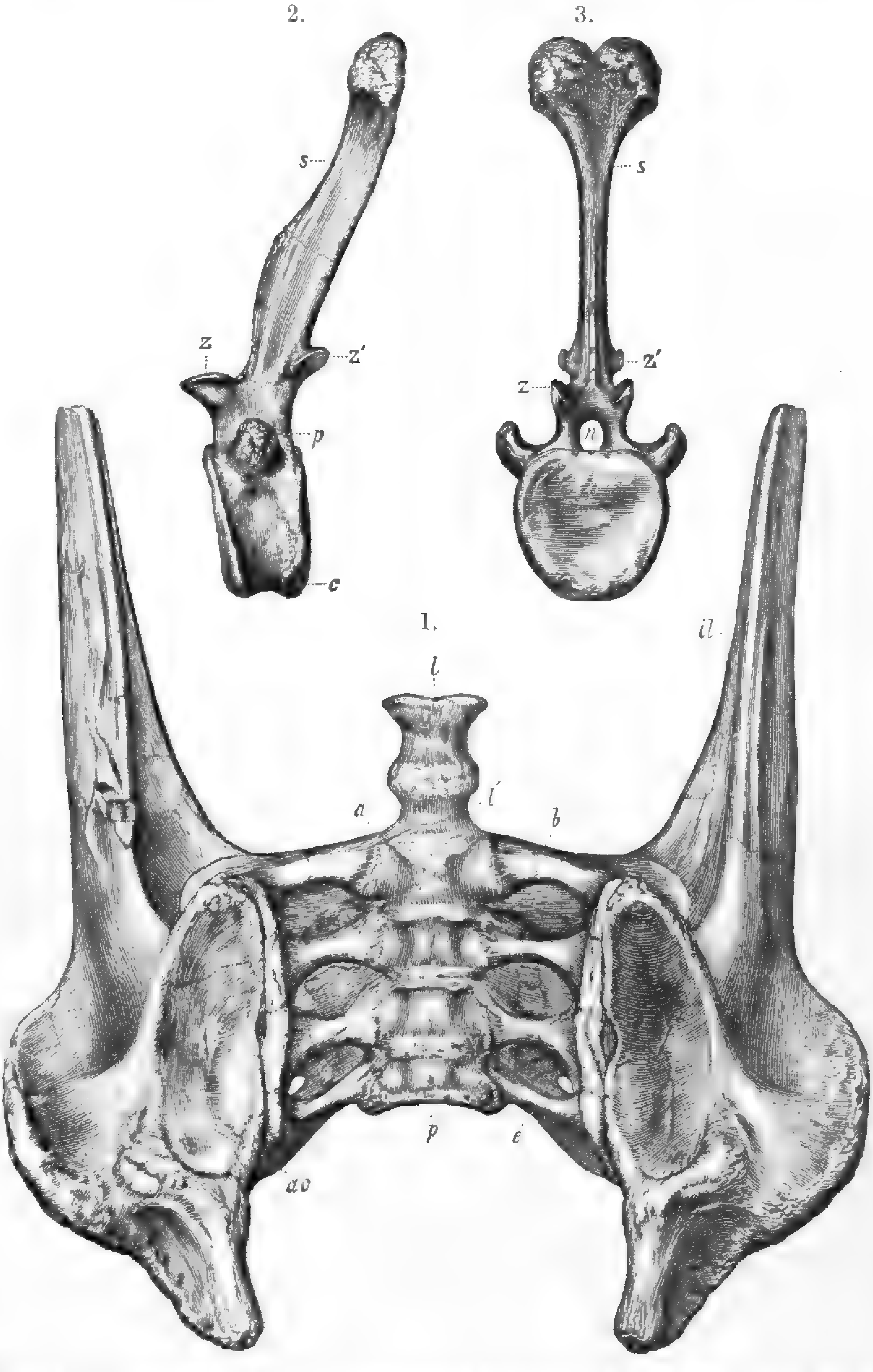

Figure 1.—Sacrum and ilia of *Stegosaurus ungulatus*, Marsh, seen from below. One-twelfth natural size. *a*, first sacral vertebra; *b*, transverse process of same; *p*, last sacral vertebra; *e*, transverse process of same; *l*, second lumbar vertebra from sacrum; *l′*, lumbar vertebra next to sacrum; *il*, ilium; *ac*, acetabulum.

Figure 2.—Anterior caudal vertebra of *Stegosaurus ungulatus*, side view; one-eighth natural size.

Figure 3.—Same vertebra, front view; *s*, neural spine; *z*, anterior zygapophysis; *z′*, posterior zygapophysis; *p*, transverse process; *n*, neural canal; *c*, face for chevron.

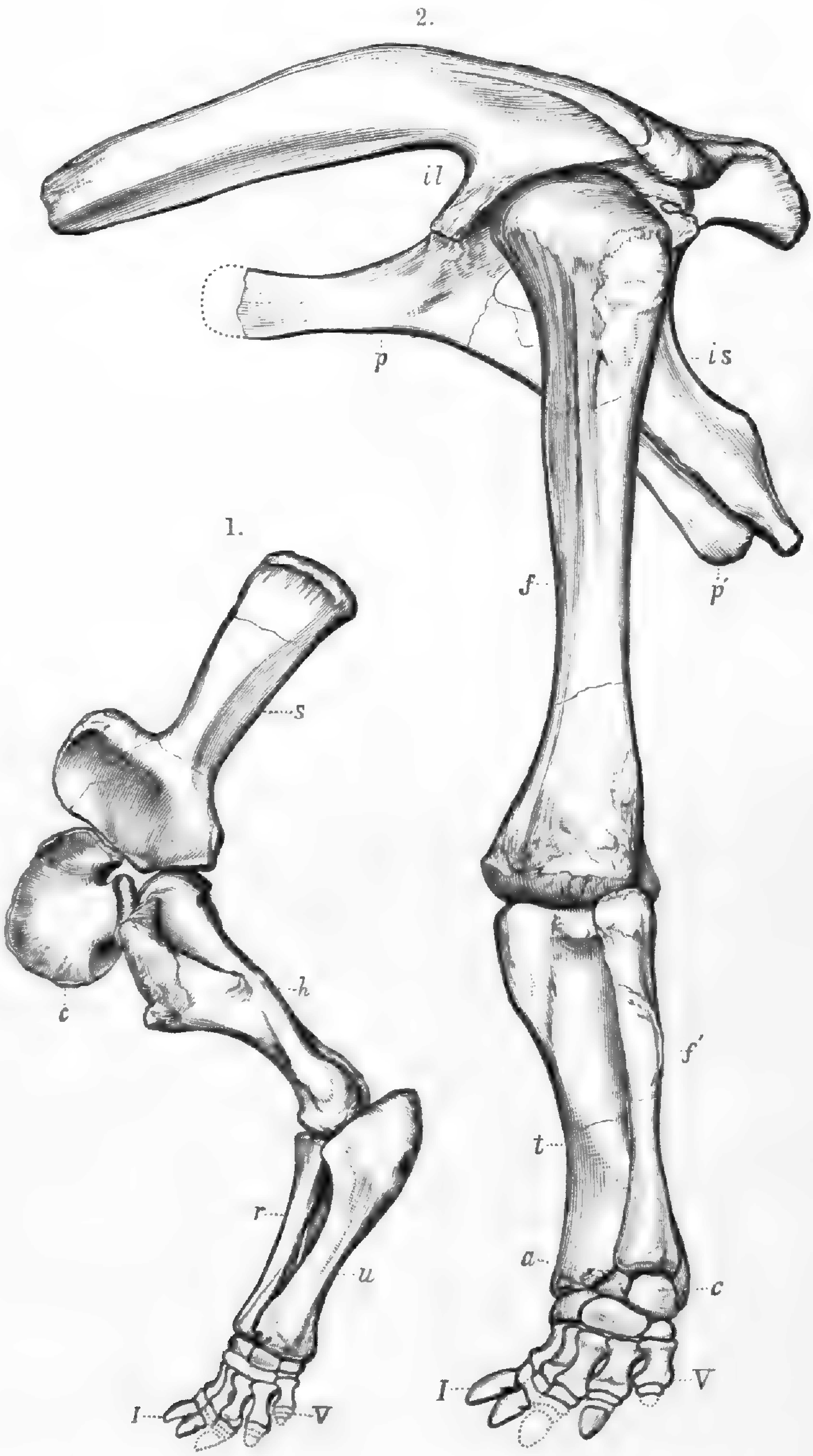

Figure 1.—Bones of left fore leg of *Stegosaurus ungulatus*, Marsh; *s*, scapula; *c*, coracoid; *h*, humerus; *r*, radius; *u*, ulna; *I*, first digit; *V*, fifth digit.

Figure 2.—Bones of left hind leg of *Stegosaurus ungulatus*; *il*, ilium; *is*, ischium; *p*, pubis; *p'*, postpubis; *f*, femur; *t*, tibia; *f'*, fibula; *a*, astragalus; *c*, calcaneum; *I*, first digit; *V*, fifth digit.

Both figures are one-sixteenth natural size.

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[THIRD SERIES.]

ART. XX.—*On the Phosphorograph of a Solar Spectrum, and on the Lines of its Infra-red Region;** by JOHN WILLIAM DRAPER, M.D., Professor of Chemistry in the University of New York.

I PROPOSE in this communication to consider: 1. The peculiarities of a phosphorograph of the solar spectrum as compared with a photograph of the same object; 2. The antagonization of effect of rays of higher by those of lower refrangibility.

There is a striking resemblance between a photograph of that spectrum taken on iodide of silver and a phosphorograph taken on luminous paint, and other phosphorescent preparations. There are also differences.

I. DESCRIPTION OF THE PHOTOGRAPHIC SPECTRUM.

In 1842, I obtained some very fine impressions of the first kind (on iodide of silver), and described them in the "Philosophical Magazine" (November, 1842), and again in February, 1847. One of these was made the subject of an elaborate examination by Sir J. Herschel. His description and explanatory views of it may be found in that Journal, February, 1843.

From these it appears that such a photograph, *taken in presence of a weak extraneous light*, may be considered as presenting three regions. 1. A middle one extending from the boundary of the blue and green to a little beyond the violet; in this region the argentic iodide is blackened. 2. Below this, and

* From the Proceedings of the American Academy of Arts and Sciences.

extending from the boundary of the blue and green to the inferior theoretical limit of the prismatic spectrum, is a region strongly marked in which the action of the daylight has been altogether arrested or removed, the daylight and the sunlight having apparently counterbalanced and checked each other. 3. A similar protected region occurs beyond the violet. This, however, is very much shorter than the preceding. The sketch annexed to Herschel's paper represents these facts as well as they can be represented by an uncolored drawing.

II. Description of the Phosphorographic Spectrum.

In a phosphorograph on luminous paint the same general effects appear. If the impression of the spectrum be taken in the absence of extraneous light, there is a shining region corresponding to the blackened region of the photograph. But if, previously or simultaneously, extraneous light be permitted to be present, new effects appear. The shining region of the phosphorograph has annexed to it, in the direction of the less refrangible spaces and extending toward the theoretical limit of the spectrum, a region of blackness in striking contrast to the surrounding luminous surface. The blackness is, however, broken at a distance below the red by a luminous rectangle of considerable width. This occupies the space, and indeed arises from the coalescence of the bands, α, β, γ, discovered by me in 1842. It may be separated into its constituent bands, which are very discernible when registered on gelatine as presently described. And since this is not so easily done with the upper lines of the spectrum, we may infer that these are very much broader than the Fraunhofer lines, a result strengthened by the fact that these dark intervals can be more easily recognized by the thermopile than those lines. The blackness is then resumed. It extends to a short distance, and there the phosphorographic impression comes to an end.

This shining rectangle has long been known to students of phosphorescence, but its interesting origin has not until now been explained.

But more, just beyond the region of the violet, the same kind of action occurs,—a dark space, which, however, is of very much less extent than that beyond the red.

The photograph and the phosphorograph thus present many points of similarity. But though there are these striking points of resemblance, there are also striking differences.

In a spectrum four or five centimeters long, though the photograph may be crossed by hundreds of Fraunhofer lines, not one is seen in the phosphorograph, except those just referred to. The spectrum must be dispersed much more before they can be discerned.

III. Of the Propagation of Phosphorescence from Particle to Particle.

The explanation of this disappearance of the Fraunhofer lines is obvious. A phosphorescing particle may emit light enough to cause others in its neighborhood to shine, and each of these in its turn may excite others, and so the luminosity may spread. In a former memoir I examined this in the case of chlorophane, and concluded that in that substance such a communication does not take place. But now, using more sensitive preparations, as follows, I have established in a satisfactory manner that it does.

The test plate referred to in the next paragraph was thus made. A piece of glass was smoked on one side in a flame, until it became quite opaque. When cool a few letters or words were written on it. Some photographic varnish was poured on it and drained. This, drying quickly, gave a black surface which could be handled without injury.

A phosphorographic tablet was made to shine by exposure to the sky. It was then carried into a dark room, and the test plate laid upon it. On the test plate another non-shining phosphorographic tablet was laid, and kept in that position a few minutes; then, on lifting this from the test plate, the letters were plainly visible, especially if it were laid on a piece of hot metal. So the light radiating from the first tablet through the letters of the test could produce phosphorescence in the second tablet, through glass more than a millimeter thick.

This lateral illumination is therefore sufficient to destroy the impression that is left by the fixed lines, unless indeed their breadth be sufficiently exaggerated, and as short an interval as possible permitted between the moment of insolation and that of observation.

It has been remarked that a photograph taken from a phosphorograph is never sharp. It looks as if it were taken out of focus, and this even though it may be a copy by contact. The light has spread from particle to particle. Under such circumstances, sharpness is impossible, because the phosphorograph itself is not sharp.

For this reason, also, the bright rectangle in a phosphorograph of the solar spectrum, arising from the coalescence of the infra-red lines α, β, γ, is never sharp on its edges. It seems as if it were fading away on either side. It is also broader than would correspond to the actual position and width of those lines, and, particularly, it is somewhat rounded at its corners.

If we could obtain a thermograph of the solar spectrum, it would correspond very closely to the phosphorograph. The particles heated would radiate their heat to adjacent ones.

Nothing like sharpness of definition could be obtained except in very brief exposures before the effect had had time to spread.

IV. Examination of Phosphorescent Tablets by Gelatine Photography.

The examination of a phosphorescent surface can be made now in a much more satisfactory manner than formerly. The light we have to deal with, being variable, declines from the moment of excitation to the moment of observation. And, though the phosphori now prepared are much more sensitive and persistent than those formerly made, they must still be looked upon as ephemeral. To examine them properly, the eye must have been a long time in darkness to acquire full sensitiveness.

It was recommended by Dufay to place a bandage over one eye that its sensitiveness might not be disturbed, whilst the other being left naked could be used in making the necessary preparations. But this on trial will be found, though occasionally useful, on the whole an uncomfortable and unsatisfactory method.

The exceedingly sensitive gelatine plates now obtainable remove these difficulties. The light emitted by blue phosphori, such as luminous paint, consists largely of rays between H and G, and these are rays which act at a maximum on the gelatine preparation. So if a gelatine plate be laid on a shining blue phosphorus it is powerfully affected, and any mark or image that may have been impressed on the phosphorus will on development in any of the usual ways be found on the gelatine. The gelatine has no need to wait after the manner of the eye. It sees the phosphorus instantly. It is impressed from the very first moment, and while the eye is accommodating itself and so losing the best of the effect, the gelatine is gathering every ray and losing nothing. Moreover, the effect upon it is cumulative. The eye is affected by the intensity of the emitted light, the gelatine by its quantity. Each moment adds to the effect of the preceding. The gelatine absorbs all the light that the phosphorus emits from the moment of excitation, or by suitable arrangement any fractional part thereof. It has another most important advantage. The phosphorus is yielding an ephemeral result, and is momentarily hastening to extinction, so that for a comparison of such a result with others of a like kind the memory must be trusted to. But the gelatine seizes it at any predetermined instant and keeps it forever. These permanent representations can at any future time be deliberately compared with one another.

To these still another advantage may be added. Very frequently an impression is much more perceptible on a gelatine copy than it is on the phosphorus from which that copy was taken. This arises from the fact that the eye is made less sensitive by the light emitted from surrounding phosphorescent parts, and cannot perceive a sombre point or line among them. That is a physiological effect. But a gelatine copy in no respect dazzles or enfeebles the eye. For this reason, for instance, we may not be able in a phosphorograph to resolve visually the infra-red bright rectangle into its constituent lines, but we recognize them instantly in the gelatine.

I have made use of sensitive gelatine plates ever since their quality of being affected by phosphorescent light was announced by Messrs. Warnecke and Darwin. The more sensitive of these plates receives a full effect by an exposure of less than one minute.

But all kinds of phosphori will not thus affect a photographic tablet: there must be a sympathy between the phosphorescent and the photographic surfaces. Thus a phosphorus emitting a yellow light will not affect a photographic preparation which requires blue or indigo rays. This principle I detected many years ago. In my memoir on phosphorescence (Phil. Mag., February, 1851), it will be seen that the green light emitted by chlorophane could not change the most sensitive photographic preparation at that time known—the daguerreotype plate—and hence I was obliged, in measuring the light it emits, to resort to Bouguer's optical method. The result would have turned out differently had the light to be measured been more refrangible, blue or indigo or violet.

A photographic surface agrees with the retina in this, that it has limits of sensitiveness. The eye is insensible to rays of much lower refrangibility than A, and much higher than H. Gelatine cannot perceive rays lower than F, but it is affected by others far higher than H. There is therefore a range for each, having its limits and also its place or point of maximum sensitiveness. But some substances, such as the iodide and bromoiodide of silver, under special methods of treatment are affected either positively or negatively throughout the entire range of the spectrum.

In experiments for obtaining quantitative results, it should be borne in mind that there is generally a loss of effect. Between the moment of insolation and that of perception, either by the eye or by gelatine, emitted light escapes. The moment of maximum emission is the moment of completed insolation, and from this the light rapidly declines. It is necessary, therefore, to make that interval between the two moments as short as possible.

V. Of the Extinction of Phosphorescence by Red Light.

I turn now to an examination of those parts of the phosphorographic spectrum from which the light has been removed. They are from the line F to the end of the infra-red space, and again for a short distance above the violet. The effect resembles the protecting action in the same region of a photograph.

Now, if similar effects are to be attributed to similar causes, we should expect to find in the photograph and phosphorograph the manifestation of a common action.

Several different explanations of the facts have been offered. Herschel suggested that the photograph might be interpreted on the optical principle of the colors of thin films. Very recently Captain Abney has attributed the appearance of the lower space to oxidation. But this can scarcely be the case in all instances. Mr. Claudet showed, in a very interesting paper on the action of red light, that a daguerreotype plate can be used again and again by the aid of a red glass, and that the sensitive film undergoes no chemical change. (Phil. Mag., February, 1848.)

It was known to the earliest experimenters on the subject that if the temperature of a phosphorescent surface be raised, the liberation of its light is hastened, and it more quickly relapses into the dark condition. In the memoir to which I have previously referred (Phil. Mag., February, 1851), I examined minutely into this effect of heat, and determined the conditions which regulate it. And since, on the old view of the constitution of the solar spectrum, the heat was supposed to increase toward the red ray, and when flint-glass or rock-salt prisms are employed to give its maximum far beyond that ray, it was supposed that this heat expelled the light, and consequently in all those parts of the phosphorus on which it fell the surface became dark through the expulsion or exhaustion of the light.

I speak of this as "the old view," because, as I have elsewhere shown, the curves supposed to represent heat, light, and actinism so called, have in reality nothing to do with those principles. They are merely dispersion curves having relation to the optical action of the prism and to the character of the surface on which the ray falls. (Phil. Mag., August, 1872, December, 1872.)

But this heat explanation of the phosphorescent facts cannot be applied to the photographic. Nothing in the way of hastened or secondary radiation seems to take place in that case.

In phosphorescence the facts observed in the production of this blackness are these. If a shining phosphorescent surface be caused suddenly to receive a solar spectrum, it will instantly become brighter in the region of the less refrangible rays, as will plainly appear on the spectrum being for a moment extinguished by shutting off the light that comes into the dark room to form it. If the light be re-admitted again and again, the like increase of brilliancy may again and again be observed, but in a declining way. Presently, however, the region that has thus emitted its light begins to turn darker than the surrounding luminous parts. If now we no longer admit any spectrum light, but watch the phosphorescent surface as its luminosity slowly declines, the region that has thus shot forth its radiation becomes darker and darker, and at a certain time quite black. The surrounding parts in the course of some hours slowly overtake it, emitting the same quantity of light that had previously been expelled from it, and eventually all becomes dark.

Now, apparently, all this is in accordance with the hypothesis of the expulsion of the light by heat. There are, however, certain other facts which throw doubt on the correctness of that explanation.

On that hypothesis, the darkening ought to begin at the place of maximum heat, that is, when flint glass apparatus is used, below the red ray, and from this it should become less and less intense in the more refrangible direction. But, in many experiments carefully made, I have found that the maximum of blackness has its place of origin above the line D, and indeed where the orange and green rays touch each other. Not infrequently, in certain experiments the exact conditions of which I do not know and cannot always reproduce, the darkening begins at the upper confines of the green, and slowly passes down to beyond the red extremity; that is to say, its propagation is in the opposite direction to that which it ought to show on the heat hypothesis.

Still more, as has been stated, there is a dark space above the violet. Now it is commonly held that in this region there is little or no heat. If so, what is it that has expelled or destroyed the light?

The experiments above referred to I made with the recently introduced luminous paint. It presented the facts under their simplest form. But I have also tried many other samples, for which I am indebted to the courtesy of Professor Barker of Philadelphia. Among them I may mention as being very well known the specimens made by Dubosc, enclosed in flat glass tubes, contained in a mahogany case, and designed for illustrating the different colored phosphorescent lights emitted. They are to be found in most physical cabinets. These, however, do not show the facts in so clear a manner. On receiving the impress of a solar spectrum they present patches of light and shade irregularly distributed. Though in a general way they confirm the statements made above, they do not do it sharply or satisfactorily.

Dubosc's specimens to which I have had access are enumerated as follows: 1. Calcium violet; 2. Calcium blue; 3. Calcium green; 4. Strontium green; 5. Strontium yellow; 6. Calcium orange. Restricting my observation to the space beyond the red,—which, as has been said, presents a bright rectangle in the darkness, about as far below the red as the red is below the yellow,—I found that this rectangle is not given by 1 and 2. In 3 it is doubtful. In 4 it is quite visible, and in 5 and 6 strikingly so.

Is the blackening then due to heat? That it occurs beyond the violet, that is, beyond the lines H, seems to render such an opinion doubtful, for it is commonly thought that the effect of heat is not recognizable there. And in the phosphorographic spectroscope I have used, the optical train, prism, lenses, etc., is of glass, which must of course exercise a special selective heat-absorption; but the traces of this in the phosphorograph I could never detect.

In the diffraction spectrum, I had attempted nearly forty years ago to ascertain the distribution of heat (Phil. Mag., March, 1857), but could not succeed with the experiment in a completely satisfactory manner, so small is the effect. I exposed a tablet of luminous paint to such a diffraction spectrum formed by a reflecting grating having 17,296 lines to the inch, and was not a little surprised to see that from the blue to the red end of the spectrum there is an energetic extinction of the light, and darkness is produced. I repeated this with other gratings, and under varied circumstances, and always found the same effect.

Now, considering the exceedingly small amount of heat available in this case, and considering the intensity of the effect, is there not herein an indication that we must attribute this result to some other than a calorific cause?

I endeavored to obtain better information on this point by using the rays of the moon, which, as is well known, are very deficient in heating power. Many years ago I had obtained some phosphorographs of that object. With the more sensitive preparations now accessible, and with a telescope 11 inches in aperture and 150 inches focus, there was no difficulty in procuring specimens about 1·4 inch in diameter. These represented the lunar surface satisfactorily. At half-moon an exposure of three or four seconds was sufficient to give a fair proof. But, on insolating a phosphorescent tablet, and causing the converging moon rays to pass through the red glass which I commonly use as an extinguisher, no effect was produced by the red moonlight on the shining surface.

I repeated this experiment using a lens 5 inches in diameter and 7 inches focus so arranged that the moon's image could be kept stationary on the phosphorescent tablet. That image was about $\frac{1}{5}$ inch in diameter. Then, insolating the tablet, the moon rays, after passing through a red glass, were caused to fall upon it. The exposure continued ten minutes, but no effect was produced on the shining surface. The lunar image was so brilliant that when the red glass was removed, and a non-shining phosphorescent surface was exposed to it, a bright image could be produced in a single second.

But in order to remove the effect of the more refrangible rays by the less, the latter must not only have the proper wave length but also the proper amplitude of vibration. This principle applies both to photographic and phosphorographic experiments. In my memoir on the negative or protecting rays of the sun (Phil. Mag., February, 1847) it is said, "Before a perfect neutralization of action between two rays ensues, those rays must be adjusted in intensity to each other." It requires a powerful yellow ray to antagonize a feeble daylight.

It is owing to the difference in amplitude of vibration that the heat of radiation seems so much more effective than the heat of conduction. A temperature answering to that of the boiling point of mercury must be applied to a phosphorescent tablet for quite a considerable time before all the light is extinguished. But the red end of the spectrum and that even of the diffraction spectrum, in which the heat can with difficulty be detected by the most sensitive thermometer, accomplishes it very quickly.

VI. Of the Infra-red Lines or Bands in the Sun's Spectrum.

At a distance about as far below the red as the red is below the yellow in the solar spectrum, I found in 1842, in photographs taken on iodide of silver (Daguerre's preparation), three great lines or bands, with doubtful indications of a fourth still further off. I designated them as α, β, γ, and published an engraving of them in the Philosophical Magazine for May, 1843.

In 1846, MM. Foucault and Fizeau having repeated the experiment, thus originally made by me, presented a communication to the French Academy of Sciences. They had observed the antagonizing action above referred to, and had seen the infra-spectral lines α, β, γ. They had taken the precaution to deposit with the Academy a sealed envelope, containing an account of their discovery, not knowing that it had been made and published long previously in America.

Sir J. Herschel had made some investigations on the distribution of heat in the spectrum, using paper blackened on one side and moistened with alcohol on the other. He obtained a series of spots or patches, commencing above the yellow and extending beyond the red. Some writers on this subject have considered that these observations imply a discovery of the lines α, β, γ. They forget, however, that Herschel did not use a slit, but the image of the Sun,—an image which was more than a quarter of an inch in diameter. Under such circumstances, it was impossible that these or any other of the fixed lines could be seen.

I have many times repeated this experiment, but could not obtain the same result, and therefore attributed my want of success to unskillfulness. More recently Lord Rayleigh (Phil. Mag., November, 1877), having experimented in the same direction, seems to be disposed to attribute these images to a misleading action of the prism employed. Whatever their cause may be, it is clear that they have nothing to do with the fixed lines α, β, γ, now under consideration.

In these experiments, and also in others made about the same time on the distribution of heat in the spectrum, I attempted to form a diffraction spectrum without the use of any dioptric media, endeavoring to get rid of all the disturbances which arise through the absorptive action of glass by using as the grating a polished surface of steel on which lines had been ruled with a diamond, and employing a concave mirror instead of an achromatic lens; and, though my results were imperfect and incomplete, I saw enough to convince me that it is absolutely necessary to employ a spectrum that has been formed by reflection alone. (Phil. Mag., March, 1857, p. 155.)

In 1871, M. Lamanski succeeded in detecting these lines or bands by the aid of a thermomultiplier. He was not adequately informed on what had already been done in the matter in America, for he says that "with the exception of Foucault and Fizeau, in their well-known experiments on the interference of heat, no one as yet has made reference to these lines." Nearly thirty years before the date of his memoir I had published an engraving of them. (Phil. Mag., May, 1843.)

After I had discovered these three lines, I intended to use the grating for the exploration of that region, since it extends it, far more than the prism can do; but, on making the attempt, was discouraged by the difficulty of getting rid of the more refrangible lines belonging to the second spectrum. I had hoped to eliminate these by passing the ray on its approach to the slit through a solution of the bichromate of potash. But the bichromate in long exposures permits a sufficiency of the more refrangible rays to pass, to produce a marked photographic effect; and hence I feared that any experiments supposed to prove the existence of lines in the infra-red would be open to the criticism that they, in reality, belonged to the more refrangible regions of the spectrum of the second order, and that a satisfactory examination of the case would exclude the use of the grating and compel that of the prism. With the prism I could not obtain clear evidence of the existence of more than three lines, or perhaps groups, and doubtful indications of a fourth. If in these examinations we go as far as wave length 10,750, the limit of Captain Abney's map, we nearly reach the line H^2 of the third spectrum. This would include all the innumerable lines of spectrum 2, and even many of those of spectrum 3. In such a vast multitude of lines, how would it be possible to identify those that properly belonged to the first, and exclude those of the second and third spectra? Besides, do we not encounter the objection that this is altogether beyond the theoretical limit of the prismatic spectrum?

This brings us to Captain Abney's recent researches, which, by the aid of the grating, carry the investigation referred to the prismatic spectrum as far below the red as the red is below the yellow. They are not to be regarded as an extension of exploration in the infra-red region,—for they really do not carry us beyond my own observations in 1842,—but as securing the resolution of these lines or bands into their constituent elements. I had never regarded them as really single lines. The breadth or massiveness of their photographs, too, plainly suggests that they are composed of many associated ones. The principle of decreasing refrangibility with increasing wave length incapacitates the prism from separating them, but the grating which spreads them out according to their wave length reveals at once their composite character.

In Captain Abney's map, after leaving the red line A, we find three groups: (1) ranging from about 8150 to 8350; (2) from 8930 to 9300; (3) from 9350 to 9800. These, admitting that the lines of the subsequent grating spectra have been excluded, are then the resolution of α, β, γ.

I suppose that care has been taken to make sure of that, either by absorbent media or by a subsidiary prism. If the grating had been ruled in such a manner as to extinguish the second spectrum, inconveniences would arise from the characteristics thereby impressed on the first.

In the phosphorographic spectrum on luminous paint, this vast multitude of lines is blended into a mass which probably can never be completely resolved into its elements, on account of the propagation of phosphorescence from particle to particle. I have resolved it into two or three constituent groups, and frequently have seen indications of its capability of resolution into lines, in the serrated aspect of its lateral edges.

I believe that luminous paint enables us to approach very nearly, if not completely, to the theoretical limit of the prismatic spectrum.

The history of these interesting infra-red lines is briefly this. They were discovered by me in 1842, and an engraving and description of them given in the "Philosophical Magazine." They were next seen by Foucault and Fizeau in 1846, and a description of them presented to the French Academy of Sciences. They were again detected by Lamanski with the thermopile in 1871. Their resolution into a great number of finer lines was accomplished by Abney, who gave a Bakerian lecture describing them before the Royal Society in 1880. Finally, they have been re-detected by me in the shining rectangle, just above the theoretical limit of the prismatic spectrum, given by many phosphorescent substances.

University of New York, Dec. 1, 1880.

ART. XXI.—*The structure and affinities of* Euphoberia *Meek and Worthen, a genus of Carboniferous Myriapoda;* by SAMUEL H. SCUDDER.

THE genus *Euphoberia* was established in 1868, for some remarkable spiny Myriapoda found in the ironstone nodules of Mazon Creek in Illinois, and which were first fully described and figured in the third volume of the Geological Report of the Illinois Survey. The only characteristics then noted, in which they differ from modern types, were the tapering form of the body, and the presence of branching spines on all the segments in longitudinal rows. An opportunity of examining a series of these animals from the same locality, due to the kindness of Messrs. Carr and Worthen, and especially of studying a fine fragment of *Euphoberia major* M. & W., giving an admirable view of the ventral plates, proves that the differences between these ancient types and modern forms are so numerous and important, as to compel us to refer them to a distinct suborder, for which the name of Archipolypoda is proposed.

One main distinction between the two groups, Diplopoda (or Chilognatha) and Chilopoda, into which existing Myriapoda are generally divided, consists in the relation of the ventral to the dorsal plates of the various segments of which the body is composed. In the Chilopoda there is a single ventral plate, bearing one pair of legs, for every dorsal plate: in the Diplopoda on the contrary, there are two such ventral plates, each bearing a pair of legs, for every dorsal plate (with the exception of a few segments at the extremities of the body).

The Diplopoda are universally considered the lower of the two in their organization, and it is therefore not surprising to find that no Chilopoda have been found in rocks older than the Tertiary series;* while Myriapods with two pair of legs corresponding to each dorsal plate may be found as far back as the Coal-measures. In such comparisons as are here instituted, the Chilopoda may therefore be left out of account.

In modern Diplopoda, each segment of the body is almost entirely composed of the dorsal plate, forming a nearly complete ring, for it encircles, as a general rule, nine-tenths of the body, leaving small room for the pair of ventral plates. On the side of the body it is perforated by a minute foramen, the opening of an odoriferous gland. Usually the ring is nearly circular, but occasionally the body is considerably flattened, and the sides are sometimes expanded into flattened laminæ with a smooth or serrate margin; a few species are provided with minute hairs, sometimes perched on little papillæ; and the surface of the body, ordinarily smooth or at best wrinkled, is occasionally beset with roughened tubercles, which may even form jagged projections. So far as I am aware, no nearer approach to spines occurs on this dorsal plate than the serrate edges of the lateral laminæ, the roughened tubercles or the papilla-mounted hairs.

In the Euphoberiæ from the Coal-measures a very different condition of things obtains. The segments of the body may be circular, or laterally compressed, or as in many modern types, depressed; but in all, the dorsal plate occupies scarcely more than two-thirds of the circuit of the body, or even less, being opposed by broad ventral plates. This dorsal plate is not perforated for foramina repugnatoria,† but, as means of defence, it is armed with two or three huge spines upon either side; one row (for they occur on all the segments alike) lies above, near the middle line of the body; another is placed low down upon the sides, near the lower margin of the dorsal plate; and a third row is sometimes found between them. These spines are sometimes forked at the tip, and they are (probably) always provided to a greater or less extent with spinules, springing from the base or the stem; sometimes these are so numerous as to form a *whorl* of little spines around the main stem; usually the main spines are at least half as long as the diameter of the body: often they are as long as the diameter, and one may readily picture the different appearance between one of these creatures, perhaps a foot or more in length,

* *Geophilus proavus* Germ., from the Jura, is certainly a nereid worm, as stated by Hagen.

† This is what would be expected from the presence of spines, for two such means of defence should not be looked for in the same animal; offensive glands are present only in slow-moving or otherwise defenceless creatures, as in Phasmidæ among Orthoptera for example.

bristling all over with a coarse tangle of thorny spines, and the smooth galley-worm of the present day.

If we pass to the ventral plates we shall find differences of even greater significance. In modern Diplopoda these plates are minute; the anterior forms the anterior edge of the segment, continuous with that of the dorsal plate; together, however, they are not so long as the dorsal plate at their side, and the latter appears partly to encircle the posterior of the ventral plates by extending inward toward the coxal cavities. The legs are attached to the posterior edge of each ventral plate, and those of opposite sides are so closely crowded together that they absolutely touch. The stigmata, of which there is a pair to each ventral plate, are placed at the outer edge, rather toward the front margin, and their openings are longitudinal, i. e., they lie athwart the segment; the coxæ of the legs of the anterior plate are therefore opposite the stigmata of the posterior plate. No other organs are found upon the ventral plates; one might indeed say there was not room for them. The legs themselves are composed of six simple, cylindrical joints, subequal in length, the apical armed with a single terminal claw; the whole leg is short, generally not more than half as long as the diameter of the body.

In the ancient Euphoberiæ, all is very different. The ventral plates occupy the entire ventral surface, perhaps may be said to extend partly up the sides of the rounded body, and no part of the dorsal plate passes behind the posterior ventral plate; they are together equal in length to any part of the dorsal plate, the segments of the body being equal in length throughout; while in modern Diplopoda the upper portion of the dorsal plate is always considerably longer than the ventral portion, allowing the creature to coil ventrally without exposing any intersegmental portion of the back devoid of hard armature; while in these ancient forms, the animal appears to coil dorsally as readily as ventrally; at least, when not extended straight upon the stones in which they are preserved, they are as frequently found bent upward as downward; and there is certainly nothing in their structure to prevent such mobility.

Then the legs, instead of being inserted at the extreme posterior edge of the plate, are planted almost in its very center, and are indeed so large that they occupy nearly its entire width; neither are those of opposite sides inserted close together, but are removed from one another by a space equal to their own width, giving them ample play. The legs themselves differ from those of modern types in having the second joint as long as the others combined, and the whole leg at least as long as the diameter of the body, and sometimes nearly twice as long; moreover they are not cylindrical but compressed and slightly expanded, strengthened also on the flattened surface by longitudinal carinæ, and in every respect, in those specimens in which the legs are best preserved, have the aspect of *swimming organs.* No aquatic forms are known among recent myriapods.

The stigmata, instead of having the position they hold in modern Diplopoda, where they are necessarily minute, are very large, situated in the middle of each ventral plate, each spiracle opposite to and indeed touching the outside of the coxal cavity of the plate to which it belongs, and running therefore with and not athwart the plate, i. e., across the body. But in addition to these structures, which make up the sum of the furniture of the ventral plate in modern Diplopoda, we find in these ancient myriapods some further interesting organs, which are so perfectly preserved that no doubt can be entertained concerning their presence and their adherence to the ventral plate. The coxal cavities are not circular but oval and are situated with the major axis in an oblique line, running from near the middle line of the body forward and outward; this and the slight posterior insertion of the legs leave even a wider space between them at the anterior border of the plate than posteriorly, and this place is occupied by a pair of peculiar organs, situated one on either side of the median line at the very front edge of every ventral plate. These I think may be supports for branchiæ; they consist of little triangular cups or craters, projecting outward from the under surface, through which the branchial appendages protruded. Until recently no other organs than branchiæ have been found in any arthropod, situated within the legs, and repeated on segment after segment. The only exceptions known are Peripatus, a strange creature, allied certainly to the myriapods, but of lower organization, in which Balfour has found segmental organs (heretofore known only in worms) having their external openings somewhat similarly situated; and Scolopendrella, a minute chilopodous myriapod, in which Ryder has just described organs which he calls tracheæ, opening externally between the legs. But as branchiæ also occur *together with spiracles* in some low organized insects, and then in essentially similar relative positions to that in which they are here found; and as the possession of legs adapted to swimming leads us to presume in these creatures an aquatic or amphibious life: it would seem as if we might fairly conceive these crateriform appendages to be branchial supports,* and conclude that we are dealing with a type of myriapods very different from any existing forms,—suited to an amphibious life, capable of moving and breathing both on land and in water. Moreover the assemblage of forms discovered in the Mazon Creek beds lends force to this proposition; for the prevalence of aquatic Crustacea, of fishes and ferns, indicates that the fauna

* Even if they were segmental organs, they may still have been connected with respiration.

and flora was that of a region abounding in low and boggy land and pools; and the presence of marsh-frequenting flying insects does not contradict such a belief.

These, however, are not the only points in which the ancient forms differed from the recent. We have so far examined only a typical segment; let us now look at the body as a whole and at special segments. The modern Diplopoda are of uniform size throughout, tapering only at the extreme tips; while these ancient forms, at least when seen from above, diminish noticeably in size toward either end, and especially toward the tail, giving the body a fusiform appearance, its largest part being in the neighborhood of the seventh to the tenth body segments, which were often two, or even three, times broader than the hinder extremity, and considerably broader than the head or the first segment behind it. A single segment seems to have carried all the appendages related to the mouth parts, while in modern Diplopoda two segments are required for this purpose; this peculiarity of the fossil is inferred solely but sufficiently from the fact, perhaps even more remarkable, that every segment of the body (as represented by the dorsal plates), even those immediately following the single head-segment, is furnished with *two* ventral plates and bears *two* pair of legs; as is well known, each of the segments immediately following the head-segments in existing Diplopoda bears only one ventral plate, and only a single pair of legs,—a fact correlated with the embryonic growth of these creatures, since these legs and these only are first developed in the young diplopod. The mature forms of recent Diplopoda, therefore, resemble their own young more than do these Carboniferous myriapods, a fact which is certainly at variance with the general accord between ancient types and the embryonic condition of their modern representatives, and one for which we offer no explanatory suggestion worth consideration.

Unfortunately the preservation of the appendages of the head in these Carboniferous forms is not sufficiently good in any that have yet been found to allow any comparison with modern types. This is the more to be regretted since these parts are those on which we depend largely for our judgment of the relationship of the Myriapoda to other Insecta and to Crustacea. If they were present and sufficiently well defined, we may well suppose that they would afford some clue to the genetic connection of these great groups.

The structure of the Carboniferous Euphoberiæ have thus been shown to differ so much from that of modern Diplopoda that, as stated at the outset, we seem warranted in placing them in a group apart from either of the sub-orders of modern Myriapoda and of an equivalent taxonomic value.

Cambridge, January 7, 1881.

Art. XXII.—*The Actinic Balance;* by S. P. Langley.

The writer has been, during some time, making experiments on the device and construction of an instrument more delicate and more prompt than the thermopile; an advance which his recent researches into the distribution of radiant energy in the spectrum have proved to be indispensable. These researches have involved expenses for special apparatus which have been in part met by a grant from the American Academy of Arts and Sciences as trustees of Count Rumford, and the writer has with gratitude to acknowledge his past indebtedness to this aid. A communication of some of the principal results obtained was made to that society in the early part of December, and will appear with illustrations of the apparatus in a forthcoming volume of their Proceedings, to which the reader who desires fuller details is referred.

The following independent description of the newly devised apparatus is rendered necessary here, as an introduction to a future account of researches in the true distribution of radiant energy in the solar spectrum.

We see within the past few years a greatly increased attention to this subject and an attempt by many skilled observers to measure the distribution of heat for each individual ray with the minimum of error which the vicious method of the prism admits. Even the use of the prism, however, demands most delicate means of measurement. Tyndall, employing every instrumental aid science commanded in his experiments on the electric light, was obliged to operate on a spectrum only an inch and a half in length, and it is from this that the well-known heat curves of our text-books are derived. When we form a much longer spectrum, we must either make the face of our thermopile larger, or expect to find the radiation so weakened that we cannot measure it.

Now the use of the prismatic spectrum involves two prominent causes of error. One of these (well-known and partly guarded against) concerns the selective absorption of the material employed, the other, far more important and pernicious in its results, has been almost completely neglected. It concerns the fact that the prism acts a part analogous to that of a cylindrical lens, concentrating the rays in the lower part of the spectrum as compared with the upper and entirely falsifying in its specious results the true distribution of the heat. Even if there were no theoretical difficulty the measure of the refracted heat as distributed by the prism is far from easy on account of its feebleness, but there has seemed to be no choice, for if the measurement of sensibly homogeneous rays of heat in the prismatic spectrum is difficult, the corresponding measurement in the diffraction spectrum is impossible, or has, at any rate until lately, been considered so. Under the most favorable circumstances, the total heat in the brightest spectrum formed by a diffraction grating is but about one-tenth of that in a prismatic spectrum of equal length, and this latter is itself, as we have just seen an all but vanishing quantity. Müller and others have attempted its evaluation without obtaining the least measurable effect, even from the aggregate heat of the entire spectrum. The elder Draper, baffled by the same difficulty, succeeded nevertheless in dividing the heat of the spectrum formed by a diffraction grating into two parts, which led him to announce, that the position of the maximum of heat did not differ greatly from that of light, a conclusion which has not apparently met the general attention it deserves from physicists thus far, at least in Europe.

In these most delicate measurements, the experimenter's great difficulty is to avoid the disturbing influence of extraneous sources of heat, which (since radiations of this latter class are almost wholly invisible), is extremely difficult, for we *see* nothing of the hundreds of insidious actions which are incessantly affecting our thermopile from sources that have nothing to do with the result we seek. There is probably no instrument in the whole range of scientific apparatus which demands a longer experience for its successful use than the thermopile, where we are employing it not for the purpose of a lecture experiment, but for the determination of some one almost infinitesimal radiation in the midst of numberless others which our only concern with, is to avoid. In fact the successful use of the thermopile, as employed by Melloni and by Tyndall may almost be assimilated to a kind of handicraft, requiring long familiarity and the almost instinctive and unconscious adoption at every moment of precautions which would certainly never suggest themselves to the untried observer. The writer, having served a long apprenticeship in previous years to this craft, had flattered himself that he might turn his familiarity with the thermopile to some useful account here, and might perhaps succeed from this cause, where others had failed. He was obliged, however, to admit to himself that his success was so partial as to be very like failure. He succeeded with the thermopile in obtaining feeble indications of heat on comparatively homogeneous rays in the diffraction reflection spectrum but these indications were all too feeble, and obtained at too great a cost of time and labor to make it possible to carry on our knowledge of the distribution of heat in the spectrum by means of the thermopile to any great extent beyond the point where others had left it.

These first experiments were made by letting the sun-light, which had passed through a distant slit, fall (without the intervention of a collimating lens), upon a grating, whence the diffracted rays fell upon a metallic mirror which concentrated them into a spectrum, pure enough to give even with a widely open slit all the leading Fraunhofer lines, but in this case, as has been said, the most delicate thermopiles procurable and the best galvanometer, then in the writer's possession, gave no results which could be relied on to anything like the desired degree of accuracy, and although something was gained it was too small an advance upon what had been done already, to seem worthy of publication. Satisfied that nothing more could be done here with the apparatus employed, and that the whole march of progress in this direction was arrested for want of a better instrument than science possessed, the writer attempted to find one. He commenced his investigations in November, 1879, and continued them almost without intermission until the autumn of 1880, when he found himself in possession of an instrument, not only greatly more sensitive than any thermopile, but also far more prompt, and as he believes more accurate.

The thermopile, it will be remembered, employs as the source of the force which swings the needle of the galvanometer, the feeble ray which falls upon the pile's face. There is no other force to move the needle than the excessively feeble energy locked up in the ray itself. It occurred to the writer (as it had occurred to others before him, doubtless), that he might use a feeble energy, not directly, but as the modulator of some greater force. The whole energy in one of the rays we are dealing with, for instance, will not give one-millionth part of the impulse upon a magnetic needle, which could be derived from a single Daniell's cell. But with the cell whose potential energy bears somewhat the same relation to that of the ray, that the strength of a steam-engine does to the strength of the human finger, we might make the feeble power of this ray play the same part that the finger would when laid on the engine's throttle-valve.

When (to use a common illustration), the finger is applied to the trigger of a gun, the little force liberates an indefinitely greater one, which has no certain relation to the energy of the original impulse. But what we here need is a rigorous *proportionality* between the feeble but momentarily varying energy of the original ray, and the amount of power it releases from a battery or other source of energy. It is only on these conditions that the indications of our instrument will be accordant and that it will be truly a meter. If we are in search only for extreme sensitiveness, and are satisfied to have a delicate thermoscope rather than an accurate thermometer, I believe that by employing some of the metalloids such as sulphur, selenium, or tellurium it is possible to make an instrument far more sensitive than that about to be described, but I repeat this sensitiveness is not all. What the working physicist wants is not an enormous result, bearing no definable relation to the original cause, but one which is strictly proportional to it. The useful instrument, then, is one which shall always give nearly the same results under repeated trials, or which shall in more technical language have a small probable error. I commenced, guided by these considerations, and with the aid of Mr. F. W. Very, in December, 1879, to experiment in the following direction. The *principle* has been employed by Jamin, by Siemens and by others, before. The following *application* is, I believe, new. Let us suppose that from a battery two wires of equal length and equal section pass to a differential galvanometer so that one current tends to move the needle to the right, the other and equal current, tends to move it to the left, and the needle solicited in opposite ways by equal forces, remains motionless at zero. Suppose now a ray from the sun, from a vessel of hot water, from a candle, or from any source, of radiant energy of higher temperature than the wires themselves, to fall on one of them; this wire becomes heated and therefore a worse conductor than before, and as its resistance increases in nearly the ratio of its increased temperature, there is less current through the heated wire, and the needle is deflected by a force which is strictly proportional in theory to the energy in the original ray, to the energy of the battery, and to certain constants of the galvanometer and the rest of the circuit. In what has just been said, it is temporarily assumed that all the energy of the original ray is represented by heat in the wire, and that none of it has been lost by conduction, convection, or by re-radiation. It is also supposed that no large change of temperature has taken place in the wire, but that the heating energy of the original ray is small. The last condition is only too easily met in practice. The consideration of the first will be resumed in another place.

We have just indicated merely the fundamental conception which is to guide our search for an actual instrument. Between this conception and the partial realization a great many months of assiduous and often disheartening labor have been expended, and complete success is far from having been reached even now, but as I believe it certain that the instrument in its actual stage of progress has been already successful in doing important work quite out of the thermopile's reach, I shall describe briefly the considerations which have led to its execution in its present form. Some of these are obvious. The motion of the galvanometer needle will be proportional, other things being equal, to the change of resistance, and this change of resistance will be proportional to the actual resistance of the wire, as well as to the cross section of the ray falling upon it. If for instance we employ a naked copper wire one hundred meters in length, whose resistance is one ohm, the resistance of any given centimeter of its length will not exceed one ten-thousandth of an ohm, and accordingly, if from any source of radiant heat we let fall on the wire a ray which we will suppose to be one square centimeter in section, if it altered the resistance of the wire by so much as one one-hundredth part where it fell, we should have but one one-millionth of an ohm to produce the requisite change in the recording instrument. Evidently we must form the particular minute portion of the circuit on which the ray is to fall of some conductor which has a very high resistance indeed, as compared with the average resistance of the wires. If for instance we introduce a bit of gold-foil having a resistance of one ohm to the single centimeter so that it shall form a virtual portion of one of the wires, and if we let the ray fall on this, we now produce a change equal to the one one-hundredth part of one ohm, which is ten thousand times the effect produced before by the same cause. Similar considerations show us that the cylindrical form of the wire is a bad one, and that the metal used for the part exposed to radiant heat should be laminated, when it may be made to present a much greater surface to the source of radiant heat, with precisely the same conductibility. It is clear then that the following conditions should unite; great electric resistance; considerable change in resistance for a given change in heat, and a form which enables it to take up and part with heat very rapidly.

To this we may add among the minor conditions that it is desirable that the exposed portion should be of a metal readily reduced to thin laminæ, that it should be non-oxidizable, since it is to be in an excessively thin strip, and that it should also have sufficient rigidity to preserve its form. The whole of these conditions can rarely or never be found in the same substance. We must select our metal with a view to those conditions which are of most importance. Experiments were made in December, 1879, and in January and February, 1880, on a great variety of metals. They finally conducted me to the use of iron (or steel), platinum and palladium as the most available ones. Gold in the form of foil is unsuitable on account of minute rents made by the blows of the hammer. Metals on glass do not work as well on account of the heat taken up by the glass; but to attempt to narrate all the trials made would be useless. To comprehend the apparatus used, not in its ordinary form, but in its most elementary type, let us suppose that we have succeeded in rolling steel until its thickness is $\frac{1}{300}$ to $\frac{1}{500}^{mm}$. In this state 8,000 to 12,000 sheets laid one on the other will make but about one English inch. It may be easily supposed that it is no light task to procure such a sheet of steel in the first instance. This, however, has been done successfully.

In order to fix our ideas let us now suppose two such pieces of steel, each rather less than $\frac{1}{2}$ inch long and $\frac{1}{20}$ inch wide, to be stretched side by side and almost in juxtaposition, within a small cylinder open at one end, which can be directed to the source of radiant heat, while the two strips are made to form each a portion of a circuit leading from the battery to the differential galvanometer. Since the change of resistance in iron is about $\frac{4}{10}$ of one per cent for each degree Centigrade, as minute a change of temperature as is represented by a single degree will cause a difference of resistance in the strips of $\frac{1}{250}$. Thus supposing the resistance of the exposed part to be $\frac{1}{4}$ that of the whole circuit, there will be a differential effect upon the galvanometer equal to nearly $\frac{1}{1000}$ of the entire power of the battery, an enormous amount of force as compared with that represented by the heat required in warming such a minute mass as the strip by 1° C. Further, since the strip is so thin it will take up and part with the heat almost instantly. Where the thermopile often requires an exposure of five, ten or fifteen minutes, the strip will take up sensibly all of the heat it is capable of holding within a single second. There is here then a great gain in sensitiveness over the pile and also a great gain in rapidity. In the case of the pile, if we have a beam of heat of $\frac{1}{4}$ the cross-section, we employ to utilize it a pile of $\frac{1}{4}$ the size and get (roughly speaking) but $\frac{1}{4}$ the effect. With the strips we have the paradoxical result (in appearance at least) that $\frac{1}{4}$ the heat may produce the same effect as the whole. To see this more clearly, let us suppose another strip to be but $\frac{1}{2}$ as long and $\frac{1}{2}$ as wide as the first. This exposes but $\frac{1}{4}$ the area, but the resistance is obviously the same as before and any given percentage of that resistance will produce the same effect as before. From any thing which has been said, it might seem to follow then, that with a strip of the size of 1 square mm. we shall get the same effect as with one a meter square, or, in the last result that an infinitesimal source of heat will through this means produce the same effect as an infinitely great one under similar circumstances. This of course indicates a fallacy whose seat is found in our assumption that no change takes place in the temperature of the strip except from radiant heat. In reality it is not so. The current received from the battery itself of course produces heat in all parts of the circuit, and this is particularly noticeable in the strips which offer large resistance in small compass. There is then a practical limit beyond which we cannot go without the battery heating of the strips becoming prejudicial, but the paradox we have alluded to is so near to fact, that it is found to be the case in actual practice that within certain limits the action of the strip is nearly independent of its size. Accordingly if we take ten contiguous parallel strips each one mm. wide and one cm. long and joining their alternate ends place them side by side (but not in contact) so as to present a total area of one cm. square, the effect on the galvanometer will be, i. e. approximately, ten times that of a single strip one cm. square carrying the same current, if that current be small. Of course, the single wide strip can carry a much greater current while being heated to no greater temperature than one of the narrow ones, and we thus see that we may choose between a feeble current, carried through numerous narrow strips with high local resistance, and a relatively strong current. The latter construction is far easier, but particular considerations have determined the actual trial of the former plan (of higher resistance and feeble currents) in the instruments employed.

In the latter case the current is led through all these strips in succession, and each of the two strips we have spoken of as existing in the simplest type of the instrument may then be very advantageously replaced in practice by a complete system of such strips. If the two systems are placed side by side, enclosed within non-conducting walls, they are evidently exposed, as far as possible, alike, to all changes of temperature arising from their immediate environment. When the containing cylinder is warmed or cooled, each system is warmed or cooled in an equal degree, and the galvanometer needle remains unmoved.

It is found in practice often more convenient not to use the differential galvanometer, but to make each system one of the arms of a Wheatstone's bridge. The little cylinder containing the strips is connected by insulated wires with a quite distant galvanometer, and this cylinder, containing the effective part of the apparatus, can be carried then by hand from one room to another, and so long as no radiant heat from a source directly in the prolongation of its axis enters it, the galvanometer needle remains unmoved; but if such a beam of radiant heat be allowed to enter and fall on one of the strips only, the instrument will instantly respond, while it remains unmoved by all accidental surrounding radiations. A still further improvement in the disposition of the strips is made by leading one of them in the center of the cylinder and by dividing the other into two equal parts, which are left one either side of the central one, so as to be in identical circumstances of environment. The instrument therefore acts by any change in the equality of these two arms of the bridge in a manner quite analogous to the action of a chemist's balance, but with an extent of range which it is not probable that any chemist's balance can approach.

Under any circumstances, in view of the measurements we expect to make, a very delicate galvanometer of moderate (though not the lowest) resistance, will be a suitable instrument. The one used is of the most recent form of the Thomson galvanometer pattern. This instrument, just made by Elliott Bros., is more sensitive than any the writer has before used, and to its excellence he is no doubt in part indebted for the results attained.

It is perhaps well to introduce here the remark that nothing is gained by pushing the battery power beyond ordinary limits; both wires heat equally, as far as this battery current is concerned, but the air within the cylinder is no longer still, but fluctuates irregularly even when no radiant heat disturbs the "Actinic Balance," as the instrument just described will be provisionally called. As it is difficult to make an absolutely perfect balance within the strips themselves, a resistance box is commonly introduced in the circuit. The same battery power is used whether the resistance in the strip portion of the circuit be greater or less, but changes in the condition of the battery are kept from affecting the result by introducing an easily varied battery-shunt. The current employed is usually not enough to warm the strips, at the most, as much as 5° C. above the temperature of the environment, a condition best obtained with the strips actually used by an absolute current of less than $\frac{2}{10}$ Webers. Even with $\frac{1}{100}$ Webers we have a greater force at disposal than the excitant radiation here dealt with could ever develop in a thermopile.

It will be understood that experiments are still in progress with this instrument, but as it is doubtful when they will be concluded, and as it is certain it is capable of doing some things even in its present state, which the thermopile cannot, it seems proper to give the preceding description, without waiting for further improvement. It may be observed that the three metals which have hitherto been found best are steel, platinum and palladium. Steel fulfills every condition which may be desired save one. It is, unfortunately, oxidizable and is therefore difficult of preservation. Platinum may perhaps be found, upon the whole, more advantageous, though this is not yet certain. Palladium has hardly been experimented upon sufficiently to pronounce on with confidence, though it seems to promise well.

The instrument in its present condition has been used without any lamp-black upon the steel strips, for fear that its well-known hygrometric qualities might injure them by causing rust, but this objection will not apply to the platinum. The writer, however, has grave doubts about the advisability of treating the lamp-black as absorbing all heat-rays indifferently, although such a statement of its capacity is given by Melloni, and is very widely adopted on his eminent authority. A special investigation into the absorptive power of lamp-black will probably form a part of the present series of researches undertaken here. In its unblackened condition the instrument appears to be, roughly speaking, from 5 to 100 times as sensitive as the most sensitive thermopile the observer possesses, area for area. With the lowest degrees of sensitiveness its probable error is very small. The higher degrees, however, involve the pushing of the battery power to such an extent as to cause sensible heating of the wires and the consequent fluctuations on the galvanometer already alluded to, and increase of all accidental irregularities. The probable error will of course depend also on the condition of the galvanometer. If the source of heat is feeble, and the galvanometer adjusted to the condition of nearly complete astaticism (in other words of nearly complete instability), the probable error cannot fail to be considerable. If the source of heat is considerable and the needle's period of vibration brief, the probable error is of course less. These are general considerations, which affect alike the thermopile and actinic balance, but the latter instrument, putting a greater amount of power at our disposal, enables us to use the galvanometer needle in a much more stable condition, and for this and other causes enables readings to be obtained which are not only certainly far more rapid than the thermopile's, but apparently more exact. Under favorable circumstances, in repeating some of Melloni's experiments on radiation through distilled water and alum solutions with the unblackened steel balance, we have found the probable error of a *single* observation very much within one per cent. On the other hand, when working with an extremely faint source of heat, such for instance as the lunar rays give in a refracting telescope, the probable error of a single observation may be much larger.

A few observations are given here just as they are found in the note books, and which probably represent fairly the average accuracy of the instrument in its present condition, except that the source of heat being the sun, whose radiation varies from moment to moment from atmospheric causes, the probable error is larger than it would have been with a constant source of heat. The galvanometer used in the repetition of Melloni's measures was an old and comparatively rough one, adjusted as nearly to *in*sensitiveness as possible by its directing magnet, so that the image should not be thrown off the scale. The actual readings are given of a series of seven measurements on the transmissibility of solar rays by water and by a solution of common alum containing ten per cent by weight, as taken by Mr. F. W. Very, on Sept. 22d, 1880, 11¼ A. M. to 1 P. M.

The liquids being enclosed in glass cells (sides $2·5^{mm}$ thick, distance between sides $=19·0^{mm}$) were interposed or withdrawn by sliding the stand, on which the cells were held perpendicular to a sunbeam, so that the center of the circular cell should fall opposite the aperture of the actinic balance case, which was inclined so as to point to the sun. Each reading on the sun is the mean of two taken directly before and after the interposition of the liquid.

Deflection by Radiation of full Sun.		Through Water.	Per cent Transmitted.	Deflection by Radiation of full Sun.		Through Alum sol.	Per cent Transmitted.
205, 215	210	123	58·6	277, 287	282	152	53·9
214, 219	217	127	58·5	291, 272	287	153	53·3
226, 239	233	132	56·7	275, 240	253	130	51·4
	253	149	58·9	283, 283	283	150	53·0
	225	135	60·0	285, 272	279	148	53·1
286, 289	288	174	60·4	283, 265	274	145	52·9
299, 284	292	178	61·0	270, 248	259	138	53·3

Solar radiation transmitted by water and glass = 59·2 per cent ± ·36.
Probable error of one observation = ± 0·96 per cent.
Solar radiation transmitted by alum and glass = 53·0 per cent ± ·19.
Probable error of one observation = ± 0·51 per cent.

These readings are given merely as fair samples of the average (not of the best) work where sensitiveness is not demanded.

As an instance of a by far more delicate class of measurements, we will use the following preliminary observations upon the heat of the moon, taken with another and more sensitive galvanometer, on the night of November 12th, 1880, with the equatorial of the observatory; employing its 13-inch achromatic lens and a smaller condensing lens near the focus. A great variety of precautions were used which are not here detailed, and the measurements were varied by taking them under as diverse conditions and in as many different ways as possible. Eighteen measures were taken in about an hour and a half.

All are given here exactly as they were obtained, except one, which involved an obvious error, but this one equally indicated heat.

		Actual deflections (heat).
Balance cover open. Balance exposed at all times to sky and lens radiation. Lunar image brought in by moving the telescope by hand.	West limb enters first.	53
		28
		53
		56
		44
		36
		70
	East limb enters first.	62
		39
		30
		50
Balance covered except during exposure and image kept in the same position at all times by the equatorial clock.		19
		26
		23
		41
		27
		51

Mean deflection = $41 \cdot 6 \pm 2 \cdot 4$. (Prob. error of a single observation = $9 \cdot 9$).

The preceding measures on lunar heat will doubtless be improved on. They are the first taken and are given here not for any intrinsic value of their own, but as aids in judging the capacity of the balance, to not merely indicate, but *measure* forms of radiant energy hitherto supposed beyond reach; for I am not aware of any previous authentic measures of the lunar rays which have passed through the *glass* lenses of a refracting telescope.

It may be mentioned that with this very feeble radiation the strips occupied no sensible time in heating, the galvanometer indications being smaller but as prompt and decisive as though the observations were on the sun.

A far more important practical result has been the measurement of nearly homogeneous rays of heat in the diffraction spectrum, which is now going on and of which an account will shortly be published. It may be stated briefly that with a diffraction spectrum so pure as to show all the principal lines on the screen, but in which the most delicate thermopile gives no satisfactory indications of heat, the actinic balance is found to determine the energy not only in the ultra red but in the ultra violet. The results promise to be of theoretical and practical interest. It may be said generally that they *experimentally* prove the absence of any maxima in the spectrum, such as are shown in the curves of "actinism," "light" and "heat," given in the text-books, and that they show that the actual solar energy (as it reaches us through our atmosphere), is nearly at its minimum precisely where the so-called "actinic" curve is shown at its maximum. The special sensitiveness of certain salts of silver, then, to wave-lengths of from $0{\cdot}0003^{mm}$ to $0{\cdot}0004^{mm}$ and not any special solar energy or special modification of it, is the cause of the once-supposed peculiar "actinic power" of this part of the spectrum. *The maximum of "heat" is found to be not in the ultra red but in the orange, and the curve of "heat" is found to at least approximately agree with that of "light,"* by direct experiment, and other results of equal theoretical interest, and still more practical importance begin to appear.

The need to precede their statement in an early publication by some account of the means by which they were derived has been the occasion of this article.

Allegheny Observatory, Dec. 23, 1880.

ART. XXIII.—*Notices of Recent American Earthquakes.* No. 10; by Professor C. G. ROCKWOOD, Jr., Ph.D., Princeton, N. J.

THE present article embodies such information as has been obtained in regard to earthquakes occurring upon the American continent and adjacent islands since March 1, 1880; with notice of some earlier shocks not previously reported in this Journal. Items which depend upon single sources of information have their source indicated, and if regarded as at all doubtful are printed in smaller type.

In addition to the persons mentioned in the notices, the author would express his indebtedness to J. M. Batchelder, Esq., of Boston; Prof. F. E. Nipher, of the Missouri Weather Service; J. H. VanDoren, Esq., of Morristown, N. J.; to the Superintendent of the Meteorological Service at Toronto, and to Pres. J. W. Dawson, of Montreal, for assistance in collecting information.

1878, Jan. 1. An earthquake in Peru at 1.05 A. M., Lima time.

1879, April (day not stated). Earthquakes at Chilpancigo, on the west coast of Mexico, about 75 miles inland from Acapulco. —From Ann. Report of Dr. Fuchs in Miner. u. Petrog. Mittheilungen, Vienna.

May 17. The shock at Vera Cruz and vicinity, previously noted (xix, p. 227) as 16th or 17th, is given by Dr. Fuchs as 17th.

June 8. A shock at 6 A. M. at Cerro de Pasco, Peru.

Aug. 15. A shock at 6.10 A. M. at Cerro de Pasco, Peru.

Dec. 21. The period of disturbance which began on this date in San Salvador, C. A. (xix, pp. 299, 415) continued for several weeks, and during the last ten days of 1879 it was estimated that over six hundred shocks occurred, of which, however, only two were destructive, viz: those at 12.38 P. M., Dec. 27th, and 7.34 P. M., Dec. 31. The center of disturbance was Lake Ilopango and the damage was confined to its immediate vicinity. On Jan. 20th a new volcanic cone appeared in the lake, a description of which, with illustration from photograph, appeared in Nature (June 10, 1880). Mr. W. A. Goodyear, State Geologist of San Salvador, made careful observations of the phenomena, and his interesting report thereon has been published by the government of San Salvador in a pamphlet of thirty pages. In the expectation that his results will in due time be printed in English, further details are omitted here.

1880, Jan. 4. In connection with the eruption of volcanic dust in Dominica, W. I. (xix, p. 426); a letter from Mr. L. Bert (Comptes Rendus, Mar. 15, 1880) reports an earthquake shock at 11 A. M. at Marigot, a small village on the flank of the mountain chain in which the crater is situated.

Jan. 28, 29 and Feb. 10. Shocks and rumbling reported from Bald Mountain, N. C.—*J. M. B.*

Feb. 5. Advices of this date report recent earthquakes in various parts of Mexico, particularly the districts of Cordoba, Orizaba, Tehuacan and Vera Cruz.—Nature.

Feb. 8. The shock at Ottawa previously reported in small type (xix, p. 299) is confirmed by letter.

March 21. At 6.25 A. M. a heavy shock at Los Angeles, Cal., lasting about five seconds, vibration N.E. to S.W.—U. S. Weather Review.

March 25. At 2.30 A. M. a moderate shock at San Gorgonia, Cal., duration about three seconds, direction S.E. to N.W.—U. S. Weather Review.

April 3. At 10 P. M. a slight shock at Quebec and Ottawa.—J. W. D.

Same day, between 2 and 3 A. M., a shock at Fort Fairfield and Maysville, Me. —*J. M. B.*

April 14. A strong shock at San Francisco at 1.05 P. M.

May 5. A slight shock reported at San Francisco, from south to north, at 11 P. M., and at San Jose at 11.35 P. M. A heavy shock, presumably the same, was felt at Tlactula, State of Oaxaca, Mexico, on the same day, hour not stated; direction north to south.

May 12. At 7.45 A. M. an earthquake was felt in northeastern Massachusetts, affecting the seaboard towns from Amesbury and Newburyport to Salem, and inland to Lawrence and Acton. At most places a rumbling sound was heard. The shock continued about five seconds.

June 24. At 12.47 A. M. a shock at San Francisco.—U. S. Weather Review.

June 29. The eruption of the volcano Fuego, in Gautemala, which began at 3 A. M. on this date, was preceded by violent earthquakes, whose effect, however, was confined to the surrounding country within a radius of twenty or thirty miles.

July 12. About 11 P. M. a slight shock at Concord, N. H.

July 13. About 8½ P. M. a shock occurred at Memphis, Tenn. and at Gayoso, Mo. Mr. H. Dow reports the time at Memphis as $8^h\ 24^m\ 52^s$, and Mr. H. Tresenriter at Gayoso at $8^h\ 40^m$, both local time. It was from N.W. to S.E. and lasted several seconds. The U. S. Weather Review notes two shocks at Memphis with an interval of fifty seconds.

July 16. At 10.25 P. M. (Washington mean time) a slight shock at Kingston, Jamaica, oscillation from north to south, lasting about three seconds.—U. S. Weather Review.

July 20. About 7 P. M. an earthquake occurred at Manchester, Milford, Contoocook and Antrim, N. H.; at the latter place two shocks.

July 21. At 10.50 P. M. at Valparaiso, Chili, a "long and rather strong" shock followed by several slight ones during the night.—N. Y. Times.

July 22. At 2 A. M. a shock at Ottawa, Ont., from west to east with rumbling noise.

Aug. 1. At 7 P. M. a heavy shock at Caracas, Venezuela.—*Nature.*

Aug. 10. About 12.15 P. M. a slight shock at Morristown, Dover, Mendham and vicinity in Northern New Jersey, accompanied by a noise as of a "distant explosion."

Aug. 14. A violent earthquake occurred in Chili from Valparaiso to Coquimbo and inland. The duration was nearly ninety seconds. No serious damage was done at Valparaiso, but churches and buildings were overthrown in Quillota and other towns near; and the town of Illapel suffered very severely.

Aug. 18. Two distinct earthquake shocks were reported from St. Dorothy district in Jamaica, during the severe cyclone which swept over the island on that night.—*U. S. Weather Review.*

Aug. 20. At 6.30 A. M. strong shocks were felt in the Vuelta Abajo region, in Candelaria and San Cristobal, in Cuba. The oscillation lasted seven seconds and was from east to west.—N. Y. Tribune.

Aug. 21. A shock at Barrington, N. H.—*U. S. Weather Review.*

Aug. 22. At 1.23 P. M. an earthquake was felt at Victoria, (British Columbia) and many other places in the southern part of Vancouver Island, and also at Port Townsend, Seattle and other points in the northwest of Washington Territory. At Victoria, two lighter ones were felt at 2.10 and 2.19 P. M.

Aug. 29. At 1.10 P. M. a slight shock at San Diego, Cal.—U. S. Weather Review.

Aug. 30. Several earthquake shocks about 2 or 3 A. M. were reported from Nonsuch Island and St. David's Island, in the Bermudas, during the severe cyclone which passed over the Islands on that day.—U. S. Weather Review.

Sept. 1. About ten or fifteen minutes before 5 A. M. a very slight shock was felt in Morristown and Dover, N. J., and vicinity. It lasted about ten seconds with a distant rumbling sound.

Sept. 6. A slight shock a little after midnight at Montreal, Huntington and Cornwall, on the St. Lawrence. The time given at Huntingdon is 0.30 A. M.; at Cornwall, 2 A. M.; and at the former a "rushing noise loud enough to awake every one" is mentioned.

Sept. 16. At 10.27 P. M. a shock lasting fifteen seconds, was felt in Utah, at various places from Salt Lake City to Provo. The movement was from S.W. to N.E., and in some places a low rumbling noise preceded it. At Provo a second shock was felt about 1 A. M.

Sept. 23. About 6 P. M. a shock at Charlotte, Vt.—*U. S. Weather Review.*

Sept. 26. At 5.40 P. M. a shock at Los Angeles, Cal., from west to east, lasting three seconds.—U. S. Weather Review.

Oct. — Middle of the month, the Ship "Ivy" experienced an earthquake shock when off the coast of Chili.—*San Francisco Bulletin.*

Oct. 26. At 1.30 P. M. a severe shock was felt at Sitka, Alaska, followed half an hour later by a second shock, and by seven or eight more in the succeeding forty-eight hours. The first and most violent shock continued twenty or thirty seconds, none of the others more than two or three seconds. This earthquake appears to have been felt along the coast of British America and to have been accompanied by a tidal wave, of which, however, no details have been received.

Nov. 4. At 7.37 P. M. a sharp shock at San Francisco and vicinity, vibrations east to west, duration five seconds; felt also slightly at San Jose.

Nov. 6. Under this date it is reported that "a shock of earthquake has been felt at Newcastle, Ont."—*Princeton Press.*

Nov. 12. At 8.45 P. M. at Los Angeles, Cal., a slight shock, duration three seconds.

At 10.30 P. M. the same night, a shock was felt at Santa Barbara, direction N.E. to S.W. lasting several seconds.

Nov. 21. At Los Angeles, Cal., and places south and east, three shocks were felt in the evening. The times are differently reported as 8.10 and 11 P. M. and 2.30 A. M., and from other sources as 7.45, 9.45 and 11 P. M. The first shock was the longest and most severe.

Nov. 24. At 11.45 P. M. a shock at Quebec.—J. W. D.

Nov. 28. At 8.30 A. M. a shock at St. Paul's Bay on the St. Lawrence.

Dec. 7. At 5.54 P. M. a slight shock from the S.W. at Olympia, W. T., lasting a few seconds; felt also at Bainbridge Island, where the direction was N. to S.

Dec. 10. A shock at 5 A. M. at Bainbridge Island, W. T., motion perpendicular.—U. S. Weather Review.

Dec. 12. About 8.40 P. M. a severe shock occurred in the vicinity of Puget Sound, W. T. It was felt from Victoria on the north to Portland on the south. At Olympia four shocks were reported, lasting ten or fifteen seconds. At Seattle the direction was S.E. to N.W.; at Bainbridge Island it was N. to S.

Dec. 14, 20. Slight shocks were felt at Bainbridge Island, W. T., at 7 P. M. of the 14th, and 11.16 P. M. of the 20th.—U. S. Weather Review.

Dec. 19. Between 2 and 3 A. M. a shock occurred at Los Angeles, Cal. At 3.40 P. M. another felt from Los Angeles to San Diego and vicinity, oscillations S.E. to N.W.

Dec. 21. At 11 P. M. a sharp shock at San Diego and Campo, Cal., from S.E. to N.W. At the latter place another similar shock, accompanied by a rumbling noise, occurred at 3.22 A. M. the next morning.

Dec. 26, 28. At Tecaluma, San Diego Co., Cal., a slight shock at 2.30 P. M. on the 26th and a severe one at 11 P. M. on the 28th. —U. S. Weather Review.

Dec. 29. At 11.25 P. M. a slight shock at Bainbridge Island, W. T.—U. S. Weather Review.

1881, Jan. 20. At 9.40 P. M. a decided earthquake, lasting about ten seconds, shook the vicinity of Bath, Me. It was felt at Brunswick, Bowdoinham and other places as far as Portland and Lewiston.

Princeton, N. J., Jan. 29, 1881.

ART. XXIV.—*On liquid Carbon dioxide in Smoky Quartz*; by GEORGE W. HAWES.

THE presence of two immiscible fluids in the cavities of certain minerals has been so long known, and the number of such occurrences has been so multiplied by microscopic study of the rocks, that no especial interest is attached to new discoveries of this nature, save as they have a geological significance, or are associated with mineral peculiarities. I wish to show that such inclusions are common in smoky quartz, and to call attention to some occurrences which are very remarkable for the number and size of these inclusions. As my supply of excellent specimens is nearly limitless, a knowledge of these occurrences will be welcome, since most of the specimens of this nature that have been described contain only cavities that are minutely microscopic.

On examining the specimens of quartz in the cabinet of Professor Brush a number of crystals were found to contain cavities in which were included two fluids, one of which had the properties of carbon dioxide. All of these crystals had a smoky tint, and this I consider a circumstance of interest, as connected with the observation of Forster * that such crystals contain organic compounds. Forster found that from dark smoky quartz he could distil a brown fluid which had an empyreumatic odor, and which gave reactions for ammonia and carbonic acid; that a sooty deposit formed on the neck of his retort, and that the quartz was decolorized by this distillation. He therefore concluded that the coloring matter was a nitrogenous hydrocarbon decomposable by heat.

I have not considered it necessary to make any extended series of observations, since the few specimens examined indicate sufficiently that such inclusions are not rare in smoky quartz. The following localities furnish specimens with very large cavities.

Pike's Peak. Cavities ½ mm. in diameter and smaller. Some cavities contain only liquid carbon dioxide and its vapor. Some contain apparently only water. Some cavities contain cubic crystals in the water, and some are crystalline in form.

White Plains, North Carolina. Cavities fewer than in the preceding.

Monte Sella. Same as in the smoky quartz of Pike's Peak.

Fibia, St. Gothard. Cavities 2 mm. in longest diameter, large enough to be studied with a simple pocket lens.

* Pogg. Ann., cxliii, 173, 1871.

The smoky quartz from Branchville, Conn.,* is, however, the most wonderful in the number, size and diversity of the included cavities, and as I think that no specimens of this nature that are so remarkable have before been found, these deserve a description. In the great pegmatite vein from which Professors Brush and Dana have taken so many new minerals, smoky quartz occurs in considerable quantity, which is so full of cavities containing condensed gas, that a report like the explosion of a percussion cap takes place when a fragment is knocked off with a small hammer. When heated it decrepitates with such violence that bits fly whistling through the air to a distance of twenty feet. Any little chip broken off with a hammer will present under the microscope the appearance represented in fig. 13. Besides these cavities the quartz shows but few inclusions. These are in part pyrites, and in part iron oxide, and some appear to be black coaly particles. Some of the specimens are entirely free from all inclusions save the fluids in cavities. The quartz has a sp. gr. of 2·625, which is lower than that of pure quartz.† It has a very well marked rhombohedral cleavage, all three planes of the primary rhombohedron being frequently finely developed on pieces broken off at random.

Fig. 1 represents a cavity in which the outer zone is water, the middle liquid carbon dioxide, and the inner gaseous carbon dioxide. When such a cavity is gently warmed, the carbon dioxide in liquid form expands causing the inner zone to contract, and the liquid will expand sufficiently to occupy the whole space, causing the inner zone to disappear at a temperature lower than 31° C.

Fig. 2 represents a cavity of the same nature save that the inner zone is relatively larger. When warmed, the expansion of the liquid CO_2 is counterbalanced by the evaporation into the zone of the vapor within, and no especial change is noted till the critical point of carbon dioxide is reached, which is 31° C., when the inner and middle zone suddenly become one. The disappearance and reappearance of the inner bubble on cooling are, in the large cavities, attended with violent ebullition.

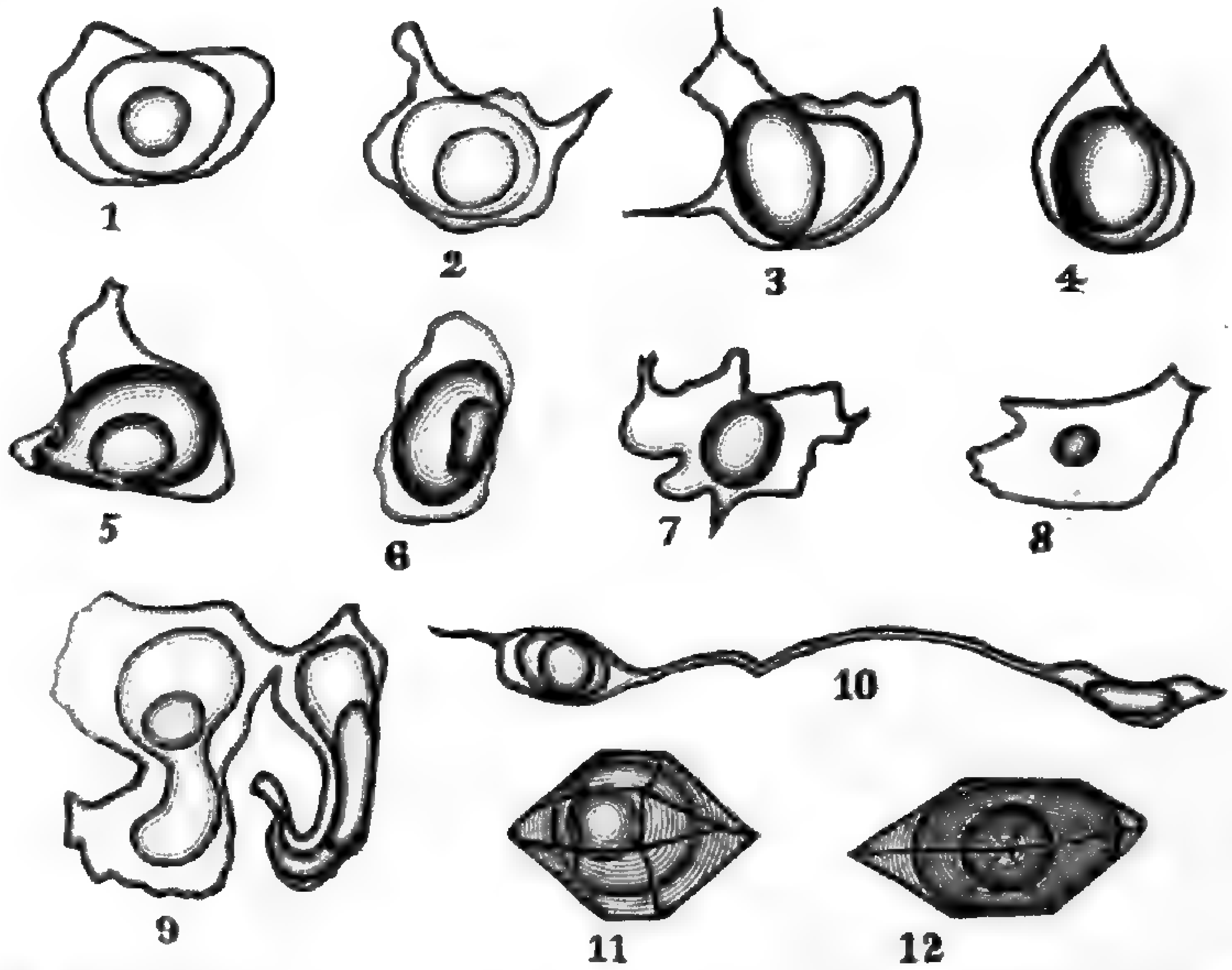
Figs. 3 and 4 represent cavities in which the bubble of vapor predominates more and more over the liquid carbon dioxide. In such cavities the bubbles will begin to expand as soon as heat is applied, and the whole fluid will evaporate into the inner zone, causing the bubble to disappear at a temperature below the critical point of the CO_2.

Figs. 5 and 6 represent cavities in which there is not sufficient liquid carbon dioxide to wet the walls between it and the

* The quartz that contains these inclusions is, however, not all smoky.

† Sp. gr. of pure quartz 2·65. Smoky quartz of Forster (l. c.) 2·65027.

water. It therefore gathers into a globule, and the liquid now takes its place as the inner zone. In such cavities again the inner zone grows smaller and disappears at a temperature below the critical point of the carbon dioxide, and the smaller the inner globule is, the quicker it will evaporate into the zone of vapor. In such cavities the line which divides the water from the middle zone is much blacker, and more deeply shaded, because the difference in the indices of refraction of water and vapor of carbon dioxide is much greater than between water and liquid carbon dioxide.



Cavities in Branchville quartz containing water and liquid and gaseous carbon dioxide in variable proportions, magnified fifty diameters.

Figs. 7 and 8 represent cavities in which if carbon dioxide exists, it is not in sufficient amount to be condensed to liquid form, and in which the volume of water is relatively much larger. These cavities, therefore, possess but two zones, the outer of water, the inner of vapor. The temperature at which such bubbles disappear is very much higher and dependent upon their size.

No relationship between the position of the cavities and the relative size or method of arrangement of the three zones could be detected. The cavities figured form an interesting series, dependent upon the relative volumes of the two fluids, and any or all the members of the series are liable to be simultaneously present in the field of the microscope. The temperatures at which the inner bubbles disappeared and reappeared in cavities simultaneously visible were noted as follows:

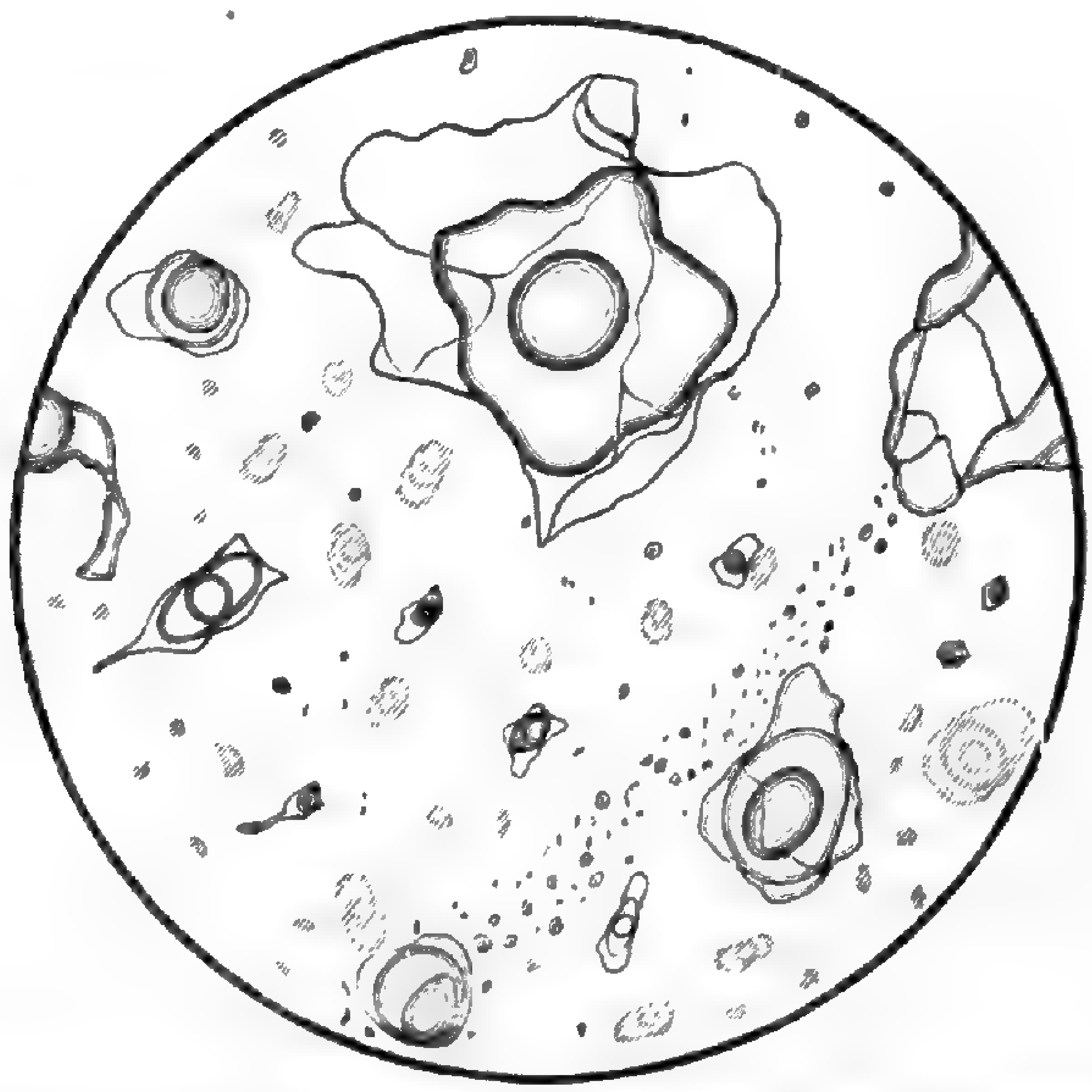
	Disappeared.	Reappeared.
(1)	24°	24°
(2)	25°	25°
(3)	27°	27°
(4)	30°	30°
(5)	31°	31°
(6)	32°	32°
(7)	110°	25°
(8)	114°	After more than two weeks.

The cavities numbered from 1 to 6 contained three zones and the bubbles disappeared and reappeared as described; but the cavities numbered 7 and 8 were like figure 8 and possessed but two zones. The bubble which disappeared at 110° returned suddenly as a cloud of minute bubbles like the bursting of a sky rocket when the specimen had cooled to 25°. The bubble which disappeared at 114° could not be induced to return by long immersion in a freezing mixture. At the end of two weeks it had not returned, and it was only by chance that after this article was complete, and I had written that it had finally disappeared, that I discovered that it had returned in full size. I have thought these phenomena might be explained as follows: The inner bubble is not, as in the other cases, a space filled with the vapor of an expansible liquid with which it is in contact, but it is a space filled with the vapor of carbon dioxide in contact with water. When heated the water can expand and fill the space, but it must act not merely by virtue of its expansibility to do this; it must also condense or dissolve this gas, and under the generated pressure it could dissolve it. The conditions for the reappearance of the bubble on cooling would be different from those which exist when a space is formed by the contraction of a homogeneous liquid. The dissolved gas might separate from the contracting liquid, as a multitude of bubbles adherent to the walls of the cavity, and too minute to be detected by the microscope. The bubble which disappeared at 110° and returned at 25° came back as a large number of small bubbles which only reunited to one after being jostled about for an hour or more, and the bubbles may have returned in the other cavity in still greater number, forming an undetected film upon some portions of the walls.

Figures 9 and 10 represent some of the strangely deformed cavities, which exist in limitless diversity in this stone. In the cavity shown in figure 9 there are two connected chambers, each of which contains the three zones. But owing to the difference in relative volume of liquid and gaseous carbon dioxide, on warming, the bubble in the left chamber contracted and the one in the right expanded at the same time. After both had disappeared, on cooling both reappeared, but their relative volumes had changed, the bubble to the left becoming twice as large as formerly, and the one to the right becoming correspondingly small. A part of the water had been transferred therefore to the right hand chamber

Many cavities, especially those in well-developed crystals, are bounded by planes parallel to the outer planes of the crystal. Such are represented in figs. 11 and 12. These usually appear dark in color, by transmitted light, because so much light is reflected away by the crystalline planes. Their inclusions are frequently better seen by reflected light. These cavities attain sometimes to a diameter of two millimeters.

13.



A fragment of Branchville quartz as it appears when magnified twenty-five diameters.

Fig. 13 represents the general appearance of the rock, as seen with a low magnifying power, a cavity 1^{mm} in diameter being in the field. Such a bubble as this cavity contains will contract when heat is applied, but before it disappears the critical temperature will be reached when the bubble will expand and occupy all the space of the two inner zones. The most violent ebullition will occur when the section cools to the critical temperature. A multitude of small globules will appear, and will finally unite, and the reverse processes of contraction and expansion will follow.

The character of the included gas has been determined by Professor Wright, who gives the results of his investigation in another article.

Having observed bubbles both in liquid carbonic acid and in water that were in rapid erratic motion, the old question of the cause of these motions was suggested. The lack of a conclusive explanation of these movements has never been felt since the phenomenon is physical, and has no special bearing upon geological science, further than that the motion furnishes a ready means for the demonstration of the presence of a mobile fluid, in distinction from glass. A sufficient number of explanations have been offered, yet so late a book as the Minéralogie Micrographique* of Fouqué & Levy, gives a choice of explanations, and an admission of doubt.

The following experiments I think may form the basis for an opinion. If a cavity containing a bubble of vapor floating in a fluid is warmed upon one side, the bubble will move toward the source of heat. If the enclosing fluid be carbon dioxide, this movement is produced by a very slight change in temperature. With a globule of hot glass on the end of a rod such a bubble can be brought into a slow vibration, by moving the source of heat from side to side. The motion will not alter in direction when the bubble has become very small, by the expansion of the containing fluid, but the velocity of the motion is much increased. If the containing liquid be water, bubbles of large size will not be affected so quickly, but when the bubbles have become small, they move with great rapidity.

In water cavities, the bubbles of which have been absorbed by the expanding liquid, the bubbles appear upon the colder side, and shoot rapidly toward the warmer side of the cavity.

Currents of heat can then produce very rapid motion in bubbles of small size, and these motions are definite in direction, when the direction of the current is definite. They can all be explained as being caused by the evaporation of the liquid into the space, the evaporation taking place upon the warmer side, and condensation upon the colder side. When one thinks of the exquisite balance which exists between the temperature and the number of molecules which exist in a closed space within a fluid acted upon simply by the pressure of its own vapor, one can imagine the difficulty of restraining action, for physicists know what great precaution is necessary to obtain anything like a uniform temperature; a condition almost impossible to secure on the stage of the microscope. The following experiments were tried with the object of observing the effect of an approximately equalized temperature.

A section of gold quartz, containing most active bubbles included in liquid carbon dioxide, was placed in a tank of water upon the stage of the microscope. The instrument was placed in the middle of the room and the window was opened to equalize the temperature within and without. Four cavities were especially noticed in the field of view. The bubbles all possessed different rapidity of motion. After standing over

* Minéralogie Micrographique Roches Eruptives Francaises, Paris. 1879.

night the vibration of the two bubbles having the slower rates of motion had ceased.

A specimen of granite containing very movable bubbles, included in water cavities, was likewise treated. In the morning the motion had ceased in the cavity especially noticed, but it began again after I had stood by the microscope a moment.

I think that these experiments are sufficient to show that currents of heat, by producing alternations of evaporation and condensation, can cause motions like those seen in the bubbles floating in these fluids, and that the changes of temperature sufficient to move these bubbles are very small in amount, and very difficult to avoid. This explanation is not new, and would, I think, suggest itself to most physicists, but it has not been shown to be sufficiently probable to receive acceptation.

A result of my examination of the cavities in quartz from Branchville has been most plainly to identify these cavities as being of the same nature as those that have been studied by several eminent microscopists in topaz and other crystals, and in granites, gneisses, basalts and other rocks. Quantities of condensed gas sufficient for exhaustive analysis have not however been heretofore found, and therefore the associated communication of Professor Wright will have a general interest to geologists, since it bears upon a class of long studied phenomena.

Art. XXV.—*On the Gaseous Substances contained in the Smoky Quartz of Branchville, Conn.*; by Arthur W. Wright, Yale College.

The existence in quartz of numerous cavities containing a liquid substance is a matter of familiar occurrence, and great interest has attached to the investigation of the character of these inclusions. Although the presence of carbon dioxide and water had been well established, the difficulty of separating the contents of the cavities in sufficient quantity has hitherto prevented a direct examination of them. The quartz from Branchville is remarkable for the great size and number of the cavities, the peculiar characteristics of which are described by Mr. Hawes in the preceding article. The fortunate circumstance, noticed by him, that when exposed to a moderately high temperature it decrepitates and is speedily resolved into small fragments, made it possible to obtain with great ease and convenience enough of the enclosed substances for an extended examination. The material employed was derived from the collection of minerals from Branchville, of Professors Brush and Dana.

The temperature required for the disintegration of the quartz is much below that of red-heat, and the bursting of the solid material is evidently due to the increased tension of the gas, as it does not occur in those fragments which contain no cavities. The first trials were made with glass vessels, but the sharp fragments of the mineral were shot off with such violence as to destroy them immediately. Recourse was therefore had to a porcelain tube about one centimeter in diameter, glazed inside. This was carefully cleaned with pure distilled water, one end stopped with a plug cemented in, and the other provided with a perforated brass cap, into which could be screwed a piece through which passed a slender glass tube, the joint being rendered tight by a thin washer of india-rubber or paper. The closed end of the tube was filled for some 12 centimeters with pieces of clean glass rod, and upon these rested a loose plug of calcined asbestus. The quartz, broken into fragments of such a size as to permit their entrance, was dropped into the tube, filling it to within 10 or 12 centimeters of the mouth. When heated in a Bunsen flame, the whole of the material could be brought to the requisite heat without causing any perceptible elevation of the temperature of the cement joints. This receptacle, when charged, was connected by means of the glass tube with a Sprengel pump, all joinings of the glass tube being made by fusing, and the whole was easily rendered absolutely free from leakage.

The pump having been kept in action until no gas appeared to pass down, heat was cautiously applied to the tube, and gradually increased until a little gas was liberated from the quartz. When this had been thoroughly pumped out, removing thus the last portion of air, the heat was again applied and continued until the cessation of the decrepitation showed that no more gas could be obtained. The mercury was then set running in the pump carrying the gas into the measuring tube used for the analysis. A preliminary examination showed the greater portion of the gas to be carbon dioxide, the remainder apparently consisting chiefly or wholly of nitrogen. A considerable amount of water was also found to be present. In the succeeding operations this was collected for examination by causing the gas as it issued to pass through a U-tube of small caliber which was placed in a freezing mixture. As the temperature of the refrigerating mass was such as to reduce the tension of the vapor to less than one millimeter nearly the whole of the water was thus retained.

For the more careful analyses two portions of the rock were selected representing the greatest differences in the material. The first, No. 1, was of a light gray color, somewhat milky in appearance, and contained many cavities easily visible without the aid of a lens. The weight of the material employed was 21·70 grams, which, divided by the specific gravity 2·63, gives for the volume 8·25 cubic centimeters. The second portion was of the darker variety, having a smoky brown color, appearing nearly black in large masses. The gas cavities in this were not so conspicuous, and apparently were less numerous. The amount of the material placed in the tube for examination was 19·49 grams, and the volume 7·41 cubic centimeters. This portion is designated as No. 2 in the following paragraphs. The total quantity of gas collected from No. 1 was 13·61 cubic centimeters, or 1·65 times the volume of the quartz. From No. 2, 7·20 cubic centimeters of gas were obtained, or 0·97 times the volume of the material employed. From the first portion examined in the preliminary work 1·33 volumes were obtained.

The eudiometer having been transferred to the mercury cistern, an absorption pellet moistened with solution of potassic hydrate was introduced into it, causing a rapid diminution of the volume of the gas. When this operation was complete the residual gas had been reduced to a small bubble in the top of the tube, which could not be measured directly with sufficient accuracy. To find its volume a little of the potash solution or of distilled water was admitted giving a meniscus concave toward the top of the tube. The position of this was carefully noted, and the tube emptied. Mercury was now introduced until the surface of the meniscus occupied exactly the former position of the surface of the water, and the metal was then weighed. The mean of five separate measurements being taken the volume of the gas was thus readily calculated. The results of the determinations with the two different portions of the material gave

	I.		II.	Mean.
CO_2	98·34	CO_2	98·32	98·33
N	1·66	N	1·68	1·67
	100·00		100·00	100·00

Cuprous chloride produced no perceptible absorption, showing the absence of carbonic oxide. Potassium pyrogallate introduced into the tube with caustic potash solution produced a slight discoloration of the latter, but no change in the volume of the gas was visible, indicating that oxygen if present was not in recognizable quantity.

To ascertain the presence of hydrogen or other combustible gases a number of tests were made. A spark passed through the gas directly produced no effect, nor upon the addition of oxygen or air alone could any combustion be produced. When the proper quantity of pure electrolytic gas was added the explosion produced no apparent change in the volume. This, if, from the small amount of gaseous substances operated with, it might not safely be concluded that hydrogen or hydrocarbons were entirely absent, shows that the quantity was exceedingly small. The residual substance then was nitrogen. In these operations, as already mentioned, the gas had passed through a tube placed in a freezing mixture. A later experiment, to be described in a succeeding paragraph, gave a somewhat different result.

The rock when broken or crushed with a hammer exhales a fugitive but unmistakable odor of hydrogen sulphide, but the proportion of the gas was too small to be directly detected with the ordinary lead-paper even when directly applied as a cover to a diamond mortar in which a considerable quantity of the material had been powdered. But when a slip of the paper was introduced into a tube filled with the extracted gases, a slight but distinct coloration was produced. The same was true in a somewhat more marked degree with a paper moistened with mercurous nitrate, indicating sulphurous oxide. To test this more fully separate slips of filtering paper were wet with plumbic acetate, sodium nitro-prusside, and mercurous nitrate. When dry they were introduced into a small tube through which gas freshly liberated was made to pass. Snow applied for a few moments to the tube ensured the presence of sufficient water to moisten the paper slightly. The first underwent a slight discoloration, which after a time disappeared, the second assumed a pinkish tint, while the third was distinctly blackened, thus proving the presence of a trace of both the gases in question, a conclusion moreover which was verified by other and independent trials.

As both hydrogen sulphide and sulphurous oxide are absorbed by potassic hydrate it was important to ascertain whether these gases were in sufficient quantity to affect the conclusion given above as to the amount of carbon dioxide. A portion of the gas collected in a clean tube was therefore submitted to a special examination. A pellet of ferric oxide formed upon the end of a platinum wire produced no effect at all, though kept in the gas for several hours. A similar pellet of manganese dioxide moistened with syrupy phosphoric acid likewise caused no perceptible effect, thus proving that these gases were not present in any measurable quantity.

An approximate estimation of the amount of water was made as follows: The U-tubes in which the water had been condensed were sealed after the gas had been thoroughly pumped out. The temperature of the freezing mixture was from $-19°$ to $-20°$ C., so that the tension of the residual vapor was less than one millimeter, which was confirmed by the reading of the guage of the pump at the end of the operation. The connecting tubes were fused off and the portion containing the water withdrawn. The amount of liquid thus obtained was considerable. The tubes were carefully weighed, then opened, and after an examination of the liquid, thoroughly dried, and weighed again. The weight of the water in No. 1 was thus found to be 13·4 milligrams, in No. 2, 12 milligrams, corresponding respectively to 13·4 and 12 cubic millimeters at 4°. The volume of the quartz in the first instance being 8·25, and in the second, 7·41 cubic centimeters, we have for the amounts contained in one cubic centimeter of the mineral, 1·63 and 1·62 cubic millimeters respectively, no correction being made for temperature, as the results are only approximate. This would indicate a comparative uniformity in the distribution of the water, while the amount of the gas varies. But such a conclusion is at best doubtful, inasmuch as the darker quartz is not as thoroughly broken up by the heat as the lighter variety, and the refrigeration of the tube No. 1 was not made complete at first, so that some water doubtless escaped with the gas uncondensed.

A small portion of the water removed with a minute pipette was dropped upon red litmus paper, where it produced a strong but fugitive alkaline reaction, implying the presence of free ammonia. This was confirmed by adding Nessler's test solution to the remainder of the liquid in the end of the tube, in which it caused the characteristic yellow coloration, and, in one instance, a slight precipitate. Before the tubes were opened it had been noticed that the water, though to all appearance perfectly transparent and colorless, left a white deposit upon the glass where a drop of it had evaporated. When this was heated by the application of a small gas flame, it did not fuse, but appeared to shrink or to diminish in amount very slightly, while the glass around it and over it lost its transparency as if corroded. A similar but very slight action upon the glass where the moist gas had come in contact with it had previously been observed. This suggested the presence of fluorine. The glass of the tube in which the effect was most marked contained some lead, but the other showed it also to some extent. A special experiment with a tube free from lead, which had been most carefully cleaned, gave the same result, though in a somewhat less marked degree. Its appearance would be accounted for by the supposition that the water of the cavities contained some hydro-fluo-silicic acid in solution, resulting from the decomposition of silicon fluoride, or, as ammonia was also present, from an ammonium compound of the acid.

As was mentioned in a preceding paragraph, no evidence of the presence of a hydro-carbon compound was discovered in the examination of the gas which had passed slowly through the cooled tubes. The tubes themselves, however, contained what appeared like minute drops of some oily substance, so small as to be scarcely visible without a lens, and quite insufficient for examination. In order to investigate this point more satisfactorily, as also to obtain a greater quantity of the residual gas left by absorption of the carbon dioxide, an experiment was made as follows: A bolt-head of porcelain, glazed interiorly, and having a capacity of about 300 cubic centimeters, was employed for the reception of the quartz, of which 196 grams, making 75·4 cubic centimeters, were used. It was arranged that after the air had been pumped out, the gas from the quartz should pass through a strong solution of potassic hydrate contained in a large U-tube, all connections being made with fused glass joints as before. The greater portion of the carbon dioxide was thus absorbed. Unfortunately just at the close of the operation a slight crack in the porcelain vessel admitted some air, but the tube leading to the pump was sealed immediately, so that the amount mixed with the gas was not too great to permit a quantitative examination of the gas to be made. A portion of the latter being transferred to the eudiometer, and just sufficient electrolytic gas being admitted to ensure combustion, the volume of the gas after explosion was found to be considerably increased, with the production of carbon dioxide. Repeated tests gave uniformly the same result, but the expansion was greater at first than after the gas had been kept for two days in the pump. This must be regarded as evidence of the presence of the vapor of some condensable hydrocarbon having a large number of carbon atoms in the molecule.

The quartz on heating entirely loses its color, the coarse powder which is left being almost snow-white. Now, in the experiment just described, a dark brownish deposit was formed in the tube leading from the bolt-head, and the potash solution after the passage of the gas had become brown, the color being almost exactly the same as that of the quartz before the heating. After standing a day or two a small amount of a dark brown, nearly black, substance separated out as a precipitate and the liquid lost its color. The potash solution was now decanted and the dark deposit examined. Treated with alcohol it dissolved but partially, communicating its color to the liquid, and taking on a tarry consistency. On evaporating the alcohol, the substance was volatilized by more intense heat, with a strong bituminous odor, very much like that given off by cannel coal when burning. The brown deposit in the tube also gave off the same odor when strongly heated. These results imply that the smoky color of the quartz is due to the presence of a hydrocarbon of the nature of bitumen, which is driven off by heat, and the partial decomposition of which, at the high temperature reached, accounts for the heavy hydrocarbon found in the residual gas, or condensed upon the walls of the cooled tubes. These facts, moreover, are entirely in harmony with and confirm the conclusion of Forster* from an examination of the remarkable smoky quartz from the canton of Uri, that the color of the latter is due to the presence of some volatizable hydrocarbon, though they do not directly connect the ammonia with the latter, as his observations appear to do.

After the operation just described had been concluded, some pure distilled water was introduced into the bolt-head, and after standing for some time was then withdrawn. Tested with argentic nitrate it gave a considerable precipitate of argentic chloride, while when examined spectroscopically it afforded satisfactory evidence of the presence of sodium, but of no other metal. The water previously examined was found to be free from both chlorine and sodium. The bolt-head had been scrupulously cleansed before use, and great care was taken in this, as in all the experiments, to prevent contact of the quartz with things that might communicate to it any impurity. This result would indicate that the cubical crystals observed by Mr. Hawes in some of the cavities were chloride of sodium. Search was also made for chlorine or chlorine compounds in the gas. A quantity of this freshly liberated was passed through distilled water. This, on the addition of argentic nitrate, was very slightly clouded, making the existence of a trace of some chlorine compound probable. Not unlikely a minute proportion of ammonium chloride is among the contents of the cavities.

The quantitative relation of the water to the gases obtained from the quartz may be made more evident if calculated for a temperature of 100° C. at which the former would be entirely converted into vapor. Taking the amount of water per cubic centimeter at 1·62 cubic millimeters as found above, this multiplied by 1694·3 gives 2·74 cubic centimeters for the volume of the water vapor at 100°. If we take the gaseous volume for one cubic centimeter of the quartz at 0·97 cubic centimeter, the result derived from No. 2 above, where the water determination was most satisfactory, the temperature of the room at the time of measurement being about 20° C., we have for the volume at 100°, neglecting the correction for the barometric pressure which was not greatly different from 760 mm., 1·23 cubic centimeters. Reduced to parts in 100 these volumes give

* Pogg. Ann., cxliii, 173, 1871.

CO_2	30·48
N	0·50
H_2O	69·02
	100·00

For the reasons mentioned above this must be regarded, so far as the water is concerned, as merely an approximate result.

For the gases alone, leaving out of view the bituminous matter, which is not known to be specially connected with the cavities in the material, and probably is not, we have the following summary:

CO_2	98·33
N	1·67
H_2S	*trace*
SO_2	"
H_3N	"
F	"
Cl?	"
	100·00

The ammonia, if derived from the gas cavities, undoubtedly existed there in combination with the carbon dioxide, as ammonium carbonate. From the considerations mentioned above the fluorine and chlorine detected by the tests applied also represent compounds of these elements with some of the other substances present. The results of the investigation show that the contents of the cavities are chiefly water and carbon dioxide, with a small portion of nitrogen, thus essentially confirming the conclusions derived from microscopical examination.

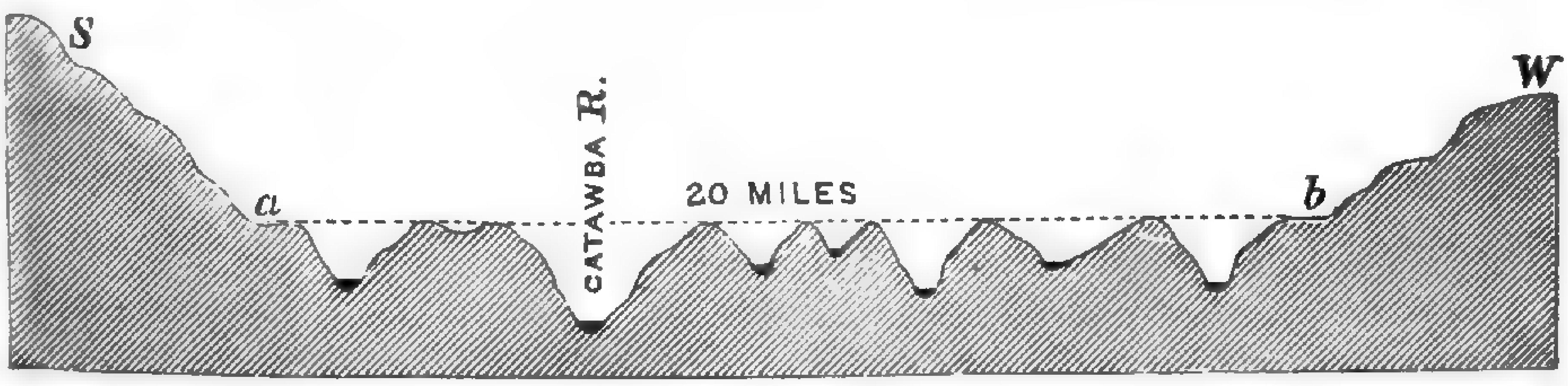
Yale College, Feb. 11, 1881.

Art. XXVI.—*Origin of some new points in the Topography of North Carolina;* by W. C. Kerr, State-geologist of North Carolina.

Although all the ordinary indications of glaciation are wanting in North Carolina, even in the higher plateaus of the western mountainous region, as ascertained and announced more than ten years ago, yet, singularly enough, long after I had ceased to look for evidences of glacial action, I have arrived, by two entirely independent lines of investigation, at the conclusion, unexpected and unsought, that glaciation has occurred here on a large scale, and at two different periods. Moreover, the evidences of the existence and action of glaciers is totally different from the commonly recognized marks and results of glacial action.

I have elsewhere described briefly one of these classes of phenomena, and shall discuss them more at length very soon; of the other I give here some outlines, sufficient to indicate the character of the evidence and to direct the attention of observers to similar phenomena elsewhere.

The accompanying diagram represents the facts better than any description can do. It is an ideal cross section of the hydrographic basin of the Catawba River, which takes its rise in numerous tributaries along the flanks of the Blue Ridge, and after gathering up a multitude of these, traverses the Piedmont, or cismontane plateau (of an elevation of 1,000 to 1,500 feet),



Ideal section of the Catawba River basin, between S., South Mountains, and W., Warrior Mountains.

in a wide basin or trough, flanked by two ranges of mountains, which rise on either hand to an additional elevation of a thousand feet and upward. The direction of the axis of this trough and of the bordering ranges is 60° to 70° east of north, which is about coincident with the strike of the rocks.

These rocks are Archæan — hornblendic and feldspathic gneisses, and micaceous and hydro-micaceous schists, of varying hardness and durability. The river and its several affluents have dug their channels along the softer and more yielding strata, and have left the tougher and more resisting masses in ridges and low spurs, knobs and domes, which rise above the beds of the intervening streams, from a hundred to three, four and five hundred feet. But the singular and significant fact, as indicated in the diagram, is, that to one standing at *a*, for example, a bench on the flanks of the mountains to the south, or at *b*, of the mountains to the north of the basin, and looking across, all the intervening ridges, knobs and hills *rise to the same level eye-line*, which might be represented by a water-line, so level does it seem from side to side; and one imagines that he is scanning a broad level valley, flat as a prairie. It is only at this particular elevation, about 1,400 feet in the meridian of Morganton,—less as you go east, more as you approach the Blue Ridge, with a very gradual ascent,—that the observation is practicable. A few feet lower you see nothing but the next ridges and hills on either hand; a little higher on the flanks of the mountains, above the line *a b*, nothing strikes the eye but a chopping sea of low mountain spurs and knobs and hills and peaks, stretching away in confused and disorderly succession into the foot hills of the opposite bounding range. I had crossed this valley many times and in many directions, and ascended these mountain chains and measured most of their summits, mapping out in detail their intricate topography for half a dozen years, before this remarkable fact caught my eye. And it was not until the observation had been repeated from different points in the Catawba basin, and the same phenomenon had been observed on a grander scale in the great transmontane valley, the hydrographic basin of the French Broad,—a plateau of nearly a thousand feet greater elevation and of correspondingly greater breadth,—that the full significance of it began to appear.

In the summer of 1877, I stood on one of the foot-hills of the Black Mountains, near the head waters of Ivy River, within the horizon which cuts the level tops of the ridges and knobs and mountain spurs of this rugged and cañon-gashed valley-plateau. During the same summer, ascending the slope of the South Mountains, from a jutting spur, I happened to catch the summit level of the Catawba plateau, at a point which gave the whole sweep of it in length as well as breadth; it stretching westward thirty miles, to the foot of the Blue Ridge, and twice that distance eastward, until the last ridges of the Piedmont became merged into the western margin of the Midland plateau. One readily imagines the valley to have been an arm of the sea during some ancient period of subsidence, and these numerous hill-tops rising as islands to the surface, like the thousands of atolls in the Pacific; and the grand generalization of Darwin came into mind. But no subsidence or action of water seemed adequate to meet the conditions of this problem; nothing, it appeared to me, could explain it except the presence of a great glacier, which in some ancient time had moved down the valley and left the surface nearly level, and then, the subsequent action of meteoric agencies through long ages, channeling out of the plateau thus made the present rugged topography, leaving only this faint trace of its former extent. Nor does any other solution yet occur. The reasonableness of this hypothesis will appear, if it is considered what would be the consequence of the movement of such a glacier over the present surface of the valley for a few thousand years.

As to the time of this supposed glaciation, we note that the opinion seems to be gaining among geologists that there have been several, perhaps many, glacial periods, whether Croll's theory be accepted or not. And there is some ground for the view which introduces the Triassic period with an epoch of extensive glaciation, and the phenomena in question may be connected with the rapid accumulation of the basal deposits of that formation. Or it may hereafter be ascertained, by a more minute study of the Appalachian regions of the middle latitudes, that glaciers established themselves at the higher levels in the earlier times of the Glacial period, but did not recur during the second accession of cold, while the more extensive and long-continued Diluvial denudations and erosions may have sufficed to remove the debris, striæ and other indications of earlier glacial action.

Raleigh, N. C., Dec. 24, 1880.

ART. XXVII.—*Occurrence of Realgar and Orpiment in Utah Territory;* by WILLIAM P. BLAKE.

THE minerals realgar and orpiment occur together in a thin bed or layer in the horizontal sedimentary formations underlying the lava of Coyote Mining District, Iron County, Utah. The formation, with its lava cap, forms the divide between the head-waters of the Sevier river and the Colorado drainage, and is known as the "Rim of the Basin." The horizontal beds of stibnite, recently described by Professor J. S. Newberry, occur in the same formation, but chiefly in a sandstone of a different horizon.

The arsenical sulphides are found in a compact, sandy clay, in a horizontal seam or layer about two inches thick, not distinctly separated from the clay, but lying in its midst, in lenticular and nodular masses. The bulk of the layer consists of realgar in divergent, bladed crystals, closely and confusedly aggregated, sometimes forming groups of brilliant crystalline facets in small cavities towards the center of the mass.

The orpiment, which is closely associated with the realgar, is in small and delicately fibrous crystalline rosettes, and small spherical aggregations, made up of fine radial crystals, and also, in bright yellow amorphous crusts in and around the mass of the realgar.

Above and below the layer, and in close contiguity, there are thin parallel seams of fibrous gypsum. The strata above, for thirty feet or more, are arenaceous clays charged with soluble salts which exude and effloresce upon the surface of the bank and form hard crusts. The whole appearance and the association of the arsenical sulphides indicate that these sulphides have been formed by aqueous infiltration since the deposition of the beds. This, I have no doubt, is the fact; and, also, that the antimony sulphide had a similar origin.

MILL ROCK, New Haven, Jan. 15, 1881.

ART. XXVIII.—*On the Solubility of Chloride of Silver in Water;* by JOSIAH P. COOKE. (Contributions from the Chemical Laboratory of Harvard College.)

THIS subject has already been studied by Stas, whose observations are summed up by Dr. John Percy* in his recent volume on the Metallurgy of Silver in the following words:

"The solubility of the chloride is greatest when in the flaky state, as precipitated in the cold from a sufficiently dilute solution of silver; the solubility diminishes as the flakes shrink when left to themselves, or as they are rendered pulverulent by long agitation with water. Flaky or pulverulent chloride of silver, dissolved in water pure or acidified by nitric acid, is precipitated by the addition of a salt of silver or of hydrochloric acid or of an alkaline chloride." . . . "The solution of the chloride is wholly effected by pure or acidified water, as the case may be, and is not caused by the soluble salt formed simultaneously with the chloride of silver. The presence of nitric acid in the water does not affect the solubility of flaky chloride of silver; but it increases the solubility of the pulverulent chloride in proportion to the quantity of acid present. The precipitation of the dissolved chloride is the exclusive result of its insolubility in the solution formed by adding an excess either of the silver salt or of the alkaline chloride."

So also in Liebig and Kopp, Jahresbericht, 1871, 339: "According to Stas, the granular scaly and crystalline chloride is wholly insoluble in cold water: in boiling water the solubility is comparatively great, but decreases rapidly with the temperature."

In our investigation on the atomic weight of antimony we have had occasion to confirm and extend these observations of Stas, and our results may be of interest as showing that in the very familiar method of determining chlorine by precipitation with nitrate of silver, which is generally supposed to be extremely accurate, a sensible error may arise from the solubility of the chloride of silver in the hot distilled water used in washing the precipitate. It would be well for every analyst to make the following very striking experiment, which will enable him to appreciate the extent of the action in question.

Take from five to ten cubic centimeters of pure hydrochloric acid and precipitate the chlorine in the usual way with nitrate of silver, avoiding a large excess. After pouring off the supernatant liquid and washing the precipitate once or twice with cold distilled water, pour upon the white flaky chloride of silver a comparatively large volume of boiling water. As soon

* Metallurgy of Silver and Gold. Part I, page 60.

as the precipitate settles, pour off the clear hot water, dividing the solution between two precipitating jars. To one of these add a few drops of a solution of nitrate of silver, and to the other a few drops of hydrochloric acid. In both cases a precipitate of chloride of silver will fall, and most chemists, certainly, will be surprised at the effect; for it is not a mere turbidness that results, but a well-defined precipitate, whose amount is easily estimated. Successive portions of boiling water poured upon the precipitate give the same reaction. In one experiment the reaction was still perceptible in the fourteenth wash-water. But under the action of the boiling water, the precipitate becomes crystalline or granular and the action lessens, until at last the water does not dissolve sufficient chloride of silver to cause even a cloudiness on the addition of nitrate of silver, as just described. Mr. G. M. Hyams, a student in this laboratory, washed two different portions of chloride of silver with boiling water until the action ceased, and then weighed and examined the residue. In the first experiment, 1·4561 grams of chloride of silver were washed with 66 liters of water. The chloride of silver was then collected and found to weigh 1·2320 grams. Hence, 0·2241 grams, corresponding to 15·39 per cent had passed into solution. In the second experiment, 60 liters of water were used, and 16·03 per cent of the chloride of silver originally precipitated were dissolved. These numbers, however, are only approximately accurate, for as the precipitate becomes granular, it settles with less readiness, and there was necessarily some loss in filtering off so large a volume of liquid.

In the experiments above described the boiling water produced only a very slight decomposition of the chloride of silver. The precipitate, granulated by the washing, readily dissolved in aqua ammonia, leaving less than a milligram of a black powder, which was proved to be metallic silver.

The solvent power of water on freshly precipitated chloride of silver did not appear to be influenced by the presence of free nitric acid even in large quantities. We tried the effect both of dropping the nitric acid on the precipitate before pouring on hot water, and also of previously adding nitric acid to the boiling wash-water. We used amounts of nitric acid ($\delta = 1·355$) varying from five to two hundred cubic centimeters to the liter of water, but without finding any marked difference in the result.

The presence of a small amount of nitrate of silver in the water entirely prevented its solvent action, so far as we could discover. In order to determine the limit of the action, we added different quantities of nitrate of silver to the boiling water before pouring it on to the precipitated chloride of silver. With one centigram of nitrate of silver to the liter of water, there was a marked turbidness on subsequently adding an excess of the same reagent to the filtrate. With two, three, or even four centigrams to the liter, an opalescence could still be distinguished, although constantly diminishing with the increasing amount of the salt. With five centigrams, there was no opalescence, and we concluded that one decigram of nitrate of silver to the liter of boiling wash-water would certainly prevent all action.

A few drops of hydrochloric acid added to the wash-water greatly diminishes its solvent action on flaky chloride of silver, but does not wholly prevent it, as is evident from the fact shown in the table below, that hydrochloric acid does not precipitate chloride of silver from its solution in water nearly as effectually as nitrate of silver; and, as is well known, hydrochloric acid if in any considerable excess exerts a strong solvent action on the precipitated chloride.

As shown by Stas, the precipitation of chloride of silver from its solution in hot water by the reagents we have named, depends solely on the change which the reagents produce in the solvent. That the action is an example of simple solution is shown by the fact that a considerable portion of the chloride of silver dissolved in boiling water is deposited when the solvent cools. This phenomenon is a striking one and can easily be observed by pouring into a glass crystallizing pan some of the clear solution obtained in the experiment described above. As the water cools it becomes cloudy and deposits a granular powder which adheres to the bottom of the glass. The grains are usually very small, but if the solution cools slowly the crystalline form can readily be distinguished under the high powers of a good microscope, and the little cubes present all the characteristic of the native crystals of chloride of silver. It is evident, therefore, that the granular condition of chloride of silver is a crystalline condition, and this experiment may elucidate the manner in which the native crystals are produced.

We have thus far only spoken of the solubility of chloride of silver in boiling water. As is evident from the crystallization just described, the solubility rapidly diminishes as the temperature falls; but even at the ordinary temperature the solubility is distinctly marked. Luke-warm water poured on and off, freshly precipitated chloride silver becomes decidedly opalescent on the addition of nitrate of silver, and even if cold water is used the opalescence is perceptible.

In order to obtain an approximate measure of the effects we have described, Mr. Hyams precipitated about fifteen grams of chloride of silver, and, after thoroughly washing it, boiled the precipitate with a large volume of water in a glass flask.

At the end of an hour he decanted through a filter about one liter of the boiling water, and, having divided the filtrate into two portions, he added to one portion nitrate of silver, and to the other, hydrochloric acid. The precipitated chloride of silver was in each case collected and weighed. At the end of two hours' boiling, two other portions were filtered off and treated in a similar way. These determinations were then repeated with a fresh quantity of chloride of silver, and afterwards taking with a third quantity of chloride of silver, the boiling water was simply poured on twice in succession and the similar portions thus obtained treated as before. The results in every case were nearly the same as shown in the following table. In this table

1 and 3 are results after one hour's boiling of 1st quantity.
3 and 4 " " " two hours' " " " "
5 and 6 " " " one hour's " " 2d quantity, etc.
7 and 8 " " " two hours' " " " " "
9 and 10 after simply pouring on boiling water.
10 and 12 " " " " " "

No.	Wght. of Water.	Wght. of AgCl.	Wght. of AgCl per liter.	Precipitant.
1	523·6 gram.	0·0011	0·0021	Nitrate of silver.
2	469·5	0·0004	0·0009	Hydrochloric acid.
3	115·0	0·0002	0·0017	Nitrate of silver.
4	402·1	0·0004	0·0010	Hydrochloric acid.
5	225·0	0·0004	0·0018	Nitrate of silver.
6	462·0	0·0004	0·0009	Hydrochloric acid.
7	696·4	0·0014	0·0020	Nitrate of silver.
8	825·4	0·0007	0·0008	Hydrochloric acid.
9	700·4	0·0014	0·0020	Nitrate of silver.
10	747·2	0·0007	0·0009	Hydrochloric acid.
11	520·9	0·0011	0·0021	Nitrate of silver.
12	287·5	0·0003	0·0010	Hydrochloric acid.

If we assume that the amount of chloride of silver precipitated by nitrate of silver under the conditions described above is a correct measure of the solubility of the chloride, it appears from the above determinations that about two milligrams of chloride of silver are dissolved by each liter of boiling water, and further that only about one half of the amount thus dissolved is precipitated by hydrochloric acid.

In making chlorine determinations it is a very common practice to wash with very hot water in order to secure the prompt settling of the chloride of silver or to wash away any occluded material, and it was the chief object of this investigation to determine the extent to which the solubility of the chloride in distilled water might effect the result. For this purpose we may make two series of determinations of the chlorine in chloride of antimony; in both cases precipitating with nitrate of silver the chlorine from a solution of the chloride of antimony in tartaric acid and water with the usual precautions. But, while in the first series the precipitated chloride of silver was washed with boiling hot distilled water to about the $\frac{1}{100,000}$ according to Bunsen's scheme; in the second series although hot water was also used in washing, one decigram of nitrate of silver per liter was added to each successive portion of the wash-water poured upon the precipitate, until the last two portions, which were poured on cold. By this simple device the advantages of washing with hot water may be secured while its solvent action is prevented. The results are given in the following table.

First Series.

No.	Weight of $SbCl_3$ taken.	Weight of AgCl obtained.	Per cent of Cl calculated.
1	2·3856 gram.	4·4784 gram.	46·441
2	3·1300	5·8712	46·407
3	3·4207	6·4243	46·462
4	5·0031	9·3790	46·377
		Mean value,	46·422
		Max. diff. from mean,	0·047

Second Series.

No.	Weight of $SbCl_3$ taken.	Weight of AgCl taken.	Per cent of Cl calculated.
1	3·4059 gram.	6·4188 gram.	46·624
2	3·6603	6·9014	46·643
3	2·4762	4·6658	46·617
4	2·5567	4·8212	46·651
		Mean value,	46·634
		Max diff. from mean,	0·017
	Difference between means of two series,		0·212

It is evident from these results that when great accuracy is required the solubility of chloride of silver may become a very serious source of error in determinations of chlorine, and in our investigation * of the atomic weight of antimony this was the chief cause of the discrepancy between the analyses of chloride of antimony on the one hand and the bromide, iodide and sulphide of antimony—analyses of which closely agreed among themselves—on the other hand. It was shown in the paper just referred to that, although the greatest care was taken in purifying the material, the chloride of antimony used actually left behind on evaporation a sufficient amount of oxichloride to reduce the per cent of chlorine 0·116.† The mean

* This Journal, III, xv, 41.

† This Journal, III, xv, 118.

results which we actually obtained from seventeen analyses of chloride of antimony was 46·620, and when to this we add 0·212 and 0·116 the sum is 46·948, which differs from 47·020—the theoretical value when Sb = 120, and Cl = 35·5—by only 0·072. In this estimate we leave out of the account the known solvent action on chloride of silver of the tartaric acid used to keep the antimony in solution. This must equally affect both of the series of determinations given above and fully accounts for the small difference that remains to be explained. This whole discussion, however, only serves to confirm the conclusion previously expressed, that chloride of antimony is a most unsuitable material for the basis of an atomic weight determination, and having explained the anomaly to which we gave prominence in a previous paper we shall here take leave of the subject. We have also studied the solubility of bromide of silver in water, but this is so small that we found it difficult to measure the amount. In water at the ordinary temperature, or even in tepid water, bromide of silver is practically insoluble. In boiling water it is perceptibly soluble but not more so than is chloride of silver in water at the ordinary temperature. Hence the determination of bromine does not require the same precautions and is susceptible of greater accuracy than that of chlorine; and on this account, as well as for other reasons which we have previously discussed, the atomic weight of antimony can be deduced from the analyses of the bromide of antimony with as great accuracy as can at present be reached in such determinations. In the seven determinations of the per cent of bromine in bromide of antimony which we have published,* the maximum difference from the mean value 66·6651 was only 0·0045, and Professor Mallet in his analyses of bromide of aluminum has obtained with the same method a similar degree of accuracy.†

In conclusion we would again express our obligations to Mr. G. M. Hyams, who has assisted us in the work of this investigation.

* This Journal, III, xix, 385.

† Philosophical Transactions, Part III, 1880, 1022.

ART. XXIX.—*Papers on Thermometry from the Winchester Observatory of Yale College;* by LEONARD WALDO.

[Continued from page 61.]

THE observation of the freezing point of "Kew 585" for Nov. 2d, is not entitled to the weight of the ones made Dec. 1st because it was made by the eye alone, while the readings for Dec. 1st depend on the cathetometer.

We may assume therefore that the constants of these standards for the present are as follows:

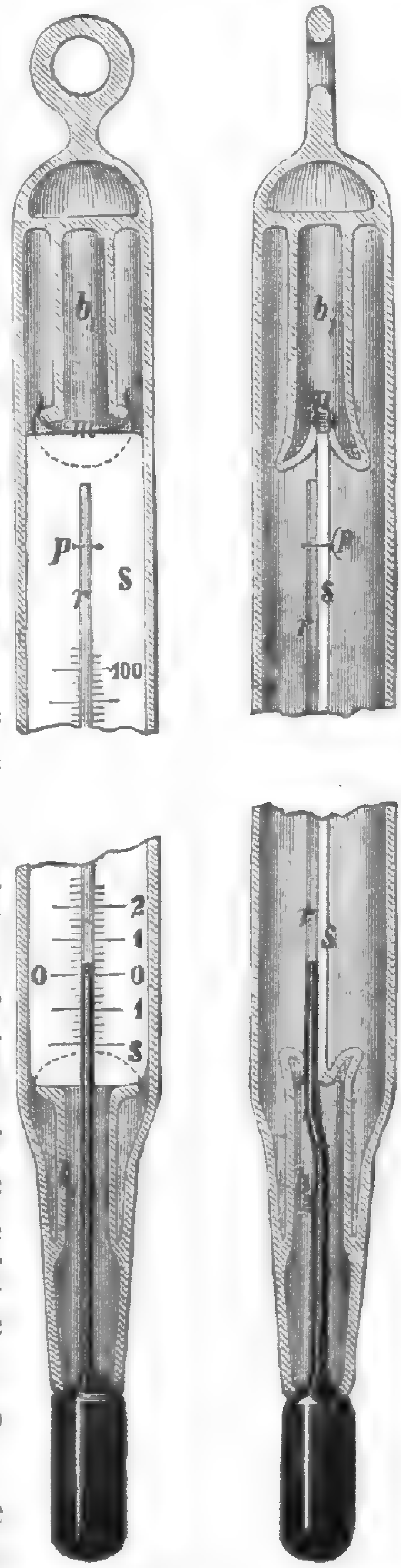
	Kew 578.	Kew 584.	Kew 585.
Correction at the permanent freezing point	0°·00	+0°·10 F.	0°·00
Correction at the boiling point	+0°·03 C.	+0°·20 F.	+0°·14 C.
Depression of the freezing point after an exposure to the boiling point	0°·18 C.	0°·25 F.	0°·22 C.

These are the constants which have been inserted in the formulæ for computing the corrections to the Kew thermometer readings. I shall now investigate the constants of the thermometers similar to the standards of the "Kaiserliche Normal-Eichungs-Kommission" and which have been carefully compared with these standards through the kindness of Dr. Fœrster in Berlin. These thermometers were made by R. Fuess, and I cannot better describe them than by giving their dimensions in the following table and then adding a free translation from the "Bericht über die wissenschaftlichen Instrumente auf der Berlin Gewerbeausstellung im Jahre, 1879," pages 213 and 214.

Designation.	R. Fuess, Berlin, 89.	R. Fuess, Berlin, 50.
How graduated	−6° to +105° C.	−2° to +105° C.
Length of 1°	4·15 mm	4·05 mm
Smallest graduation	0°·1	0°·2
Length of tube	650 mm	573 mm
Outside diameter of tube	12 mm	12 mm
Shape of bulb	Cylindrical.	Cylindrical.
Length	15 mm	12 mm
Diameter	5·5 mm	5·5 mm

* * * * * * *

"Fuess has succeeded in devising a construction for thermometers which is free from all those imperfections, and combines great stiffness with elegance of form. Any displacement of the scale and all slipping or bending of the capillary tube is prevented, and it is possible for the outside tube, the capillary tube and the scale, each to expand independently of either of the others. The normal thermometers made by Fuess which Professor Wild of St. Petersburg describes* 'as the best' which he has 'up to this time become acquainted with,' were made according to this construction, which is protected by patent (D. R.—P. No. 389)."



The figure shows a thermometer of this kind. A hollow glass cup b_2, open at the top, is hermetically sealed to the so-called neck of the surrounding tube. The upper edge of the cup is deeply indented in two diametrically opposite places, so that the two indentations offer a sure bed for the scale plate *s*. To the glass top of the thermometer there is a similar fixed cup b_1, hermetically sealed, the indentations of which, diametrically opposite to each other, receive the upper end of the scale. To hold the scale in its place there is a spring placed between it and the cup b_1, which always presses the scale against its lower bed, without hindering its expansion. The capillary tube *r* passes freely through the hollow cup but is guided by loops *p* of platinum wire as fine as hairs, which are drawn through minute holes in the scale; so that without hindrance from the loops *p* it can freely expand but cannot bend."

Both of these standards are exquisite specimens of the glass-blower's skill, and reflect credit upon the artist who made them. They possess the great conveniences of this form of mounting, in being

* "Bericht über Art. 10 des Programmes der zweiten internationalen Meteorologen-Kongresses in Rom., St. Petersburg, 1878, S. 8. The remark there made that these thermometers are constructed 'partly according to Mr. Pernet's designs' has been universally misunderstood, and to the clearing up of this misapprehension, which has been given on another page, the writer hopes to contribute by means of the following statement derived from his own recollection.

At the end of the year 1876 there had a rivalry arisen between the members of the Normal-Eichungs-Kommission and the mechanics who made the last thermometers, concerning a sure fastening for the scales of normal thermometers. This happened especially in connection with the studies in thermometry which the writer had made in the autumn of 1876 at the South Kensington exhibition and easily read and in the certainty with which the eye may be so placed that the readings have no sensible parallax. They seem to leave little to be desired unless it be calibrating chambers at the upper ends, in order that the observer may easily separate just the length of the mercury column he may wish for calibration. Still it is generally possible to separate a column of about the length desired, with a little patience.

The following is a resumè of the results obtained by Dr. Fœrster at Berlin in the determinations of the constants of these standards. These results are reduced to latitude 45°, a barometric pressure of 760mm. and to the level of the sea.

Date.	Thermometer.	Correction at the Freezing Point after exposure to 0° C.	Correction at the Boiling Point.	Correction at the Freezing Point after exposure to 100° C.
1880. June 4	Fuess 50	— 0°·163	----	----
8	"	— 0·170	----	----
8	"	----	— 0°·035	+ 0°·145
17	"	----	— 0·012	+ 0·135
17	"	----	— 0·011	+ 0·135
Sept. 17	"	— 0·18	----	----
June 4	Fuess 89	— 0·334	----	----
8	"	— 0·347	----	----
8	"	----	— 0·027	0·000
17	"	----	— 0·023	— 0·005
17	"	----	— 0·047	— 0·023
Sept. 17	"	— 0·37	----	----

And Dr. Fœrster further finds that the depression of the freezing point after an exposure to the boiling point is for

Fuess 50 = 0°·35 C.
Fuess 89 = 0°·32 C.

Dr. Fœrster made a careful determination of the corrections to be applied to the Fuess thermometers owing to the errors of calibration for each consecutive degree. These tabular corrections are computed for a freezing point of +0°·37 in the case of Fuess 89 and of +0°·18 in the case of Fuess 50.

from the report of which Professor Neumayer's account contains an extract. In the spring of 1877 a thermometer was injured, in the calibration and comparison of which much trouble had been taken, and Dr. Pernet, who was then active in the Commission, became quite interested in this question. He attempted to obtain a sure fastening for the scale by using various kinds of cement, and attempted, among other things, to obtain an unchangeable position of the capillary tube and the scale by making a small mark on the former, and fastening it opposite a small mark on the scale. About the same time Fuess conceived the new and striking idea, not to fasten the scale directly, but only to place it immovably in a firm resting place. Later he tried to carry out this idea without the use of any cement, by a construction made entirely of glass. The use of platinum threads as guides for the capillary tube on the other hand is an invention of Dr. Pernet."
—*Dr. L. Loewenherz.*

After we had received these thermometers we made the following determinations of the freezing point corrections:

Date.	Fuess 50.	Fuess 89.
1880. Sept. 21	— 0°·20	— 0°·40
28		— 0·40
Oct. 16	— 0·20	— 0·40
28		— 0·45
Nov. 25	— 0·20	— 0·43

from which it will be seen that the thermometers are slowly increasing their freezing point readings with time. We may assume the following as the corrections at the dates given.

Date.	Fuess 50.	Fuess 89.	Kew 578.
1880. June	— 0°·17	— 0°·35	0°·00
Sept.	— 0·18	— 0·37	0·00
Nov.	— 0·20	— 0·41	0·00

The thermometer Fuess 50 had a part of its upper scale support (the front lip of *m* in the figure) broken in coming from Germany. This does not affect the accuracy of its readings, I think, but in order to obtain a comparison up to 40° C. between a Kew and a Fuess standard I have chosen the thermometer Fuess 89, which reads to 0°·1 and is in excellent condition, and the Kew standard 578, of which the errors are extremely small.

In the following comparison the readings have been freed from the zero and 100° point errors, as well as those arising

Date.	Fuess 89.	Kew 578.	F. 89 — K. 578.
1880. Sept. 28	10°·67 C.	10°·62 C.	+ 0°·05 C.
21	10·81	10·75	+ 0·06
28	16·24	16·09	+ 0·15
21	21·14	21·00	+ 0·14
28	21·36	21·20	+ 0·16
Oct. 28	21·80	21·64	+ 0·16
28	21·81	21·66	+ 0·15
Sept. 21	24·21	24·03	+ 0·18
28	26·60	26·45	+ 0·15
21	31·66	31·50	+ 0·16
28	32·17	32·00	+ 0·17
Oct. 28	32·67	32·50	+ 0·17
28	33·31	33·15	+ 0·16
Nov. 26	34·08	33·90	+ 0·18
26	34·21	34·00	+ 0·21 ?
Sept. 28	37·31	37·15	+ 0·16
28	42·40	42·25	+ 0·15

from imperfect calibration. Both standards had been kept for three months previously hanging in a room whose temperature never exceeded 30° C. The comparison therefore represents the comparison of a stem graduated Kew standard with a porcelain-scale-graduated normal of the German form, up to 40° C. It is, however, only preparatory to a more rigorous comparison of the scales of two Kew and two Fuess standards between 0° and 100° C.

It did not occur to me until after these thermometers had been heated that the discrepancy could be so great as it is between these standards, and therefore there are no comparisons between 0° and 10° recorded in our note books until after the thermometers had been exposed to 1· 0° C. I shall recur to this point in the continuation of the paper.

[To be continued.]

ART. XXX.—*On the Determination of the Coefficient of Expansion of a Diffraction grating by means of the Spectrum*; by T. C. MENDENHALL, of Tokio, Japan.

IN all precise measurements of wave-lengths, a correction for variations in the temperature of the grating is very essential. If the ruling be upon glass the coefficient of expansion resulting from any of the many well known determinations may be accepted as sufficiently accurate, because it is not large and because the results do not differ much among themselves. Neither of these statements can be made, however, concerning a ruling upon metal. Many of the beautiful gratings produced within a few years upon Mr. L. M. Rutherfurd's engine, are upon an alloy of tin and copper. As far as I have been able to learn, the coefficient of expansion of this alloy has not previously been determined, and, not being able to make use of any other method, a series of experiments was made for the purpose of obtaining the desired result from the spectrum itself.

From the well-known equation

$$\lambda = s \sin b$$

in which λ represents the wave-length, s, the distance between the centers of two adjacent lines upon the grating and b the angle of deviation, we easily obtain the following:

$$\frac{\delta s}{s} = -\cot b \, \delta b$$

from which it appears that, in order to determine the coefficient of expansion, it is not necessary to know either the wave-length of the line upon which the measurements are made or the value of the grating space.

Unfortunately there are considerable difficulties in the way of the direct application of this formula. It is not easy to contrive any plan by means of which the temperature of the grating can be varied by any considerable and known amount, and, at the same time, to insure that these changes in temperature shall not be accompanied by even a slight shifting of the position of its plane in relation to the collimating telescope. To accomplish the first of these results, a box, measuring about 8 cm. long, 5 cm. wide, and 8 cm. deep, was cut out of a solid block of wood, and of this box the grating was made to serve as one of the longer sides. The box was made waterproof, and a thin layer of paint along the edges to which the grating was applied was sufficient to prevent leakage at that point. The grating was bound to the wooden box by two wires, running one about the upper and the other about the lower portion. This box was placed upon a thin slab of wood, of somewhat larger size, through which passed three levelling screws, and the whole was then placed upon the table of the spectrometer and properly adjusted. A similar box, made of metal, with the grating sealed in as one side, was first used, but it was promptly rejected on account of a tendency to shift its position slightly at each change of temperature. It is believed that the use of wood obviated this difficulty to a great extent. When adjusted so that its plane was over the center of motion, normal to the collimator, etc., the box was filled with water, in which was held a thermometer graduated to ·1° C., and capable of being read with considerable certainty to hundredths. The grating used was ruled with 8648 lines to the inch. The line set upon was one due to iron, wave-length about 5913, situated about 14′ or 15′ away from D, the spectrum being of the fourth order. The micrometers upon the reading microscopes were divided to single seconds, and the tenths were easily estimated. The set upon the line was made when the thermometer indicated something like a constant temperature, and then a portion of the water was removed and replaced by other at a higher or lower temperature as was desired. It was found desirable to confine the temperature within a moderate range. By working a few degrees above and below the temperature of the room, it was easier to secure constancy for a brief period at both points, and the thermometer would be much more likely to represent the real temperature of the grating. In addition to this, considerable changes in temperature were much more likely to be accompanied by a shifting of the plane of the grating.

Twenty measurements, in all, were made, the range of temperature varying from 5° C. to 16° C. From these the following result was obtained:

$$\delta\, b = 5''\cdot66 \pm 0''\cdot13.$$

The probable error is larger than would be desirable, and a good deal of irregularity in the results is to be attributed to the fact that we cannot be quite sure that the thermometer gave the true temperature of the grating, and also to slight shiftings in the plane of the grating, which doubtless sometimes occurred. Indeed, it is hoped and expected to secure a more accurate value by making a very exact determination of the position of the line in the winter, and then again in the summer when the difference in temperature may amount to as much as 15° C., and in this we shall be almost entirely free from both of the principal sources of error.

From the above value the coefficient of expansion is—

$$\varepsilon = \cdot0000202,$$

with a probable error of a little more than two per cent of the whole. As spectrum observations are generally made within a small range of temperature, this value is, perhaps, sufficiently accurate for their correction. I am unable to refer at present to any determinations of the coefficient of expansion of alloys similar to this which contains eight parts of tin to seventeen parts of copper. Most authorities agree fairly as to the coefficient for copper, but as to tin there is a considerable range—from ·0000217 to ·0000248. It is difficult, therefore, to determine what the coefficient for this alloy *ought* to be, but I venture the opinion that the above result is more likely to be too high than too low.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Density of Iodine Vapor.*—Shortly after Victor Meyer's discovery that at high temperatures iodine vapor had a density two-thirds of its normal value, Crafts and Meier studied the subject and found that this density decreased regularly from 650° to 1350°. Subsequently Meyer repeated his experiments, using Crafts' method of measuring the temperature, and found that at a very high temperature, the value approached one-half of the normal density. The numbers obtained in the two investigations differed considerably, however, especially at 1050°, at which point Meyer found 5·83 and Crafts and Meier 7·1. More recently Troost obtained 5·7 at 1250°; from which Meyer concluded that Dumas' method should give the same re-

sult as his own. But the influence of tension upon dissociation is so considerable, that Crafts and Meier undertook an investigation of the variation of the density of iodine vapor with the tension as well as the temperature. They have now given the results, some of them graphically in the form of curves, in which the ordinates represent densities, the abscissas temperatures. The densities are in all cases referred to air at the same temperature and pressure as unity. These plottings show (1) that up to 355° all the curves are contained in a single line parallel to the axis of abscissas, and the density is normal; (2) that with rising temperature, the variation is more rapid up to the middle of each curve, then it diminishes and becomes zero at the highest temperature, so that under low tensions the density becomes constant again at 1400° to 1520°, being then equal to one-half the normal value; and (3) that the curves which depart first from the straight line and which first unite again to form the high temperature line are those which represent the lowest tensions. These results explain the discrepancies before observed, and appear to confirm the hypothesis already advanced by the authors, that at low temperatures iodine exists molecularly as I_2 and at high temperatures atomically as I; and that the variations of density with temperature and pressure correspond to a progressive dissociation.—*C. R.*, xcii, 39, Jan., 1881. G. F. B.

2. *Researches upon Ozone.*—HAUTEFEUILLE and CHAPPUIS have presented to the Chemical Society of Paris a valuable memoir upon ozone. They first studied the effect of temperature and pressure on the transformation of oxygen into ozone, using the silent discharge for this purpose, in the apparatus of Berthelot. At 760 mm. pressure 0·106 of ozone by weight was formed at 20°, 0·149 at 0° and 0·214 at −23°. Under 180 mm. pressure, the quantity was 0·089 at 20°, 0·137 at 0° and 0·181 at —23°. Next the effect of mixture with other gases was investigated, and it was found that while at 0° no effect was observed, at −23° the amount of ozone was increased to 0·216 when the oxygen was mixed with four times its volume of nitrogen, and to 0·240 when twice as much nitrogen was present. Hydrogen and silicon tetrafluoride increase still more the quantity of ozone. The authors then examined the physical properties of ozone, the density as determined by Soret, and the heat of formation by Berthelot being the only data heretofore known. The production of a gaseous mixture containing 21 per cent of ozone—which is permanent at −23°—enabled the authors to obtain interesting results on compressing it. The oxygen cooled by methyl chloride, was ozonized and placed in the compression tube of a Cailletet apparatus, care being taken to keep the temperature at −23°. On working the pump, the first few strokes developed an azure blue color in the tube, which deepened as the compression increased till under a pressure of several atmospheres, it became indigo-blue. Cooling the tube to −88° by immersion in liquid hyponitrous oxide, the color became three or four times darker.

Upon filling a tube a meter long with the ozonized oxygen at the ordinary pressure, and looking through it at a white surface, the gas was seen to have a sky-blue color, darker as the amount of ozone was greater; thus proving ozone to be a colored gas. The question next arose, is liquid ozone colored? By a sudden expansion from a pressure of 75 atmospheres at $-23°$, a thick mist was momentarily produced (this result not taking place with oxygen below 300 atmospheres). Compression to 200 atmospheres at a temperature of $-88°$ did not give on expansion any visible liquid. By adding, however, carbon dioxide gas whose point of liquefaction is not far from that of ozone, a liquid layer was obtained, blue in color and not differing in shade from the gas above it. When slightly expanded and then immediately compressed, an azure blue liquid is obtained much deeper in color than the gas, the cooling produced by the expansion reducing the temperature of the ozone below its critical point. Hence a mixture of oxygen and ozone containing above 50 per cent of the latter gas compressed below $-88°$ would give drops of a dark blue liquid. The mixture of ozone and oxygen should be compressed slowly with care and be well cooled; otherwise the ozone is decomposed with detonation. It must therefore be classed with explosives, since Berthelot has shown that 24 grams of oxygen absorbs 14·8 calories in conversion into ozone. Finally, the authors made use of this blue color of ozone to ascertain whether the products of the decomposition of carbon dioxide by the silent discharge, contained this gas. Upon compressing the products of the action of the electric discharge upon carbon dioxide in a Cailletet apparatus, not only was a colored gas obtained, but the undecomposed CO_2 liquefied and became blue.—*Bull. Soc. Ch.*, II, xxxv, 2, Jan., 1881. G. F. B.

3. *On the Chlor-hyponitric acid of Gay Lussac.*—GOLDSCHMIDT has submitted to examination the product obtained by Gay Lussac by distilling aqua regia, and called by him "acide hypochloronitrique." Three parts of hydrochloric acid of sp. gr. 1·16 was mixed with one part of nitric acid of sp. gr. 1·36 and submitted to distillation on the water bath. The evolved vapors were passed first through an empty flask, then through a chloride of calcium tube and finally condensed in small flasks, placed in a mixture of calcium chloride and ice, which were subsequently sealed. Weighing, before and after, gave the quantity of liquid in them. Breaking the flask under water decomposed the liquid and in the resulting solution the chlorine was determined and found to vary from 60·77 to 68·23 per cent, the formula $NOCl_2$ requiring 70·30 per cent. On fractioning this distillate, three portions were obtained containing respectively 58·89, 56·91, 56·39 per cent Cl, the formula NOCl requiring 54·2. The first distillate, therefore, was evidently a mixture. To determine whether the gases as evolved from the aqua regia contained nitrosyl chloride and chlorine, or nitrosyl chloride and chlorhyponitric acid, or all three, their vapor density was determined and found

to be 2·358, 2·385 and 2·350 in three experiments, the total chlorine present being 80·5, 81·6 and 78·9, per cent. Hence it cannot be a mixture of NOCl and $NOCl_2$. If a mixture of $NOCl_2$ and Cl, then from the above data there would be 3 molecules free Cl to 4 molecules $NOCl_2$ which would give a vapor density of 3·049. If a mixture of NOCl and Cl, it would contain 5 molecules free Cl to 4 molecules NOCl, giving a vapor density of 2·372 very near that actually found. The first distillate had a vapor density of 2·315, which taken in connection with its content of chlorine, 68·4 per cent, shows it to be a mixture of NOCl and Cl_2. Hence Gay Lussac's chlor-hyponitric acid is a mixture of nitrosyl chloride with a varying proportion of absorbed chlorine gas.—*Liebig's Ann.*, ccv, 372, Nov., 1880. G. F. B.

4. *On Mercuric Fulminate and its Decomposition.*—Berthelot and Vieille have studied the properties and conditions of decomposition of mercuric fulminate. Their material was that used in the service and it gave on analysis numbers agreeing with the formula $C_2N_2HgO_2$. Its decomposition products were determined by exploding about three grams of it electrically in a steel eprouvette, previously filled with pure dry nitrogen under known pressure and temperature. As a mean of five experiments, one gram gave 234·2 c. c. of gas, theory requiring 235·8. In 100 volumes this gas contained HCy and CO_2 0·15, CO 65·70, N 32·28 (Ratio 2·04 : 1) and H 1·87. Hence the reaction is: $C_2N_2HgO_2 = (CO)_2 + N_2 + Hg$. It appears, therefore, that no compound capable of dissociation is formed, and that consequently no gradual reunion takes place capable of moderating the expansion of the gas and of diminishing the violence of the initial shock. Hence the energy of the explosion. The heat produced was measured by placing the eprouvette in the above experiments in the water of a calorimeter. As a mean of the five experiments, one gram gave 403·5 gram-degrees; a quantity of heat which applied to the products of the detonation would heat them to nearly 4200°. From these data the heat of formation may be calculated: C_2 (diamond) $+N_2+O_2+$Hg (liquid) $=C_2N_2HgO_2$ absorbs $51·6-114·5=-62·9$, which is negative as would be expected. Hence the heat resulting from its explosion has two sources: First, the separation of its elements; and second, the union of the carbon and oxygen to form CO. In contact with air, more heat is evolved because the CO burns to CO_2; but the force of the explosion is not increased thereby, since this combustion follows it. When mixed with potassium chlorate or nitrate, the amount of heat is doubled; but the initial force of the explosion is modified by the dissociation of the carbon dioxide, so that the total effect is less than before. The pressures developed by the explosion were measured in a special eprouvette called a "crusher," by means of the compression produced upon a cylinder of copper. With 2·43 grams fulminate, the pressure developed was 477 kilograms per square centimeter. With 4·86 grams, 1730 kilos. With 7·39 grams, 2697 kilos. And with 9·72 grams, 4272 kilo-

grams. Hence, though sudden, the pressure produced by the explosion is not very great; that produced by gun cotton being nearly twice as great, and that produced by dynamite, containing 75 per cent of nitroglycerin, being about the same. The effectiveness of the fulminate arises from (1) the instantaneousness of its decomposition, (2) the absence of dissociation products, and (3) its great density, 4·42. It develops at the point of contact an enormous instantaneous pressure which has no relation to the mean pressure in the vessel. This pressure Berthelot estimates at 48,000 atmospheres, while gun cotton develops on contact only 24,000 atmospheres.—*Ann. Chim. Phys.*, V, xxi, 564, Dec. 1880.

G. F. B.

5. *On the Direct production of Chloroform and Bromoform.*—DAMOISEAU has studied the action of porous bodies in causing the reaction of chlorine upon methyl chloride. A regular current of chlorine gas mixed suitably with methyl chloride is passed through a long tube filled with animal charcoal and heated to 250°–350°. By washing with water the hydrochloric acid gas is removed, and the condensed product corresponds to the mixture employed. Chloroform is produced with great ease and uniformity in this way. Bromine acts similarly, producing from CH_3Br, CH_2Br_2, $CHBr_3$ and CBr_4. Acetic acid treated with 2, 4, 6 atoms of bromine in this way, gives carbon dioxide and brominated derivatives of formene. Chlorine and acetic acid gives chloroform in considerable quantity.—*C. R.*, xcii, 42, Jan. 1881.

G. F. B.

6. *On the Identity of Arabinose with Lactose.*—KILIANI has examined the sugar obtained by Scheibler by the action of dilute sulphuric acid upon gum arabic, and which he called arabinose. One part of pure gum arabic was boiled for 18 hours with 8 parts of a two per cent solution of sulphuric acid in an open dish, the evaporated water being replaced. The acid was then removed by barium hydrate, the filtrate evaporated to a syrup, agitated with alcohol, decanted, the alcohol distilled off, and the syrup allowed to crystallize over sulphuric acid. On analysis, it gave the formula $C_6H_{12}O_6$; it rotates the polarized ray $[\alpha]_D = 79°$, reduces Fehling's solution, ferments with yeast, yields mucic acid when oxidized with nitric acid, and dulcite when reduced with sodium. For these reasons, the author thinks the arabinose of Scheibler is identical with milk sugar or lactose.—*Ber. Berl. Chem. Ges.*, xiii, 2304, Jan. 1881.

G. F. B.

7. *On the absorption of dark Heat rays by Gases and Vapors.*—Herr ERNST LECHER and Herr JOSEPH PERNTER criticise the results of previous observers, especially those of Tyndall and Magnus. Taking Tyndall's numbers, they show that the absorption of radiant heat is different when a polished metallic tube is employed instead of partly blackened tubes or tubes of glass, and therefore point out that Tyndall's results are subject to an error. They show, also, that vapor adhesion introduces another source of error in Tyndall's work. In order to avoid all possible errors

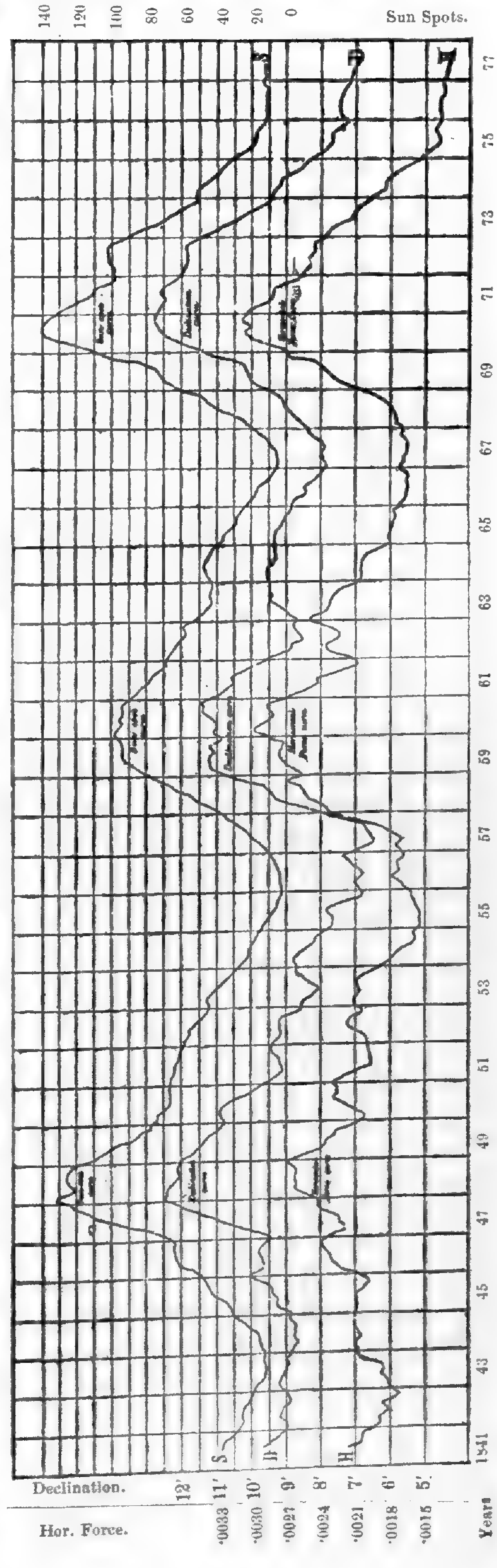
the author placed a thermopile as well as the radiating surface inside the experimental space. The experimental vessel consisted of an inverted glass bell jar with the open end placed upward. The thermopile with one face placed upward and toward the source of radiation and the other carefully protected by a packing of cotton-wool, was supported at the bottom of this jar. The entire jar and the cover was surrounded by water which was kept running from a tap. The radiating surface at the mouth of the bell jar was heated by a jet of steam, and the details of the experiment were so arranged that equal quantities of heat were communicated to the plate in equal times. The copper wire of the galvanometer was wound with white silk in order to avoid any trace of iron, and it was protected from sudden changes of temperature. No binding screws were employed. The wires leading from the galvanometer were carefully wound with those of the external circuit, and the junctions having been varnished were placed in running water so as to avoid the production of thermo-electric currents. One of the two conducting wires was completely insulated, for the authors confirmed the earlier result of Lamont, that perfectly dry wood is not an insulator for feeble currents. The experiments with pure dry air made it apparent that the absorption of heat rays from a source of heat at 100° C. in passing through a layer of air thirty-one centimeters in thickness is so small that it cannot be measured. From experiment it was found that out of 100 incident rays 99·78 pass through. With moist air no absorption was found. This result was surprising, since the well-known absorption of heat rays of the sun by the atmosphere has generally been attributed to aqueous vapor. After a general discussion of the meteorological bearing of these results it is concluded that the question of the amount of absorption of radiation by our atmosphere can not be solved at present; and it will be necessary in order to obtain a true solution to arrive at the proportion of carbonic acid in the air and also the amount of vegetable and animal organisms. It is pointed out that an accurate solution can also only be obtained when the absorption is known for the different parts of the spectrum.—*Sitzb. der K. Akad. der Wissensch. in Wien*, July, 1880; *Phil. Mag.*, Jan. 1881. J. T.

8. *Dust, Fogs, and Clouds.*—Mr. JOHN AITKEN, in a paper presented to the Royal Society of Edinburgh, maintains the theory that dust is essential for the formation of fogs and clouds. Steam was mixed with air in two large glass receivers; one of these receivers was filled with common air, the other with air which had been carefully passed through cotton-wool so that all dust might be removed. In the one receiver the air presented the usual cloudy appearance on the entrance of the steam, while in the other no cloudiness was apparent, the air remaining supersaturated and perfectly transparent. In another experiment water was placed beneath a receiver and the temperature of the enclosed air lowered by reducing its tension. With unfiltered air the

receiver was immediately filled with a dense vapor, with filtered air, however, no cloudiness was perceived. It was concluded from these experiments: (1) Whenever water vapor condenses in the atmosphere it always does so on some solid nucleus; (2) that dust particles in the air form the nuclei on which the vapor condenses; (3) that if there was no dust there would be no fogs, no clouds, no mists, and probably no rain, and that the supersaturated air would convert every object on the surface of the earth into a condenser on which it would deposit; (4) our breath when it becomes visible on a cold morning and every puff of steam shows the impure and dusty condition of the atmosphere. Among the sources of atmospheric dust is the spray of the ocean. By simply heating a piece of metal—the one hundredth of a grain of iron wire—the dust driven off will give a cloudiness in the experimental receiver. Common salt burned in an alcohol lamp gave an intense fog, and burned sulphur gave a fog so intense that it was impossible to see through a thickness of 5 cm. of it. It is calculated that more than 200 tons of sulphur are burned with the coal every winter's day in London, and this quantity is sufficient, in the writer's opinion, to account for London fogs.—*Nature*, Dec. 30, 1880. J. T.

9. *On the relation between the Diurnal Range of the Magnetic Declination and Horizontal force, as observed from* 1841 *to* 1877 *at the Royal Observatory, Greenwich, and the period of Solar Spot frequency;* by WILLIAM ELLIS, F.R.A.S.—Observations of the magnetic elements have been carried on at Greenwich since 1841. Until 1847 actual readings of the various instruments were taken at two-hour intervals, but since the beginning of 1848, in addition to the absolute determinations of declination, intensity and dip, a continuous record of the variations of the declination and the horizontal and vertical components of the total force has been obtained by the method of photographic registration, devised by Mr. Charles Brooke. The fact that during this long period the observations of the declination and horizontal force, discussed in this paper, have been made on the same plan and with the same instruments, gives especial value to the conclusions which are drawn from them.

The mean diurnal range of declination in each month is taken to represent, relatively to other months, the magnetic energy of the month; and similarly for the horizontal force. This mean diurnal range for each month is obtained by taking the difference between the greatest and least of the mean indications for each separate hour through the month, days of great magnetic disturbance being rejected. A table is thus formed giving two series of numbers: the variation in declination is expressed in minutes of arc; for the variation of the horizontal force the unit is ·0001 of the whole horizontal force. The numbers thus obtained show a marked increase for the summer months. This annual inequality having been, by special calculation, eliminated, a second table is formed giving the annual mean of the monthly mean diurnal range of the declination and horizontal force. From this table the curves *D D*, *H H* in the figure are plotted (the original plate, one of three illustrating the memoir, has been here reduced to one-third by photography.) The scales for the curves of declination (*D D*) and horizontal force (*H H*) are so arranged that each minute of arc of declination is represented by ·0003 of horizontal force, and so on in proportion. The third curve (*S S*), that of sun-spot frequency, is constructed by taking one minute of declination to correspond to 20·0 in sun-spot number.



A comparison of the three curves shows strikingly the correctness of the view generally held, that *the diurnal ranges of declination and horizontal force are subject to a periodical variation corresponding to the* 11*-year sun-spot period.*

Other conclusions deduced by Mr. Ellis are as follows: (1.) That the epochs of minimum and maximum magnetic and sun-spot effect are nearly coincident, the former occurring on the whole somewhat later. The variations of duration in different periods appear to be similar for both phenomena.

(2.) The occasional more sudden outbursts of magnetic and sun-spot energy, extending sometimes over several months, appear to occur nearly simultaneously and progress collaterally.

(3.) It seems probable that the annual inequalities of magnetic diurnal range, are subject also to periodical variation, being increased at the time of a sun-spot maximum, when the diurnal range is increased, and diminished at the time of a sun-spot minimum, when the mean diurnal range is diminished.

The evidence in favor of this final conclusion is considered as not entirely decisive; the other conclusions are regarded as sufficiently certain.

10. *U. S. Coast and Geodetic Survey,* CARLILE P. PATTERSON, Superintendent in charge. *Methods and Results: American Standards of Length* (Appendix, No. 12—Report for 1877). 36 pp. 4to. Washington, 1880.—This memoir contains the report by Professor J. E. Hilgard on the details of observations made to establish the relation between the American and British standards of length. The general results reached (published in Appendix 22, Report for 1876), show—(1) That there is no difference between the standards of weight of Great Britain and those of the United States; (2) This is also true of the standards of length; (3) The standards of volume in the United States are the same as those lawful in Great Britain prior to 1826. Also, (4) the relation of American and British standards to the French metric standard is not determined with extreme precision, but the legal enactments will suffice for all purposes except those of great scientific accuracy.

The standards of length described in the report are the Troughton 86-inch scale and the British standards, the bronze yard, No. 11, and the iron yard, No. 57. The Troughton scale (London, 1814), is a bronze bar, 86 inches long, $2\frac{1}{2}$ inches wide, and $\frac{1}{2}$ inch thick, it has an inlaid silver scale; it was made for the survey of the coast of the United States. The yard of 36 inches, between the 27th and 63d inch was adopted as the standard yard of the United States by the Treasury Department, in 1832. The two other standards were presented by the British Government in 1856.

A detailed discussion is given, in the report, of the coefficients of expansion of the three standards, and of the results of comparisons between them, and also of each of them with the Imperial yard and other British standards. As the result of this it is found that the Troughton scale is equal to the standard British yard at 59°·62 F., the bronze yard, No. 11, at 62°·25 F., and the iron yard, No. 57, at 62°·10 F. Furthermore it is stated that between 1856 and 1872 both the last two standards, for want of proper provision for their safe keeping, have been subjected to great variations of temperature, varying fully 75° F. As a result of this it is concluded that the bronze yard has shortened relatively to similar measures which have been kept at a nearly constant temperature. This standard was made, on account of its great rigidity, of Baily's metal consisting of 16 parts copper, $2\frac{1}{2}$ parts tin, and 1 part zinc, and it is suggested that the molecules of such a casting are probably in a state of great tension, likely to yield under changes of temperature, and perhaps in less degree to the simple effect of continuance. The wrought-iron bar, No. 57, Low Moor iron, on the other hand, which has been subjected to the same vicissitudes as the bronze bar before mentioned, has maintained its relative length to the Imperial standard. As bearing upon the persistence of material reduced to the plastic condition, the fact is mentioned that in 1867 one of the original meters, long in the possession of the U. S. Coast Survey, was compared with the platinum meter of the Conservatoire des Arts et Métiers, made about 1800, and no difference of so much as a thousandth part of a millimeter after so many years was detected, although it had been twice transported across the ocean and had experienced extreme vicissitudes of temperature.

11. *Magnetic Declination in Missouri.*—A chart has been issued by Professor Francis E. Nipher, of St. Louis, giving the declination of the magnetic needle in Missouri for 1879, and with the lines of equal declination deduced from the observations. The map is published for use of surveyors, but it is interesting as showing the remarkable irregularity in these isogonic lines. For example, immediately west of St. Louis the lines have a sharp bend to the westward, while on the same parallel toward the center of the State there is a correspondingly sharp bend to the eastward. (See this Journal, xix, 234, 1880).

II. Geology and Mineralogy.

1. *Pennsylvania Geological Survey: The Geology of McKean County, and its connection with that of Cameron, Elk and Forest;* by Charles A. Ashburner. Report of Progress, No. R. 372 pp. 8vo. With 33 plates and 2 maps. Harrisburg: 1880.—McKean, one of the northern counties of Western Pennsylvania, adjoins Cattaraugus County and a part of Allegany County of New York, and its geological and topographical relations to the latter region give the facts which Mr. Ashburner has carefully studied out special importance. It is further, the location of the northern oil area of the State—the Bradford. Mr. Ashburner's report treats first of the topographical features and surface geology; next, of the general geological structure; thirdly, of the economic products of the county; and then, in Part II, he gives the detailed geology of the county, under which are brought out many sections illustrating the Bradford oil district.

The region is part of the elevated plateau that stretches west and northwest from the Appalachians, and apparently makes, along with that of Southern New York and the Cumberland Table land to the south, the northwestern flank of the mountain range. The surface has "a mean height of nearly 2000 feet above the ocean," but many elevations over it reach to 2200 feet, and one to 2500.

The rocks at the outcrops—which are not numerous or good—are so nearly horizontal that what there are of anticlinals and synclinals consist mostly of slightly curving "domes and dimples," the latter only occasionally taking the form of a trough. The strata are a continuation of those of the Appalachian region to the southeast, but all the formations are greatly reduced in thickness. They belong to the following groups, commencing below:

A. DEVONIAN.—(1) The *Chemung* sandstones and shales (VIII) which include the productive "oil-sands" of the Bradford district;* (2) the *Catskill* sandstone (IX), 250 feet thick at Bradford (while 2560 feet in Blair County, just southeast of the center of Pennsylvania, and 5000 to 6000 feet at the extreme eastern outcrops on the Lehigh and Susquehanna Rivers).

B. SUBCARBONIFEROUS.—(3) The *Pocono sandstone* (X), 250 feet in average thickness (while 2133 feet in Broad Top Mountain, in Huntingdon County, east of Blair County) having, at middle, the Sub-Olean conglomerate, 40 feet thick; and overlaid by (4) the *Mauch Chunk Red shale* (XI), only 10 feet thick (while 3000 feet at Mauch Chunk in Carbon County); the two together correspond to the Subcarboniferous.

C. CARBONIFEROUS.—(5) The *Pottsville conglomerate*, or the so-called *Millstone Grit* (XII), 160 feet thick (while 1000 feet at Pottsville, in Schuylkill County), which consists, at bottom, of the Olean conglomerate (the rock which, on account of its tower-like and other bold features, suggested the name of Rock City to a place in Cattaraugus County, N. Y., and which is the same as the Sharon conglomerate of Western Pennsylvania and the conglomerate of the Ohio geologists), and, above this, of two sandstone strata with the *Alton Coal-bed* between. Next (6) The *Lower Productive Coal-measures* (XIII) 140 feet thick, which contain the *Dagus Coal-bed* and the *Clermont Coal-bed*, and are the most northern outliers of the Appalachian coal formation. The Clermont coal-bed (3 feet thick) is the same as the Clarion coal-bed of Western Pennsylvania, and the Dagus, situated above the "Clermont ferriferous limestone (4 to 8 feet thick) and some beds of sandstone and shale, is the Lower Kittaning.†

The Bradford Oil District is described geologically and economically, and illustrated by excellent maps and sections. It is elongated in the direction northeast-and-southwest. The length of the principal area is about sixteen miles (the northern two to three miles of it in the State of New York), and the greatest breadth is nearly eight miles. In its line, six miles to the southwest, lies the small Kinzua oil district, and half way between the two the "Big Shanty" district and toward the southern boundary of the county there are a few wells near Smethport and

* The "oil-sands" (or sandstones) of Western Pennsylvania, the Venango oil-district—are beds in the Catskill sandstone (IX) and thus have a higher position stratigraphically than those of the Bradford oil-district.

† With regard to the total thickness of the Paleozoic of Pennsylvania, Mr. Ashburner states that 40,000 feet, or about eight miles, "is certainly not excessive" in view of the fact that a section from the top of the Lower Productive Coal to the base (?) of the Trenton, carefully measured by him, showed a thickness of 3½ miles.

Kane. Thus the trend of the whole is approximately parallel to the course of the Appalachians. The depth of the wells is in nearly all cases 1100 feet, the borings extending from 40 to 150 feet below the top of the Chemung. To the south the depth is 1700 to 2000 feet; this is owing partly to a thickening southward of the overlying strata, but, about Smethport, to the oil-bearing sand-bed being at a lower level in the Chemung by nearly 300 feet.

The Bradford oil district has been worked less than ten years. The production of oil amounted to but seventy-five barrels a day in 1874, but was 58,000 a day in the year ending June, 1880. Of the 2539 wells sunk in 1879, only 3 per cent were dry holes or unproductive; and of the 6249 between the beginning of 1875 and January, 1880, only 3·77 per cent.

The special peculiarities of the oil-bearing sand-rock of the Bradford district have already been mentioned in this Journal, (xix, 415, 1880) from a paper by Mr. Ashburner, and also the phenomena of the remarkable Kane Geyser well (xviii, 394) on the southern borders of the county, and the Wilcox Spouting well (xvi, 144, 1878) about three miles to the east of the Kane.

2. *Report of Progress of the Geological Survey of Canada, for* 1878–79. ALFRED R. C. SELWYN, Director. 8vo. Montreal, 1880. (Dawson Brothers).—This volume contains the following reports: Introduction, by Mr. SELWYN (6 pp.); on the Queen Charlotte Islands, by Mr. G. M. DAWSON; on explorations of the Churchill and Nelson Rivers, etc., by ROBERT BELL; on the Geology of Southern New Brunswick, by Messrs. BAILEY and ELLS; and Chemical contributions, by C. HOFFMANN. Mr. Dawson's report describes, and illustrates on colored maps, the distribution of Triassic and Cretaceous rocks over the Queen Charlotte Islands.

The map (for which only approximate correctness is claimed), makes the southern half of the islands, between the parallels 52° and 53°, Triassic (Alpine Trias, it containing *Monotis subcircularis* Gabb and *Halobia Lommeli* Wiss., etc.); a middle portion, about Skidegat Inlet, crossing the island obliquely, and a northern angle (north of the parallel of 54°), of Graham Island, Cretaceous; and the rest of Graham Island, Tertiary and "probably" Miocene. The Cretaceous rocks are stated to have *a thickness of* 13,000 *feet*. They are generally much flexed, and toward the head of Skidegat Inlet there is a very sharp and steep flexure bending double a coal-bed; and the coal is *anthracite*. Cretaceous fossils (including Ammonites, Belemnites, etc.) are numerous, and some of them have been described by Mr. Whiteaves in Mesozoic Fossils, Vol. I, Part 1. The Cretaceous and Triassic rocks are unconformable, and so also the Cretaceous and Tertiary. The close of the Tertiary was a time of igneous eruptions, as well as the Tertiary itself.

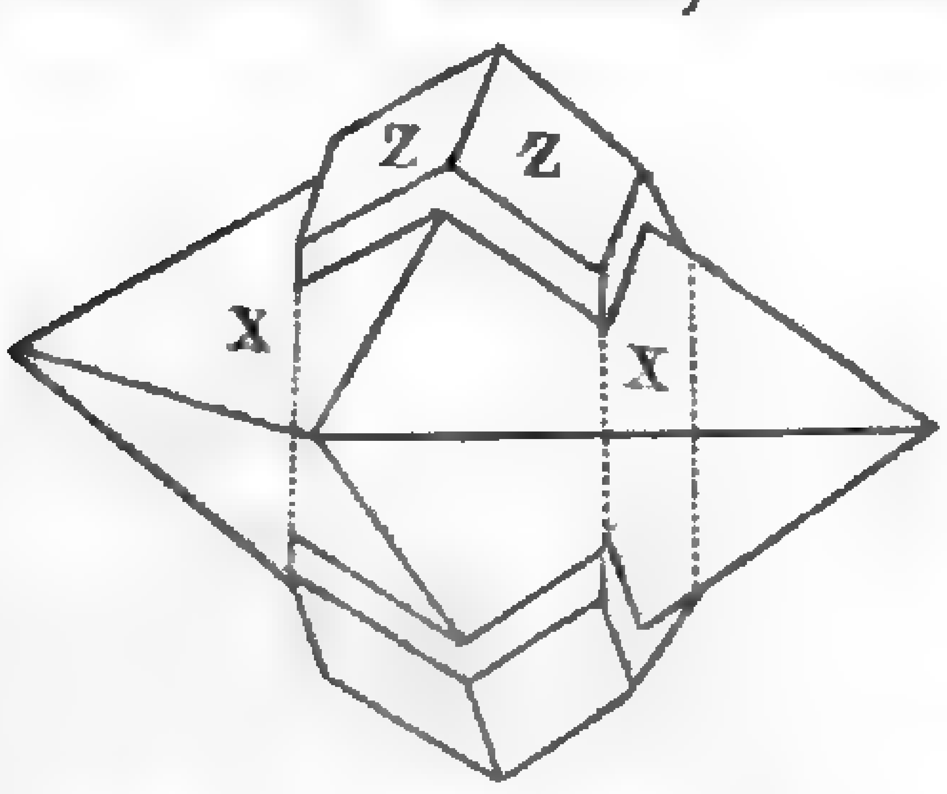
3. *A Monograph of the Silurian Fossils of the Girvan District in Ayrshire*, with special reference to those in the "Gray *collection*;" by Dr. H. ALLEYNE NICHOLSON and R. ETHERIDGE, Jr.

Fasciulus III.—This concluding part of vol. i contains pp. 237 to 334 (8vo), of the text and plates xvi to xxiv, and treats of the Annelids and Echinoderms, with supplements on the Protozoans, Cœlenterates, and Crustaceans. The first three of the excellent plates are devoted to fossil corals of the genera Heliolites, Plasmopora, Propora, Pinacopora and Halysites.

4. *Revue de Géologie pour les Années*, 1877 et 1878, par M. Delesse et M. de Lapparent, tome xvi, 268 pp. 8vo. 1880. (Librarie F. Savy).—This volume of Delesse's Geological Annual, like its predecessors, gives a valuable résumé of geological papers, especially those relating to Lithological, Dynamical, Historical or Stratigraphical, Geographical and Agrinomic Geology. The abstracts are well prepared and in general quite full.

5. *Annelid Jaws from the Wenlock and Ludlow formations of the west of England.*—Several species of these annelid jaws are described and figured by Mr. G. J. Hinde, in the Quarterly Journal of the Geological Society for August, 1880 (p. 368).

6. *Xenotime, from Burke County, N. C.;* by W. E. Hidden. (Communicated.)—Symmetrically compounded crystals of xenotime and zircon, much like those first noticed by E. Zschau (this Journal, II, xx, 273) have been lately discovered by the writer in the auriferous gravels of Brindletown, Burke county, N. C. The accompanying figure shows the form to be somewhat different from those of Zschau, from Hitteröe, Norway; but the occurring planes are the same. The Burke county crystals are compounds of a *light-brown* zircon, with a *yellowish-gray* xenotime. The crystals are sometimes $\frac{1}{4}$ inch in diameter, though rarely; they are oftener $\frac{1}{10}$ inch through. About one in fifty of the xenotimes from this locality are thus compounded.



7. *Geological Charts of the Yellowstone Park, and of the region adjoining on the south in the territories of Wyoming, Idaho and Utah.*—Three large and beautifully colored geological charts have recently been issued as part of the results of the Geological and Geographical Survey of the Territories under Dr. F. V. Hayden for the years 1877 and 1878. The topography is given by contour lines. One chart (the most northern) is of the Yellowstone Park; the second, is a chart of parts of Western Wyoming and Southeastern Idaho; the third, of an adjoining part, to the south, of Wyoming and Idaho and part of Northeastern Utah. The area comprised by the three is nearly all that included between the parallels of 45° and 41° 45′, and the meridians, 100° 30′ and 112°. The first of these charts is on a scale of two miles to an inch and the others on that of four miles to an inch.

III. Botany and Zoology.

1. *The Power of Movement in Plants;* by Charles Darwin, LL.D., F.R.S., assisted by Francis Darwin. With illustrations. (London: John Murray. 1880. Appleton & Co., N. Y.) pp. 592. 18mo.—First let us congratulate the scientific community, no less than the author, that Mr. Darwin's experimental researches are seconded, and are we hope long to be continued, by the son whose name appears upon the title-page, and whose independent papers already published approve his worthiness for that honor. This volume is, from beginning to end, the record of a series of researches and of the inferences which they directly warrant. Naturally it will not fascinate the general reader after the manner of "The Origin of Species" and some of the volumes which succeeded that epoch-marking production; nor has it the fresh charms of the treatises "On the Movements and Habits of Climbing Plants," and of "Insectivorous Plants," of which it is the proper continuation and supplement.

The organs of plants take certain determinate positions and execute certain movements, some of them universal or general, some of them special, some of them very striking and seemingly strange, most—but not quite all of them—evidently advantageous to the plant or essential to its well-being. Roots point toward the earth; stems point away from it; young stems bend towards the light, and the upper face of leaves is presented to it. Stems that twine "*circumnutate*" (a capital term), i. e. bend successively to all points of the compass, and this wholly irrespective of external influences; and the twining around a support is a direct consequence of the circumnutation. Most tendrils freely circumnutate, and thereby are enabled to reach the object which they grasp. Most tendrils (and in certain cases some other parts) are very obviously sensitive to external contact or irritation, to which they respond by movement and change of form, and thus they grasp or do other advantageous acts. Some movements, especially of leaves, occur with regularity upon the access of light, others upon its withdrawal; a few, such as of the small leaflets of *Desmodium gyrans*, proceed irrespective of night and day. The specification need not be extended. The general facts in all their great variety are familiar to scientific readers. The inquiry of this volume is as to their ground and origin, or, as in this connection we should rather say, their development and history. For instance, circumnutation gives rise to twining and gives efficiency to other ways of climbing. But Darwin is bound to suspect, and even to show, that circumnutation is not a special endowment of the stems and tendrils of climbing plants, but rather a more developed manifestation of a general faculty. And the same is to be said of the movements of tendrils and leaves, or their appendages, whether automatic or in response to external irritation or stimulus. All this is what the experimental researches detailed in this volume undertake to ascertain and have satisfactorily made out.

An abstract of the volume might be somewhat tedious, and is certainly unnecessary for biological readers, who are sure to possess and study it. But the *gist* is readily to be gathered, without running through the iterated details or scanning many of the illustrative and curious figures which record the movements under investigation, by the simple perusal of the introduction and of the concluding chapter, in which the matter of the volume is summed up.

The sum and substance of the case is, that all these powers and faculties are manifested in the seedling immediately upon germination, and most of them are then remarkably exemplified. The caulicle or initial portion of stem below the cotyledons (with the elongation and protrusion of which the germination of dicotyledonous seeds usually begins) circumnutates as soon as it comes out into the open air, and even earlier: this is the earliest manifestation of an automatic movement which is shared by all the succeeding portions of stem developed from it, in the early life of most plants whether climbers or not. In the latter, and especially in twining plants, we see this general faculty at its maximum and in beneficial exercise. More remarkable and novel it is to learn that the initial root, growing from the lower end of the caulicle (not inaptly called by Darwin the *hypocotyl*) also shares in this faculty of circumnutation. As it penetrates the soil in its downward course, it cannot largely manifest this faculty, and indeed its power of circumnutation is always small; "but the circumnutating movement will facilitate the tip entering any lateral or oblique fissure in the earth or a burrow made by an earth-worm or larva; and it is certain that roots often run down the old burrows of worms. The tip, however, in endeavoring to circumnutate will [successively] press against the earth on all sides, and this can hardly fail to be of the highest importance to the plant" (being supplemented by another faculty, that of sensitiveness at the tip presently to be mentioned); for "when the tip encounters a stone or other obstacle in the ground, or even earth on one side more compact than on the other, the root will bend away as much as it can from the obstacle or the more resisting earth, and will thus follow with unerring skill the line of least resistance." Then, beside the almost universal heliotropic movement, by which each leaf or leaflet presents its superior surface to the direction of the greater light, Mr. Darwin shows that these organs also circumnutate, beginning even with the cotyledons or seed-leaves; although their sweeps generally form so narrow an ellipse that they move up and down in nearly the same vertical plane, a movement describing a circle being converted into one up and down.

These circumnutatory movements are of the most fundamental and therefore mysterious character. Although most commonly connected with growth, they are at bottom independent of it. This—contrary to some German physiologists—we must conclude from both DeVries' and Darwin's investigations. They are produced by the changing turgescence of the cells on different sides of a stem or footstalk, which may or may not be fixed by consequent growth or solidification. This Mr. Darwin, we presume rightly, concludes to be the faculty or susceptibility upon which heliotropism, geotropism and the like (not to speak of *apheliotropism*, *apogeotropism*, *paraheliotropism*, *diaheliotropism*, *hyponasty*, *nyctotropism*, and other terms which the incautious student may take to be powers instead of abbreviated expressions)—in other words, upon which the solar rays and some occult influence of the earth—act, modifying the sweeps or converting them into forth and back or other special movements. Among these, that which has been termed the sleep of leaves, better and briefly designated by the word nyctotropism, is thoroughly investigated in this volume, is shown to be far more general than has been supposed; and the conclusion is that the end subserved is a needful protection of the surfaces, mainly the superior surface, against cold from nocturnal radiation. *A priori*, looking at the structure of the leaf, one would have thought that the under surface had the greater need of such protection.

Not only are all these movements incipient in the seedling, but some of them are manifested more rapidly and extensively than in most mature plants. This should needs be, since, as Mr. Darwin states it, "Seedlings are subjected to a severe struggle for life, and it appears to be highly important to them that they should adapt themselves as quickly and as perfectly as possible to their conditions." Very properly, therefore, no small part of this volume is devoted to the seedling and to the behavior of its several parts. The most novel and unexpected results relate to the young root. Judging from its simplicity and from the medium in which it is developed, one would not look there for the endowments which Mr. Darwin finds in it. But this root-tip and the vegetable cells which compose it conspire to teach us that most simple structures may be wonderfully gifted. The tiny root exhibits three kinds of movement; first that of circumnutation, in which, endeavoring to bend in all directions its tip "will press on all sides, and thus be able to discriminate between the harder and softer adjoining surfaces, . . . and to bend from the harder soil and follow the lines of least resistance," so modifying advantageously its course from that to which geotropism constantly tends to give it. Moreover, the growing end of the root is sensitive to contact, and in a complex manner. If pressed above the tip, it bends there toward or around the impinging body, much as the end of a tendril bends around a support: thus it may follow, as roots do, along the unequal surface of a solid body. But, thirdly, if the tip itself be locally pressed, it exhibits different and more surprising sensitiveness, for it transmits an influence to an upper adjoining part, causing it to bend away from the affected side. This sensitiveness to contact is confined to little more than one millimeter of the tip; the part which bends is 6 or 7 or even 12 millimeters above. So, when the sensitive tip in its downward growth strikes obliquely upon a stone or other obstacle, the part above at this distance, to which some influence must be transmitted, bends and carries the point away from the obstacle. Yet later, whenever a new portion of the side impinges upon the stone or other body, it will bend at that part toward instead of away from it, and so follow along its surface. It is the tip, likewise, which can discern that the air is moister on one side than on the other, and which thence "transmits an influence to the upper adjoining part, which bends toward the source of moisture." It is the tip only which is sensitive to gravitation. Well may Mr. Darwin affirm that there is no structure in plants more wonderful, as far as its functions are concerned, than the tip of the radicle. Also, that, "it is impossible not to be struck with the resemblance between the foregoing movements of plants and many of the actions performed unconsciously by the lower animals." "But the most striking resemblance is the localization of their sensitiveness and the transmission of an influence to an excited part which consequently moves. Yet plants do not of course possess nerves or a central nervous system; and we may infer that with animals such structures serve only for the more perfect transmission of impressions and for the more complete intercommunication of the several parts." The closing sentence of the book may be appended to this. "It is hardly an exaggeration to say that the tip of the radicle, thus endowed, and having the power of directing the movements of the adjoining parts, acts like the brain of one of the lower animals."

The movements "excited by light and gravitation," as well as the nyctotropic or sleep-movements so-called, are (as we have already stated) all referred by Mr. Darwin to modified circumnutation, "which is omnipresent whilst growth lasts, and after growth has ceased whenever pulvini are present," as in several classes of leaves. As respects the relation of external agents to the movements, note Mr. Darwin's remark: "When we speak of modified circumnutation we mean that light, or the alternations of light and darkness, gravitation, slight pressure or other irritants and certain innate or constitutional states of the plant, do not directly cause the movement; they merely lead to a temporary increase or diminution of those spontaneous changes in the turgescence of the cells which are already in progress."

Certain parts of plants turn or grow earthward. When this is attributed to gravitation, as it commonly is, the physicists have opportunity to complain of a misuse of the term. Although Mr. Darwin, like other writers, speaks of the influence of light and of gravitation in the same breath, without discrimination, we note with satisfaction his disagreement with those who "look at the bending of a radicle towards the center of the earth as the direct result of gravitation," and note especially the concluding *dictum.* "Gravity does not appear to act in a more direct manner on a radicle than it does on any lowly organized animal, which moves away when it feels some weight or pressure."

Why, we would ask, need the word *gravity* or *gravitation* be used at all in this connection?

The introduction to this volume contains a short article upon the terminology which is adopted in it, chiefly as regards such words as *epinasty* and *hyponasty*, geotropism and related terms, which it is most convenient to employ, and also the names of the several parts of the embryo and seedling. This is, we believe, almost the first English book in which the axial part of the dicotyledonous embryo below the cotyledons (the *radicle* of the systematic botanists even of the present day) is distinctly recognized as hypocotyledonous or initial stem, although on the continent and in America this has long been taught and accepted. None the less so although the term *radicle* has been retained for it (until recently by the present writer, at least), in order not to break with the terminology of systematic works. Mr. Darwin, in this volume, shortens the expression of "hypocotyledonous stem" into the term *hypocotyl*,—a fairly good English term, certainly better than the French *tigelle.* The objection to both is that the words will not take a substantive Latin form, as all such terms should. Wherefore the better name—an old one which we have reverted to in the last edition of the Botanical Text-book (Structural Botany)—is *caulicle* or *cauliculus.* The initial root, which grows from the lower end of the caulicle (or "hypocotyl") Mr. Darwin calls the radicle, following in this the ordinary English usage, except in very definitely distinguishing it from the cauline part above it. Being simply *root*, we have preferred uniformly to call it so, thus avoiding a word which the systematists have all along applied to the caulicle. Although initial stem and initial root are most clearly discriminated in the present volume, yet, in the accounts of the germination of the ordinary Dicotyledons, it appears to be implied or stated, either that it is the root-part which first projects from the seed-coats and that the stem-part begins its development later, or that the axial part of the embryo conspicuously preëxisting in the seed is root and not stem. We take it to be quite otherwise, namely, that this axial part in the seed is cauline, and that ordinarily it protrudes or makes some growth in length before root-formation begins.

A few misprints of names of plants will in nowise mislead or trouble any botanist, except possibly in the case of *Apium graveolens*, which on p. 422 and 424, and in the index, is printed *Apios.* A. G.

2. *Eucalyptographia: A Descriptive Atlas of the Eucalypts of Australia and the adjoining islands;* by BARON FERD. VON MÜLLER, K.C.M.G. London and Melbourne: 1880.—This is the sixth decade of the Atlas, and contains descriptions of the following species: *Eucalyptus buprestium, globulus, megacarpa, miniata, occidentalis, peltata, punctata, setosa, stellulata* and *tetragona.* The detailed account of *Eucalyptus globulus*, the ordinary "Blue Gum-tree," contains many facts of interest, which may be here briefly noticed.

(1.) Degree of resistance to frost. This depends on the age of the plant (older trees standing best), on the amount of moisture in its surroundings (dry places most favorable), and on the degree of shelter from the wind. Grown-up trees did not suffer at all during the cold winter of 1879–80 at Antibes, although the temperature fell as low as 15° F., and the monks of Tre Fontane, after repeated observations, maintain that the tree will bear a temperature of 17° F., and this appears to be in accord with experience in parts of Australia. In the cool, elevated but sheltered region, surrounding the alpine height of Mt. Buller, Baron von Müller observed snow lodging in large masses, and for protracted periods, on the branches of the tree, eventually injuring even strong limbs, but the stem and main branches remained unhurt, pushing forth new shoots and foliage in the spring. Professor Göppert, Dr. Raveret-Wattel and others "observed that *E. globulus* will bear a severe degree of cold transiently (about 20° F.), if it lasted not sufficiently long to congeal the sap to any great extent and provided also, that the new wood was well matured and the spot of growth a dry one."

(2.) The drainage of swamps by Eucalyptus. According to Baron von Müller, it was through the Archbishop of Melbourne, that plantations of this tree were first established for diminishing the miasmatic exhalations of the Pontine marshes. The following is an extract from a letter from the Archbishop to Baron Müller, under date of 17th Dec., 1879: "The *Eucalyptus globulus* was first raised in the Campagna from seeds kindly presented to me by you on my visit to Rome in 1869, to attend the Vatican General Council. I handed the seeds to the Superior of the Trappist-monks, who occupied the monastery and grounds of the Tre Fontane, a most fever-stricken locality. On my next visit to Rome, made a few years later, I had the pleasure to see the good results of your kind and thoughtful presentation in the vigorous growth of many Gum-trees acting most wholesomely on poisonous air of that portion of the Campagna."

But at Gaëta, trees were planted by Royal order in 1854, and in 1878 one of them measured eleven feet in girth, and was 100 feet high. It may be remembered that another species of this genus, *E. amygdalina*, surpasses this one both in rapidity of growth, and in the height which it ultimately attains.

The author deals to some extent with the medicinal properties of the products of the tree, and has also some remarks upon the influence of the forests of Blue-gum trees upon phthisis.

(3.) Strength of the timber. In one set of experiments the pieces subjected to test were seven feet long by two inches square.

No. 4,	seasoned 8 months,	broke with a total weight of	819 lbs.
No. 6,	" 2 to 3 years,	" " "	1029 "
No. 15,	" 20 years,	" " "	1330 "

In some experiments with wood of the same dimensions, Mr. Laskett found that when the weight was suspended in the middle, both ends free, the average was 712 lbs., being very much less than that recorded by Mr. Mitchell. Experiments by Baron von Müller and J. H. Lühmann, upon wood two feet long and two inches square, gave the following results:—Weight required to break a truncheon of

Eucalyptus globulus,	2252 to 3752	lbs.
Eucalyptus Leucoxylon, Victorian Iron Bark Tree,	3144	"
Eucalyptus obliqua, "Messmate,"	1776	"
Quercus alba, American White Oak,	2086	"
" " "	1644	"
Pinus silvestris, Baltic Deal	1358	"

The vertical or crushing strain on cubes of two inches was from ten to twelve tons.

So much for the strength of this wonderful wood. Now one word regarding the yield of wood by a single tree. At South-Port, Mr. James Dickinson noticed a tree of *E. globulus*, which, according to a local shipwright, would fully suffice to build a ninety-ton schooner. In addition to the figures of the species and the usual analytic details, the present decade contains a well-executed plate showing the histology of the bark of Blue-Gum, and a full bibliography of the same species. The latter well bears out the statement of the author, that "Perhaps not even to the Royal Oak of England has such an extensive literature been devoted at any particular period as to our Blue-Gum tree within the last twenty years." G. L. G.

3. *The Flora of Essex County, Mass.*; by JOHN ROBINSON. Salem, Essex Inst., 1880.—This is a substantial octavo of 200 pages. It is not a systematic description of the vegetation of the district, as might perhaps be inferred from the title, but it is far more than a mere catalogue. It comprises a list of the flowering plants and a large part of the Cryptogams, with copious notes upon the localities, where such information seemed necessary. Mr. Robinson's valuable annotations deal with a wide range of subjects, but never wander out of sight of the plant. A short and discriminating sketch of the early Botanists of Essex County adds greatly to the interest of the volume. G. L. G.

4. *Botany of California*, Vol. 2; by SERENO WATSON. University Press, Cambridge, Mass. 1880.—This volume completes the Flora of the State of California. The first volume has been re-issued with typographical corrections; the second volume containing all the important additions to the earlier orders. A notice of this very attractive and most useful work will be given in a subsequent number of this Journal. The volumes can be procured from the Curator of the Herbarium of Harvard University, Cambridge, Mass. The price to botanists is $5.00 for each volume, (postage 45 cts. additional). G. L. G.

5. *Giant Squid* (*Architeuthis*) *abundant in* 1875, *at the Grand Banks*; by A. E. VERRILL.—From Capt. J. W. Collins, now of the U. S. Fish Commission, I learn that in Oct., 1875, an unusual number of giant squids were found floating at the surface, on the Grand Banks, and mostly entirely dead, and more or less mutila-

ted by birds and fishes. In very few cases they were not quite dead, but entirely disabled. These were seen chiefly between N. lat. 44° and 44° 30′; and between W. long. 49° 30′ and 49° 50′. He believes that between twenty-five and thirty specimens were secured by the fleet from Gloucester, Mass., and that as many more were probably obtained by the vessels from other places. They were cut up and used as bait for cod-fish. For this use they are of considerable value to the fishermen. Capt. Collins was at that time in command of the schooner 'Howard,' which secured five of these giant squids. These were mostly from ten to fifteen feet long, not including the arms, and averaged about eighteen inches in diameter. The arms were almost always mutilated. The portion that was left was usually three to four feet long and, at the base, about as large as a man's thigh.

One specimen, when cut up, was packed into a large hogshead tub, having a capacity of about seventy-five gallons, which it filled. This tub was known to hold 700 pounds of cod-fish. The gravity of the *Architeuthis* is probably about the same as that of the fish. This would indicate more nearly the actual weight of one of these creatures than any of the mere estimates that have been made, which are usually much too great. Allowing for the parts of the arms that had been destroyed, this specimen would, perhaps, have weighed nearly 1,000 pounds.

Among the numerous other vessels that were fortunate in securing this kind of bait, Capt. Collins mentions the following: The schr. "Sarah P. Ayer," Capt. Oakly, took one or two. The "E. R. Nickerson," Capt. McDonald, secured one that had its arms and was not entirely dead, so that it was harpooned. Its tentacular arms were thirty-six feet long. The schr. "Tragabigzanda," Capt. Mallory, secured three in one afternoon. These were eight to twelve feet long, not including the arms. These statements are confirmed by other fishermen, some of whom state that the "big squids" were also common, during the same season, at the "Flemish Cap," a bank situated some distance northeast from the Grand Banks.

The cause of so great a mortality among these great Cephalopods can only be conjectured. It may have been due to some disease epidemic among them, or to an unusual prevalence of deadly parasites or other enemies. It is worth while, however, to recall the fact that these were observed at about the same time, in autumn, when most of the specimens have been found cast ashore at Newfoundland, in different years. This season may, perhaps, be just subsequent to their season for reproduction, when they would be so much weakened as to be more easily overpowered by parasites, disease, or other unfavorable conditions.

IV. Miscellaneous Scientific Intelligence.

1. *Zeitschrift für Instrumentenkunde: Organ für Mittheilungen aus dem gesammten Gebiete der wissenschaftlichen Technik.* No 1, January, 1881. 40 pp. small 4to. Berlin (Julius Springer—B. Westermann & Co., agents in New York.)—The prospectus of this new Journal states that it will be devoted to the discussion of all subjects immediately connected with the design and construction of scientific instruments and apparatus. These will be treated both from the standpoint of the investigator and also that of the mechanician, in order that the scientific learning of the former and the technical knowledge and experience of the latter may be combined to produce the best results. The list of editors comprises twenty names, including many of those who have the best reputation in Germany for the manufacture of scientific instruments, as well as able physicists. In the highest class of research in all branches of physical science, and too in their practical applications, the use of instruments of precision takes so prominent a place that every effort that is made with the object of improving them cannot fail to have an immediate useful effect. This the new Journal promises to do, and the names of those who appear in the editorial staff, and of those from whom articles are promised, in early numbers, are a guarantee that its standard will be a high one.

The January number contains the following articles:—Normal barometer and manometer, by R. Fuess; on the illumination of micrometer arrangements, by W. Förster; on the construction and investigation of micrometer screws, by C. Reichel; on spectrum apparatus, by H. C. Vogel; a rotating spectrum apparatus, by O. Lohse; on the graphic method in Physiology and on a telegraphic kymometer, by H. Kronecker. In addition, there are also short notices, reports of society transactions, and abstracts from periodical and patent literature. In the numbers next to follow are promised articles on the present stand of thermometry, the construction of balances of precision, the application of electricity to meteorological registration apparatus, and many others of equal interest.

2. *Academy of Sciences, Paris.*—Dr. B. A. Gould, of Boston, who has been for many years Director of the Observatory at Cordoba, and has published within the past year the Uranometria Argentina, as a first part of the results of his telescopic study of the Southern heavens, has been elected a member of the Section of Astronomy of the French Academy of Sciences, in place of the late Professor C. A. F. Peters, of Kiel.

3. *Bibliographie Générale de l'Astronomie.* Tome II. *Mémoires et Notices insérés dans les Collections académiques et les Revues.* 1st fasciculus; by J. C. Houzeau and A. Lancaster, Brussells, Dec. 1880. Large 8vo, pp. 86, and 336 columns.—This is the first part of the second volume of a general Bibliography

of Astronomy, the first volume not yet having appeared. The first eighty-six pages are devoted to lists of the Academic collections and journals, giving the leading bibliographic details of the several series. The rest of this number contains two sections, *History and Study of Astronomy* and *Biographies of Astronomers*, also the first part of Section 3d, Spherical Astronomy. The second section, containing references to the biographical literature for apparently about 2,500 men more or less connected with the progress of astronomy, is of peculiar value and appears to be very complete. The work, as a whole, will be one of the highest value. H. A. N.

4. *Washburn Observatory, University of Wisconsin.*—Professor Henry S. Holden, of the Naval Observatory, Washington, has received the appointment of Director of the Washburn Observatory, in place of Professor Watson, deceased.

5. *A Text Book of Elementary Mechanics for the use of Colleges and Schools;* by EDWARD S. DANA. 291 pp. 12mo, with 190 wood cuts. New York, 1881. (John Wiley & Sons).—The character of this elementary text book will appear from the following quotation from the preface: "The chief aim has been to present the fundamental principles of the subject in logical order and in as clear, simple and concise a form as possible, yet without any sacrifice of strict accuracy. For the sake of making the portions of the subject, which necessarily involve some difficulty, more intelligible to beginners, and also to increase the interest of the general principles demonstrated by showing something of their practical bearing, simple illustrations have been introduced rather more fully than usual; these are sometimes given in a few words, sometimes in more extended form," etc. The first fifty pages are devoted to the subject of Kinematics; then follow several chapters on the laws of motion, central forces, work and energy, etc., embraced under Dynamics or Kinetics, and the remainder is devoted to Statics. The relations involved in the various simple machines are developed both from statical principles and too in accordance with the principles of work. A large number of examples are given at the close of each section, and a supplementary list of examples involving the metric units is added at the end of the volume.

6. *Massachusetts Institute of Technology—Abstract of the Proceedings of the Society of Arts for the 18th-year*, 1879–80; meetings 242–255 inclusive. 108 pp. 8vo. Boston: 1880.—This volume contains a record of the meetings of the Society of Arts from Oct. 23d, 1879, to May 13th, 1880, including abstracts of the various papers presented; the subjects of some of these are: the parabolic reflecting camera, by W. H. Clarke; an instrument for the determination of latitude, by S. C. Chandler, Jr.; artificial alizarine, by Professor J. M. Ordway; battery and copper plate amalgamation, by Professor R. H. Richards; American interoceanic ship transit, by Dr. S. Kneeland, etc.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XXXI.—*Monograph by Professor* MARSH *on the Odontornithes, or Toothed Birds of North America.**

IT is a source of great satisfaction to the friends of science that a discovery which called out at first some incredulity should rest, as Professor Marsh's work shows, on the most complete range of evidence and perfection of material ever at the disposal of the author of a monograph in paleontology. The illustrations on the many beautiful plates of this monograph, instead of being figures of uncharacteristic and scarcely recognizable fragments, as in many memoirs on fossil vertebrates, might be, for the most part, so far as completeness is concerned, representations of recent bones, and, we might almost say, of recent skeletons. In fact, in the case of one species, the type of the genus *Hesperornis*, not more than half a dozen of the small bones are missing; and in *Ichthyornis* and *Apatornis*, also, the remains are remarkably perfect, considering the fragile character of birds' bones. The success of the author in getting together all this so nearly complete material is marvelous, especially when we consider the rare occurrence of Cretaceous fossil birds any where; that only two or three species are known from European Cretaceous beds, and that those are based on fragments that are scarcely characteristic. As a reward for his energy, Professor Marsh has the satisfaction of having obtained, so far as known, all the bird remains that have ever been collected from the Kansas

* *Odontornithes:* A Monograph on the Extinct Toothed Birds of North America; with thirty-four plates and forty woodcuts. By OTHNIEL CHARLES MARSH, Professor of Palæontology in Yale College. 4to, pp. i–xv. 201. Exploration of the 40th Parallel, Vol. VII. Washington, D. C. 1880.

beds, and of having published all the original matter that has yet been brought out on the American Odontornithes.

The present work, which appears as volume VII of the Survey of the 40th Parallel, is also the first of the Memoirs of the Peabody Museum of Yale College. It contains, in its Preface, an outline of the plan of the series to be issued, of which this is the initial volume; and as this subject is one of general interest to paleontological science, we cite the following paragraphs.

"The present volume is the first of a series of monographs designed to make known to science the Extinct Vertebrate Life of North America. In the investigation of this subject, the writer has spent the past ten years; much of it in the field, collecting, with no little hardship and danger, the material for study, and the rest in working out the characters and affinities of the ancient forms of life thus discovered.

"During this decade, the field work, extending from the Missouri River to the Pacific Coast, has so predominated, as the subject unfolded, that a plan of gradual publication became a necessity. The more important discoveries were briefly announced soon after they were made, but only where the specimens on which they were based could be accurately determined. The principal characters of the new groups were next worked out systematically, and published, with figures of the more important parts. When the investigation of a group is completed, the results, with full descriptions and illustrations, will be brought together in a monograph. This system has been carried out with the *Odontornithes*, in the present memoir, and will be continued with the other groups. The investigation of several of these is now nearly completed, and the results will soon be ready for publication.

"The material is abundant for a series of monographs on the marvelous extinct vertebrates of this country, and the results already attained are full of promise for the future. A somewhat careful estimate makes the number of new species of extinct vertebrates, collected since 1868, and now in the Yale College Museum, about 1,000. Nearly 300 of these have already been described by the writer, and some have been noticed or described by other authors, but at least one-third remain to be investigated.

"Among the new groups brought to light by these researches, and already made known by descriptions of their principal characters, are the following, which will be fully described in subsequent volumes of the present series.

"The first Pterodactyles, or flying reptiles, discovered in this country, were found by the writer in the same geological horizon with the *Odontornithes*, described in the present volume.

These were of enormous size, some having a spread of wings of nearly twenty-five feet; but they were especially remarkable for the absence of teeth, and hence resembling recent birds. They form a new order, called *Pteranodontia*, from the type genus *Pteranodon*. Of this group, remains of more than six hundred individuals are now in the Yale College Museum; ample material to illustrate every important point in their osteology.

"With these fossils, were found also great numbers of Mosasauroid reptiles, a group which, although rare in Europe, attained an enormous development in this country, both as to numbers and variety of forms. Remains of more than fourteen hundred individuals, belonging to this order, were secured during the explorations of the last ten years, and are now in the Museum of Yale College.

"The most interesting discoveries made in the Jurassic formation were the gigantic reptiles belonging to the sub-order *Sauropoda*, including by far the largest land animals yet discovered. Another remarkable group of large reptiles found in the same formation were the *Stegosauria*. Other Dinosaurs from the same horizon, the "Atlantosaurus beds," show that this was the dominant form of vertebrate life in that age, and many hundred specimens of these reptiles are now in the Yale Museum. In a lower horizon of the same formation, the "Sauranodon beds," were found the remains of a peculiar new group of reptiles, the *Sauranodonta*, allied to *Ichthyosaurus*, but without teeth.

"In the Eocene deposits of the Rocky Mountains, the writer discovered a new order of huge mammals, the *Dinocerata*. Remains of several hundred individuals were secured, and a monograph on the group will follow the present memoir. In the same formation were found the remains of another new order of mammals, the *Tillodontia*, in many respects the most remarkable of any yet discovered. In the same Eocene deposits were secured the first remains of fossil Primates known from North America, as well as the first Chiroptera, and Marsupialia. Abundant material also was found in the same region to illustrate the genealogy of the horse, and a memoir on this subject is in course of preparation."

We confine our notice of Professor Marsh's volume to a brief résumé of the facts relating to the structure of the Toothed Birds; an account of the interesting facts pertaining to the brains of these ancient birds as compared with the same in related modern kinds; and to a presentation at length, chiefly by quotations from the work, of the author's important biological and paleontological conclusions. These conclusions and many of the facts have not yet been brought out in this Journal.

The Cretaceous deposits of Kansas, which have afforded all the remains of *Odontornithes*, thus far found in America, consist of beds of a fine yellow chalk and a calcareous shale, which have been little disturbed, and to this fact, the wonderful preservation of the fragile bones here described is due. The strata containing them correspond to what has been called by Marsh the "Pteranodon beds," a part of Meek and Hayden's Cretaceous Number 3. This horizon is extremely rich in vertebrate fossils, and contains many fishes, Mosasauroid reptiles, Plesiosaurs and Pterodactyles.

The first specimen of *Odontornithes* found was the distal end of a tibia collected by Professor Marsh in 1870. Other portions of the skeleton were soon afterward brought to light, and the importance of the group being early recognized, an unremitting search for these fossils was kept up for ten years. As the result of this field work, there are now in the Yale Museum more than one hundred individuals of this group, among which are several almost complete skeletons of *Hesperornis* and rich material of *Ichthyornis*.

"A study of this extensive series of Bird remains brings to light the existence of two widely separated types in this class, which lived together during the Cretaceous period, in the same region, and yet differed more from each other than do any two recent birds. Both of these types possessed teeth, a character hitherto unknown in the class of Birds, and hence they have been placed by the writer in a separate sub-class, the *Odontornithes*. One of these groups includes very large swimming birds, without wings, and with the teeth in grooves (*Odontolcæ*), represented by the genus *Hesperornis*. The other contains small birds, endowed with great powers of flight, and having teeth in sockets (*Odontotormæ*), and biconcave vertebræ; a type best illustrated by the genus *Ichthyornis*. Other characters, scarcely less important, appear in each group, and we have thus a vivid picture of two primitive forms of bird structure, as unexpected as they are suggestive. A comparison of these two forms with each other, and with some recent birds, promises to clear away many difficulties in the genealogy of this class, now a closed type; and hence they are well worthy of the detailed description and full illustration here devoted to them."

Hesperornis, the type of the order *Odontolcæ*, was an aquatic bird of great size, measuring almost six feet from the tip of the bill to the end of the toes. Owing to the completeness of the remains, its affinities and probable habits have been very fully and clearly made out.

The teeth had conical pointed crowns covered with smooth enamel and somewhat directed backward, and their fangs were very stout. In form they closely resemble the teeth of some Mosasauroid reptiles.

There were fourteen functional teeth in the maxillary bone of *Hesperornis regalis*, the premaxillary being edentulous, while in each ramus of the lower jaw there were thirty-three, extending from near the anterior extremity along the entire upper margin of the dentary bone. These teeth were implanted in a continuous groove, and were no doubt held in place during life by cartilage, and thus probably had a slight fore and aft motion. The method of replacement of the teeth was similar to that which obtains in some reptiles. The young tooth was formed on the inner side of the fang of the one which it was to replace, and a pit was there excavated for it by absorption. As it increased in size, the fang of the old tooth became more and more eaten away, and it was finally expelled by the new one, which occupied the same position. Thus the number of teeth always remained the same.

The results of Professor Marsh's investigations of the law of brain growth in Tertiary Mammals are supplemented in a very interesting manner by his study of the brains of these Cretaceous birds, and he concludes that the same principles hold good for them as for the former class.

The brain of *Hesperornis* (figure 1) was very small and was far more reptilian in type than that of any other known bird. The olfactory lobes were large and their nerves passed out of the cranium through separate foramina, one on each side of the interorbital septum. The cerebral hemispheres were small, narrow and elongated, and were separated by a median ridge of bone depending from the roof of the skull. The cerebellum is relatively very large. The optic lobes were large and prominent and present resemblances in size and position to those of reptiles.

Compared with the brain of *Colymbus* (figure 2) the brain of *Hesperornis* presents some interesting features. It was less than one-third the size of that of the Loon, but the most remarkable difference is in the cerebral hemispheres, which in *Colymbus* are much expanded transversely and constitute by far the larger portion of the brain.

The bill of *Hesperornis* was long and slender, and the skull, as a whole, was shaped somewhat like that of the loon, *Colymbus torquatus* Brünnich. The cranium in its more important features presents many resemblances to that of some living Struthious birds, and these point, no doubt, to a real affinity with this group. The neck was long and flexible, the scapular arch very feeble, and there were no functional wings; the only bone of the arm represented being the humerus, which had no articular surface at its distal end. The sternum was broad and

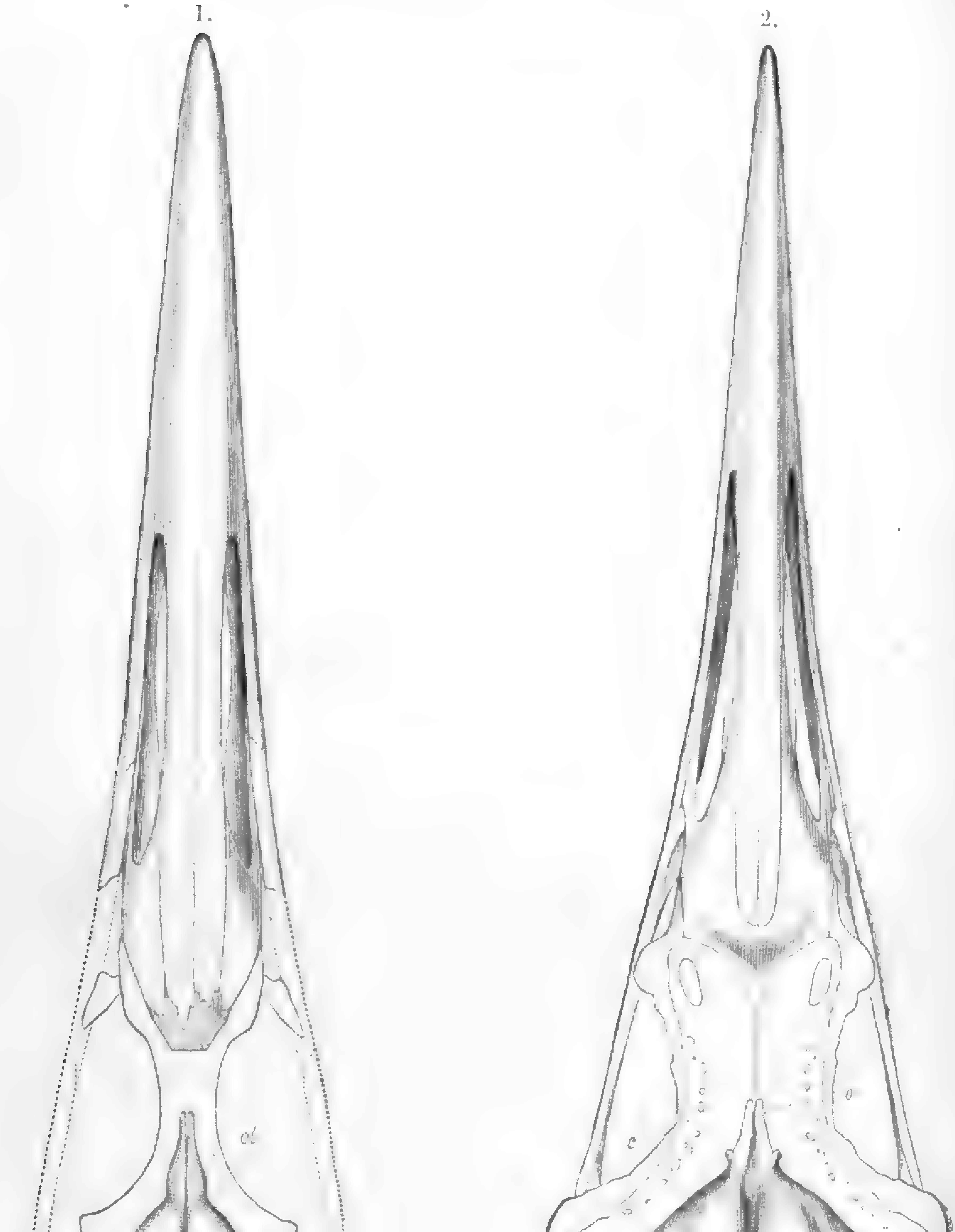


Figure 1.—Outline of skull and brain-cavity of *Hesperornis regalis*, Marsh; seen from above; three-fifths natural size.

Figure 2.—Outline of skull and brain-cavity of the Loon. (*Colymbus torquatus*, Brünnich); same view; natural size.

ol. olfactory lobes; *c.* cerebral hemispheres; *op.* optic lobes; *cb.* cerebellum; *f.* flocculi; *m.* medulla.

long, but was wholly without a keel. The pelvis was greatly elongated and somewhat resembles that of the Grebes. The acetabulum, instead of being a mere ring of bone, as in most birds, is wholly closed internally, with the exception of a foramen perforating the inner wall. The posterior extremities of the ilium, ischium and pubis are free, as in some *Ratitæ* and in *Tinamus*. The tail is long, being composed of twelve vertebræ, a greater number than is found in any recent bird, except possibly the great Auk (*Alca impennis*). The middle and distal caudals have extremely long and widely expanded transverse processes, and by these lateral movement was much restricted, so that the principal motion of the tail must have been vertical, and it was no doubt a powerful aid in diving. The so-called plowshare bone of modern birds is represented by the coössification of the last three or four vertebræ, which, however, form a flat depressed bone not at all resembling its homologue in the bird of to-day.

The legs of *Hesperornis* resemble those of *Podiceps*, and are very large. As they constituted the sole means of locomotion, they had been brought to the highest perfection, but were adapted solely for progression through the water. "Provision was made for a very powerful backward stroke followed by a quick recovery, with little loss by resistance, a movement quite analogous to the strong stroke of an oar, feathered on its return." The motion of the limb was in a vertical plane, but by a peculiar articulation of the digits, present also in some existing diving birds, these members, as the foot was moved forward, were partially rotated so that the narrowest edge of the fourth and longest was brought to the front, and thus the least possible resistance presented to the water. The remaining digits followed behind the fourth, and the foot was not expanded until the beginning of the backward stroke.

Professor Marsh, in his chapter on the Restoration of *Hesperornis*, gives the following among his conclusions with regard to this order:

"*Hesperornis* was a typical aquatic bird, and in habit was doubtless very similar to the Loon, although, flight being impossible, its life was probably passed entirely upon the water, except when visiting the shore for the purpose of breeding. The nearest land at this time was the succession of low islands which marked out the present range of the Rocky Mountains. In the shallow tropical sea, extending from this land five hundred miles or more to the eastward, and to unknown limits north and south, there was the greatest abundance and variety of fishes, and these doubtless constituted the main food of the present species. *Hesperornis*, as we have seen, was an admirable diver, while the long neck with its capabilities of rapid flexure, and the long slender jaws armed with sharp recurved teeth formed together a perfect instrument for the capture and retention of the most agile fish. As the lower jaws were united in front only by cartilage, as in Serpents, and had on each side a joint which admitted of some motion, the power of swallowing was doubtless equal to any emergency.

"Having thus shown what the skeleton of *Hesperornis* is, and what its mode of life must have been, it remains to consider the more important question of how the peculiar combination of general and specialized characters manifested in its structure originated. The two most striking features of *Hesperornis* are the teeth, and the limbs, and an inquiry in regard to them first suggests itself.

3. 4.

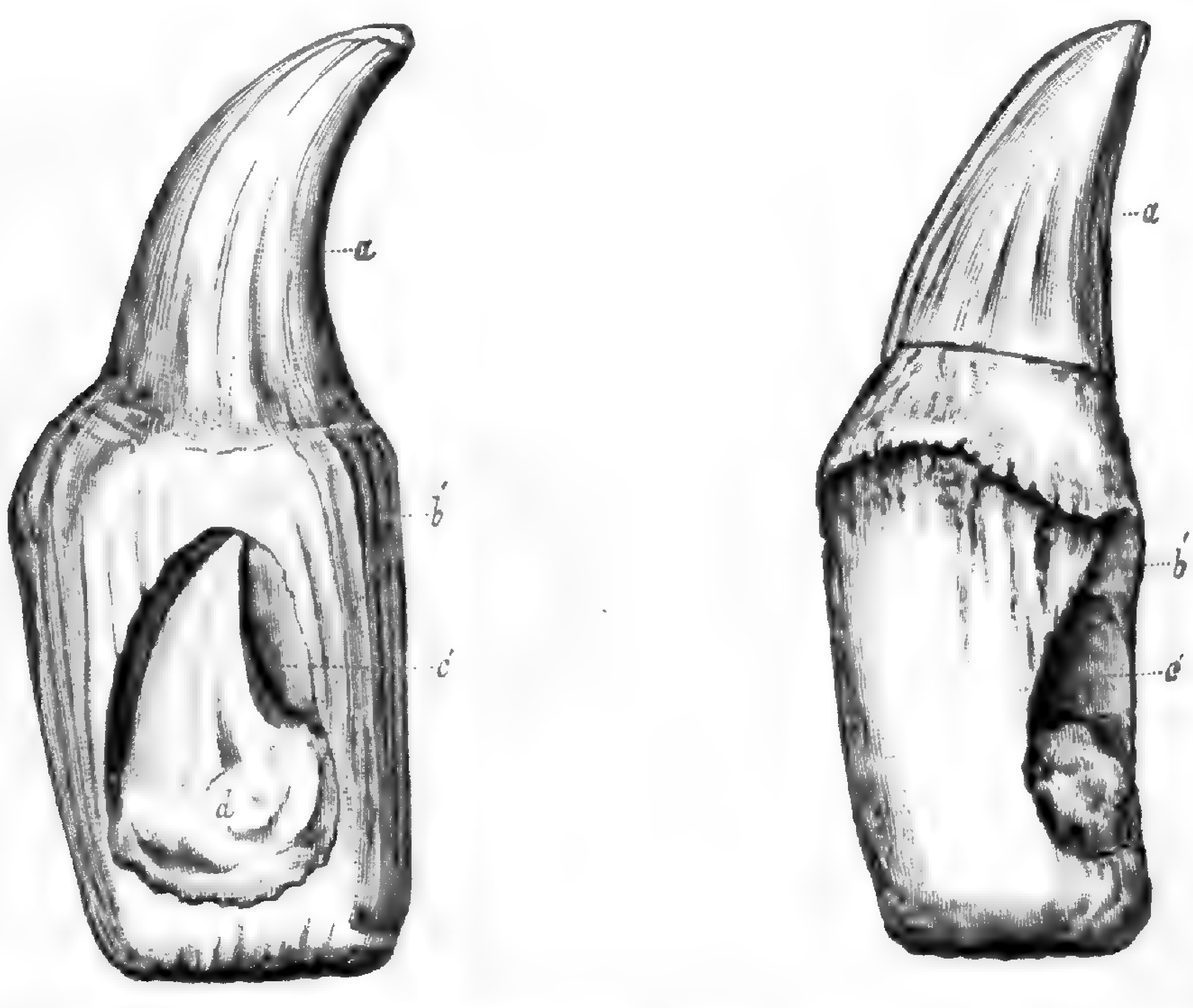


Figure 3.—Tooth of *Hesperornis regalis* (No. 1206); enlarged eight diameters.
Figure 4.—Tooth of *Mosasaurus princeps*, Marsh; half natural size.
a. enamel of crown; *b.* dentine; *b′*. root of tooth; *c′*. absorbed cavity in root; *d.* young tooth.

"The teeth of *Hesperornis* may be regarded as a character inherited from a reptilian ancestry. Their strong resemblance to the teeth of reptiles, in form, structure, and succession, is evidence of this, and their method of implantation in a common alveolar groove (Holcodont), conforms strictly to what we have in one well known group of reptiles exemplified by *Ichthyosaurus*. This method of insertion in the jaw is a primitive dental character, quite different from what we should naturally expect as an accompaniment of the modern style of vertebra, and is a much lower grade than the implantation of the teeth in distinct sockets (Thecodont), a feature characteristic, as we shall see, of another group of Odontornithes, of which *Ichthyornis* is the type. These teeth indicate unmistakably that *Hesperornis* was carnivorous in habit, and doubtless was descended from a long line of rapacious ancestors."

"In considering the limbs of *Hesperornis*, two explanations of their peculiar modifications naturally suggest themselves. The rudimentary wings, viewed in the light of modern science, clearly indicate that *Hesperornis* was in this respect a degraded type. The Struthious characters which we have noticed in various parts of the skeleton might be regarded, not as evidence of close relationship, but rather as general reptilian characters, common to the two groups through inheritance from a remote reptilian ancestry. According to this view, the wings may have been gradually lost by disuse, after the aquatic life was assumed. In proportion as the wings diminished, the legs and feet increased in size, for their work increased. This change would be strictly in accordance with the law of compensation, and the well known economy of nature. We might suppose, moreover, the ancestors of *Hesperornis* to have been at one time on an equality with the Loon, and later with the Penguin, in respect to means of flight and swimming. As the wings slowly diminished in size, first came the loss of flight, while the wings retained, doubtless for a long time, their power of propulsion through the water. As this too became gradually restricted, the legs and feet gained proportionally. The power derived from them, aided indirectly by the tail, in time so predominated, that the wings became entirely aborted, a remnant of the humerus alone remaining. During the life-history as thus indicated, *Hesperornis* would exemplify in the waters of the Cretaceous period the evolution that has recently taken place in ocean navigation, in the gradual change of the side-wheel steamer into the modern propeller.

"Another explanation seems on the whole more reasonable, and more in accordance with the known facts. The Struthious characters, seen in *Hesperornis*, should probably be regarded as evidence of real affinity, and in this case, *Hesperornis* would be essentially a carnivorous, swimming Ostrich. The diminutive wings and very large posterior extremities would then have been acquired on land, by the same means that have given similar characters to the *Ratitæ*, and subsequently have been adapted to an aquatic life. Against this view, the carnivorous character of *Hesperornis* would be no valid objection. The long neck and peculiar jaws and teeth would be equally effective in seizing prey on the land, and many of the herbivorous cotemporaries would doubtless have been easy victims. This would be precisely analogous to what we have among the corresponding groups in the Dinosaurs.

"There is to-day no evidence that any of the Struthious birds, or their ancestors, ever possessed the power of flight, although this is generally assumed. The case is even stronger with *Hesperornis*, as this genus stands much nearer the ancestral type, both in structure and in time. The absence from the sternum of any trace of a keel is alone strong proof against flight; the peculiar Dinosauroid union of the scapula and coracoid, unlike that of any volant bird or reptile, confirms this; and other testimony bearing in the same direction is not wanting.

"All Carinate birds, moreover, so far as known, indicate by their embryology that they have passed through the Struthious, or lower stage; and some of them, *Tinamus*, for instance, still retain one or more of its general characters. There are, indeed, various flightless birds, recently extinct, which do not belong to the Ostrich group, but are truly Carinate in all their essential features. The Dodo (*Didus*), Solitaire (*Pezophaps*), *Cnemiornis* and *Notornis* are well known examples; but these all show in their shoulder-girdle unmistakable traces of the lost power of flight. The characters necessary to volant movements, once attained, would appear never to be completely lost, and this alone seems to furnish a crucial test. When such suggestive indications are wanting in the skeleton, we may fairly challenge any assumption of previous flight.

"Although *Hesperornis* may thus, like its Reptilian ancestry, have always been incapable of flight, the anterior limbs may have long continued limited aids to locomotion. Whether used actively in the air, like the wings of the Ostrich, or of young swimming birds, or passively, like the sail-set pinions of a Swan, or later as imperfect paddles, the wings of *Hesperornis* were certainly not well fitted for diving, and hence they gradually became useless, and virtually disappeared. We may imagine among the reasons for the gradual loss of wings, the fact that they were too weak to be of much service under water, while from their position they added greatly to the resistance, especially during rapid diving. To diminish this resistance, they would naturally be applied closely to the side, and from such disuse, would gradually suffer atrophy.

"In this great swimming bird, as thus modified, we have presented to us an interesting problem in animal mechanics. The wings may be regarded as wanting, since the remnant of the humerus was attached closely to the side, as in *Apteryx*, if not entirely concealed beneath the skin, like a scapula. The locomotion was therefore entirely performed by means of the posterior limbs, a specialization here seen for the first time in aquatic birds, recent or fossil. Those who have observed a Penguin or a Loon swimming beneath the water know what a vigorous use such birds then make of their wings, however useless these members may appear to be on land. Not only do the wings, in such a case, assist in the forward movement through the water, but they are of much service in steering. A Penguin, when in swift sub-aqueous flight, can turn around, by the aid of its wings, while moving twice its length. *Hesperornis* had no such aid, but the legs and feet were far superior, for swimming and diving, to those of the Penguins, not merely in power, but in the more perfect adaptive mechanism. This was doubtless the main reason why the posterior limbs of *Hesperornis* became so predominant.

"The tail of *Hesperornis* was clearly of great service in its aquatic life. In the number of vertebræ and length, it exceeds nearly all known birds, and it is unique in its widely expanded transverse processes, and in its depressed, horizontal, plough-share bone. This broad horizontal tail reminds one of that of the beaver, and was undoubtedly of great assistance in steering and in diving. Whether it was, like the beaver's tail, destitute of feathers, or, like the tail of *Plotus*, was furnished with long stiff feathers, so as to act as a rudder, cannot at present be determined with certainty, although the latter view seems more probable. That *Hesperornis* was provided with feathers of some kind, we can hardly doubt."

5.

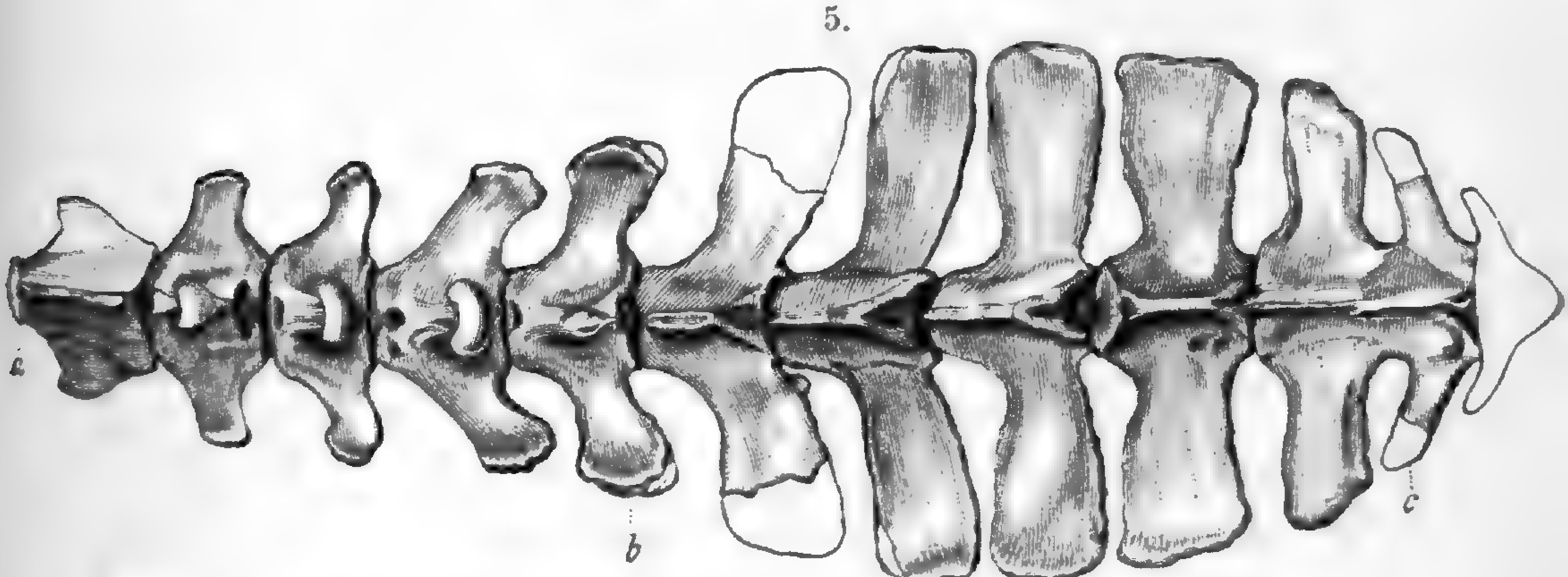


Figure 5.—Caudal vertebræ of *Hesperornis regalis*, Marsh; seen from above, in position; two-thirds natural size.

It is interesting to observe that Professor Marsh, working from an entirely different standpoint, reaches the same conclusions that were arrived at by Haughton with regard to the volant powers of Struthious birds. The latter, from his studies of the myology of the wings of the *Ratitæ*, concludes that these birds could never have possessed the power of flight. The gradual atrophy of the arm resulting from disuse, the extreme of which is seen among living birds in *Apteryx*, had proceeded so far in *Hesperornis* that it was no better provided with fore limbs than are the Cetaceans with hind limbs.

The enormous development of the legs and feet, supposed by some writers to point to an affinity with the *Pygopodes*,

6.

Figure 6.—Restoration of *Hesperornis regalis*, Marsh. One-eighth natural size.

does not really suggest any such relationship. That the legs are much alike in both groups is true; but to suppose that *Hesperornis* is merely a loon or grebe with teeth, is to take a very superficial view of the structural characteristics of this type. The feet and legs are purely adaptive, and have simply been developed into most perfect instruments for progression through the water. That these members in another and widely different group of birds should have proceeded along the same path of development is nothing surprising and is paralleled in several other groups of vertebrates.

The order *Odontotormæ*, described in Part II of Professor Marsh's work, is represented by two genera, *Ichthyornis* and *Apatornis*. These birds were small and wholly unlike *Hesperornis* in structure, being, perhaps, as different from that type as from that of any modern birds. They were about the size of a pigeon and were provided with very large strong wings, but had small legs and feet. The sternum is strongly keeled, and the bones are extensively pneumatic. They present some resemblances in structure to the existing Terns, and are thought to have somewhat resembled those birds in their mode of life.

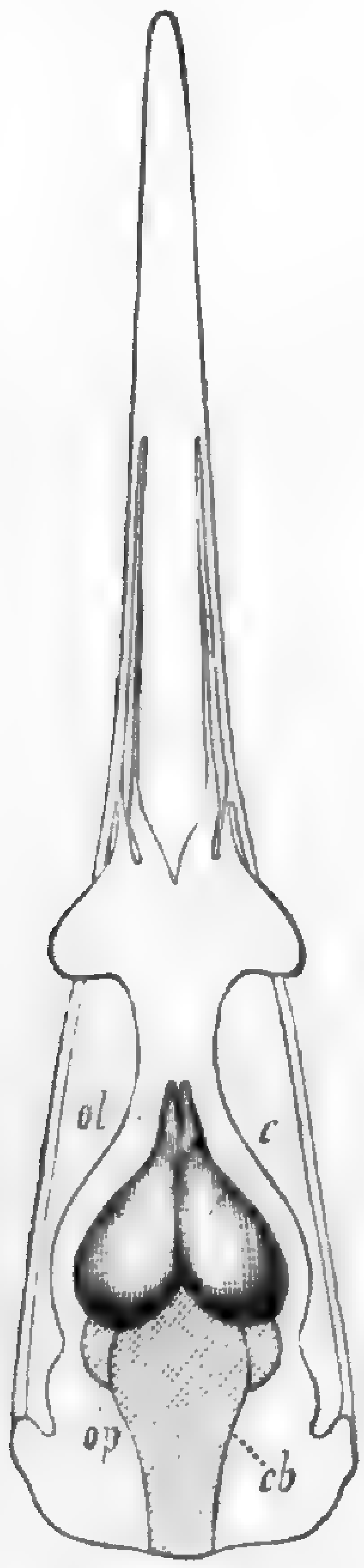
The teeth of *Ichthyornis* and *Apatornis* were implanted in distinct sockets, instead of in a groove, as in *Hesperornis*. They are somewhat compressed and strongly recurved, and the cutting edges in front and behind are sharp and smooth, without serrations. The teeth in the maxillary seem to have been larger than those opposed to them. In *Ichthyornis dispar*, the type of the order, there were twenty-one teeth in the lower jaw. The anterior one is very near the extremity of the jaw and from this point they extend back to the posterior extremity of the dentary. The method of replacement of the teeth was not lateral, as in *Hesperornis* and the Mosasaurs, but vertical, as in the Crocodiles and Dinosaurs—an important and highly interesting fact.

An examination of the brain cavity of *Ichthyornis* presents results similar to those arrived at from the comparison of the same part in *Hesperornis*. If we compare the skull of *Ichthyornis* with that of *Sterna*—the two being reduced to the same absolute size—we find the brain of the former to have been less than one-third the size of the latter. The differences between these two smaller birds are the same in kind as those between *Hesperornis* and *Colymbus* (figures 1 and 2), but the cerebral hemispheres in *Ichthyornis* are relatively less elongated than in its Cretaceous contemporary.

The similarity in the results of these comparisons is especially interesting, since in no other cases have the brain cavities of Mesozoic birds been studied.

A feature of this group, not less interesting than the possession of teeth, is their biconcave vertebræ. The presence of this reptilian character in vertebrates so highly organized as birds, was wholly unexpected, and is only another illustration of the fact, so constantly obtruded upon the attention of the anatomist, that some low character may persist while specialization in certain directions is reaching a high degree of perfection. If we leave out of account the skull and presacral vertebræ of this group, its structure is essentially that of a modern bird, but the combination of such specialized and primitive characters renders it not less remarkable than its larger toothed ally.

7.



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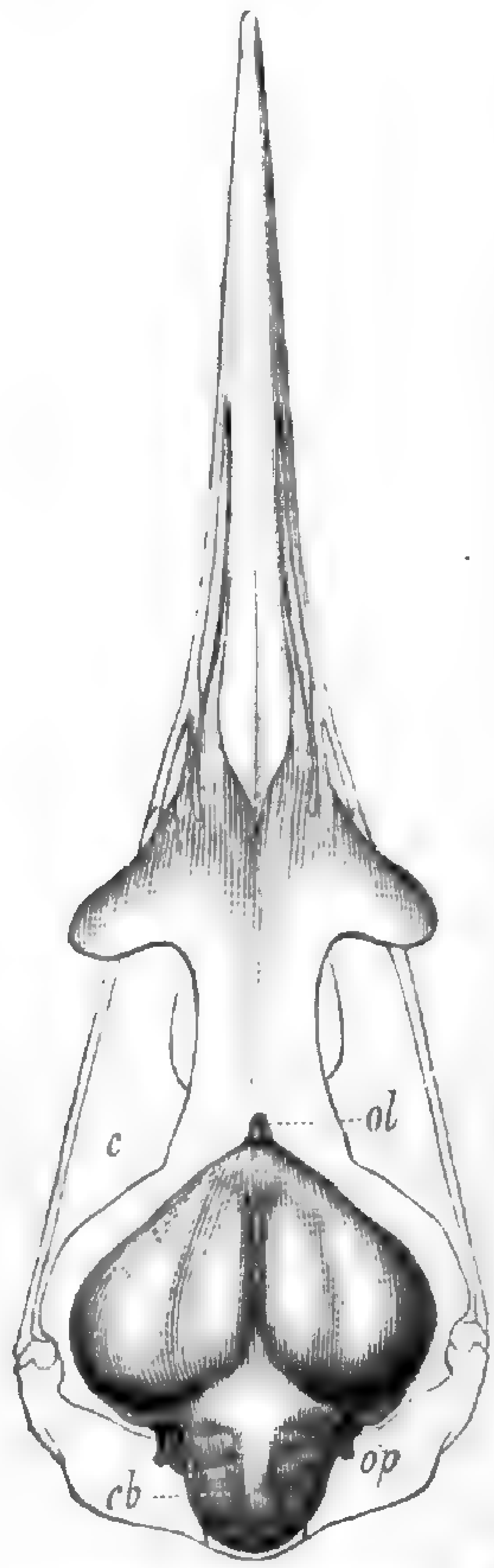


Figure 7.—Outline of the skull and brain-cavity of *Ichthyornis victor*, Marsh; seen from above; five-sixths natural size.
Figure 8.—Outline of the skull and brain-cavity of *Sterna cantiaca*, Gmelin; same view; natural size.
ol. olfactory lobes; *c.* cerebral hemispheres; *op.* optic lobes; *cb.* cerebellum.

With respect to *Ichthyornis* as a whole, Professor Marsh says: "In considering the skeleton of *Ichthyornis*, the anatomist is at once confronted with a strange combination of characters. The wing-bones are conclusive proof that *Ichthyornis* was a highly specialized bird, with great powers of flight. The individual bones correspond closely with those of birds living to-day. The legs and feet, also, are much like those of some modern birds. With these portions alone before him, the comparative anatomist would unhesitatingly refer the remains to the class of Birds, and would naturally conclude that they belonged to the modern type. If, however, the skull should then be found with the wings and feet, very strong evidence would be required to convince him that they were parts of one and the same bird. The jaws and teeth present reptilian characters wholly unknown in modern birds, while the base of the skull and the small brain point strongly in the same direction. The biconcave vertebræ lead *Ichthyornis* still farther away from all known birds, recent and extinct, and, if found alone with the jaws and teeth, would force any anatomist to the conclusion that he had before him the remains of a reptile.

"The skeleton of *Ichthyornis*, as we know it to-day, can be interpreted only, in the light of modern science, by supposing that certain parts have become highly specialized in the direction of recent birds, while others have been derived, with but little change, from a reptilian, or even a more lowly, ancestry. In the wings, the most characteristic modern feature is the coössification of the metacarpal bones, a character universal among existing birds. In reptiles, however, and in the only known Jurassic bird, *Archæopteryx*, these bones are separate. The sternum of *Ichthyornis* is very similar to that of modern carinate birds. In the feet of *Ichthyornis*, also, the compound tarso-metatarsal is another modern feature, especially characteristic of recent birds.

"If, now, we consider the skull of *Ichthyornis*, we find the avian and the reptilian characters strangely blended. The teeth are evidently a strong reptilian feature, and, before the discovery of *Ichthyornis*, were entirely unknown in the class of Birds. Their method of implantation in distinct sockets is a specialized character in reptiles, and was not shared even by *Hesperornis*, the contemporary of *Ichthyornis*. The diminutive elongated brain, also, points back to the reptiles. Other features of the skull, for example, the single headed quadrate, are shared only by the most reptilian of birds. The union of the lower jaws in front, by ligament only, is characteristic of many reptiles, and is seen in *Hesperornis*, but is unknown in all other birds. The form of the skull and the obliteration of most of the cranial sutures are points of resemblance to many modern birds.

* * * * * * *

"In considering the mode of life, and habits of *Ichthyornis*, many important suggestions may be derived from its structure, as well as from the localities where the remains are found. The sharp cutting teeth of *Ichthyornis* prove, beyond a doubt, that it was carnivorous; its great powers of flight, long jaws, and its recurved teeth suggest, moreover, that it captured its prey alive. Its food was probably fishes, as their remains are found in great abundance mingled with those of *Ichthyornis*. These fossils occur in the bed of the old Cretaceous ocean in which *Hesperornis* swam. Both of these birds were clearly aquatic in habit, as shown by various points in their structure, already described, and the conditions under which their remains were deposited. In many respects, *Ichthyornis* probably resembled the modern Terns in its mode of life. The powerful wings and small feet suggest similar habits in flight, and rest.

9.

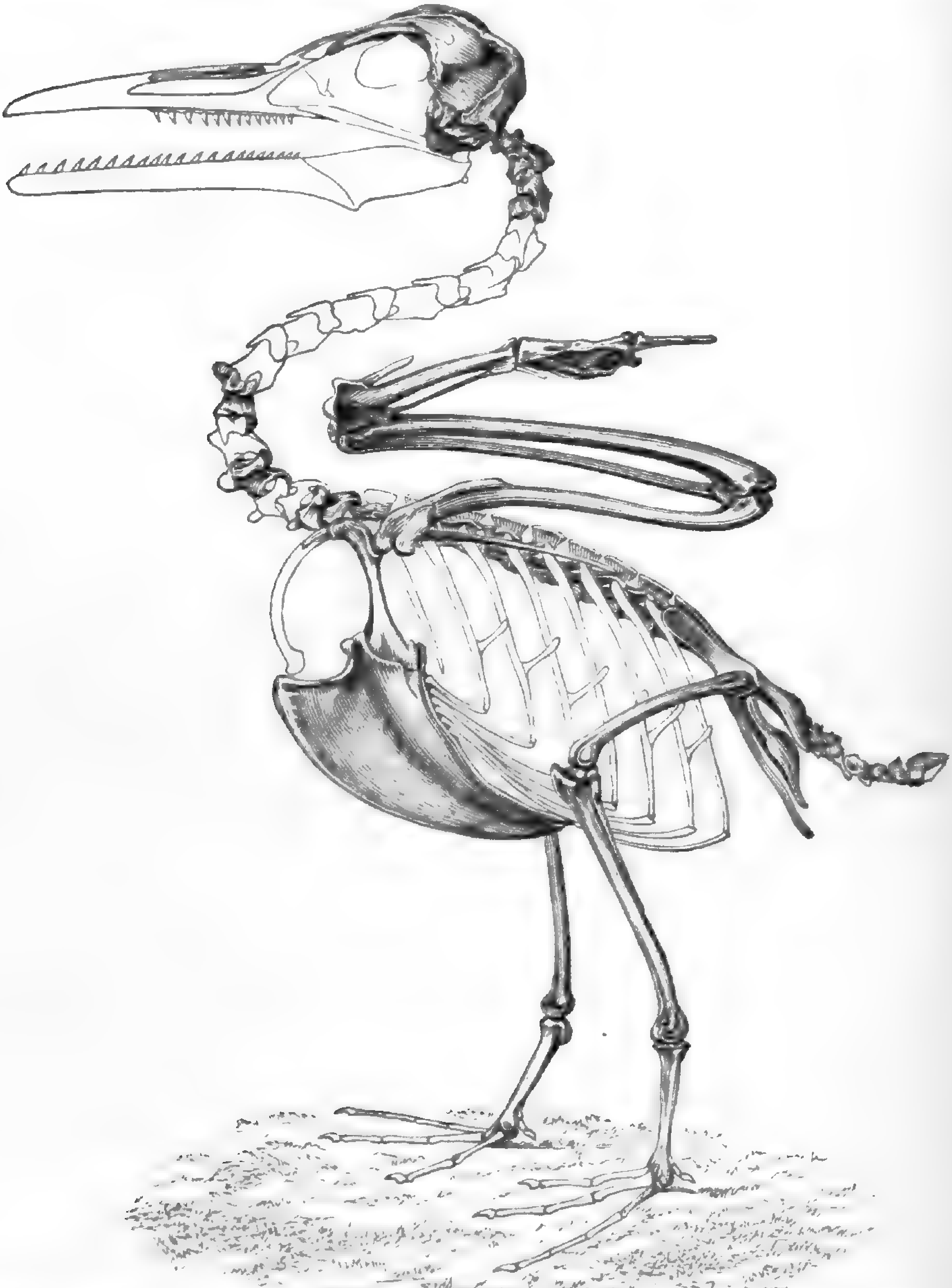


Figure 9.—Restoration of *Ichthyornis victor*, Marsh. One-half natural size.

That *Ichthyornis* was provided with feathers is proved beyond question by the tubercles for the attachment of quills on the forearm.

"Besides *Ichthyornis* and its allies, the only other denizens of the air at present known to have then inhabited the same region were the toothless Pterodactyles. *Ichthyornis* doubtless competed with these huge dragons for the fishes in the tropical ocean about which they lived."

The discovery of these two ancient types of birds, so widely different from each other and from all known members of the class, gives us, as might be expected, many hints as to the genetic origin of birds, and proves especially interesting as confirming the generally accepted view of the close relationship between birds and reptiles. These two types with *Archæopteryx* and *Compsognathus* lead us directly back from the birds of to-day to the reptiles of Mesozoic, if not of still earlier, time. While other Cretaceous birds have been described both from this country and from Europe, only the *Odontornithes* are represented by remains sufficiently perfect to warrant us in drawing any satisfactory conclusions in regard to their relationship with other members of the class. And only through the discovery of their remains in such a wonderful state of preservation, could we have learned how extremely unsafe it is to generalize from single bones or portions of a skeleton, no matter how characteristic they may appear to be. The discoverer who should find only the legs and vertebræ of *Hesperornis* would be justified in assigning to them a place very near the existing *Podicipidæ*, and the conclusion would be sustained by the judgment of every anatomist. Or, if the skeleton of *Ichthyornis* were discovered without the skull and anterior vertebræ, no one would find any characters to warrant the separation of this form from our modern birds. On the other hand, an examination of the skull in either form, the remainder of the skeleton being unknown, might well lead the student as far from the truth in the other direction. So untrustworthy, in the light of modern science, has Cuvier's law of correlation proved to be.

The conclusions drawn by Professor Marsh from his study of all the known remains of *Odontornithes* are as follows:

"Having now described the more important characters in the structure, so far as known, of the two groups of Cretaceous *Odontornithes*, or Birds with teeth, it remains to consider what relation these birds bear to each other, and to allied members of the class; and, also, to inquire if the facts presented throw any light on the profounder question as to the origin of Birds.

"In comparing *Hesperornis* and *Ichthyornis*, as the types of their respective orders, the *Odontolcæ* and *Odontotormæ*, the contrast in their principal characters is as striking as it is unexpected. *Hesperornis* had teeth implanted in a continuous groove, a low, generalized character; with, however, the strongly differentiated saddle-shaped vertebræ. *Ichthyornis*, on the other hand, had the primitive biconcave vertebræ, and yet the highly specialized feature of teeth in distinct sockets. Better examples than these could hardly be found to illustrate one fact brought out by modern science, that an animal may attain great development in one set of characters, and at the same time retain other low features of the ancestral type. This is a fundamental principle of evolution.

"The more superficial characters of the absence of wings and the strong swimming legs and feet of *Hesperornis* are in striking contrast, also, with the powerful wings and diminutive legs and feet of *Ichthyornis*. These and other characters, already mentioned, separate the two birds so widely that a more detailed comparison seems here unnecessary.

"It would be highly desirable to carefully compare both *Ichthyornis* and *Hesperornis* with *Archæopteryx*, the still older Mesozoic bird. This unfortunately cannot be done at present, as the two skeletons of *Archæopteryx*, now known, have not yet been fully described, nor even prepared for examination by removal of the matrix. That *Archæopteryx* belongs to the *Odontornithes*, the writer fully satisfied himself by a personal examination of the well known specimen in the British Museum. This examination was made in 1878, several years after the writer had become familiar with the American forms of toothed birds. The teeth seen on the same slab with this specimen of *Archæopteryx*, and referred to it by Evans, although imperfectly preserved, agree so closely with the teeth of *Hesperornis*, that the writer identified them at once as those of Birds, and not of Fishes. It has since been announced that the specimen of *Archæopteryx*, more recently found in Germany, also possessed teeth, although only two of small size were detected. The separate metacarpal bones, and especially the elongated tail, of *Archæopteryx*, moreover, remove it widely from the known American genera of *Odontornithes*. It will probably be found, however, that *Archæopteryx* possessed biconcave vertebræ, something like those of *Ichthyornis*.

"The other Mesozoic birds now known from the deposits of this country, and the few discovered in Europe, may, some or all of them, have had teeth, but their remains are too fragmentary to determine this point, or even their near affinities.

"It is an interesting fact that the Cretaceous birds at present known, some twenty species or more, were all apparently aquatic forms, which of course are most likely to be preserved in marine deposits, while the Jurassic *Archæopteryx*, the only one from that formation, was a true land bird.

"The birds found in more recent formations all belong apparently to modern types, and hence present few points for profitable comparison with the *Odontornithes*. The existing birds with reptilian characters are nearly all confined to the *Ratitæ*, or Ostrich tribe. These are evidently the remnants of a very numerous group, once widely extended over different parts of the earth; and it is to the fossil forms of these birds that we must look eventually for the intermediate types between them and the less specialized Mesozoic birds.

"For the present, at least, it seems advisable to regard the *Odontornithes* as a sub-class, and to separate them into three orders, according to the characters given below. These orders are all well marked, but evidently are not of equal rank. *Archæopteryx* is clearly separated much more widely from both *Ichthyornis* and *Hesperornis* than are these two genera from each other. The free metacarpals and long tail of *Archæopteryx* are significant characters. Gegenbaur and Morse, however, have shown that young birds of existing species have the metacarpals separate, and this is true for all these birds up to a certain age. Hence this character is of less importance than the presence of true teeth, since in no recent birds, young or old, have these been found. The length of tail is perhaps a character of more value, but this is a variable feature in modern birds.

Sub-class ODONTORNITHES (or Aves Dentatæ), Marsh.

Order, Odontolcæ, Marsh.	Odontotormæ, Marsh.	Saururæ, Hæckel.
Genus, *Hesperornis*, Marsh.	*Ichthyornis*, Marsh.	*Archæopteryx*, von Meyer.
Teeth in grooves.	Teeth in sockets.	Teeth in ——— ?
Lower jaws separate.	Lower jaws separate.	Lower jaws ——— ?
Vertebræ saddle-shaped.	Vertebræ biconcave.	Vertebræ ——— ?
Wings rudimentary.	Wings large.	Wings small.
Metacarpals wanting.	Metacarpals ankylosed.	Metacarpals separate.
Sternum without keel.	Sternum with keel.	Sternum ——— ?
Tail short.	Tail short.	Tail longer than body.

"That the three oldest known birds should differ so widely from each other points unmistakably to a great antiquity for the class. *Archæopteryx*, *Hesperornis* and *Ichthyornis*, are all true birds, but the reptilian characters they possess are convergent toward a more generalized type. No Triassic birds are known, and hence we have no light on this stage of the development of the class. They will doubtless be found, however, and, if we may judge from Jurassic Mammals and Reptiles, the next classes above and below birds, the avian forms of that period would still be birds, although with even stronger reptilian features. For the primal forms of the bird-type, we must evidently look to the Paleozoic; and in the rich land fauna of our American Permian we may yet hope to find the remains of both Birds and Mammals.

"The genera *Archæopteryx*, *Hesperornis* and *Ichthyornis*, each possessed certain generalized characters not shared by the others. These characters were undoubtedly united in some earlier form, and this fact gives us a hint as to what the more primitive forms must have been, and suggest the more prominent features of the ancestral type.

"In the generalized form to which we must look back for the ancestral type of the class of birds, we should therefore expect to find the following characters:

(1.) Teeth, in grooves.
(2.) Vertebræ biconcave.
(3.) Metacarpal and carpal bones free.
(4.) Sternum without a keel.
(5.) Sacrum composed of two vertebræ.
(6.) Bones of the pelvis separate.
(7.) Tail longer than the body.
(8.) Metatarsal and tarsal bones free.
(9.) Four or more toes, directed forward.
(10.) Feathers rudimentary or imperfect.

"These various characters may indeed have been combined in an animal that was more reptile than bird; but such a form would be on the road toward the Birds, rather than on the ancestral line of either Dinosaurs or Pterodactyles, as feathers were not a character of these groups. With this exception, all of the characters named belong to the generalized Sauropsid, from which both birds and the known Dinosaurs may well have descended. An essential character in this ancestral type would be a free quadrate bone, since this is a universal feature in birds, and only partially retained in the Dinosaurs now known.

"The Birds would appear to have branched off by a single stem, which gradually lost its reptilian characters as it assumed the ornithic type, and in the existing Ratitæ we have the survivors of this direct line. The lineal descendants of this primal stock doubtless early attained feathers and warm blood, but, as already shown, never acquired the power of flight. The volant birds doubtless separated early from the main avian stem, probably in the Triassic, since, in the formation above, we have *Archæopteryx*, with imperfect powers of flight.

"This power of flight probably originated among the small arboreal forms of reptilian birds. How this may have commenced, we have an indication in the flight of *Galeopithecus*, the flying squirrels (*Pteromys*), the flying lizard (*Draco*), and in the flying tree-frog (*Rhacophorus*). In the early arboreal birds, which jumped from branch to branch, even rudimentary feathers on the fore limbs would be an advantage, as they would tend to lengthen a downward leap, or break the force of a fall. As the feathers increased, the body would become warmer, and the blood more active. With still more feathers, would come increased power of flight, as we see in young birds of to-day. A greater activity would result in a more perfect circulation. A true bird would doubtless require warm blood, but would not necessarily be hot-blooded, like the birds now living.

"The short wings and clumsy tail of *Archæopteryx* were quite sufficient for short flights from tree to tree, and if the body were essentially naked, as now supposed, we have in this Jurassic form an interesting stage in the development of birds before full plumage was attained. Whether *Archæopteryx* was on the true Carinate line cannot at present be determined, and this is also true of *Ichthyornis;* but the biconcave vertebræ of the latter evidently suggest that this form was an early offshoot. It is probable that *Hesperornis* came off from the main Struthious stem, and has left no descendants.

"These three ancient birds, so widely different from each other, and from all modern birds, prove beyond question the marvelous diversity of the avian type in Mesozoic time; and also give promise of a rich reward to the explorer who successfully works out the life-history of allied forms, recorded in ages more remote."

The discovery of birds so highly specialized in certain directions as are the *Odontornithes*, certainly points to a much earlier origin than has hitherto been acknowledged for this class, and we are not surprised that Professor Marsh suggests that the original bird stem branched off from the reptiles during Paleozoic time. In view of the results of the past ten years' investigations upon this and kindred points, we may fairly hope that future discoveries will add much to our knowledge of this subject as well as to our comprehension of the relations existing between the three ancient types of birds, *Hesperornis*, *Ichthyornis*, and *Archæopteryx*, and the two existing ones, *Carinatæ* and *Ratitæ*.

Paleontologists will look forward with much interest to a comparison of *Archæopteryx* with the *Odontornithes*. This will no doubt be made as soon as full descriptions and figures of the recently discovered specimens of the former shall have been published. That it is widely different from the Cretaceous toothed birds is sufficiently apparent, but it will be most interesting to learn what other primitive characters besides teeth it has in common with this group.

Too much cannot be said in praise of the mechanical execution of the present volume. The plates are marvels of drawing, and present to the eye an absolutely accurate representation of the bones figured. We cannot do better than repeat Professor Geikie's remark in regard to them. He says:—"They are strictly and rigidly scientific diagrams, wherein every bone and part of a bone is made to stand out so clearly that it would not be difficult to mold a good model of the skeleton from the plates alone. And yet with this faithfulness to the chief aim of the illustrations there is combined an artistic finish which has made each plate a kind of finished picture."

Professor Marsh's volume on the *Odontornithes* stands almost if not quite alone among works on fossils, as regards the completeness of the material described and figured, the paleontological interest attaching to this material, and the importance of the biological conclusions drawn from it. As the first volume of the Memoirs of the Yale Museum, it gives a rich promise of what we may hope to see when the extensive collections at New Haven shall have been fully investigated.

GEO. BIRD GRINNELL.

ART. XXXII.—*On some Elements in Orographic Displacement;* by W. J. McGEE.

IN his masterly treatise on the "Systematic Geology of the Fortieth Parallel," Clarence King has succinctly outlined many of the fundamental elements in orographic disturbance; but a series of factors doubtless predominant in some cases seems to have been overlooked. It is shown (pp. 728, 746, and elsewhere), in the case of the Wahsatch region, (*a*) that the gradual submergence of an area of deposition was followed by paroxysmal upheaval, (*b*) that in the contiguous area of degradation gradual elevation was succeeded by paroxysmal submergence, and (*c*) that the original locus of fracture remained a line of weakness and of recurrent displacement throughout the whole of the geological history of the region; and these phenomena seem to be considered anomalous and inexplicable.

To the writer the phenomena described seem to be in perfect harmony with established physical principles; and, in their simplicity and uniformity of action through vast periods, to accord most fully with the regularity and general conformity in the succession of events everywhere attested by the magnificent section so well described in the work mentioned. This will appear from the following analysis, in which, for the sake of simplicity, all disturbing factors are disregarded, and a high degree of uniformity in the character of the earth's crust assumed. It is believed, however, after a careful scrutiny, that essentially identical results would follow the most rigid analysis.

The solid crust of the earth may be assumed to consist of three layers of equal thickness (which may be designated as n, o, and p), but of density varying as $2d$, $3d$, and $4d$ respectively, resting upon a mobile substratum.* Tangential strain due to

* The "critical shell" of Mr. King might be equivalent to such a mobile substratum.

contraction of the globe might give rise to a fault, which, as indicated not only by physical considerations but also by the testimony of existing faults, would form an angle with the vertical. At the same time the region (A) on the side of the fault forming an acute angle with the surface would be upheaved, and the region (B) on the opposite side depressed. Such a displacement might altogether relieve the tangential strain. The elevation and depression on opposite sides of the fault may each be assumed to equal n. Suppose now the upheaved portion of region A to be removed by denudation and deposited within the depressed region B. The thickness of the crust at A and B will then be $o+p$ and $n+n+o+p$ respectively. The effects of radial and tangential strain may now each be considered separately.

Over region A the weight of the solid crust would be but $3d+4d$, while over B it would be $2d+2d+3d+4d$. In the effort of the continuous and slightly flexible crust to assume statical equilibrium the absolutely heavier region would undergo a further depression, while the lighter area would be correspondingly elevated, as long since shown by Babbage, Herschel, Hall, and others. This movement would be counteracted and retarded by the rigidity of the crust, and would tend to produce rupture in the vicinity of the original fault. If now rupture supervene, the two regions will become comparatively independent bodies resting upon the mobile substratum; and each will assume the position due to its density relative to that of the substratum. But since the density of region A is $\frac{3d+4d}{2}$, while that of region B is only $\frac{2d+2d+3d+4d}{4}$, it is obvious that the former region will be depressed and the latter elevated; and the relative elevation of the two regions will accordingly be reversed, and in a paroxysmal manner. If subsequent movements are now considered it will be seen that, if only radial strain is taken into account, the tendency is toward an alternate series of successive and unequal, but constantly diminishing and mutually approaching, elevations and depressions on each side of the original locus of displacement, each paroxysmal in its nature and occurring at the close of a period of comparative repose and quiet sedimentation.

Since the secular refrigeration of the globe would eventually re-introduce tangential strain, its effect upon the crust, at the stage when fracture was supposed to be imminent in the last case, may be considered. Manifestly, when the pressure became sufficient to produce fracture, the crust would give way at its thinnest and weakest point; but the precise plane of dislocation would be determined in a great measure by the incipient tendency to bend upward or downward. Now since the previous dislocation had perhaps equally shortened the chord of region B and lengthened that of A, there might be an equal tendency upward in B and downward in A; but the crust being weakest in A, and near to the original locus of displacement (where erosion would naturally be greatest), here the rupture would be likely to occur; and on account of the downward tendency of A, this region would be depressed. In this case, as in the last, therefore, the relative elevation of the two regions would be reversed. The tendency toward a succession of similar displacements is the same also as in the last case, provided secular refrigeration went on, except that there would be no diminution in intensity. The coördination of the two forms of pressure would tend to prolong the series of disturbances, and, if the relation between the rates of degradation and secular cooling remained constant, to perpetuate them.

Though the rise of the iso-geothermal planes below region B and their depression under A brought about by the deposition and erosion in these regions respectively (which movement was long ago pointed out by Babbage and Herschel, and has been considered by Hall, Hunt, Dana and LeConte to explain the formation of mountain flexures in areas of antecedent deposition) has been disregarded in the above analysis, the results of such movements are important. Obviously, if the shifting of the iso-geotherms kept pace with the degradation of A and the sedimentation in B, the portion of the rigid crust forced below the normal position of p would be rendered mobile, while that part of the mobile substratum forced above the same plane would be made rigid (the mobility being assumed to vary with the temperature). In such a case none of the results above indicated would follow. But since the rapid conduction of heat from ocean bottoms (which has recently been considered by Milne* and others) tends to prevent the rise of the iso-geotherms beneath regions of deposition, and since, further, the thermal effect of any surface revolution can only be conveyed far beneath the surface after a considerable interval, it seems probable that the results indicated above might or might not follow according as local conditions were favorable or otherwise. These conditions (including the rates of erosion and deposition, specific heat and conductivity of the rocks, etc.), are so complex and so imperfectly understood that it seems impossible to determine *a priori* whether or not the above detailed results would follow in any given case.

Farley, Iowa, Sept. 8th, 1880.

* Geol. Mag., II, vii, 169.

ART. XXXIII.—*On the Indices of Refraction of certain Compound Ethers;* by JOHN H. LONG.

ABOUT two years ago, while at work in the laboratory of the University of Tübingen, I undertook the determination of the Indices of Refraction of a number of Ethers of the $C_nH_{2n}O_2$ series. This work was commenced at the suggestion of Professor Lothar Meyer, who was at the same time engaged in an investigation concerning the rates of transpiration of these and other bodies. It might also be remarked that the same substances were being used by Herrn Emil Elsässer for the determination of specific gravity and coefficient of expansion, and his results I have made use of in the calculation of the tables found below.

Other duties prevented the publication of my results at the time, but the elegant work of Brühl,* which has since appeared, having added a new interest to the subject of refraction, I deem it not too late to make them known now. The method employed was essentially that of Landolt.† A large Meyerstein spectrometer, kindly loaned me by Professor v. Reusch of the Tübingen physical laboratory, permitted results exact to four decimal places of n (as explained below) to be readily obtained. The fifth decimal place is in most cases uncertain.

As source of light I used the sodium flame and the refractive indices for the D line were determined for several different temperatures. This was accomplished as follows: The hollow glass prism containing the liquid to be examined, together with its metallic support, was placed on a hot iron plate and left there until the temperature of the liquid had risen (in most cases) to about 30° C., as shown by the small thermometer firmly secured by a cork in the orifice of the prism. Then the prism and support were replaced on the spectrometer, allowed to remain a few minutes, when the final adjustments were made and the observations commenced. The readings were made from degree to degree, and continued until the temperature of the liquid in the prism had fallen to that of the room. The thermometer used had been previously carefully compared with a normal thermometer in the possession of Professor Meyer and a table of corrections thus obtained, so that the temperatures given may be looked upon as exact to 0·1°.

The indices were determined by the method of minimum deviation, according to the formula

* J. W. Brühl: Die chemische Constitution organischer Körper in Beziehung zu deren Dichte u. Vermögen d. Licht fortzupflanzen. Liebig's Annalen, cc, 139; cciii, 1, 255 and 363. See also this Journal, Jan., 1881, page 70.

† Pogg. Ann., Bd. cxvii, 353.

$$n = \frac{\sin \frac{A+d}{2}}{\sin \frac{A}{2}}$$

where d is the observed angle of minimum deviation and A the refractive angle of the prism. This latter was determined before each observation (as the sides of the prism were formed of glass plates fastened by rubber bands) and varied between 60° 2′ 30″ and 60° 3′ 30″.

In every case at least two complete sets of observations were made for each substance and the mean of the results, which never showed variations beyond the fifth decimal place, was taken. The following table contains these results.

Under T I have given the temperature in degrees Cent. at which the observations were made. Under n are given the indices, and under *diff.* the variations in the same for a change in temperature of one degree. In every case the boiling point of the ether in question is given, and when the same was determined under diminished pressure, this latter element is given. In other cases the usual barometric height in Tübingen—about 735mm—is to be understood.

Methyl formate.

Bp = 32°·8

T.	n.	diff.
20	1·34386	
19	1·34430	·00044
18	1·34473	43
17	1·34516	43
16	1·34559	43
15	1·34601	42

Propyl acetate.

Bp = 87°·8–88°·2 P, 470mm

T.	n.	diff.
22	1·38352	
21	1·38404	·00052
20	1·38456	52
19	1·38507	51
18	1·38558	51
17	1·38608	50

Propyl formate.

Bp = 67°–67°·3 P, 431mm

T.	n.	diff.
23	1·37604	
22	1·37656	·00052
21	1·37706	50
20	1·37756	50
19	1·37806	50
18	1·37855	49
17	1·37904	49

Methyl propionate.

Bp = 79°·5–80°

T.	n.	diff.
20	1·37763	
19	1·37822	·00059
18	1·37875	53
17	1.37927	52
16	1·37980	53
15	1·38032	52

Isobutyl formate.

Bp = 99°–99°·4

T.	n.	diff.
22	1·38641	
21	1·38693	·00052
20	1·38745	52
19	1·38796	51
18	1·38845	49
17	1·38893	48
16	1·38941	48

Ethyl propionate.

Bp = 81°·4–82° P, 402mm

T.	n.	diff.
20	1·38421	
19	1·38471	·00050
18	1·38520	49
17	1·38568	48
16	1·38616	48
15	1·38663	47

PROPYL PROPIONATE.

Bp = 101°·5–102° P, 384mm

T.	n.	diff.
23	1·39199	
22	1·39253	·00054
21	1·39305	52
20	1·39356	51
19	1·39405	49
18	1·39452	47
17	1·39497	45

ISOBUTYL PROPIONATE.

Bp = 135°·2–135°·5

T.	n.	diff.
20	1·39748	
19	1·39793	·00045
18	1·39838	45
17	1·39882	44
16	1·39925	43

AMYL PROPIONATE.

Bp = 159°·5–160°

T.	n.	diff.
23	1·40523	
22	1·40567	·00044
21	1·40610	43
20	1·40653	43
19	1·40696	43
18	1·40738	42
17	1·40780	42

ISOBUTYL BUTYRATE.

Bp = 154°·5–155°

T.	n.	diff.
20	1·40443	
19	1·40485	·00042
18	1·40527	42
17	1·40570	43
16	1·40612	42
15	1·40654	42

AMYL BUTYRATE.

Bp = 178°–178°·5

T.	n.	diff.
22	1·41010	
21	1·41052	·00042
20	1·41094	42
19	1·41135	41
18	1·41176	41
17	1·41217	41

METHYL ISOBUTYRATE.

Bp = 89°·8–90°

T.	n.	diff.
26	1·38082	
25	1·38136	·00054
24	1·38190	54
23	1·38243	53
22	1·38296	53
21	1·38348	52
20	1·38399	51

ETHYL ISOBUTYRATE.

Bp = 107°–107°·3

T.	n.	diff.
25	1·38537	
24	1·38589	·00052
23	1·38641	52
22	1·38693	52
21	1·38745	52
20	1·38797	52

PROPYL ISOBUTYRATE.

Bp = 130°·5–131°

T.	n.	diff.
25	1·39369	
24	1·39414	·00045
23	1·39459	45
22	1·39504	45
21	1·39549	45
20	1·39593	44
19	1·39637	44

ISOBUTYL ISOBUTYRATE.

Bp = 144°–145°

T.	n.	diff.
25	1·39775	
24	1·39819	·00044
23	1·39863	44
22	1·39906	43
21	1·39949	43
20	1·39992	43
19	1·40034	42

AMYL ISOBUTYRATE.

Bp = 166°–166°·5

T.	n.	diff.
25	1·40548	
24	1·40591	·00043
23	1·40634	43
22	1·40676	42
21	1·40718	42
20	1·40759	41
19	1·40800	41
18	1·40841	41

PROPYL VALERATE.

Bp = 155°·5–156°

T.	n.	diff.
24	1·40182	
23	1·40229	·00047
22	1·40275	46
21	1·40321	46
20	1·40366	45
19	1·40411	45
18	1·40455	44

ISOBUTYL VALERATE.

Bp = 169°–169°·4

T.	n	diff.
25	1·40393	
24	1·40441	·00048
23	1·40489	48
22	1·40536	47
21	1·40583	47
20	1·40630	47

From the above table it is seen, as has already been shown by Landolt and others, that the increase in n for one degree C. is in the mean about ·00045. As a rule this difference is not constant, but increases with the temperature; in a few cases, however, as for instance ethyl isobutyrate and isobutyl butyrate there are no second differences. Although the differences vary from ·00041 to ·00059, they seem quite irregular, and it is not easy to connect them with any chemical property of the bodies in question, and still more difficult is it to account for the appearance of the second differences in some cases and in others not. But I shall not attempt a further explanation of these points here.

Of the above-named ethers the refractive indices of propyl acetate alone have been determined, as far as I am aware. Brühl gives for this for a sample boiling between 99°–101° the index $n_D=1·38438$ at 20°, and for another portion boiling from 97°–99° $n_D=1·38360$. It will be noticed that the first of these values corresponds very closely with that obtained by me. Indeed the agreement is better than one might expect, when the great liability of the ether to dissociation is taken into consideration. Brühl mentions this fact, and I have reason to believe that the sample used by me had likewise been slightly decomposed by the fractional distillation.

In order to show the results obtained above, in their most general aspect, as well as for the purpose of better comparison with the work of others, I have arranged them in a more complete form below. In the columns headed d are contained the densities of the substances for each degree of temperature, calculated as explained at the outset. Under n are given the refractive indices to four places, the somewhat uncertain fifth place being omitted. Under $\frac{n-1}{d}$ is given the "specific refractive energy," and under $M\left(\frac{n-1}{d}\right)$ the "molecular refractive energy" for each compound at the various temperatures. M represents the molecular weight of the ether in question. I use these terms in the sense in which they have been employed by Dale & Gladstone and Landolt, and they need no further explanation. Propyl acetate I here omit, as I do not know the variations in its density with the temperature.

The quotients $\frac{n-1}{d}$ are on the whole quite satisfactory, although the fourth decimal places are not always the same. Some seem constant with the temperature, two increase, while the others are seen to decrease. The same irregularity has been already noticed by Landolt and Wüllner,* yet it still remains to be explained. In the above ethers it will be noticed

METHYL FORMATE.

$M = 60 \quad d_0 = ·99840$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
15	·9767	1·3460	·3543	21·26
16	·9753	1·3456	·3544	21·26
17	·9738	1·3452	·3545	21·27
18	·9723	1·3448	·3546	21·28
19	·9708	1·3443	·3547	21·28
20	·9694	1·3438	·3547	21·28

PROPYL FORMATE.

$M = 88 \quad d_0 = ·91838$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
17	·8996	1·3790	·4213	37·07
18	·8985	1·3785	·4213	37·07
19	·8974	1·3780	·4212	37·07
20	·8962	1·3775	·4212	37·07
21	·8951	1·3770	·4212	37·07
22	·8940	1·3765	·4211	37·06
23	·8928	1·3760	·4212	37·07

ISOBUTYL FORMATE.

$M = 102 \quad d_0 = ·88543$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
16	·8697	1·3894	·4477	45·67
17	·8687	1·3889	·4477	45·67
18	·8677	1·3884	·4476	45·66
19	·8667	1·3879	·4476	45·66
20	·8657	1·3874	·4475	45·64
21	·8647	1·3869	·4474	45·64
22	·8637	1·3864	·4474	45·64

METHYL PROPIONATE.

$M = 88 \quad d_0 = ·93725$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
15	·9277	1·3803	·4099	36·07
16	·9271	1·3798	·4097	36·05
17	·9265	1·3793	·4094	36·03
18	·9259	1·3788	·4091	36·00
19	·9252	1·3782	·4088	35·97
20	·9246	1·3776	·4084	35·94

ETHYL PROPIONATE.

$M = 102 \quad d_0 = ·91238$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
15	·8959	1·3866	·4315	44·01
16	·8948	1·3862	·4316	44·02
17	·8937	1·3857	·4316	44·02
18	·8926	1·3852	·4316	44·02
19	·8915	1·3847	·4315	44·01
20	·8904	1·3842	·4315	44·01

PROPYL PROPIONATE.

$M = 116 \quad d_0 = ·90191$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
17	·8857	1·3950	·4460	51·73
18	·2848	1·3945	·4459	51·72
19	·8838	1·3940	·4458	51·72
20	·8828	1·3935	·4457	51·71
21	·8818	1·3930	·4457	51·70
22	·8809	1·3925	·4456	51·69
23	·8799	1·3920	·4455	51·68

ISOBUTYL PROPIONATE.

$M = 130 \quad d_0 = ·88759$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
16	·8732	1·3992	·4572	59·43
17	·8722	1·3988	·4572	59·43
18	·8713	1·3984	·4572	59·43
19	·8704	1·3979	·4571	59·42
20	·8694	1·3975	·4572	59·43

AMYL PROPIONATE.

$M = 144 \quad d_0 = ·88767$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
17	·8729	1·4078	·4672	67·27
18	·8721	1·4074	·4671	67·27
19	·8712	1·4070	·4672	67·27
20	·8703	1·4065	·4671	67·27
21	·8694	1·4061	·4671	67·27
22	·8685	1·4057	·4671	67·27
23	·8676	1·4052	·4671	67·27

ISOBUTYL BUTYRATE.

$M = 144 \quad d_0 = ·88178$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
15	·8674	1·4065	·4686	67·49
16	·8665	1·4061	·4687	67·49
17	·8655	1·4057	·4688	67·50
18	·8645	1·4053	·4688	67·50
19	·8636	1·4049	·4689	67·52
20	·8627	1·4045	·4689	67·52

AMYL BUTYRATE.

$M = 158 \quad d_0 = ·88231$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
17	·8673	1·4122	·4753	75·10
18	·8664	1·4118	·4753	75·10
19	·8655	1·4114	·4753	75·10
20	·8646	1·4110	·4754	75·11
21	·8637	1·4105	·4753	75·10
22	·8628	1·4101	·4753	75·10

METHYL ISOBUTYRATE.

$M = 102 \quad d_0 = ·91118$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
20	·8893	1·3840	·4318	44·04
21	·8882	1·3835	·4318	44·04
22	·8871	1·3830	·4317	44·03
23	·8860	1·3824	·4316	44·02
24	·8849	1·3819	·4316	44·02
25	·8838	1·3814	·4315	44·01
26	·8827	1·3808	·4314	44·00

ETHYL ISOBUTYRATE.

$M = 116 \quad d_0 = ·89037$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
20	·8697	1·3880	·4461	51·75
21	·8686	1·3875	·4461	51·75
22	·8676	1·3869	·4460	51·73
23	·8665	1·3864	·4459	51·73
24	·8655	1·3859	·4459	51·72
25	·8644	1·3854	·4459	51·72

Propyl isobutyrate.

$M = 130 \quad d_0 = \cdot 89299$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
19	·8748	1·3964	·4531	58·90
20	·8738	1·3959	·4531	58·90
21	·8728	1·3955	·4531	58·90
22	·8719	1·3950	·4530	58·89
23	·8709	1·3946	·4531	58·90
24	·8699	1·3941	·4530	58·89
25	·8690	1·3937	·4531	58·90

Propyl valerate.

$M = 144 \quad d_0 = \cdot 88092$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
18	·8652	1·4046	·4676	67·34
19	·8643	1·4041	·4676	67·33
20	·8634	1·4036	·4675	67·32
21	·8626	1·4032	·4674	67·31
22	·8617	1·4028	·4674	67·31
23	·8608	1·4023	·4674	67·30
24	·8599	1·4018	·4673	67·29

Isobutyl isobutyrate.

$M = 144 \quad d_0 = \cdot 87496$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
19	·8584	1·4003	·4663	67·15
20	·8575	1·3999	·4664	67·16
21	·8566	1·3995	·4664	67·16
22	·8557	1·3991	·4664	67·16
23	·8548	1·3986	·4663	67·15
24	·8539	1·3982	·4663	67·15
25	·8530	1·3978	·4663	67·15

Amyl isobutyrate.

$M = 158 \quad d_0 = \cdot 87597$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
18	·8598	1·4084	·4750	75·05
19	·8589	1·4080	·4750	75·05
20	·8580	1·4076	·4751	75·06
21	·8571	1·4072	·4751	75·07
22	·8562	1·4068	·4751	75·07
23	·8553	1·4063	·4750	75·06
24	·8544	1·4059	·4751	75·06
25	·8535	1·4055	·4751	75·07

Isobutyl valerate.

$M = 158 \quad d_0 = \cdot 87360$

T	d	n	$\frac{n-1}{d}$	$M\left(\frac{n-1}{d}\right)$
20	·8558	1·4063	·4748	75·01
21	·8549	1·4058	·4747	75·01
22	·8540	1·4054	·4747	75·00
23	·8531	1·4049	·4746	74·99
24	·8522	1·4044	·4745	74·98
25	·8513	1·4039	·4745	74·98

that the constancy of $\frac{n-1}{d}$ is attained in eight cases, while in an equally great number it is not. An attempt to connect this peculiarity with others of the same bodies has not been successful.

An opportunity is afforded by the above experiments of comparing the physical characteristics of some of the butyrates and isobutyrates. The constants for methyl and ethyl butyrate are taken from Landolt's paper,† n_D being computed by means of the formula of Cauchy,

$$n_D = A + \frac{B}{\lambda^2_D}$$

in which A is the coefficient of refraction, and B that of dispersion. For the wave length of the line D, I have used the mean value given by Wüllner,‡ expressed in ten-thousandths of a millimeter, $\lambda_D = 5{\cdot}893$.

From Landolt I take

Methyl butyrate...............	$A = 1{\cdot}37879$	$B = 0{\cdot}35077$
Ethyl butyrate	$A = 1{\cdot}38580$	$B = 0{\cdot}35310$

* Lehrbuch d. Experimentalphysik, vol. ii, p. 150.

† Pogg., cxxii. 545, where the values for A and B are given.

‡ Lehrbuch, etc., vol. ii, p. 136.

Making the necessary calculations I find the values as in the following table:

	Bp	d_{20}	n_{20}
Methyl butyrate	103–104°	·8976	1·3889
Methyl isobutyrate	90°	·8893	1·3840
Ethyl butyrate	114°	·8906	1·3960
Ethyl isobutyrate	107°	·8697	1·3880
Isobutyl butyrate	155°	·8627	1·4045
Isobutyl isobutyrate	144–145°	·8575	1·3999
Amyl butyrate	178°	·8646	1·4110
Amyl isobutyrate	166°	·8580	1·4076

As might be expected, the constants in the case of the iso compounds are in every instance lower than in those of the corresponding normals. Here as in several compounds examined by Brühl, the characteristic differences of ethers of normal and iso acids are seen to extend to their action on light.

It will not be without interest to find what values for the atomic refractive power can be deduced from the above observations. For this purpose I have grouped the ethers as in the following table. Arranging the isomers together, there are seven groups with different molecular weights, and for the molecular refraction of each I have placed the mean value of those of the several members of each group.

		$M\left(\frac{n-1}{d}\right)$	diff. for CH_2
Methyl formate	$C_2H_4O_2$	21·28	
			7·65
Propyl formate Methyl propionate	$C_4H_8O_2$	36·57	
			7·99
Ethyl propionate Isobutyl formate Methyl isobutyrate	$C_5H_{10}O_2$	44·56	
			7·16
Propyl propionate Ethyl isobutyrate	$C_6H_{12}O_2$	51·72	
			7·44
Isobutyl propionate Propyl isobutyrate	$C_7H_{14}O_2$	59·16	
			8·16
Amyl propionate Isobutyl butyrate Isobutyl isobutyrate Propyl valerate	$C_8H_{16}O_2$	67·32	
			7·74
Amyl butyrate Amyl isobutyrate Isobutyl valerate	$C_9H_{18}O_2$	75·06	

Mean diff. for CH_2 = 7·69.

It thus appears that the differences for CH_2 from group to group are not quite constant, but the variations are not greater than one might expect when the character of the compounds is taken into consideration. The average of the differences gives for the refractive power of CH_2 7·69. Substituting this in the different groups, we find for O_2 the refractive powers 5·90, 5·81, 6·11, 5·58, 5·33, 5·80 and 5·85. Of course it is not intended that these numbers represent the atomic refraction in any particular groups. They are simply mean values obtained by combining the numbers $M\left(\frac{n-1}{d}\right)$ of the last table in a certain way. From other combinations it is plain that slightly different values would be obtained. The average of the results just given makes 5·77 the refractive power of O_2, that is of one linking and one saturating O as shown by Brühl. It will be seen that these values do not differ greatly from the mean refractive equivalents as given by Landolt—i. e., 7·60 for CH_2 and 3·00 for O, which it must be remembered were calculated from numbers differing as widely perhaps as the above. Whether these variations depend for their explanation on the possible impurity of the liquids examined, or whether they are to a greater extent due to peculiarities of each individual compound, is as yet not quite plain. It seems probable, however, in view of all that has been thus far done on the subject, that the latter is the more plausible supposition. But it is only by refined and extended investigations of various physical properties and correlation of the results thus obtained, that the complete solution of the problem may be expected. For this purpose, I had wished to make use of some of the results obtained by Pribram and Handl on the transpiration of liquids (Wien. Sitzungsbr. 80), but unfortunately I was unable to obtain this journal.

There are many other interesting peculiarities of these ethers which might be mentioned, but their discussion belongs more properly to an investigation soon to be expected (or perhaps recently published), from Herrn Emil Elsässer, to whom, as was mentioned, I am indebted for the data from which I calculated the densities of the liquids corresponding to the different temperatures. To Professor Meyer I would also express my sincere thanks for assistance, without which the completion of the above experiments would not have been possible.

Wesleyan University, February, 1881.

Art. XXXIV.—*On the Whitfield County, Georgia, Meteoric Iron;* by W. Earl Hidden.

This iron was discovered in 1877 on a farm about twenty miles northeast of Dalton, Georgia, near the Tennessee and North Carolina State lines, a region which it will be remembered is remarkable for the number of meteorites it has afforded. As has happened in similar cases the specimen was locally considered to be *native iron* and was preserved as such until Dr. Geo. B. Little, then State Geologist of Georgia, visited the region in 1878, and recognizing its real nature procured it for the State Museum at Atlanta. The writer saw it there in August, 1879, and with the consent of Dr. Little had a small piece planed off, an engraving of which is here given (exact natural size).

In its complete condition this meteorite is said to have weighed 13 lbs. Its present weight is 9¾ lbs. Dr. Little informs me that one end of it became detached on its journey to Atlanta, which piece he presented to the college at Athens, Ga. The mass remaining is thin oblong in shape, and much resembles a very rusty mass of ordinary iron. It is about ten inches long and five inches wide and varies in thickness from an inch to an inch and a half. Its surface is very irregular and has many jagged points. Only a preliminary analysis has been made on the piece in my possession; this has showed it to be not unusual in its composition; chloride of iron is largely present, its deliquescence was observed in many spots on the mass. The Widmannstätten figures are remarkably well shown on this iron, as the accompanying engraving proves. (This engraving was made from a photograph taken direct from the iron: its angles and measurements are therefore correct.)

Dr. Little informed me that this iron had not been, as yet, described, and accorded me the privilege of making public this account of its history. The cabinet of minerals, of which this meteorite forms a part, has been packed up in boxes and stowed away in the cellar of the Department of Agriculture building in Atlanta, and it is reasonable to suppose that this interesting mass of meteoric iron will sooner or later disappear through decomposition and oxidation; it seems right therefore that some record should be made in this Journal of its history and final location.

Note.—In a recent letter from Dr. A. Brezina of Vienna, I learn that he received a small piece of this meteorite in Nov., 1879, and that he published a notice about it in the "Anzeiger der K. K. Akad. der Wiss., Wien." I have not seen his note. The data of this article were personally obtained by the writer in August, 1879.

ART. XXXV.—*The Basin of the Gulf of Mexico.* A communication to the National Academy of Sciences made Nov. 18, 1880, by authority of C. P. PATTERSON, Supt. U. S. Coast and Geodetic Survey, by J. E. HILGARD, M.N.A.S. With a Map of the Gulf (Plate IX).

AT the meeting of the National Academy of Sciences in New York, Nov. 18, 1880, Mr. J. E. Hilgard presented, on the part of Hon. C. P. Patterson, Superintendent of the U. S. Coast and Geodetic Survey, a model of the Gulf of Mexico, constructed from the numerous soundings taken in the progress of that work. The accompanying plate (IX) is a reduced plan of the model, the full size of which is 24×32 inches, being on a horizontal scale of 1 : 2,400,000, and on vertical scale of 1 inch : 1000 fathoms; making the proportion of horizontal to vertical scale 1 : 33. The plan shows the horizontal curves for every 500 fathoms of depth, as well as the curves of 100 and 10 fathoms. The same curves are delineated on the model, the forms of which are shaped in conformity with all the detail obtained from the soundings.

The number of soundings taken within the depth of 100 fathoms is very large, varying according to the configuration and importance of the locality. Beyond 100 fathoms, where the work pertains rather to physical exploration than to navigation, 1,055 soundings have been obtained, which is an average of ten to a rectangle comprised within a degree of latitude and longitude; of these, 355 are in depths greater than 1000 fathoms.

The object of this communication being merely to give a general description of the orographic features of the basin of this great inland sea—the American Mediterranean—it is only necessary to mention here that in connection with the soundings, temperatures were observed at various depths and the organic life was explored by means of dredges. The results of these physical and biological explorations are in the ablest hands for discussion and interpretation but are not yet ready for publication. It is therefore only necessary to state here, as a general fact, that below the depth of about 800 fathoms the temperature is everywhere found to be between 39° and 40° F.

Before reviewing the structural features of the Gulf-basin which the model reveals in a most striking manner, it is proper to recite here briefly the history of the exploration of the Gulf by the United States Coast Survey. The surveys of the shores and soundings of the approaches were begun as long ago as 1846 under the superintendency of Professor A. D. Bache and were continued until the outbreak of the Civil War.

From the earliest date of his work, Bache had in view the exploration of the Gulf Stream and its attendant physical facts in addition to the surveys requisite for navigation. As early as 1845 temperatures were observed over sections across the Gulf Stream on the Atlantic part of our coast which observations were systematically extended southward. In 1850, Professor L. Agassiz examined the structure of the Florida Reefs in connection with the Coast Survey hydrographic party under the command of Lieut., now Admiral John Rodgers, U. S. N. In 1855, a cross section from Cape Florida to the Bahama Banks, observed by Lieutenant Craven, U. S. N., developed the fact that the Strait is a comparatively shallow channel, a greatest depth of 370 fathoms only being found. In 1860, Lieutenant Murray, U. S. N., found a greatest depth of 344 fathoms in a section across from Indian River, not far from the former line. Some deep soundings in the Gulf reaching nearly 1200 fathoms were obtained by Lieut. Sands, U. S. N., about the same time.

When after the close of the Civil War the Coast Survey resumed its former activity, under the administration of Professor Benjamin Peirce, soundings across the Florida and Yucatan Channels were obtained by Master R. Platt, U. S. N., accompanied by a dredging party under the direction of the late L. F. Pourtales.

It was not, however, until the present Superintendent of the Coast Survey, C. P. Patterson, LL.D., organized a systematic exploration of the whole Gulf, that its character became rightly understood. This exploration was begun in 1872 by Commander Howell, U. S. N., on the west coast of Florida in comparatively shallow water and was continued and brought to a successful conclusion by Commander Sigsbee, U. S. N. (1875–78) in the Coast Survey Steamer Blake, accompanied by Professor A. Agassiz, who had charge of the biological explorations.

The methods of sounding and obtaining temperatures at great depths as well as those of dredging have been described in the Coast Survey Reports for several years, and more especially in a work recently written by Commander Sigsbee, U. S. N., and published by the U. S. Coast Survey. It will suffice to mention here that the method of sounding employed was that of using a fine steel wire, indicated by Sir Wm. Thomson, with the mechanical appliances perfected by Commanders Belknap and Sigsbee, of the U. S. Navy.

Turning now to our model or map we perceive that the basin of the Gulf of Mexico is an oval connected with the general ocean circulation by two outlets, the Yucatan Channel and the Florida Straits.

The area of the entire Gulf, cutting it off by a line from Cape Florida to Havana, is 595,000 square miles. Supposing the depth of the Gulf to be reduced by 100 fathoms, a surface would be laid bare amounting to 208,000 square miles, or rather more than one-third of the whole area. The distance of the 100 fathom line from the coast is about six miles near Cape Florida; 120 miles along the west coast of Florida; at the South Pass of the Mississippi it is only 10 miles; opposite the Louisiana and Texas boundary it increases to 130 miles; at Vera Cruz it is 15 miles, and the Yucatan Banks have about the same width as the Florida Banks.

The following table shows the areas covered by the trough of the Gulf to the depths stated:

Depth.	Area.	Differences.
2,000 fathoms	55,000 square miles	
1,500 fathoms	187,000 square miles	132,000
1,000 fathoms	260,000 square miles	73,000
500 fathoms	326,000 square miles	66,000
100 fathoms	387,000 square miles	61,000
Coast line	595,000 square miles	208,000

This table shows that the greatest slopes occur between the depths of 100 and 1,500 fathoms. The maximum depth reached is at the foot of the Yucatan Banks—2,119 fathoms. From the 1,500 fathom line on the northern side of the Gulf to the deepest water close to Yucatan Banks, say to the depth of 2,000 fathoms, is a distance of 200 miles, which gives a slope of five-ninths to 200, and may be considered practically as a plane surface.

The large submarine plateau below the depth of 12,000 feet has received the name of the "Sigsbee Deep," in honor of its discoverer.

The Yucatan channel with a greatest depth of 1,164 fathoms has a cross section of 110 square miles, while the strait of Florida in its shallowest part opposite Jupiter Inlet, with a depth of 344 fathoms, has a cross section of only 11 square miles.

A view of the model reveals at once some important facts which a study of the plan only conveys imperfectly to the mind, and which were unsuspected before this great exploration was completed: Thus the distance between the visible coast lines of the northeastern point of Yucatan and the west coast of the Florida Peninsula is 460 miles, while the distance between the submerged contours of 500 fathoms is only 190 miles; between the contours of 1,000 fathoms only 90 miles. These facts at once characterize the Gulf of Mexico as a Mediterranean Sea.

The most striking features displayed by the model are the following:

1. The great distance to which the general slope of the continent extends below the present sea level before steeper

slopes are reached. The 100 fathom curve represents very closely the general continental line; the *massifs* of the peninsulas of Florida and Yucatan have more than twice their present apparent width. As previously stated, one-third of the whole area of the Gulf has a depth of less than 100 fathoms.

2. Very steep slopes lead from this submerged plateau to an area of 55,000 square miles, as great as that of the State of Georgia, at the great depth of over 12,000 feet. There are three ranges on the Florida and Yucatan slopes extending in the aggregate to more than to 600 miles, along which the descent between 500 to 1,500 fathoms, or 6,000 feet, is within a breadth of from six to fifteen miles. No such steep slopes and correspondingly elevated plateaus appear to exist on the unsubmerged surface of the earth. The suggestion occurs that while the latter have suffered atmospheric erosion, the submerged surfaces have not sensibly changed from the positions determined by the mechanical shaping of the earth's crust.

3. The far protrusion of the Mississippi delta toward the deep water of the Gulf seems to give evidence to the engineer of the probably permanent success of the Mississippi Jetties, as delivering the silt of the river into water of so great depth, that but few extensions will ever become necessary. In connection with the same feature, the strong indentation to the westward of the present mouths of the Mississippi, indicating the probable site of the original fracture between the two slopes of the Mississippi Valley deserves attention.

4. In regard to the problem of general ocean circulation in connection with the Gulf Stream, the most important feature is the shallowness and small cross section of the Strait of Florida between the Peninsula and Bahama Banks, having at the shallowest part a cross section of 11 square miles only with a greatest depth of 344 fathoms. From observations reported elsewhere in the Coast Survey Reports, the average northwardly current of the warm water through this strait is probably not greater than two miles per hour, certainly not more than $2\frac{1}{2}$ miles. It is evident at once that the warm water which so greatly modifies the climate of the western coasts of Europe cannot all be supplied by the flow through this small channel. The concentration of the warm surface current from the Gulf of Mexico gives to this vein of the general circulation of the Atlantic Ocean a marked velocity which is very perceptible to the navigator, and has given its name of "Gulf Stream" to the whole system of northeasterly surface flow in the Atlantic Ocean. In view of the foregoing facts it appears to be necessary to assume now that the so-called Gulf Stream is largely reinforced by a general northerly current from the outside of the West Indian Islands.

ART. XXXVI.—*On the Geology of Florida*; by EUGENE A. SMITH, of the University of Alabama. With a Map.

DURING an excursion into Florida, made last summer for the purpose of collecting data for the Cotton Culture Report of the Tenth Census, I made incidentally some notes on the geological formations of that State, which, with the kind consent of the Superintendent, are now made public.

The literature of this subject is extremely meagre, and I propose first to give a concise account of the published observations of my predecessors in this field, so far as I have been able to consult them.

In this Journal, I, xxxv, pages 47 et seq., are found some "Cursory Remarks upon East Florida in 1838, by Maj. Henry Whiting, U. S. Army." This paper is chiefly descriptive of the topography, natural productions and climate of the country, yet it contains some observations upon the geology. The author states that the "rocks found *in situ* are all calcareous, though siliceous bowlders of small size are occasionally seen, and nodules of hornstone are here and there mingled with the limestone, which elicit sparks, and are sometimes used by the Indians for flints." . . . . . . "The coast, as far as Cape Florida, is alluvial, a seeming mass of comminuted shells, resting on a rocky formation, composed also of shells, more or less broken and abraded. From Cape Florida, the formation is mostly coralline, the Keys being of that character." . . . . . . "As high as Indian River Inlet, the beach is still formed of shells, ... mingled with some sand; while about Cape Canaveral the sand predominates, until shelly fragments almost disappear to the naked eye. Still it seems probable that the whole beach is of a calcareous character."

The author then describes the "coquina" rock quarries of St. Augustine, adding some conjectures as to the mode of formation of this singular rock, which he states is generally considered as of recent formation, and that causes are still operating to produce it. This conjecture, while apparently plausible, wants, in his opinion, the support of deeper investigation into the character and force of these causes.

He speaks of the shell formations of the Upper St. Johns, which are made up chiefly of a species of Helix—the soil at Volusia and Fort Mellon consists half of shells, generally perfect in shape but occasionally slightly broken or abraded.

"On Black Creek, west of the St. Johns, a porous, rotten limestone appears, and this is said to be characteristic of the rock formations throughout the western part of the peninsula. Hence the many 'surth-holes' . . . . . . which appear in these regions, and the disappearance of streams for many miles beneath the surface of the earth, while others come forth in all their fullness at once."

He also speaks of the large limestone springs, frequently impregnated with sulphuretted hydrogen.

In volume i of the 2d series of this Journal, page 38, we find "Some Facts respecting the Geology of Tampa Bay, by John H. Allen, Lieut. of Artillery in U. S. Army."

This author describes a limestone occurring at Fort Brooke, at the head of Tampa Bay, as hard, white, with an earthy texture, and apparently formed of decomposed and comminuted shells; in some places it is soft and friable, very much resembling chalk. He states further, that he has noticed this rock at points more than one hundred and fifty miles distant from each other, and presenting the same lithological characters; it constitutes the bottom of the many ponds and lakes in the interior, and he has been informed that its white and jagged surface can be seen throughout the whole extent of the Everglades. He mentions fossils contained in the rock, univalves, bivalves and echini; and he ascribes the great fertility of some of the sandy soils of the territory to the loose marl disseminated through it.

According to the author, there is another rock probably dipping beneath the limestone—a dark bluish, siliceous rock, of a compact texture, somewhat vesicular, the vesicles containing minute crystals of quartz. This rock was noticed at the falls of Hillsboro River, nine miles from its mouth. Bowlders of it were also seen at several places in the interior. Large sulphur springs with clear pellucid water are mentioned as occurring in the vicinity of Hillsboro River and other streams flowing into Tampa Bay.

Near Tampa Bay are beds of marl which differ materially in their composition and organic contents; they evidently belong to different geological periods. One of the most ancient and interesting of these beds occurs two miles west of Fort Brooke, and it is well known as furnishing the beautiful fossils petrified with wine-colored chalcedony. Other beds of marl, apparently of much more recent origin, extend along the shore at Fort Brooke.

Farther south, near the mouth of the Manatee River, is an extensive bank of shells, ten feet or more in thickness, composed almost wholly of large unbroken univalves belonging principally to a species of *Pyrula*, without any admixture of earth. Although he observed many fragments of Indian pottery in these shell heaps, the immense quantity of the shells precludes the idea that they have been accumulated by the aborigines of the country. In this paper the author makes a clear distinction between the marl beds near the shore and the more ancient marls, and limestones occurring farther inland, although he does not undertake to decide upon the geological age of either.

His remarks upon the distribution of the more ancient limestone in the interior, where it forms "the bottoms of the many ponds and lakes," are particularly interesting, in the light of my recent observations.

We come next to an important paper by T. A. Conrad: "Observations on the Geology of a part of East Florida, &c."* In this, the author describes certain Post-Pliocene deposits on the St. Johns River and at Tampa Bay, occurring ten or fifteen feet above high tide; proving a considerable elevation of the whole Florida peninsula in the Post-Pliocene period, a movement which clearly raised all the Florida Keys above water. The greater part of the paper is devoted to a description of the Keys, with notices of the shells occurring on them and in the neighboring waters. At Tampa Bay and southward along the shore, he notices the Post-Pliocene deposits, but calls attention also to an underlying limestone occurring at Fort Brooke and as far inland as the Falls of Hillsboro River. This limestone he refers to an upper division of the Eocene. The same rock occurs, he says, a few miles up the Manatee River. Closer examination of the casts and shells from Tampa, brings the author to the following conclusions, viz., that the Nummulite limestone of St. Stephens and of Clarke County, Ala., and the fossiliferous bluff at Claiborne, are to be classed as Lower Eocene, while the limestone of Savannah River, containing two recent shells, he proposes to call Upper Eocene, and very probably the prevalent limestone of Florida will be included in this division."† This rock, he states, extends throughout the peninsula, as far south as Tampa Bay; and both the eastern and western shores are covered with a Pleistocene formation of recent species of shells, and remains of mammalia. The elevation of East Florida above the sea level is so inconsiderable that all or nearly all of it must have been submerged at the time the Post Pliocene species were existing, and therefore its elevation was contemporaneous with that of the Keys, which line its eastern, western and southern shores."‡

We have here the first definite attempt at the determination of the age of the Florida limestone.

In volume ii of this Journal, 2d series, p. 399, Conrad gives "Descriptions of new species of Organic remains from the Upper Eocene Limestone of Tampa Bay." In this article he

* This Journal, II, ii, 36 et seq.

† In more recent papers by Conrad these views are slightly modified.

‡ In this connection, see table of altitudes appended to the present article, and Dr. Burnett's letter below.

describes *Bulimus Floridanus, Bulla petrosa, Nummulites Floridana, Cristellaria rotella, Venus penita, Venus Floridana, Nucula tellinula, Cytherea Floridana* and *Balanus humilis.*

In this Journal, 2d series, vol. x, p. 282, Professor J. W. Bailey notes the discovery by him of an Infusorial stratum, between the mouth of Hillsboro River and Ballast Point. He is doubtful about the geological position of this bed, but states that it is associated with strata containing fossils which appear to belong to the epoch of the Eocene Tertiary.

During the summer of 1850, Professor M. Tuomey, of the University of Alabama, paid a short visit to the coast of Florida, with the view of comparing the recent deposits there with the white limestone (St. Stephens, etc.,) of Alabama, and in this Journal, 2d series, vol. xi, pp. 390 et seq., he published "A notice of the Geology of the Florida Keys, and of the Southern Coast of Florida." The author describes the limestone of the Keys—in which the fossils are all identical with the shells living in the surrounding waters—and points out the agency of the Mangrove tree in the formation of islands between the mainland and the Keys. At Tampa Bay he confirms the observation of Conrad respecting the Tertiary age of limestone there, which he says extends doubtless to Charlotte Harbor.

The limestone which underlies the Everglades he states to be similar in every respect to that at the mouth of the Miami River, which, in turn, is of the same age as the rocks examined at Key West and elsewhere inside the reef. He calls attention to the fact that an elevation of the Keys, of about ten to twenty feet, would form a ridge similar to that surrounding the Everglades, shutting out the sea from the space, at present between the reef and the mainland, thus producing a second "Everglade," differing from the present only in its greater comparative length.

In the same volume, p. 86, Professor J. W. Bailey publishes a notice of "Silicified Polythalamia in Florida," in which he speaks of large masses possessing all the mineralogical characters of flint, as occurring in the white Orbitulite limestone which is common throughout the portion of Florida between Tampa and Pilatka. The flint was collected about forty miles west of Pilatka, and upon examination of thin sections by the microscope, *Orbitulina, Nummulina, Rotalia, Textilaria,* etc., were recognized in numerous specimens.

In a letter to Professor Dana, Dr. W. I. Burnett (this Journal, II, vol. xvii, p. 407) calls attention to the circumstance that the peninsula of Florida is by no means so flat as is generally supposed, for surveys made by Gen. Barnard establish the fact that there is an elevated ridge in places 237½ feet above low tide in the Atlantic, extending slopingly from north to south, and terminating at a line drawn from Cape Canaveral to Tampa Bay. At points only fifteen or twenty miles west of the St. Johns River, there are elevations at least of 100 to 150 feet. The author believes that all Florida is of comparatively recent age, except the elevated ridge spoken of above, but he does not express any opinion as to the age of this ridge. He endorses Professor Agassiz's conclusion respecting the recent origin of the Everglades.

In the winter of 1851, Professor Joseph LeConte, in company with Professor Agassiz, visited and examined the Keys and reefs of Florida, and the results of his observations are recorded in an article in this Journal, II, vol. xxiii, pp. 46 et seq., entitled, "On the Agency of the Gulf Stream in the Formation of the Peninsula and Keys of Florida." The author states that until the time referred to (1851), nothing definite was known concerning the geology of Florida, but it was supposed to consist of a southward prolongation of the Eocene of Georgia and Alabama, and its shell limestone to bear some general resemblance to the white limestone of these States But the observations of Professor Tuomey in 1850, and the more full and careful observations of Professor Agassiz during the following winter, brought to light the remarkable fact, that the Keys and the larger portion of the peninsula of Florida are of recent origin, and as far as could be examined, the work of corals still living in the vicinity, and still engaged in the work of extension. He then goes on to give his well-known theory of the agency of the Gulf Stream in forming the submarine banks upon which the reef-building corals could grow.

The author states that the eastern coast of Florida, from Lake George as far north as St. Augustine, is of recent coral formation similar to that of the southern coast and Keys; and supposing the statements of Conrad and Tuomey concerning the Eocene age of the limestone near Tampa to be correct, though *still problematical* in his opinion, he thinks that all that portion of the peninsula lying south of a line connecting St. Augustine with Tampa Bay, is almost certainly of coral origin and formed by the growth of successive reefs.

In vol. ii, art. 8, of the Smithsonian Contributions, Professor J. W. Bailey publishes his microscopical observations made in South Carolina, Georgia and Florida. This I have not been able to consult. The monograph of Professor Agassiz, also, I have not been able to see.

The last Geological Map of the United States, by Professors Hitchcock and Blake, accompanying the publication of the Ninth Census, represents the whole of Florida as alluvial.

From the preceding notes, it will be seen that while many valuable observations on Florida geology have been recorded, yet the subject is still enveloped in obscurity, partly because of the isolated character of the earlier observations, and partly because of the failure of the later observers to give due weight to the statements of those preceding them.

I give now some notes of my own recent observations:

In the lower part of Geneva County, Ala., the Orbitoides limestone of Vicksburg age, is exposed in many places, and passing thence southward into Jackson County, Fla., the same rock is found underlying the whole county from Campbellton to Marianna, and thence eastward to Chattahoochee, and northeastward through Greenwood to the river. The Vicksburg formation in Mississippi, Alabama and Florida, is almost everywhere covered with superficial beds of pebbles and sand (Orange Sand or Stratified Drift), and of yellow or red loam (Hilgard's Yellow Loam). The sand is rarely absent, the pebbles are distributed in belts which follow more or less closely the valleys of the principal rivers; the loam, together with the great mass of *yellow* and *red* sand of Stratified Drift age, which it overlies, thins out rather abruptly along an irregular line, which in Alabama and Florida may be roughly drawn as follows: from the northern boundary of Escambia County, Ala., eastward and southward through the lower part of Covington, diagonally across Geneva, through the lower part of Henry County; whence it is deflected southeastward so as to include parts of Gadsden, Leon and Jefferson Counties in Florida, and thence eastward and northward through parts of Madison and Hamilton Counties into Georgia. North of this line the country is more or less hilly and broken, the mean level of the uplands being perhaps 250–300 feet above the main water-courses, while southward the country slopes away to the gulf in an almost unbroken plain, the inequalities of the surface being everywhere comparatively slight, with scarcely anything deserving the name of *hills*.* This sea-ward, or rather gulf-ward, slope is covered almost uniformly with sand, which has rarely the bright yellow and red colors of the Stratified Drift sand further north. The timber is almost as uniformly long-leaf pine, with sometimes an undergrowth of small oaks, but often only of wire-grass. Exceptions to this state of things are found in the so-called "hammocks," where the soil is of

* From Clinch and Charlton Counties in Georgia, through Baker, Bradford and Clay Counties in Florida and thence southward, runs the Trail Ridge, which is 210 feet above sea level, where crossed by the Fernandina and Cedar Key railroad. And further west there is a range of sand hills 120 feet above sea level, between Archer and Bronson stations; but in both cases the local inequalities of the surface are exceedingly small, so that even upon the summit of Trail Ridge it is difficult to realize that one is upon an elevated plain, and not in a low pine barren.

darker color from intermixture of marl or disintegrating limestone, and where varieties of oak and hickory replace partly or wholly the lonely pine.

In the hilly country above mentioned, rocks of Vicksburg age are exposed along the banks of streams, ravines, etc., and sometimes as outcrops upon level ground; but on the Gulf slope, these exposures are usually at the edges and bottoms of the large "boiling springs" or "blue springs" which are so numerous throughout this entire region, and so characteristic of the formation wherever it makes a level, flat country. Occasional outcrops through the sand covering are to be noticed, and some streams like the Suwannee River, flow in part of their courses through channels cut in this limestone.

Where the limestone is hidden completely over large areas by the prevailing sands, its presence below is indicated by the sink-holes, ponds and lakes, which more than any other single feature are characteristic of the Florida landscape.

These being all due to the same cause, viz., the formation of subterranean caverns and the sinking in of superincumbent strata, the same depression may at one time be a mere lime-sink, (or "prairie" as the larger sunken areas—destitute of trees and carpeted with a dense growth of "blanket" grass—are called) or subsequently, a pond or lake, by the collection of water in the depression. A good example in point is Payne's prairie near Gainesville, which for many years was a widely-known pasture ground, to which thousands of cattle were driven from long distances. A small creek flowed through this basin, disappearing near its northern edge into an underground channel. During the great storm of 1871 this outlet was closed, and the "prairie" has become a lake several miles wide and from fifteen to twenty feet deep. As a matter of course, these phenomena are not confined to any particular limestone, and the occurrence of a *Miocene* limestone forming the basin of Rock Spring in Orange County, is noted below; still, from specimens collected by me at points widely distant from each other, from the observations of others as quoted above, and from evidence derived from other sources, I am brought to the conclusion that almost the whole State of Florida, from the Perdido River on the west, eastward and southward, including the middle and western parts of the peninsula, certainly as far south as the latitude of Tampa Bay, and probably as far as the latitude of Charlotte Harbor, has for its underlying formation the white or Orbitoides limestone of Vicksburg age, the exceptions as yet known being the Post Pliocene or recent limestones forming the Keys and the immediate coasts along the western, southern and eastern shores, and isolated patches, if not a continuous belt of Miocene limestone between the St. Johns River and the elevated table lands westward.

The following notes present proofs more or less conclusive of the statement above made:

1. *West Florida.*

The occurrence of Vicksburg limestone in Jackson County has already been noticed, and specimens of *Orbitoides Mantelli*, *Pecten Poulsoni*, and other characteristic fossils were collected *in situ* at several localities, e. g., a few miles southeast of Campbellton, at the Big Spring east of Marianna, etc., while the use of blocks of this stone in the construction of chimneys, through the eastern and northern portion of the county, attest its occurrence everywhere in those parts. In the region referred to, the limestone lies very near the surface, often outcropping over considerable areas, and to this circumstance is probably due the exceptional fertility of much of the soil of Jackson County.

Holmes Valley on the creek of same name in Washington County, another widely-known fertile tract of land, presents the same geological features as the portion of Jackson County just mentioned.

Westward, in Holmes, Walton, Santa Rosa and Escambia Counties, the surface is generally covered with sand, so that outcrops of rock are not numerous; but the great number of "boiling" springs, sink-holes, ponds and lakes, taken in connection with the distribution of the Orbitoides limestone in the adjacent counties of Alabama, make it almost certain that this rock underlies most of West Florida, down at least to the near vicinity of the Gulf coast.

2. *Middle and South Florida.*

In these portions of the State my observations have covered a larger extent of country and are correspondingly more conclusive as to their geological structure.

Near the village of Chattahoochee, the bluff of the Appalachicola River is formed in part by the Vicksburg limestone, which has here a tolerably thick covering of Stratified Drift, consisting of reddish and yellow sands with some small pebbles. The greater part of Gadsden County, as far east at least as Quincy, is a high level plateau with thick beds of Stratified Drift and Yellow Loam as surface materials. For this reason exposures of the underlying rock are not numerous, except toward the river, along the lower parts of the water courses. Liberty County was not visited, but from information obtained at Mount Pleasant, I feel very well convinced that the Vicksburg limestone makes its appearance along the river as far south as Rock Bluff.

Leon, Jefferson and Madison Counties are similarly covered with thick beds of Stratified Drift and Yellow Loam, and near the Georgia line the country is somewhat hilly. Going southward from Tallahassee, however, one descends from the elevated country, two miles from the town, to the low, flat pine woods which slope away gently toward the Gulf. Here, the usual feature of the Gulf slope are observed, viz: limesinks, ponds, lakes, boiling springs, and outcrops of limestone. Specimens of this rock collected about six miles from St. Marks, in Wakulla County, were submitted to Mr. Angelo Heilprin, and by him pronounced to be of Vicksburg age, *Orbitoides Mantelli* being prominent among the fossils.

In many places near the coast in Wakulla County, a very finely pulverized white marl is mingled with the sand, imparting to it a great degree of fertility; this is the "Gulf Hammock" land of which much has been written. From enquiries, and from the observations of Conrad and others, I learn that these "Hammocks" exist all along the coast from Wakulla, through Taylor, Lafayette, Levy and Hillsboro Counties to Tampa Bay. This marl is also of Vicksburg age where I have examined it, and from descriptions which I have had from various sources, it seems almost certain that the marls of the Gulf Hammocks in the other counties named, are of the same geological age. In Jefferson, Madison and Hamilton Counties, the Vicksburg limestone underlies the Stratified Drift everywhere, as may be seen in its outcrops along the banks of streams. In Suwannee and Columbia Counties the Vicksburg is still the underlying rock, the surface covering being here light colored sands chiefly—the yellow and reddish sands and loams of the adjoining counties westward, being usually absent. Specimens of the limestone with characteristic fossils have been collected in the vicinity of Live Oak, and an earthy limestone, the counterpart of some of the Vicksburg limestone, in which, however, no fossils were observed, was noticed by me near Lake City and thence out near to the Suwannee shoals on the river of same name. I am informed that the rock at the shoals is highly fossiliferous. At the time of my visit it was hidden by high water.

The Suwannee River, which has its head waters partly in Okefinokee Swamp in Georgia flows through most of its course in Florida, between banks of Vicksburg limestone, and several large sulphur and limestone springs break out through crevices in the rock along the river.

A bed of what I suppose is *lignite* has been found lower down the river; the exact locality I could not learn; but a large quantity was raised some years ago, and experiments, with unfavorable results, made with it in Tallahassee, to test its fitness as a material for the manufacture of illuminating gas.

Okefinokee Swamp, in Georgia and Florida, as may be seen from a map, is upon the water-shed between the Suwannee and St. Mary's Rivers; this ridge is prolonged southward and eastward as Trail Ridge, through Baker, Bradford and Clay Counties, and the elevation (whether by that name or some other) is continued, according to my own observations and those of others, nearly to the Everglades. Although observations are as yet wanting, to prove that the Okefinokee swamp reposes upon a bed of Vicksburg limestone, yet the occurrence of that rock along its southwestern and southern edges in Florida, as above mentioned, makes it very probable that such will be found to be the case, especially when we consider the fact that farther south along this ridge and particularly along its western slope in Alachua, Marion and Sumter Counties, the Orbitoides limestone is everywhere the underlying formation, sometimes hidden by overlying sands, but often outcropping over extensive areas.

The enumeration of a few localities from which characteristic fossils have been collected, will make more definite this general assertion. Orbitoides limestone is the prevailing, and I might say the only, rock in the vicinity of Gainesville, many of the chimneys and pillars of the houses there are built of it. The limestone is often a mass of shells and in places *O. Mantelli*, forms it to the almost total exclusion of every other species.

Payne's Prairie, south of Gainesville, already mentioned above, occupies a depression or sink in this limestone.

The observations of Professor J. W. Bailey quoted above, show that the same formation extends at least to within forty miles of Pilatka. Between Gainesville and Ocala in Marion County, the chimneys of the farm-houses reveal the character of the underlying rock. At Ocala, it outcrops in numerous localities, *Orbitoides Mantelli*, here as at Gainesville, often forming the entire rock. Silver Spring, six miles east of Ocala, occupies a basin in the same limestone. This is one of the largest of the very numerous sulphur springs of the peninsula. Steamers from the Ocklawaha come up into the spring where they can easily turn. The waters of the spring as well as of the stream—twenty feet or more in width, fifteen in depth, and eight miles in length, from the spring to the river,—are beautifully clear, the jagged edges of the limestone banks, the numerous fish, and even objects lying upon the bottom, being distinctly visible from the deck of a steamer.

Specimens of limestone from Silver Spring were found by Mr. Heilprin, to be composed of *O. Mantelli* Morton and *O. supera* Con., to the exclusion of other forms except polyzoa.

About Ocala, southward and southwestward, is a belt of "hammock" land, where an earthy, partly disintegrated limestone mingles with the surface soil. Reference to tables of elevations appended below, will show that this hammock land, is sixty feet higher than the sandy plain of Ocala. My own observations in the interior confirm the statement of Conrad with reference to the Gulf Coast near Tampa that the Tertiary limestone is certain to be the substratum of all the "hammock" land.*

From Sumter County I have no specimens of the limestone, but from statements made by the inhabitants, there seems to be little if any doubt that the rock which outcrops in the western and southern parts of the county toward Tampa, is Vicksburg limestone. It is described to me as being in part a mass of shells, in part earthy and disintegrated, in part flinty, all well known characters of this formation in Florida, and its use in the construction of chimneys in that part of the county, is at least *suggestive* of its age.

We have thus traced the Vicksburg limestone, by its *actual outcrops*, from Jackson County in West Florida, through Middle Florida, into South Florida below Ocala in Marion Co. The observations of Conrad, Tuomey and others, prove its occurrence at Tampa and probably at Charlotte Harbor. That it underlies also the other counties of West Florida, and part of those south of Sumter nearly to the Everglades † is open to very little doubt, still we must draw a sharp line of distinction between what has *actually been proven* by personal observation, and what is only *an inference* from the facts observed, however strongly the inference may be supported by the facts.

In Orange County between Sanford and Lake Apopka, there are several large sulphur springs of the kind already mentioned, affording streams navigable by small steamers. Three of these, Hoosier Spring, Clay Spring and Rock Spring, all within eight or ten miles of the village of Apopka, were visited by me. They all come up through fissures in limestone. At the first two, at the time of my visit, the limestone was so deep under water, by reason of recent heavy rain storms, that it could not be closely examined. At Rock Spring, however, there is a bluff of limestone some ten feet in height, and from this I was able to collect a number of fossils. They were submitted to Mr. Heilprin who determined among them the following species: *Pecten Madisonius*, *Venus alveata*, ‡*Cardita granulata*, ‡*Carditamera arata*, *Mytiloconcha incurva*; doubt-

* This Journal, II, vol. ii, p. 43.

† From the distribution of the Vicksburg limestone in the lower part of the peninsula, I am strongly inclined to believe that it will be found on further examination, to underlie a part, at least of the Everglades.

‡ Also Pliocene.

ful were also *Cardium sublineatum* and *Oliva litterata.* This would make the limestone of Miocene age, as Mr. Heilprin states his belief that *no* Vicksburg species are associated with the shells enumerated.

I do not know that Miocene limestone has been observed elsewhere in the state, but it seems probable that it will, upon examination, be found either in isolated patches, or forming a continuous belt between the Post Pliocene deposits toward the east, and the elevated country westward, which has as a substratum the Vicksburg limestone.

My observations along the St. Johns River from Sanford to Jacksonville have added nothing to what has already been recorded, although corroborating the statements quoted above in the introduction.

Summary of Observations.

From the foregoing pages it will be seen that the earlier observers, Major Whiting in 1838, and Lieutenant Allen in 1846, mention the occurrence in the peninsula of a limestone *older* than that forming the coasts and keys: the latter author making the statement that it underlies even the Everglades. In 1846 also, Conrad determined definitely the age of the older limestone occurring at Tampa Bay, and expressed the opinion that the prevailing limestone of the peninsula would be found to be of the same age. In 1850, Tuomey confirmed Conrad's statement concerning the age of the rock at Tampa.

Up to this time it appears, as LeConte states, that it was the general opinion that the Florida peninsula was substantially a prolongation southward of the Eocene limestone of Georgia; but the researches of Agassiz and LeConte in bringing more prominently into view the recent character of the coasts and keys, and of the extreme southern end of the peninsula, together with the extension of the theory of the latter author, regarding the successive additions to the end of the peninsula, by coral formations, threw a shade of doubt, to say the least, over the observations of Conrad and others, which we now know to have been correct. The result has been, that since 1856 or 1857, a general impression has prevailed, that with the exception of the problematical Tertiary limestone at Tampa, the whole of Florida was of comparatively recent origin, and so it is laid down in the latest geological map.

In what precedes, I believe that I have established, beyond doubt, the correctness of the older views concerning the geological structure of the greater part of the peninsula, which views, so far as the published records show, were based either upon casual statements or conjectures of authors, except in the case of Tampa and its vicinity.

So far as I know, this article contains also the first published record of observations upon the geology of any part of Middle or Western Florida, and the first account of the discovery of Miocene strata in the State. For these reasons it has seemed worth while to publish the foregoing notes.

Leaving out of consideration, for the present, the beds of stratified drift, it appears further, that along the Gulf coasts of Alabama, of West Florida and of the Peninsula, the Post-Pliocene strata are directly superimposed upon the Vicksburg limestone; the intervening beds, representing the Miocene and Pliocene, being, so far as we now know, absent from those localities.

On the other hand, we know that in one locality certainly, and presumbly elsewhere along the Atlantic slope of the peninsula, a Miocene limestone overlies the Vicksburg.

While rocks of Pliocene age have not yet been recognized, it is reasonable to suppose that future explorations will reveal their existence along the eastern coast in a position similar to that occupied by beds of the same age in Georgia and South Carolina.

The facts with regard to the distribution of the rocks of Florida are presented in the following map.

Those points where the existence of the Vicksburg limestone has been determined beyond doubt, by fossils collected and identified, are indicated upon the map by a slightly darker shade. This formation was first recognized at Tampa and near the mouth of the Manatee River by Conrad; between Gainesville and Pilatka, by Professor J. W. Bailey; and at the other localities marked, by myself. The locality of the Miocene limestone was first observed by myself, and the Post-Pliocene age of the coasts and keys has been determined at many points by Conrad, Tuomey, Agassiz, LeConte and others.

Between the Post-Pliocene on the eastern coast and the Eocene of the interior, a space is left blank, as *undetermined*, except in one place, Rock Spring, where the Miocene limestone was noticed. In this area other occurrences of Miocene beds will probably be found.

Professor Tuomey states that the Vicksburg limestone is probably the country rock as far south as Charlotte Harbor.

Below that latitude, however, to the Everglades, the formation is a matter of conjecture, though laid down as probably of Vicksburg age.

In how far the construction of the map is justified by the facts observed, the reader has thus the opportunity of judging for himself.

Conclusions.

From the observations of others as quoted above, and from my own, I have been brought to the following conclusions regarding the past geological history of Florida.

1st. Since no rocks have been found in Florida, older than the Vicksburg limestone, it follows that until the end of the Eocene period, this part of our country had not yet been added to the firm land of the continent, but was still submerged.

Geological Map of Florida. By Eugene A. Smith.

Abbreviations, commencing to the westward: Mn., Milton; H. V., Holmes Valley; C., Campbelltown; M., Mariana; Ch., Chattahoochee; Q., Quincy; St. M., St. Mark's; L. O., Live Oak; L. C., Lake City; Ok., Okifinokee; P., Pilatka; Oc., Ocala; R. Sp., Rock Spring, adjoining Miocene locality, near middle of eastern part of Florida.—The bathymetric lines are from Mr. Hilgard's Map of the Gulf.

2d. During the period of disturbance which followed the deposition of the Vicksburg limestone (Upper Eocene), Florida was elevated nearly to its present height above sea level, which elevation was maintained without material interruption until the Champlain period. Proofs of this statement may be found in the universal occurrence of the Vicksburg limestone as the country rock throughout the entire State, except perhaps in the southern part of the peninsula.

3d. In this upward movement, the axis of elevation did not coincide in position with the present main dividing ridge (north and south) of the peninsula, but lay considerably to the westward, probably occupying approximately the position of the present western coast.*

In other words, during the Middle and Upper Tertiary periods the Florida peninsula was much broader than it is now, toward the west; and while the eastern coast had nearly its present position, the western lay probably one hundred, in places perhaps one hundred and fifty miles beyond its present place. West Florida was also affected by this movement, and remained above sea level during the same periods.

Reasons for this conclusion are found in the total absence along the Gulf shores of West Florida and the peninsula, of all strata between the Vicksburg limestone and the Post Pliocene; while the peculiar beds of the Grand Gulf group of Hilgard overlie the Vicksburg limestone, on the Gulf borders of Mississippi, Louisiana and Texas, and a marine Miocene limestone of the usual Atlantic coast character, overlies the same rock on the eastern side of the peninsula.

This conclusion, reached as is seen above from purely geological considerations, finds a support amounting almost to demonstration, in the position of the one hundred fathom line off the Florida coasts, as shown on the accompanying map. It will be seen there that the submerged portion of the peninsula (within one hundred fathoms) on the west, is as wide as the present land surface, while on the east it is only a narrow strip.

That sediments were deposited during the Middle and Upper Tertiary periods off the Gulf coasts of Florida as well as of the other States mentioned is of course self-evident, and their absence along the coast at Tampa and elsewhere can be explained only upon the supposition that the coast line at that time was west of its present position, and that the deposits then made off that old coast are now submerged beneath the waters of the Gulf.

It may be objected that the absence of these deposits on the western coast is *apparent* and not *real:* that they have simply escaped notice: but it seems hardly probable that two such

* This assumes approximate uniformity of slope on each side of the main line of elevation. Under any other supposition, the facts would apparently require an elevation of the peninsula after the Vicksburg period, much above its present height, and a depression during the Miocene period at least thirty feet below present level.

close observers as Conrad and Tuomey should have overlooked them if they occur at least from Tampa southward.

4th. After the Miocene (or possibly after the Pliocene) period, there was again an elevation* of Florida, as is shown by the presence of a Miocene limestone on the eastern slope of the peninsula, some distance (not less than thirty feet) above present sea level.

The absence along the Gulf coasts, of Miocene and later Tertiary deposits, either of marine (limestone), or of brackish or fresh-water (Grand Gulf) origin, has already been accounted for above.

5th. We have evidence in the distribution of the beds of the Champlain period (Stratified Drift or Orange Sand), that Florida and parts of adjacent States were during this time submerged sufficiently to allow the deposition over them of a mass of pebbles, sand and clay, varying in thickness from a few feet to two hundred. The conditions under which these beds were deposited have been ably discussed by Hilgard in this Journal, and in his Mississippi and Louisiana Reports.

Of these conditions, I shall speak of one only. From the peculiar mode of stratification of most of these beds, it is concluded with reason, that they were sediments from rapidly flowing, ever varying currents. In the northern part of the State, the beds of red and yellow loam lie directly upon the Stratified Drift. These beds of loam are devoid of stratified structure as well as of fossils, and were probably deposited from slowly running or nearly stagnant waters.

The direct superposition of the Loam upon the Stratified Drift throughout Florida, Alabama and the greater part of Mississippi and Louisiana, and the fact that there is, with the exception presently to be noted, rarely, if ever, any sharp line of demarcation between the two—the upper beds of the Drift passing by imperceptible gradations into the Loam—point strongly to a community of origin, and appear to indicate that the Loam is the last of the sediments made by the floods of the Drift. Along the Mississippi River, the two are separated by the Port Hudson and Lœss deposits, both having more or less local characters; the Lœss being distinctly a river bank—and the Port Hudson, a river or gulf swamp deposit.

We can imagine that after the great rush of waters which deposited most of the pebbles and other coarse materials of our Drift, there followed, over the larger part at least of the Gulf States, a gradual checking of the currents and consequent deposition of the finer Yellow Loam, while along the axis of the Mississippi, where, as Hilgard has shown, the extremes of oscillation were experienced, this gradual change,

* On this point, compare foot-note on page 306, above.

from swiftly flowing to nearly stagnant waters, might have been interrupted by such subordinated and local oscillations as would have caused the formation of deposits like the Port Hudson and the Lœss.

6th. Following the submergence during the Champlain period, was a re-elevation, which brought up the peninsula with approximately its present configuration.*

Evidences on this point are to be found in the Post-Pliocene deposits described by Conrad, Tuomey and others, as bordering more or less uniformly, the eastern, southern and western shores, and forming the keys.

7th. In the height of these Post-Pliocene deposits above the present sea-level, Conrad and Tuomey see proofs of the elevation of the peninsula and keys (ten or fifteen feet) in still more recent times, while, on the other hand, Professors Agassiz and LeConte give a different explanation. To quote the words of the latter author: "Neither the mainland nor the Keys are anywhere higher than may be accounted for by the action of the waves, viz: from ten to fifteen feet."

8th. Since about one-fifth of the coast line of the Gulf of Mexico is formed by Florida, the present article would lack completeness if it did not take into account a theory or hypothesis which has been advanced in connection with the geological history of the Gulf region.

In view of the absence of marine formations of Middle and Upper Tertiary age along the Gulf coasts of Mississippi, Louisiana and Texas, and to account for the formation of the beds of the Grand Gulf group, without remains of marine life, which overlie the Eocene of those coasts, Professor Hilgard has been brought to the conclusion that during a part or the whole of the interval between the Vicksburg and Champlain periods, the Gulf was by some means isolated from the Atlantic, and thus converted into a fresh- or brackish-water basin, and he also further suggested that this was brought about by a land connection between Florida and Yucatan.

This hypothesis has been freely discussed in this Journal and elsewhere, and a further discussion of it would be to some extent foreign to this article, since the facts observed by me and recorded above, beyond proving that Florida during the Middle and later Tertiary periods, was part of the firm land of the continent, and was probably then nearly twice its present

* We can only speculate as to *when* and *how* the change from the broad peninsula of the Middle and later Tertiary periods, to the present narrow form took place. Two possibilities suggest themselves, viz: 1. At the beginning of the Champlain period, a more profound depression of the western as compared with the eastern half of the broad Tertiary peninsula; or 2. At the end of the period of submergence, the shifting of the main axis of elevation eastward, would have brought about this result.

width, have no direct bearing upon the hypothesis, and offer no solution of the main difficulty in the way of its acceptance, viz: the depth (7000 feet) of the straits between Yucatan and Cuba, and between Cuba and Florida (3000 feet).

And besides, so far as yet known, the Grand Gulf beds form no part of the *present* land surface of Florida, being now, as suggested in one of the conclusions above, probably submerged, if they ever formed a part of its Gulf coast deposits.

Appendix.

Lists of altitudes obtained from Maj. P. W. O. Kœrner, Engineer.

I. *Transit Railroad.*

Names.	Distances from Fernandina. Miles.		Altitude above low tide in Atlantic.	
Fernandina,	0	27 ft. highest elevation between these points.	0	
Boggy River,	20		Back tide water.	
Callahan,	27		30 ft.	
Dutton,	36		45	
Baldwin,	47		47	
Maxville,	56		57	foot of Trail Ridge.
Summit of Trail Ridge,	61		210	
Western foot of Trail Ridge,	62½		180	
Laughty,	66		140	
Starke,	73		150	
Sante Fe (Lake Outlet),	79		137	
Waldo,	84		150	
Hatchet Creek,	91		(about 100)	
Gainesville (Court House),	95		128	
Arredondo,	100 (?)		70	
Archer,	107		70	
Sand Hills (Summit),	---		120	
Bronson,	127		27	
Otter Creek, (Gulf Hammock)	134		19	
Rosewood,	144		10	
Cedar Key,	154		0	

II. *Peninsular Railroad.*

	Names.	Elevation above low tide in Atlantic.	
Topographical Features near line of Road.	Sante Fe Lake,	137 ft.	
	Pithlachooke Lake,	85	
	Payne's Prairie,	68	Rim of Prairie about 100 ft. higher.
	Lochloosa Lake and Orange Lake,	52	
	Silver Spring,	39	
Stations.	Hawthorne,	150	
	Lochloosa,	60	
	Ocala (C. H. square),	100	
	Ridge 1 m. s. of Ocala (Hammock),	160	

The average elevation of the country between Ocala and Orange Lake is 80 ft.

University of Alabama, Dec. 15, 1880.

Art. XXXVII.—*The Magnetic Survey of Missouri*; by Francis E. Nipher.

In the summer of 1878, the writer began a magnetic survey of the State of Missouri. The work of the first summer was confined to the northeastern part of the State, and no points of interest were brought out. During the summer of 1879 the work was extended over the western half of the State, and it was made apparent that diversity of surface exerted a much more important influence than had been suspected. The lines of equal declination were found to bend very sharply upon entering the large valleys, and the needle showed a tendency to set at right angles to the valleys. This tendency seemed to be greatest when the general direction of the valley made an angle of 45° with the normal position of the needle, or roughly, when the valley runs northeast and southwest or northwest and southeast. This tendency seemed to be inappreciable, when the valleys ran north and south or east and west. In the report of 1878,* it was suggested that this might result from the bending of the stream lines of the earth-current sheet, due to the greater conducting power of the moist valleys. In order to settle this point, further examination is necessary, and it is proposed to make determinations of earth currents at a number of properly selected stations.

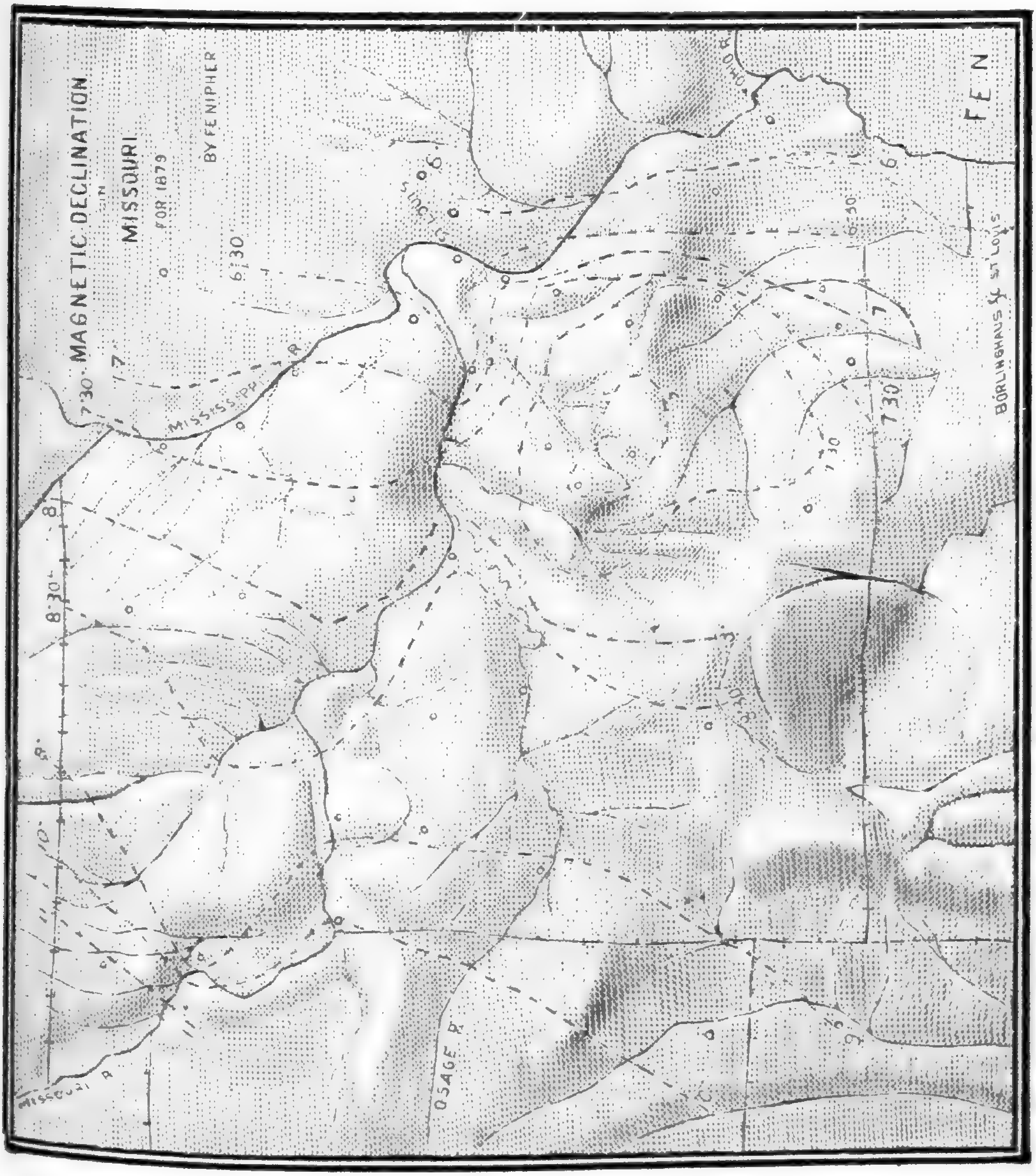
During the summer of 1880 the work extended over the southeastern part of the State, where still more important flexures of the isogonic lines were discovered. Here, however, the position of the needle is probably affected by the iron deposits, and the effect of contour is studied to less advantage. At the close of 1880, observations had been made at 45 stations. In order to bring out the effect of contour, a relief map of the State was constructed in wax, and was finally reproduced in plaster. In this work use was made of the profiles of all the railroads in the State, together with a list of over 300 elevations in the State collected by Henry Gannett. The isogonic lines which were first drawn upon an ordinary map in the usual manner to represent the observations thus far made, were then copied upon the relief map.

In doing this, it became apparent at once, that the 45 stations were wholly inadequate, and that the isogonic lines thus drawn are probably deserving of about the same weight that a topographical map would deserve if constructed from elevations at these stations.

The wood-cut is made after an artotype which will accompany the third annual report in vol. iv, no. 2, of the Transac-

* Transactions of the St. Louis Academy of Science, vol. iv, No. 1, p. 143.

tions of the St. Louis Academy of Science. In the original map, the horizontal scale is 20 miles to the inch, the elevations being exaggerated 200 times. This exaggeration was necessary in order to bring out the form in the photograph, since on



a relief map 150 feet square, the greatest difference in elevation in the State drawn to the same scale would be represented by a vertical height of one inch. The horizontal scale of the cut is 62 miles to the inch. Three stations in the Missouri valley have been inadvertently omitted in the cut. One of these (Carrollton) lies on the 8° 30′ line, a few miles north of the river. Another (Glasgow) lies on the river, a little south of east from Carrollton. The third (Columbia) lies just east of the 8° line, and southeast from Carrollton. A fourth station omitted is nearly due east of the southern terminus of the 8° line, and just outside the 7° 30′ loop. The other stations, represented by the small circles are shown on the cut, and an inspection of the map will show the weight to be given to different parts of the lines. At stations situated at points of abrupt curvature of the lines, the observations have been repeated at various localities in the region, until it was clear that no minute local effects existed.

The value in the Iron Mountain region is the mean of many hundred determinations made with a solar compass by Pumpelly and Moore, in 1872. This region is in the east part of the 7° 30′ loop. In the western iron field, which is nearly coincident with the 7° oval, our observations were repeated at various points (our aim being to avoid iron deposits), without finding any local action. In conducting this survey, a magnetometer belonging to Washington University was used, but the dip circle and declinometer were kindly furnished by Professor J. E. Hilgard, of the U. S. Coast and Geodetic Survey. Thus far the survey has been conducted wholly on private means, in which we have been aided by the railroad companies, and by citizens of St. Louis. A bill providing for the completion of the survey is now before the legislature of the State.

ART. XXXVIII.—*On American Sulpho-Selenides of Mercury;* by GEO. J. BRUSH—*With analyses of Onofrite from Utah;* by W. J. COMSTOCK. Contributions from the Sheffield Laboratory, No. LXI.

AT a meeting of the National Academy of Sciences, held in New York in November last, Professor J. S. Newberry communicated to the Academy two papers, on the occurrence of various ores in Southern Utah, mentioning, among others, the discovery of a mercuric selenide at Marysvale, a mining camp two hundred miles south of Salt Lake City.

A specimen of this mineral was given me by Dr. Newberry, and desiring to ascertain more definitely its specific relations; I made a pyrognostic examination of it, and found it to be essentially a sulpho-selenide of mercury with traces of zinc and manganese, and that the mineral was probably identical with Rose's *Onofrite.* On communicating my results to Dr. Newberry, he very kindly requested me to make a further investigation of the mineral, and placed in my hands an abundance of material for a quantitative examination. He stated that it occurs in what seems to be a fissure vein in a limestone, which he regards as paleozoic, and that the selenide was found at the bottom of a thirty-foot shaft, forming a seam about four inches wide.

Physical properties.—The specimens received from Dr. Newberry were, with a single exception, small irregular fragments, free from rock. The larger specimen was in a gangue of compact gray limestone, but the greater part of the specimen, 3 by 3 inches square and an inch in thickness, consisted of the sulphoselenide. Even the limestone was found impregnated with the same, sometimes in visible specks, while in other portions of the rock it was not to be seen until acted upon by acid, or volatilized by heat in the closed tube. A small amount of associated crystalline calcite also included minute particles of the metallic mineral. The most careful scrutiny of the gangue failed to discover any native metallic mercury, or other associated metallic mineral, and there was no difficulty in selecting an abundance of the pure mineral for analysis entirely free from the gangue.

The mineral has a blackish gray color and streak. It has no distinct cleavage, but breaks with a conchoidal fracture and shows a brilliant metallic luster on freshly broken surfaces. The irregular natural surfaces of the specimens in my possession are somewhat spongy or cavernous in aspect, but afford no clue to the crystalline form of the mineral. The hardness is about 2·5 and the specific gravity of the mineral, boiled in water to free from air, gave the figures 7·61 and 7·63, in two determinations.

Pyrognostics.—In the closed tube the mineral decrepitates at first, then volatilizes for the most part, gives reactions for sulphur and mercury, coats the tube with a grayish black sublimate, and leaves a small non-volatile residue which is bright yellow while hot, and paler on cooling. In the open tube it gives sulphurous acid fumes, and sublimates of metallic mercury and sulpho-selenide of mercury, and leaves, as before, a slight residue of a yellow color. On charcoal in R. F., the assay tinges the flame blue, and in both O. and R. F., gives copious fumes with the characteristic disagreeable odor of selenium, and coats the coal with a sublimate having a metallic luster, which last, when touched with the R. F., disappears, tinging the flame azure blue. A slight non-volatile residue remains, which treated with soda, gives a faint zinc coating. When the residue obtained from heating in the tubes or on charcoal is fused with borax on platinum wire, it gives an amethystine bead; with soda on platinum foil, it imparts to the flux the pale green color characteristic of sodium manganate.

Chemical composition.—The quantitative examination of the mineral was made by Mr. W. J. Comstock, assistant in the Sheffield Laboratory. He followed the method of H. Rose, decomposing the mineral by heating it in a stream of chlorine gas, and from the volatile portion, separating the selenium and sulphur by barium-chloride, weighing them as barium sulphate and selenate, while the mercury was separated from the filtrate from the baric precipitate as sulphide. To determine the sulphur, a separate portion of the mineral was dissolved by the aid of aqua regia and potassium chlorate, and then evaporated twice with chlorhydric acid to ensure the selenium being as selenous acid, when the sulphuric acid was precipitated by barium chloride. This precipitate was carefully tested and found to be entirely free from selenium. An examination was also made to ascertain if anything besides selenium, sulphur and mercury were carried over with the volatile portion, by the action of the chlorine gas, with a negative result. The non-volatile residue from this decomposition was found to contain only manganese and zinc. This was dissolved in water, and in the quantitative examination acidulated with acetic acid, and the manganese thrown down by bromine, in presence of sodium-acetate; from the filtrate, the zinc was precipitated as carbonate and weighed as oxide.

The following are the results of Mr. Comstock's analysis:

	I.	II.	III.	IV.	Mean.	Ratio.	
Selenium	4·69	4·47			4·58	·058	·423
Sulphur	---	---	11.62	11·73	11·68	·365	
Mercury	81·73	82·12			81·93	.409	
Zinc	0·61	0·48			0·54	·008	·429
Manganese	0·68	0·70			0·69	·012	
					99·42		

These figures prove the mineral to be essentially Hg(S, Se), or a mercuric sulpho-selenide, in which the ratio of the sulphur to the selenium is about 6:1. This brings it under the mineral species *onofrite*, which H. Rose found to be a mercuric sulpho-selenide, with the ratio of S to Se of 4:1, a relation which Rose evidently considered unimportant, for he remarks that mercuric selenide and mercuric sulphide, as isomorphous bodies, probably combine in all proportions.* The identity of the Utah mineral with onofrite is further established by their complete correspondence in physical characters, and Dr. Newberry's discovery of a considerable quantity of this rare species at a new locality is an interesting fact for mineralogical science.

In this connection it may not be amiss to review the occur-

* Poggendorff's Ann., xlvi, 318.

rence of native mercuric sulpho-selenides, which, thus far, I believe, have only been found on the North American continent. The first mention of a native sulpho-selenide of mercury is by Del Rio.* He found at Culebras, in Mexico, in a limestone which overlaid red sandstone, two ores, one red and the other gray; the former he described as "biseleniuret of zinc and bisulphuret of mercury," and the latter a "biseleniuret of zinc and sulphuret of mercury." The English mineralogist, Brooke, named the red mineral *culebrite*, after the locality, and the gray mineral *riolite*,† in honor of its discoverer. The gray mineral had a density of 5·56, and, according to Del Rio, contained Se 49, Zn 24, Hg 19, S 1·5 = 93·5. Subsequently, Del Rio, in a letter to Mr. Brooke,‡ announced that the riolite was "native selenium with a variable mixture of sulpho-seleniuret of mercury and the seleniurets of cadmium and iron." No further examination of the red mineral was made, and little confidence has been accorded Del Rio's results.

Nearly coincident with the publication of Del Rio's first paper, Kersten§ announced the discovery of a sulpho-selenide of mercury among some ores from Mexico, but no more precise locality was given. Kersten's mineral was associated with native mercury and sulphur in a gangue of calcite and quartz.

In 1839, H. Rose received from San Onofre, in Mexico, the blackish gray sulpho-selenide which he described and named *onofrite*.‖ This mineral was found in compact granular masses, associated with calcite and barite, and, according to Mr. C. Ehrenberg, one of the officials of the Real del Monte Company, the mineral occurred in such quantity that it was proposed to use it as an ore of mercury, although Rose had so little of the mineral for examination that he was unable to detach a sufficient amount of it from adhering barite to enable him to ascertain its specific gravity.¶

In 1865, Professor A. del Costillo, of Mexico, described** a sulpho-selenide of zinc and mercury from the quicksilver mines of Guadalcazar; this mineral was subsequently independently examined and analyzed by Petersen†† and named *guadalcazarite*. A more recent analysis of the same mineral is given by Rammelsberg in his Mineralchemie, p. 79. These minerals bear a close resemblance to one another in physical characters, as well as in chemical composition, as will be seen by the table of

* Phil. Mag. and Ann. Phil., vol. iv, (1828) p. 113.

† Rionite is another name given by some authors for the same mineral.

‡ L. and E. Phil. Mag., vol. viii, (1836) p. 262.

§ Kastner Archiv., xiv, 27.

‖ Loc. cit.

¶ In Dana's Mineralogy, 5th ed., p. 56, line 10 from bottom of page, the density given by Del Rio for his gray mineral is erroneously attributed to onofrite.

** Dana Min., 5th ed., p. 109, and Burkhardt, Jahrb. Min., 1866, p. 414.

†† Tschermak, Min. Mittheil., 1872, p. 69 and p. 243.

analyses given below. Furthermore, guadalcazarite approaches very nearly in composition the native black mercuric sulphide from California, discovered by Dr. G. E. Moore, and named by him *metacinnabarite*,* and, to complete the list of analyses for comparison, I add this, and also an analysis of tiemannite, the mercuric selenide from Tilkerode. The specific gravity of metacinnabarite is 7·70–7·74; of the Utah onofrite, 7·61–7·63; of guadalcazarite, 7·15; of tiemannite, 7·15–7·274.

	S	Se	Hg	Zn	Mn	Fe	Quartz.		
Metacinnabarite	13·82	---	85·79	---	---	0·39	0·25	=100·25	Moore.
Guadalcazarite	14·01	tr.	83·90	2·09	---	---	---	=100·	Rammelsberg.
do.	14·58	1·08	79·73	4·23[a]	---	tr.	---	= 99·62	Petersen.
Onofrite, Utah	11·68	4·58	81·93	0·54	0·69	---	---	= 99·42	Comstock.
do. San Onofre	10·30	6·49	81·33	---	---	---	---	= 98·12	H. Rose.
Tiemannite	0·70	23·61	74·02	---	---	---	---	= 98·33	Schultz.

(a) with trace of cadmium.

It will be noticed that guadalcazarite as analyzed by Rammelsberg differs from metacinnabarite only in containing a small amount (2·09 p. c.) of zinc. Nothing is known with certainty as to the crystalline form of any of these minerals, but a comparison of their densities renders it probable that they belong to the same system, and they may be considered as isomorphous mixtures of mercuric sulphide and selenide. Assuming this to be true in the case of the Utah onofrite, and taking the specific gravity of metacinnabarite at 7·70, and tiemannite at 7·27, we find that the calculated density is 7·64, while that observed for the mineral was 7·61–7·63, a remarkably close approximation. Onofrite may therefore be looked upon as an intermediary species with which may be classed the varieties of mercuric sulpho-selenide, which cannot be united with either metacinnabarite or tiemannite.

New Haven, January 12, 1881.

Art. XXXIX.—*The Effect of Great Cold upon Magnetism;* by John Trowbridge.

An investigation upon the magnetic condition of steel, and upon the magnetic permeability of iron is now in progress in the Physical Laboratory of Harvard University. The preliminary experiments are interesting, since they show that very low temperatures exercise far greater influence on the magnetic condition than has been noticed by previous observers.

It is stated by Wiedmann,† that the cooling below the temperature at which steel is magnetized enfeebles the magnetic condition. A bar which was magnetized at 6° C. or 8° C. gave at 4° C. and −25° C. intensities represented by 5·08 and

* Jour. f. prakt. Chem., II, ii, 319, (1870) and this Journal, III, iii, p. 36.

† Daguin, Traité de Physique, nouv. ed. Influence de la temperature d'aimantation.

4·90. This represents a loss of less than four per cent. In my experiments the magnetic bar magnetized at 20° C. when subjected to a temperature of about −60° C. loses a far greater percentage of its magnetism. In one case a bar magnetized to saturation lost sixty-six per cent of its magnetism.

The low temperature was produced by solid carbonic acid and ether; and the magnetic moments of the bar were measured by placing it east and west of a suspended magnet, which was provided with a mirror. In this case we have the magnetic moment

$$M = \frac{1}{2} r^3 T \tan \varphi$$

where r=distance of magnet; T=horizontal intensity of earth's magnetism; and φ= angle of deflection of suspended magnet. The angles were observed before the magnetic bar was surrounded with the freezing mixture and afterwards at intervals when it was subjected, without removing it from its first position, to the influence of the carbonic acid. The following table shows the variations of the deflections to which the magnetic moments are proportional:

Before freezing.	When subjected to freezing mixture. ½ min. observ.	After interval of 3½ m. ½ m. obs.	1 min. obser.	2 min. obser.	5 min. obser.
·6390	·6050	·5860	·5820	·5790	·5540
·6395	·6020	·5850	·5815	·5740	·5515
·6390	·6000	·5840	·5825	·5700	·5480
	·5980	·5840	·5815	·5650	·5480
	·5965	·5830		·5600	
	·5950	·5820			
	·5940				
	·5930				
	·5920				
	·5910				
	·5900				
	·5890				

The zero of the scale was ·5000 and the observations are expressed in fractions of a meter. It will be seen that this bar lost in forty-seven minutes nearly two-thirds of its original magnetic condition. After twenty-four hours' exposure to the temperature at which it had been magnetized, its magnetic condition was fifty per cent of its original state.

A ring of soft iron was next experimented upon according to the method of Professor Rowland, and it was found that its magnetic permeability on being subjected to very low temperature differed greatly from the results obtained for soft iron at ordinary temperatures.

It is well stated by Dr. V. Strouhal and Dr. C. Barus, in a paper on the physical condition of steel, Ann. der Physik und Chemie, 1880, No. 13, that we must regard each bar of steel, in regard to its magnetic condition, as an individual of special characteristics—and a long investigation will be necessary to determine the limits of the effect of great cold upon magnetism.

Art. XL.—*Channel-fillings in Upper Devonian Shales;* by H. S. Williams.

In the midst of the fine shales marking the passage from the Portage to the Chemung groups, as they appear in the neighborhood of Ithaca, New York, are found narrow beds of sandstone presenting several points of interest to the geologist.

The first example studied is seen at the mouth of the ravine opening where Junction, Elm and Hector streets meet at the foot of West Hill.

On the faces of the cliff on the north of the ravine are seen what appear to be wedge-shaped beds of sandstone of a few feet extent in the shales which form the main mass of the rocks. Upon a close examination these wedge-shaped masses are seen to be sections, formed at different angles (by the joint-structure of the rocks) of a continuous narrow bed of sandstone, convex on the bottom and nearly flat and horizontal on the top, running out to thin wedges at the sides, its longitudinal axis lying diagonally across both systems of joints.

By a reduction of the oblique sections as seen at several points of its exposure I determined the shape, size and direction of these sandstone masses, which I have called channel-fillings.

The first one studied is about six feet in width and nine inches thick at the center; the top nearly plane, while the under surface curves quite regularly from the center to each side.

The shales, in which the channel-fillings lie, are fine, evenly bedded, thin, fragile shales, the lines of stratification of which are uniform and horizontal.

Where they meet the channel-filling the shales are abruptly cut off, the former being solid, compact and showing no stratification. A fresh fracture of the sandstone shows faint horizontal lamination of color, but this lamination is scarcely at all recognized in any cleavage of the rock. At the upper surface a wavy lamination is seen in the coloration, and also in the cleavage planes an inch or so from the upper surface, which is continued in a more marked seam of arenaceous shale of uniform thickness indefinitely on both sides of the channel-fillings.

The material of the filling is nearly pure fine sand, while the enclosing rock is argillaceous shale with only slight admixture of arenaceous material. The dimensions (width and depth) do not appreciably vary for a distance of over one hundred feet (to the south side of the ravine where the section was discovered in the bank by following out the determined direction across the ravine). The mass has its longitudinal axis in a line lying about 15° E. of N. and 15° W. of S.

The under surface of the sandstone masses present the appearance, frequently seen on flat flagstones from the Portage group, and called by Hall mud-flow or ripple marks.

In one case I thought I could *clearly* distinguish direction of flow of the runnels by the difference of degree of abruptness of the two sides of the two ridges and furrows. The abrupt side of the elevations seem to lie on the north side, and as these are casts I conclude that the flow which made them was in a southward direction.

In other cases I could not determine this point, and am still in doubt as to the cause of the inequalities on this lower surface.

Upon further examination of the ravines about Ithaca, I discovered that these channel-fillings are numerous, and distributed vertically through about twenty feet of shales.

The shale is well characterized by its fauna. Its termination is distinctly marked above by coarse arenaceous shales and sandstone, well known in the Chemung group, but these peculiar sandstone channel-fillings are not known to occur above or below this particular horizon.

Whenever, in the neighborhood the outcrop of the shales, with its characteristic fauna was discovered, careful search brought to light also the channel-fillings, everywhere running in a uniform direction, and varying in thickness from nine to eighteen inches, and in width from five and one-half to eight or nine feet.

The thicker beds were somewhat swollen in the center on top, and wrinkles, looking very much like the shrinkage wrinkles on the surface of a firkin of lard after it has cooled, were seen on the upper surface of these thicker masses.

The swollen center of these thick masses suggested the explanation, i. e., that subsequent to the original deposition of the rocks a certain amount of shrinkage took place in the shales which was not shared by the arenaceous channel-fillings, and thus the margins of the mass were borne down by the shrinking shales while the center of the mass, resisting the pressure, caused the center of the upper surface to bulge.

On the under surface of one mass of this kind, at the foot of Cascadilla ravine, I discovered the same fine lines trending in a general uniform direction which have been observed frequently on flat flags where they lie on argillaceous shales, resembling impressions of glacier scratches, and the trend of these lines is the same as that occurring on the Portage sandstones below, i. e., nearly due east and west. In the case mentioned the lines run diagonally down the one side the channel across the bottom and up the other; some of the lines are fine and thread-like and appear entirely uninfluenced by the depth of the channel down and across which they swept.

These lines puzzle me much for explanation, and the only suggestion which appears to me worth offering is that of a swiftly moving tide or current trailing seaweeds or particles rapidly with it over the bottom.

To explain the channel-fillings there occurs to me only one series of events which begins to cover the facts. The uniformity, structure, directness and great number of the channels seems to preclude the idea of a rapidly flowing stream across a beach, and the continuity of the imbedding strata seems consistent only with under-water work.

The suggestion I have to offer is, that these channels were caused by the scratching of icebergs on the shoals represented by the imbedding shales; that the channels were then scooped cleanly out of the mud of the bottom; that the flow or runnel marks were caused by the same ocean current which bore along the icebergs, and perhaps increased in the wake of the berg.

The deposit of sand in the channels was due to the catching of the heavier sand (in the cavity thus formed) more rapidly than on the general surface represented by the thin arenaceous layers above; and I suppose it therefore to have been filled during the deposit of this thin stratum of arenaceous shale which is continuous with the upper layers of the channel-filling, and which it will be remembered is uniformly uneven with ripple-mark structure; showing that during its deposit there was considerable motion in the depositing medium, carried by tides or currents.

Before closing, it may be interesting to mention that the richest locality known of the commoner of the beautiful and graceful fern-like fronds, called *Lycopodites Vanuxemi* by Dawson, but considered to be allied with the graptolites, and named *Plumalina plumaxia* by Hall (see 30th Reg. Rep. N. Y., p. 255) is in the stratum immediately overlying one of the thickest of these channel-fillings. The stratum is a soft shale and for an inch or so in thickness is filled with these and other plant remains, with a few species of frail shells, avicula, lingula, etc., in greater or less abundance. The same stratum has yielded a large fish plate closely resembling the plate C of the ventral shield of Newberry's *Dinichthys Terrelli* from the Huron shale of Ohio (see Pal. Ohio, vol. ii, chart No. vi, and p. 31). The specimen found at Ithaca is about half the size of the Ohio specimen figured. The shales in which the channel-fillings are seen is characterized by the presence of a Lingula which I believe to be new, at least as a variety and probably as a species, and which I propose to describe at another time.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Atomic Weight of Aluminum.*—By the courtesy of Professor J. W. Mallet, we have received a copy of his paper upon the atomic weight of aluminum. After a review of the labors of other chemists, Berzelius, Davy, Thomson, Mather, Dumas, Tissier and Terreil, as well as his own previous investigations in this direction, the author passes to a description of the special research in hand, a research which occupied three years of his time and which appears to us to be a model of painstaking investigation. The principles kept in view in selecting the methods were: "1st, that each process used should be as simple as possible, and should involve as little as possible of known liability to error; 2d, that different and independent processes should be resorted to as the means of checking each other's results, even though it may fairly be assumed that one is more advantageous than another; 3d, that each process should be carried out with quantities of material differing considerably from each other in successive experiments; and 4th, that only such other atomic weights should be involved as may be counted upon among those already known with the nearest approach to accuracy." All the reagents used were tested with the greatest care, vessels of hard porcelain or platinum replacing those of glass. The weighings were made on a Becker balance in perfect order and carefully adjusted. Where absolute weights were required the method of double weighing was employed. The weights were carefully compared with the standard kilogram in the Office of the Coast Survey, the relation of which to the kilogram of the Archives is known. The density of each weight used was determined, as also that of all vessels and materials which had to be weighed. The barometer and thermometer being noted at the same time with the weights, these latter could easily be reduced to vacuo. Three methods of determining the atomic weight were employed, a series of experiments being made by each method. These were: 1st, the ignition of ammonia alum; 2nd, the precipitation of the bromine in aluminum bromide by silver; and 3d, the evolution of hydrogen by the action of metallic aluminum upon sodium hydrate, the hydrogen being determined (1) by the direct measurement of its volume, and (2) by weighing the water produced by its oxidation. The ammonia alum of commerce, carefully purified from iron, and repeatedly recrystallized, was used in the first process. The aluminum hydrate was precipitated by ammonia free from the alcoholic amines, well washed, dissolved in hydrochloric acid and reprecipitated twice, then dissolved in sulphuric acid, the necessary quantity of pure ammonium sulphate added, and the alum recrystallized three times. The ignition was effected in a platinum crucible, to the cover of which was attached a wire carrying two perforated diaphragms to prevent the loss of

solid particles. After ignition at a bright yellow heat for an hour, inside of a second crucible, it was cooled and moistened with a strong solution of ammonium carbonate, and re-ignited. The crucible containing now pure Al_2O_3, after cooling was placed in a specially constructed glass bottle and weighed. For the second method, aluminum bromide was prepared directly by the action of bromine upon aluminum and carefully purified by repeated fractional distillations until it was perfectly white and boiled steadily at 263·3° under 747 mm. pressure, the last distillation being effected in a current of nitrogen. Pure silver was prepared and dissolved in pure nitric acid, the solution being used to precipitate the aluminum bromide. The amount of silver used was something less than required to completely precipitate the bromine, the process being completed by adding a graduated solution of silver from a burette. For the third series, pure metallic aluminum was prepared by reducing pure aluminum bromide by sodium in presence of potassium and sodium chlorides in a Beaufaye crucible lined with a mixture of alumina and sodium aluminate. A known weight of the pure metal was dissolved in a solution of sodium hydrate prepared from metallic sodium. The hydrogen was collected in carefully calibrated flasks over mercury in the first set of experiments, and reduced to the normal volume. In the second set, the gas was passed through a combustion tube containing cupric oxide, the water produced being collected in a calcium-chloride tube, a sulphuric acid and pumice tube and one containing phosphoric oxide, used successively. For the details of these experiments and the minute precautions used we must refer to the original memoir. In calculating the results of these experiments, the atomic weights of Dumas and Stas were used, viz: for O, 15·961; for S, 31·996; and for N, 14·010. As to bromine and silver, correction was made for the oxygen occluded by the silver in Stas's research, and thus the atomic weight of silver became 107·649 and of bromine 79·754. The results as calculated were as follows: 1st method, series A gave 27·040±·0073 as a mean of five experiments; series B, 27·096±·0054, also a mean of five. Second method, series A gave 27·034±·0049, series B 27·023±·0052, series C 27·018±·0069, A and C being from three experiments and B from five. Third method, series A gave 27·005±·0033 as a mean of six, and series B 26·990±·0046 as a mean of three experiments. Series A of the third method the author thinks entitled to most weight and series B, first method, to the least. The mean of all thirty experiments gives Al = 27·032±·0045. If 1, B be excluded, Al=27·019±·0030. Hence the atomic weight of aluminum is 27·02, or when integers are used for O, N, C, Na, etc., 27. The paper closes by calling attention to the fact that of the eighteen elements whose atomic weights have been determined with the greatest possible precision, ten approximate to integers within less than one-tenth of a unit. Hence the law of Prout would seem to deserve a reconsideration.—*Phil. Trans.*, 1003, 1880. G. F. B.

2. *On the light which appears on Metallic Electrodes which are placed in hydrogen gas at different pressures.*—O. LOHSE describes the spectroscopic appearance of glowing metallic electrodes placed in an atmosphere of hydrogen and of magnesium vapor. The apparatus consisted merely of suitable vacuum tubes, induction coils and a spectroscope. It appears from the observations that the dependence of the formation of metallic vapor upon the density of the gas surrounding the metallic electrodes can be studied quantitatively by the use of a constant current of electricity. It is also perceived that with increasing rarefaction of the hydrogen the light intensity of the metallic vapor increases in the more refrangible portion of the spectrum.—*Ann. der Physik. und Chemie*, 1881, No. 1. J. T.

3. *The b line in the Solar spectrum.*—Professor C. A. YOUNG, by means of a Rutherfurd grating of 17280 lines to the inch, and by means of the spectrum of the third order, has discovered that b_3 and b_4 are double and are distant from each other one-sixth of a unit of Angström's scale; also, that the line 5207·4 is double. These observations possess great interest, because it is claimed by Lockyer that these lines are basic—b_4 belonging to Fe and Mg, b_3 to Fe and Ni, 5207·4 Cr and Fe.—*Observatory*, 1880, p. 271–272; *Beiblätter Ann. der Physik und Chemie*, 1881, No. 1.

J. T.

4. *Action of an intermittent beam of radiant heat upon Gaseous matter.*—Professor TYNDALL in a paper read before the Royal Society, Jan. 3, 1881, reviews the criticisms of various experimenters upon his investigations in radiant heat, and believes their interpretations to be due to a failure on the part of the critics to recognize the strength of his position as a whole. He has taken up the subject anew and proposes to submit the results in due time to the Royal Society. In the meantime he has experimented upon gaseous matter with Mr. Bell's photophone. Reasoning that highly diathermanous bodies would produce faint sounds while highly athermanous bodies would produce loud sounds, it seemed that the strength of the sound could be made the measure of the absorption. He proceeded to test the truth of this reasoning by experiment. The first source of rays was a Siemen's lamp connected with a dynamo machine worked by a gas engine. A glass lens was used to concentrate the rays, and afterwards two lenses. A circle of sheet zinc provided at first with radial slits and afterwards with teeth and interspaces was caused to rotate rapidly across the beam near the focus. A flask containing the gas or vapor to be examined was placed immediately behind the rotating disc. From the flask a tube of India rubber ending in a suitable tapering one of ivory or box-wood led to the ear. Afterwards silvered mirrors were used in place of the lenses.

Sulphuric ether, formic ether, and acetic ether were placed in bulbous flasks and their vapor was diffused above the liquid. Loud musical sounds were heard when the intermittent beams passed through the vapor. These are the most highly absorbent vapors which Professor Tyndall had previously experimented upon. Very faint sounds were obtained from chloroform and bisulphide of carbon which are diathermanous. It was found that it was the vapor and not the liquid which is effective in producing the sounds. In general, the power of vapors to produce musical sounds can be accurately expressed by their ability to absorb radiant heat. Dried air, dry oxygen and hydrogen gave scarcely any effect. Carbonic acid gave a louder note than any of the elementary gases. Thus it was found that the gases stand in the same relation to the production of musical sounds that they occupy in regard to the absorption of radiant heat. The vapor of water was next tried and Professor Tyndall heard with delight a powerful musical sound. The method is then enlarged upon as a very delicate one to test the athermancy or diathermancy of gases and vapors. In a subsequent communication to the Royal Society, Professor Tyndall renews his enquiry into the effect of an intermittent beam upon aqueous vapor and confirms the results obtained by him nineteen years ago, and believes these results to be in entire disaccord with those obtained by experimenters who have ascribed a high absorption to air and none to aqueous vapor. In the later experiments a lime light was substituted for an electric light, and it was shown that the light of a candle was sufficient as the source of the intermittent beams. The author concludes that the vapor of all compound liquids will be found sonorous in the intermittent beam, and since he questions whether there is in nature an absolutely diathermanous substance he believes even the vapor of elementary bodies will be found to be capable of producing sounds.—*Proc. Royal Society*, Jan. 3 and Jan. 10, 1881. J. T.

5. *On the tones which arise in a gas as the effect of intermittent radiation.*—Professor W. C. RÖNTGEN has also recently investigated the effect of an intermittent beam of heat-rays in producing musical tones in a gaseous medium, being led to this series of experiments by the announcement of Professor Bell's results with the photophone. As the source of heat a Drummond calcium light was employed. The rays were concentrated by two lenses on a disk of pasteboard provided with a series of openings; the dish was arranged so that it could be rapidly and silently rotated about a horizontal axis. Behind the openings in the disk was held the absorption apparatus; this consisted of a tube 12 cm. in length closed by plates of rock salt; in the side of this was attached a short (1 cm.) tube closed with a piece of rubber cloth, which could be inserted in the ear of the observer. When the disk was rotated the heat rays alternately fell upon the absorption tube and were cut off from it, producing thus an intermittent effect. The tube was filled at first with air, but no effect could be heard. When, however, coal gas was introduced in the tube a very distinct tone was heard resembling the whistling sound produced by a strong wind. The strength of the tone did not change perceptibly with the time during which the tube was exposed,

but the tones ceased immediately when the rays were cut off by an opaque body, as the hand, or a piece of board placed before the disk. A solution of alum placed in the path of the heat rays also caused the disappearance of the tones, while no perceptible weakening was noted when the rays were made to pass through a layer 10 cm. thick of a solution of iodine. With ammonia distinct tones were also obtained, but dry hydrogen and oxygen behaved like atmospheric air. The cause of these phenomena is explained to be the alternate warming and expansion and the rapidly following cooling and contraction of the absorbing body, and, as might be expected, the effect was most distinct in the case of gases which have a strong absorptive power. The author closes by expressing the intention of determining the behavior of water vapor in this respect, with the view of deciding the question as to whether or not it exerts a strong absorptive power on the heat rays (see preceding notice, and p. 236, March, 1881).—*Ann. der Phys. u. Chem.*, Jan. 1881.

II. Geology.

1. *International Geological Congress at Bologna.*—The second meeting of this Congress will be opened on the 26th of September next, under the presidency of Sign. Quintino Sella. Sign. J. Capellini, at Bologna (65 Via Zamboni), is president of the Committee of Organization, and to him all correspondence should be addressed. The Congress at Paris in 1878 appointed two committees, to make reports at Bologna: one on the unification of geological methods of representation on maps and sections by colors and otherwise; a second, on the unification of geological nomenclature. A third was appointed to consider the question of rules of nomenclature of species in mineralogy and paleontology. The first of these Committees consists of Mr. Selwyn, of Canada, President; M. Renevier, of Lausanne, Secretary; and of Messrs. Ramsay, Liversidge, von Hauer, von Hantken, Gümbel, von Möller, Torell, Dupont, De Chancourtois, Giordano, Ribeiro, Lesley. The members of the second are, M. Hébert, of Paris, President; M. Dewalque, of Liège, Secretary; and Messrs. Hughes, Liversidge, Capellini, A. Favre, Rœmer, Szabo, Stephanesco, Inostranzeff, Lundgren, Vilanova, James Hall, Sterry Hunt. Those of the third, are, for Paleontology, Messrs. Cotteau, Douvillé, Gaudry, Gosselet, Pomel, De Saporta; and those for Mineralogy, Messrs. Des Cloizeaux and Jannettaz.

Persons intending to be present at the Congress are desired to give early information to Signore Capellini, stating fully their place of residence and particular department of study. The fee for members will be twelve francs; and this entitles the person to the "Compte rendu" and other ordinary publications of the Congress. The certificates of membership will be delivered at Bologna after September 20th.

M. Renevier, Secretary of the first of the Committees, has published a pamphlet, containing some of the reports on the colors for geological maps received by him from several of its members. In these reports the recommendation from the Swiss Committee agrees with those of France and Italy in proposing to distinguish the Cretaceous by a *green* color; Jurassic, by *blue;* Liassic, by *violet;* Triassic, by *brick-red*, Permo-carboniferous, by *gray*, and crystalline schists, by *rose-carmine*. It suggests *bright yellow* for the Eocene Tertiary, *pale brown-yellow* (jaune chamois) for the Miocene, and very *pale sepia* for the Pliocene and Quaternary together. The French propose *pale yellow* for Eocene, *reddish yellow* for Miocene, *red* for Pliocene and very *pale green* for Quaternary, and the Italian, *bistre* for Eocene, *reddish yellow* for Miocene, *clear yellow* for Pliocene, and very *pale green* for Quaternary. For the Devonian and Silurian, the Italian, French and Swiss have proposed but one color—evidence that the countries contain little of either of these formations.

2. *Geological terms for Stratigraphical Subdivisions.*—Looking at the earth's strata as a historical series, it becomes natural to divide geological time into ages or eras, periods and epochs. But in descriptive geology it is indispensable also that they should be subdivided stratigraphically. In English geological works the terms commonly employed for this latter purpose are: *formation*, *system*, *series*, *group*, *beds*, but with varied use. *Formation* and *system* are often interchanged; but (as also in Germany) the latter term has most general use. *Series*, *groups* and *beds* are variously employed, but almost always subordinately to formation or system. The word *terrane*, from the French *terrain* and Italian *terreno*, has been employed, but without defined restriction.

Prof. G. Dewalque, in vol. vii of the Memoirs of the Geological Society of Belgium (issued Feb. 1881), has discussed the signification of the terms used in French and Belgian works on geology, namely, *formation*, *terrain*, *système*, *étage*, *assise*, *zone*, *couche*. He cites D'Archiac's protest in 1847, against the confusion as to their use at that time in France, and shows that the confusion is hardly less now. He favors the rejection of the terms *formation* and *group* and would confine the former to its literal signification when reference is to be made to rocks of a kind as *calcareous formations*, *granitic formations*; and gives as the best terms and their best order, commencing with that of broadest signification, *terrane*, *system*, *stage*, *substage*, the last, made synonymous with "*assise*," and *group;* adding that the terms *series* and *zone* (the latter when characterized by particular fossils), may sometimes be used with convenience, though not made to distinguish any particular grade of subdivision.

As an example of his scheme, he cites part of a table of geological subdivisions by Renevier. In this table the Jurassic *terrane* includes four *systems*, the Portlandian (Portland beds); Corallian (coral rag); Oxfordian (Oxford oolite) and Bathonian (Bath oolite); and each of these *systems* contains three to four *stages*, e. g., for the Portlandian *system* the three *stages*, Purbeckian, Portlandian and Kimmeridigian; and so on.

The scheme sets aside English usage altogether—which would write (1) Jurassic *system* or *formation;* under this, Portlandian *group* or *series;* and, under this, Purbeckian (or Purbeck) *beds.* As is seen, it gives to the term *system* a place subordinate to *terrane*, and recognizes *four systems* in the Jurassic *terrane*; when the expression *four series* would imply about all there is of true system in the succession of beds. System exists in the geological formations chiefly through the fossils; but the system so founded is geologically of the most comprehensive kind, and hence the term *system*, if used, should be given to the grander subdivisions. But it is much better to have, in place of the abstract term *system*, one that refers directly to the objects classified, such as *terrane* or *formation*, because it is more appropriate and more pliant. D'Archiac, after systematizing his views on the subject, uses, in the later volumes of his *Histoire*, the term *formation* for the highest grade; then *group;* then *stage.* It is probable that a compromise might most easily be effected by adopting the term *terrane* for the highest grade, it having been already accepted in France, Belgium, Switzerland and Italy; and for the second grade, the term *group*, which has the widest usage in its favor. The scheme, thus modified, would be—putting in for the lowest grade two terms for choice:

(1) Terrane; (2) Group; (3) Stage; (4) Beds or Substage.

The desirableness of agreement on some common terms for Europe, Britain and America is beyond question. J. D. D.

3. *Metamorphic rocks—gneiss, mica schist, crystalline limestone and others—containing fossiliferous beds.*—The occurrences of fossils in connection with metamorphic rocks are facts of great geological interest, especially since they instruct as to the several periods in the past when such rocks have been formed, and throw much light on the true value of any determinations of the age of crystalline rocks based on their mineral constitution. Facts of this kind are here cited from two papers published in the Atti Soc. Toscana di Scienza Naturali (Pisa) of Nov. 14, 1880.

The first, by Professor G. Meneghini of Pisa, gives an account of *the occurrence of Orthocerata in limestone contained in beds of gneiss and mica schist in the Apuan Alps.* The strata in the Apuan Alps (situated to the northwest of Lucca, parallel with the coast), near Fociomboli and Puntato, include beds of thin schistose gneiss and mica schist, with other beds and marble above. In the lower of these groups, in the mica schist, about twenty feet below its top occur lenticular masses of limestone (making it a calciferous mica schist); and this limestone has afforded Meneghini a number of specimens of *three* species of *Orthocerata.* Two of them have a circular section, and a central siphuncle, and resemble Triassic species; but the third is elliptical in section, has an eccentric siphon, very short chambers, and is nearest to Paleozoic kinds, with which also the other two have near relations. At Mosceta, other specimens were found in calcareous beds in the upper schists of the series, part of which may be the same with no. 2, and others that are like no. 3, and have some affinity in interior structure to *Ormoceras tenuifilum* of Hall, and *O. crebriseptum* of Hall.

The second of the papers referred to, by C. De Stefani, reviews the facts as to the *Equivalency of the formations of the Apuan Alps* about Tirreno, Serchio, Fiume di Gragnana, Canale di Sermazzana, Aulella and Magra. The following facts are taken from his enumeration of the rocks of the Paleozoic and Mesozoic formations, with the name of the author who determined the true equivalency.

The Paleozoic beds include mica schist, damourite schist, gneiss, chloritic damourite gneiss, chlorite schist, chloritic argillyte, ottrelite schist, graphite, schistose crystalline limestone, bluish, cipolin, and other marbles.

The Triassic, overlying the Paleozoic, include (De Stefani, 1874,) the ordinary "grezzoni" and also albite-bearing magnesian and carbonaceous varieties, which contain Triassic fossils in Mt. Sagro, at Vinca (Savi in 1846), in Carchio, Corchia, and at other places; (2) Marbles, ordinary white, gray, cipolin (greenish to gray and brownish talcose), the statuary of Trambiserra, of Corchia, etc., and also mica schist and chloritic mica schist; and in overlying beds (*b*), other marbles both architectural and statuary, besides quartzyte, jasper rock, *staurolite schist*, damourite schist, graphite, chloritic damourite gneiss containing oligoclase, the latter with impure limestone; with Triassic *fossils in the bardiglio and other limestones* at Tambura, Roccandagia, and numerous other localities; also, at top (*c*), arenaceous beds, slates, gray and other limestones, with traces of fossils, and among them *Encrinus liliiformis*, species of *Cidaris*, *Pentacrinus*, *Chondrites*, etc.

Next follow the subdivisions of the Lias, the Tithonian or Purbeck and Wealden, the Neocomian and Gault of the Cretaceous, and the Tertiary.

4. *Bulletin of the U. S. Geological and Geographical Survey of the Territories*, F. V. Hayden U. S. Geologist-in-Charge. Vol. VI, No. 1.—The first article in this number of the Bulletin is on the Vegetation of the Rocky Mountain Region, by Asa Gray and Joseph D. Hooker. Then follow—by E. D. Cope, on New Batrachia and Reptilia from the Permian of Texas, on a Wading Bird from the Amyzon Shales, on the Nimravidæ and Canidæ of the Miocene, and on the Vertebrata of the Wind River Eocene of Wyoming; by R. W. Schufeldt, Osteology of *Speotyto cunicularia* var. *hypogæa*, and of *Eremophila alpestris;* by A. R. Grote, a Preliminary list of the N. American species of Agrotis.

The *Amyzon shales* of Cope are Tertiary lacustrine beds "in the South Park of Colorado, in N. E. Nevada and probably in Central Oregon," including those of Florissant; they are Upper Eocene or Lower Miocene. A bird from them of the Fringillidæ, *Palæospiza bella*, was described by J. V. Allen, in 1878 (Bulletin, iv, 443). The new *wading bird* is named by Cope *Charadrius Sheppardianus*, and was from near Florissant.

5. *Description of the Coal Flora of the Carboniferous Formation in Pennsylvania and throughout the United States;* by LEO LESQUEREUX. Vol. II. 1, *Lycopodiaceæ;* 2, *Sigillariæ;* 3, *Gymnosperms.* Report P of the Second Geological Survey of Pennsylvania. Harrisburg, Pa., 1881.—The text of the coal flora of L. Lesquereux's report is nearly ready for distribution; the atlas containing illustrations of the many species has been out for nearly two years. The following statement of the contents of the volume has been received from the author.

The first part of the report, covering 600 pages, contains along with an exhibition of the essential characters of the groups, families and genera, descriptions of 635 species of coal plants.

This part is followed by general remarks in chapters headed as follows: 1st. The nature of the vegetation of the Carboniferous era and its agency on the economy of the world, giving the history of the formation of the coal and a discussion of the different theories on the subject. 2d. The geographical and stratigraphical distribution of the Coal-measures. 3d. The amount of material comprising the flora. 4th. The United States coal flora compared with that of Europe. 5th. The geographical distribution of the plants in the Coal-measures. 6th. Their stratigraphical distribution, with a table of distribution of the species. 7th. On the origin, succession and modification of the vegetable types from the base of the Coal-measures upward.

This brings the work to the 684th page, after which follow the literature, containing an enumeration, with titles, of the works quoted in the flora, an index of localities, and another index of the Latin names.

III. BOTANY AND ZOOLOGY.

1. *The British Moss-Flora;* by R. BRAITHWAITE, M.D., F.L.S. —Dr. Braithwaite, having by his *Sphagnaceæ or Peat-Mosses of Europe and America* assured his position among bryologists, in the present work undertakes a series of monographs of the true Mosses of Great Britain, to be issued in parts, in systematic order. Three parts are already issued of this work, which is to comprise descriptions, full synonymy, and detailed illustration from the author's own drawings, of all the British species. These parts complete four families of the Acrocarpous Mosses, from *Andreæaceæ* to *Polytrichiaceæ* inclusive, the order and classification followed being that of Lindberg. The fourth part is announced to contain the *Fissidentaceæ.* The form of the book is imperial octavo, the letter-press full and all in English, the synonymy seemingly complete, and historical and critical matter well chosen and sufficiently abundant. The plates are admirable, not only for the drawings and judicious selection of the details, but for the lithography, which, so far as we know, is unequalled by anything of the kind in England. One thing only we should on our part desire, and may hope the author will in future supply;

and that is the geographical range of the species, at least as respects the northern hemisphere. For the British species being almost all indigenous to North America also, and this work being so satisfactory and of comparatively small cost and withal so handsomely executed, we should expect a fair demand for it in the United States, both from public libraries and from a good number of bryological students. To facilitate the acquisition of the work in this country, we may state that the talented author is his own publisher; that the price is fixed at the rate of one shilling per plate (on an average so far of about three species to a plate), letter press included, that a prepayment of 10*s.* 6*d.* will serve for a section of twelve plates and free delivery by post to any part of the United States; and that this may be made by money orders to R. Braithwaite, 303, Clapham Road, London, payable at Clapham Common office. The first section of twelve plates will be completed by the monograph of *Fissidens*, with three plates, now on the eve of publication. A. G.

2. *On the Origin of starch grains;* by A. F. W. SCHIMPER. (Botan. Zeit., 1880, and now published separately.)—The relations of the shape of the chlorophyll-grain to the form of the starch granules produced therein, are explained at some length, and the differences in the form are shown to be dependent upon the direction of the supply of nutritive material. Since the location and the course of the material from which the starch of the chlorophyll-grain originates cannot be the same for all parts of the grain, it necessarily results that the starch deposited must be unsymmetrical in form. But this lack of symmetry is more than simple irregularity; it is governed generally by the shape of the grain of chlorophyll in which the process takes place.

The production of starch in cells which are devoid of chlorophyll, and where of course the greater part of the supply of starch is deposited, is shown to be largely dependent upon the presence in the non-assimilating cells of highly refractive ellipsoidal bodies (sometimes spindle-shaped). Under the influence of light these bodies may be converted into chlorophyll granules. They are presumably identical with the bodies termed by Nægeli "*Brutblaschen*," and which were also noticed by Trécul. The different forms of these starch-producing bodies and the characteristic shapes which the deposits assume, are conveniently classified. The author holds a view which must steadily gain ground; namely, that the starch which occurs in chlorophyll granules is not the primary product of the assimilative process. The reexamination of this subject by Pringsheim and by those who have repeated his experiments, has excited a renewed interest in one of the most important as well as most difficult fields of research. This valuable paper is copiously illustrated. G. L. G.

3. *Botany of California*, Vol. II*;* by SERENO WATSON. Cambridge, Mass., John Wilson & Son, University Press, 1880. —The first volume of this flora appeared in 1876, and bore on the title-page the names of W. H. Brewer and Sereno Watson as

authors of the *Polypetaleæ*, and Asa Gray of the *Gamopetaleæ*. That the work is now finished is due mainly to the indefatigable industry of the botanist in whose name it is issued; that it is published, as we learn from a preparatory note, is owing chiefly to the zeal and liberality of Hon. S. C. Hastings, who solicited and obtained the necessary pecuniary means for this purpose. His fellow-contributors for the present volume were D. O. Mills, Henry Pierce, Leland Stanford, J. C. Flood and Charles Crocker, all of San Francisco.

The volume contains the Apetalous orders, the Gymnosperms, the Monocotyledonous orders, and the higher orders of Cryptogamous plants. As is usual in works of this character, some portions are contributed by special collaborators, Dr. Engelmann writing the Oaks, the Mistleto family and the Pines, Spruces, etc., Mr. Bebb the Willows, Mr. William Boott the Carices, Dr. Thurber the Grasses, and Professor Eaton the Ferns and Fern-allies.

To say that Dr. Watson's work bears evidence of being very carefully done, that his classification is mainly conformed to the approved modern standard of the British botanists, that his technical characters, of orders, genera and species, are concise yet exact and reasonably full, that his statements of habitat and range are well studied, and that his remarks appended to the generic and specific descriptions are judicious,—is too feeble praise. The work is more than good; it is admirable; it is in advance of anything of the kind which has ever been seen, and will long serve as a model for a flora, and as an exalted standard.

The author's great ability as a writer of Systematic Botany is especially evident in his treatment of the Mosses of the Pacific States. He has not been hitherto classed among American Bryologists, and has certainly not devoted year after year to the microscopic study of these little plants; but he has had before him the writings of Sullivant, Schimper, Lesquereux, Mitten, James, Austin, Mueller and others, as well as the rich collection in the Harvard Herbarium, and he has collated and reduced to one well-digested system the whole mass of abundant and often contradictory material, more successfully, impartially and judiciously than any living specialist could have done. The conspectus of the genera of Mosses must be regarded as a triumph of the art of applying to one class of plants the judicious systematic facility acquired in the study of other classes.

The many additional species of polypetalous and gamopetalous plants which have been collected in California since the first volume was published, together with a few additions to the second volume, are given in the latter part of this volume, making the whole complete up to the summer of 1880. Then follows an index to the whole work, a concise glossary of technical terms, and a very interesting "list of persons who have made botanical collections in California." This is more than a list of names, for it gives some brief account of all known collectors of Californian plants from Thaddeus Hænke, in 1791, to S. F. Peckham, in 1866. The principal more recent collectors are also mentioned.

The first volume, it will be remembered, bore on the cover a blossom of some prickly cactus, or *Cereus*, with the legend "E SPINIS FLOS," alluding doubtless to the blossoming out of the work from the midst of thorny difficulties. The second volume bears in like manner a branch and cone of the "big tree," *Sequoia gigantea*, with the motto, at once triumphant and prophetic, "RES TEMPORE MAGNA." D. C. E.

4. *The Gymnosporangia or Cedar-apples of the United States;* by Professor W. G. FARLOW. From the Anniversary Memoirs of the Boston Society of Natural History. 4to. pp. 38, pl. 2. Boston, published by the Society, 1880.—The results of Oersted's experiments on Gymnosporangium and Rœstelia, made some fifteen years ago, being quite generally accepted as evidence of their genetic connection, any consideration of the one naturally includes the other; hence the present paper is a monograph of both genera as represented in our country. From their structure the author recognizes the following species of Gymnosporangium, including Podisoma: *G. Ellisii* (Berk.), *G. clavariæforme* DC., *G. macropus* Lk., *G. fuscum* DC., *G. fuscum* var. *globosum* Farlow, *G. biseptatum* Ellis, *G. clavipes*, C and P., and *G. conicum* DC. The latter, however, is represented by so few specimens that its identity is not above suspicion. What has heretofore appeared in American catalogues as *G. fuscum* is found to differ strikingly from the European *fuscum*, and in the present paper is placed under that species as var. *globosum*, though it will probably sooner or later take its place as a distinct species. On anatomical grounds the following species of Rœstelia are recognized: *R. botryapites* Schw., *R. transformans* Ellis, *R. cancellata* Rebent., *R. cornuta* Fr., *R. lacerata* Fr., *R. penicillata* Fr., *R. hyalina* Cooke, and *R. aurantiaca* Pk. It appears, therefore, that each genus is represented by eight species, or, rejecting the doubtful *G. conicum* and uniting *R. lacerata* and *R. penicillata*, as is done by many writers, there are seven species of each.

Coming to the question of the genetic connection of the species of the two genera, it appears that Oersted has connected *G. clavariæforme* with *R. lacerata*, *G. fuscum* with *R. cancellata*, and *G. conicum* with *R. cornuta*. To confirm the conclusions of the Danish botanist, and to pair off the remaining species a series of careful cultures were made during the springs of 1876, 1877, 1878 and 1880, the sporidia of the various Gymnosporangia being sown on young plants or freshly gathered leaves of the Pomeæ which are attacked by Rœsteliæ. The results of these experiments are rather startling. Spermogonia followed very few of the sowings, and upon only two out of the seven plants chosen, namely, *Amelanchier Canadensis* and *Cratægus tomentosa*. On the former they appeared once after the sowing of *G. macropus*, but as æcidia were not found, and this plant supports three Rœsteliæ, it could not be determined to which species they belonged. On the other hand, the sowing of sporidia of *G. macropus* on *Cratægus tomentosa* was twice followed by the appearance of spermogonia, and a like result was experienced in six experiments when the sporidia of *G. fuscum* var. *globosum* were used, and once when *G. biseptatum* was employed; but neither of these is the species which Oersted connected with *R. lacerata*, the common æcidium of this Cratægus. The geographical distribution of the species is also such as would not be expected if Oersted's views are correct; for while the typical *G. fuscum* and its supposed æcidial form *R. cancellata* are found in nearly equal quantity, *G. clavariæforme* is not common, yet its so-called æcidium, *R. lacerata*, is very abundant, occurring at points where the teleutosporic form has never been found; and *G. conicum*, if this species be accepted, is a southern form, while *R. cornuta* is distinctly northern in its range.

The negative results of many of Dr. Farlow's experiments, the unexpected indications of others, and the lack of correspondence in the distribution of species which have been supposed to be connected, joined to the very contradictory results of recent European culture, must, therefore, be taken as indicating that if Rœstelia and Gymnosporangium really are connected, the relations of the several species cannot be accepted as demonstrated; and there is no little probability that the spermogonia produced in successful experiments may arise from mycelium present in the leaves when they are collected, and stimulated to growth by the altered conditions under which they are placed. W. T.

5. *Regeneration of lost parts in the Squid, Loligo Pealei.* Extract from Trans. Connecticut Academy, vol. v, p. 318, Feb., 1881; by A. E. Verrill.—"I have observed in this species, as well as in *Ommastrephes illecebrosus*, numerous instances in which some of the suckers have been torn off and afterwards reproduced. In such examples new suckers of various sizes, from those that are very minute up to those that are but little smaller than the normal ones, can often be found scattered among the latter, on the same individual. It seems to me possible that some ot the specimens having the suckers on the tentacular arms unusually small, may have reproduced all those suckers, or still more likely, the entire arm.

"I have seen specimens of this species, and also of *O. illecebrosus*, which, after having lost the tips, or even the distal half of one or more of the sessile arms, have more or less completely reproduced the lost parts. In such cases the restored portion is often more slender and has smaller suckers than the normal arms, and where the old part joins the new there is often an abrupt change in size. Probably this difference would wholly disappear, after a longer time.

"An unquestionable and most remarkable example of the reproduction of several entire arms occurs in a small specimen taken off Newport, R. I., Aug., 1880. This has the mantle 70^{mm} long, dorsal arms 22^{mm}, 3d pair of arms 30^{mm}. The three upper pairs of arms are perfectly normal, but both the tentacular and both the ventral arms have evidently been entirely lost and then reproduced, from the very base. These four arms are now nearly perfect in form, but are scarcely half their normal size on the left side, and still smaller on the right side. The left tentacular arm is only 24^{mm} long, and very slender, but it has the normal proportion of club, and the suckers, though well formed, are diminutive, and those of the two median rows are scarcely larger than the lateral ones, and delicately denticulated. The right tentacular arm is less than half as long (12^{mm}), being of about the same length as the restored ventral one of the same side; it is also very slender and its suckers very minute and soft, in four equal rows. The right ventral arm is only 14^{mm} long; the left one 15^{mm} long: both are provided with very small but otherwise normal suckers.

"In another specimen from Vineyard Sound, a female, with the mantle about 150^{mm} long, one of the tentacular arms had lost its club, but the wound had healed and a new club was in process of formation. This new club is represented by a small tapering acute process, starting out obliquely from the stump, and having a sigmoid curvature; its inner surface is covered with very minute suckers. The other arms are normal."

It seems probable that some of the nominal European species of *Loligo* that have been based on the smaller size of the tentacular arms or of the suckers are due to similar instances of regeneration of these parts.

IV. Astronomy.

1. ***Reports on the Total Solar Eclipses of July** 29th, 1878, **and January** 11th, 1880.* Washington, 1880. 4°, pp. xiv and 416, with about sixty plates.—This volume is published by the Naval Observatory, the arrangement and printing being under the care of Professor Harkness. The several reports are in the words of the observers, and the aim has been to reproduce as exactly as possible in the prints *fac similes* of the drawings.

Many of the principal results of the observations have in one form or another been previously given to the public. But the full meaning of them can only be deduced by careful comparison of these records with previous eclipse observations, and specially with the collection lately made by Mr. Ranyard. The reports are from over sixty observers, among whom are Professors Harkness, Newcomb, Watson, Holden, Hastings, Langley, Hall, Wright, Eastman, and Messrs. Trouvelot, Hill, and Rogers. Perhaps it is the observations upon the corona that will be regarded as of the greatest importance, as the larger part of the observers gave their attention to it.

2. ***Report on the Polarization of the Corona during the total Solar Eclipse of July** 29, 1878*; by A. W. Wright, Ph.D., Yale College.—This memoir forms pp. 261–281, with plates 24–28, of the report of the solar eclipse of July 29, 1878, issued from the U. S. Naval Observatory, Washington (see above). Professor Wright first gives an account of some preliminary experiments with artificial coronas, which served to make clear the special

difficulties to be encountered in the actual observations made and to test the efficiency of the means adopted. The forms of apparatus employed are described in full, including, among other things, a polarimeter of novel construction, and which proved most efficient in the actual work. The observations made during the eclipse are then given in detail. The results of the various observations made are summarized as follows:

(1) With respect to the character of the polarization, the observations made by three independent methods agree in showing that it is radial. The photographs appear to indicate some deviation of the planes of polarization from the direction of the radii, in four regions situated some 20° from the poles, where they seem to be deflected outward; that is, away from the solar axis. The amount of the deflection as well as its existence is subject to some uncertainty, for the reason that it may possibly be explained by certain peculiarities in the distribution of the intensity of polarization. The effect is more strongly marked in the northern hemisphere.

(2) The polarization decreases from the moon's limb outward, as shown both by the photographs and the polarimetric measurements. The latter show that for a space vertically beneath the sun, and distant between 4′ and 10′ from the moon's limb, it amounts to 12 per cent, and between 12′ and 18′ to 6·8 per cent, being still less for a point more remote.

(3) Around the circumference the intensity appears to be approximately uniform, except for a region about the poles, extending 20° each way, where it is somewhat greater.

(4) The observations afford no answer to the question whether the polarization is confined to the light which gives the continuous spectrum, inasmuch as the expected bright line spectrum was too faint to be observed.

(5) The conclusion seems to be warranted that the passage of the polarized rays through the terrestrial atmosphere produces but very slight effects, and none that can be definitely recognized in the results of the observations. The influence of polarization in the rays reflected by the atmosphere was inappreciable. The diffuse light of the sky may have had a slight share in diminishing the apparent polarization at the extreme outer border of the corona by dilution, but it is doubtful whether it was sufficient to make it necessary to take it into consideration.

3. *Memoirs of the Royal Astronomical Society of London*, Vol. XLI, 1879, with eighteen plates.—This thick volume is exclusively devoted to the solar eclipses, and is prepared by Mr. Ranyard at the suggestion of the Astronomer Royal. The plan of the work is to bring systematically together in separate chapters all the observations of solar eclipses, classifying them according to subjects. The volume contains 44 chapters, each devoted to a special subject, and includes all the eclipses that have been well observed down to, but not including, that of 1878. There is a very large amount of new matter, especially of details of the

structure of the corona as derived from the photographs of the eclipse of 1871. The plates show that this appendage of the sun is much more complicated in form than has been hitherto supposed.

V. Miscellaneous Scientific Intelligence.

1. *Soldering by Compression.*—M. W. Spring, after describing the apparatus he used, gives the following results in an elaborate research published in the Bulletin of the Brussels Academy of Sciences for 1880 (xlix, 323):

Powdered lead became perfectly solid, like a block obtained from fusion, under a pressure of 2,000 atmospheres, and with a pressure of 5,000, run like a liquid; bismuth became perfectly solid under a pressure of 6,000; tin, 3,000; zinc, 5,000; aluminum, 6,000; copper, like aluminum; antimony with more difficulty than aluminum, the compacted mass obtained under 5,000 atmospheres being more or less pulverulent at center; platinum, not consolidated.

Powdered transparent monoclinic sulphur became perfectly solid under a pressure of 5,000 atmospheres, but was changed to orthorhombic sulphur, which has higher density than the monoclinic; orthorhombic sulphur, under a pressure of 3,000; graphite, 5,500, becoming as solid as the best native graphite.

Alumina, in powder, obtained by precipitation of aluminum sulphate by ammonium carbonate, became perfectly solid and *translucent* with a *tendency to transparency* at 5,000 atmospheres, and had a bluish reflection, but without great hardness; at 5,000, it run like a liquid so that it could not be subjected in the apparatus to higher pressure.

Silica, in powder (using fine sand, and also precipitated silica), gave only a commencement of union under any pressure used. Gypsum became only imperfectly solid, it breaking early into bits. Chalk, under a pressure of 5,000 atmospheres, became as solid as the ordinary chalk crayons; iceland spar, under 6,000, became harder than chalk, but not quite firm. Precipitated lead carbonate gave no result; glass, no satisfactory result, under a pressure of 6,000 atmospheres.

Bituminous coal in powder became perfectly solid under a pressure of 6,000 atmospheres, and may be moulded at this pressure with the greatest facility, being plastic, "which explains how the flexing of ancient coal-beds became possible." Peat, under a pressure of 6,000 atmospheres, became a brilliant black solid, hard and looking like coal, with its organic texture completely obliterated; it was also plastic, "illustrating thereby the origin of coal," and showing that heat was not needed to produce it; moreover, it yielded a coke like that of mineral coal.

Charcoal (obtained by calcining sugar) underwent no change; and the same was true of animal black.

The author gives results from trials with various other substances—83 in all, and ends his paper with some general conclusions.

2. *Geodesy*, by Col. A. R. CLARKE, R.E., F.R.S., etc. Oxford, 1880. 8°, 356 pp.—This work supplies a want long seriously felt in the English literature of Geodesy. Its late date gives it the great advantage of comprising the most recent improved methods in observation and theoretical discussion. The treatment of the subject is simple, pertinent and condensed, while illustrations are gathered with rare discrimination from the governmental reports of all nations now prosecuting geodesic operations. Col. Clarke, who has long been connected with the Trigonometrical Survey of Great Britain, and of late years has had charge of its Geodesy, adds to the general didactic treatment of the subject a brief discussion of the figure of the earth as determined from geodesic measurements and pendulum experiments, showing that the ratio of the polar and equatorial axes of the terrestrial spheroid does not differ sensibly, so far as can be ascertained from existing data. By both methods the ratio of the polar and equatorial diameters is now found to be about 292 : 293. This work should be in the hands of every student of geodesy. J. E. H.

3. *Memorial volume of Benjamin Peirce.*—The editor of the Harvard Register, Mr. Moses King, has published, in tasteful form, a little volume designed as a memorial of Professor Peirce. It contains, after the introductory note by the editor, the notice of Professor Peirce published in the Register in May, 1880, a brief statement of his final illness and of the services at the funeral, with the address of the Rev. J. F. Clarke, delivered at that time; it also contains obituary notices reprinted from other publications, several memorial sermons, and a poem by Dr. Holmes. An excellent portrait of the eminent Harvard mathematician forms the frontispiece of the volume.

4. *The Atomic Theory*, by AD. WURTZ, translated by E. Cleminshaw. 344 pp. 8vo. New York, 1881 (International Scientific Series—D. Appleton & Co.).—Prof. Wurtz has given a very clear and simple statement of the historical development and present state of the atomic theory. The book is well adapted for the class of readers for which it is especially designed, and anyone, even with but comparatively slight previous training, may gain from it a knowledge of the general principles of chemical philosophy now accepted.

5. *The Third International Geographical Congress.*—The first International Congress was held at Antwerp in 1871, and the second at Paris, in 1875. The third will be held at Venice during the week commencing on the 15th of September next. The Geographical Exhibition will be opened Sept. 1st, and close not before Oct. 1. The Congress will be divided into seven sections: (1) Mathematical Geography, Geodesy, Topography; (2) Hydrography, Maritime Geography; (3) Physical Geography, Meteorology, Geology, Botany, Zoology; (4) Historical, Ethnographical, Philological Geography, History of Geography; (5) Economical, Commercial, Statistical Geography; (6) Methodology, Tuition of Geography; (7) Exploring and Geographical Expeditions.

Correspondence should be addressed to the Managing Committee of the Third International Geographical Congress, 26 Via del Collegio Romano, Rome. Information may also be obtained at the office of the English Monthly Review, MINERVA, 56 Piazza Montecitorio, Rome.

The President of the Italian Geographical Society is Prince Di Teano, and the Chief Secretary, G. Dalla Vedova.

6. *Illinois State Laboratory of Natural History.*—Bulletin No. 3, consisting of 160 pages 8vo, contains the results of extended personal observations by Mr. S. A. FORBES, occupying 130 pages, on the food of fishes and birds, besides notes, by the same, on Insectivorous Coleoptera; and also a paper by F. M. WEBSTER, on the food of predaceous beetles.

Reports on the results of dredging, under the supervision of A. Agassiz, in the Caribbean Sea, 1878–79, along the Atlantic coast of the United States during the summer of 1880, by the United States Coast Survey steamer "Blake," Commander J. R. Bartlett, U. S. N., commanding. Two reports have recently been published (Dec., 1880) in vol. viii of the Bulletin of the Museum of Comparative Zoology of Harvard College: Études préliminaires sur les Crustacés, par M. Alph. Milne-Edwards. 1re partie, pp. 1 to 68, with 2 plates; the other. A Preliminary Report on the Echini, by A. Agassiz, pp. 69 to 84.

Bulletin of the Buffalo Society of Natural Sciences, vol. iii, No. 5, contains, besides an important archæological paper, a description of a new Argulus by D. S. Kellicott, and a new Check-list of N. A. Sphingidæ, by A. R. Grote.

OBITUARY.

Dr. JOHN J. BIGSBY, F.R.S., founder of the Bigsby Medal of the Geological Society, died at Gloucester Place, on the 10th of February, at the age of eighty-eight. Dr. Bigsby was long a resident of Canada, and a very early contributor on geological subjects to this Journal. His first article appeared in the second volume, in 1820. In 1868 he published his "Thesaurus Siluricus: The Flora and Fauna of the Silurian Period," and in 1878, just three years since, his "Thesaurus Devonico-Carboniferus: The Flora and Fauna of the Devonian and Carboniferous Periods." Both works involved a vast amount of labor, and evinced that his energies and his interest in his favorite science continued long after the time when most men begin to rest from their work.

Professor E. BORICKY, of Prague, eminent in mineralogy and lithology, and the author of several valuable memoirs on the igneous rocks of Bohemia, died on the 27th of January at the age of forty.

Professor JAMES TENNANT, long connected with King's College, London, and well known as an active collector of minerals and gems, died recently at the age of seventy-three.

Mr. JOSEPH A. CLAY, a successful amateur mineralogist and a prominent member of the Philadelphia bar, died on March 18th, in his seventy-fifth year.

APPENDIX.

Art. XLI.—*A New Order of Extinct Jurassic Reptiles* (*Cœluria*); by O. C. Marsh. With Plate X.

The remains previously described by the writer, and named *Cœlurus fragilis*,* prove on further investigation to represent a new group of much interest. Portions of the skeleton of some ten or twelve different individuals have now been secured from the same horizon in the upper Jurassic that yielded the type specimen, and all are in the Museum of Yale College. A study of these remains, which are mostly vertebræ, shows clearly that they differ widely from the corresponding parts in any of the known orders of reptiles, living or extinct, but the nearest affinities of the new group cannot as yet be determined with certainty.

The most marked feature in all the known remains of *Cœlurus* is the extreme lightness of the bones, the excavations in them being more extensive than in the skeleton of any known vertebrate. In the vertebræ, for example, the cavities are proportionally larger than in either Pterodactyls or Birds, the amount of osseous tissue retained, being mainly confined to their exterior walls. In Plate x, a cervical, dorsal, and caudal vertebra are figured, with transverse sections of each to illustrate this point. Even the ribs of *Cœlurus* are hollow, with well defined walls to their large cavities. No limb bones of *Cœlurus* are as yet known with certainty, and those provisionally referred to that genus are, owing to their fragility, too imperfectly preserved for accurate determination.

The vertebræ of *Cœlurus* now known are from various parts of the column, and most of them are in good condition. Three of these are represented natural size in Plate x. The cervicals are large and elongate, and were locked together by strong zygapophyses. The first three or four behind the axis had the front articular face of the centrum somewhat convex, and the posterior one deeply concave. All the other cervicals were biconcave, and this was the case also with the vertebræ of the trunk and tail. The articular faces of the cervicals are

* This Journal, vol. xviii, p. 504, Dec., 1879.

inclined, showing that the neck was curved. The anterior cervical ribs were coössified with the centra, as in Birds. Figures 1, 1*a* and 1*b*, Plate X, represent a cervical vertebra from near the middle of the neck. The cavities in the cervicals are connected with the soutide by comparatively large pneumatic openings. The neural canal is very large, and traces of the neuro-central suture are distinct.

The dorsal vertebræ of *Cœlurus* are much shorter than the cervicals. The centra have a deep cup in front, and a shallow concavity behind. These articular faces are nearly at right angles to the axis of the trunk. The neural spine is elevated, and compressed. The transverse processes are elongate. The ribs preserved have undivided heads. A posterior dorsal is represented in Plate X, figures 2, 2*a* and 2*b*. The suture of the neural arch is distinct in this specimen. The foramina leading to the cavities in the dorsal vertebræ are quite small.

The caudal vertebræ are elongate, and very numerous. They are all biconcave, and all appear to have been without chevron bones. An anterior caudal is figured in Plate X, and the accompanying section shows the inner structure. In most of the caudals, the neuro-central suture has entirely disappeared.

Taking the vertebral column of *Cœlurus* as a whole it clearly indicates a large and powerful neck, a trunk of moderate size, and a very long weak tail. So far as the vertebræ suggest anything in regard to the limbs, those in front should be as large or larger than those behind, as in Pterodactyls, and not the reverse, as in animals that leap.

The characters given above prove conclusively that *Cœlurus* cannot be placed in any known order. Its remains preserved suggest resemblances to Dinosaurs, to Pterodactyls, and more remotely to Birds, and it is apparently a generalized Sauropsid, which, when fully investigated, may serve to bridge over some of the present breaks in the lines of descent. The sum of its known characters indicates that it is a reptile and not a bird. Its structure so far as known presents more similarity to that of Dinosaurs, than Pterodactyls, but for its nearer affinities we must await the discovery of further remains. An arboreal Dinosaur would not surprise anatomists familiar with the marvelous diversity of forms in that comprehensive group of reptiles.

The order represented by the remains here described may be termed *Cœluria*, and the family, *Cœluridæ*, from the type genus *Cœlurus*. The remains now known are all from the Atlantosaurus beds of the upper Jurassic of Wyoming Territory.

Yale College, New Haven, March 14th, 1881.

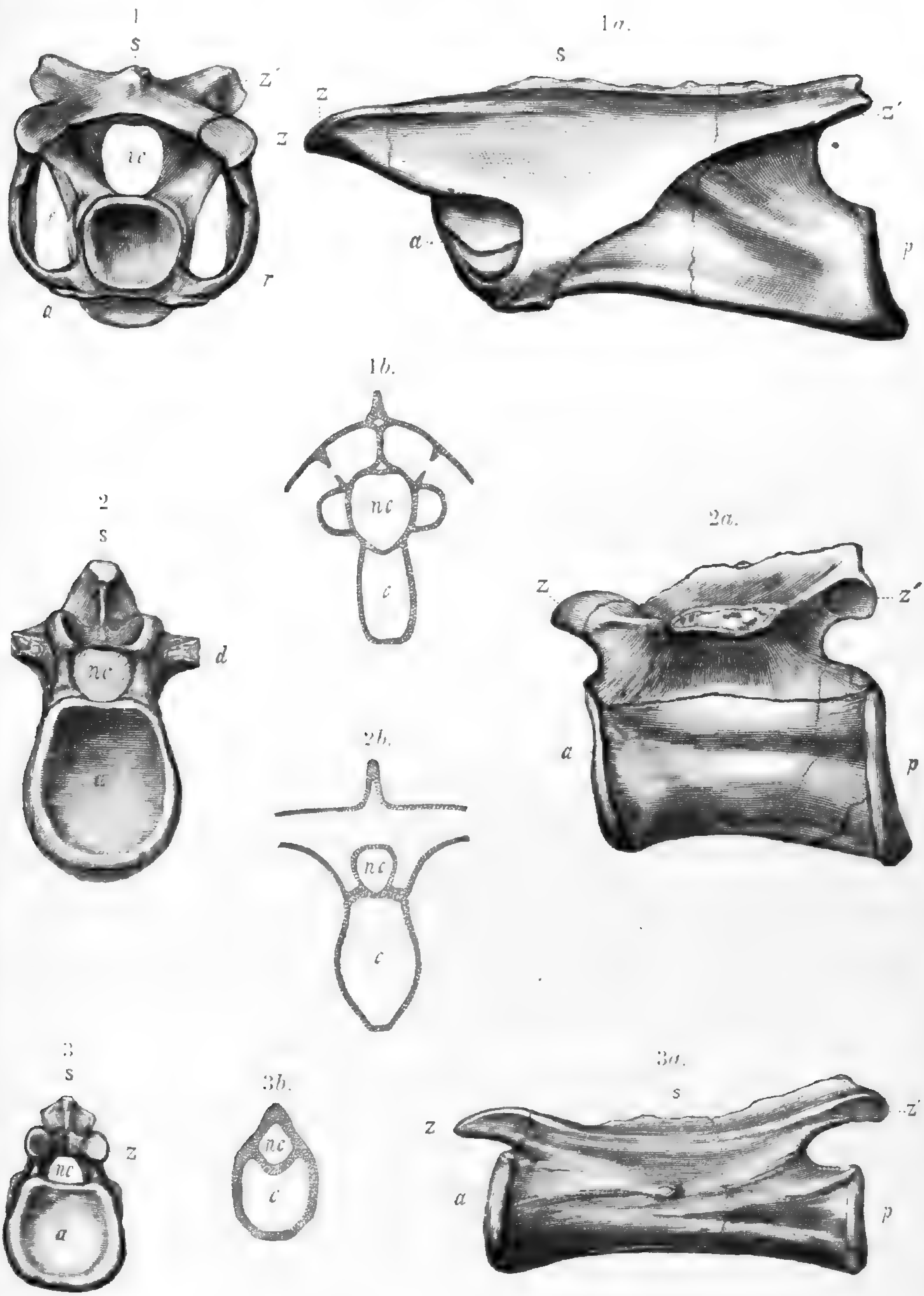


FIGURE 1.—Cervical vertebra of *Cœlurus fragilis* Marsh; front view. 1*a*. side view; 1*b*. transverse section of same vertebra.

FIGURE 2.—Dorsal vertebra of *Cœlurus fragilis*; front view. 2*a*. side view; 2*b*. transverse section of same.

FIGURE 3.—Caudal vertebra of *Cœlurus fragilis*; front view. 3*a*. side view; 3*b*. transverse section of same.

a. anterior, *p*. posterior; *c*. cavity; *f*. lateral foramen; *nc*. neural canal; *r*. coössified rib; *s*. neural spine; *z*. anterior zygapophysis; *z′*. posterior zygapophysis.

All the figures are of the natural size.

ART. XLII.—*Discovery of a Fossil Bird in the Jurassic of Wyoming;* by O. C. MARSH.

THE oldest Birds hitherto known from American strata are the toothed forms (*Odontornithes*), from the middle Cretaceous deposits, on the eastern flanks of the Rocky Mountains. In Europe, three specimens of the genus *Archæopteryx* have been found in the Jurassic, but from older formations no remains of this class have been brought to light. The writer has made a careful search for fossil Birds in the Jurassic beds of the West, and has been rewarded by the discovery of various remains, some of which are sufficiently characteristic for determination. The most important of these specimens is described below:

Laopteryx priscus, gen. et sp. nov.

The type specimen of the present species is the posterior portion of the skull, which indicates a bird rather larger than a Blue Heron (*Ardea herodias*). The braincase is so broken, that its inner surface is disclosed, and in other respects the skull is distorted, but it shows characteristic features. The bones of the skull are pneumatic. The occipital condyle is sessile, hemispherical in form, flattened and slightly grooved above. There is no trace of a posterior groove. The foramen magnum is nearly circular, and small in proportion to the condyle. Its plane coincides with that of the occiput, which is slightly inclined forward. The bones around the foramen are firmly coössified, but the supra-occipital has separated somewhat from the squamosals and parietals. Other sutures are more or less open. On each side of the condyle, and somewhat below its lower margin, there is a deep rounded cavity, perforated by a pneumatic foramen.

The cavity for the reception of the head of the quadrate is oval in outline, and its longer axis, if continued backward, would touch the outer margin of the occipital condyle. This cavity indicates that the quadrate had an undivided head. The braincase was comparatively small, but the hemispheres were well developed. They were separated above by a sharp mesial crest of bone. A low ridge divided the hemispheres from the optic lobes, which were prominent.

The following measurements indicate the size of the specimen:

Width of skull across occiput (approximate)	24·mm
Transverse diameter of occipital condyle,	5·
Vertical diameter,	4·
Width of foramen magnum,	5·
Height,	6·
Distance from occipital condyle to top of supra-occipital,	11·

In its main features, the present specimen resembles the skull of the *Ratitæ*, more than that of any existing birds. Other parts of the skeleton will doubtless show still stronger reptilian characters.

In the matrix attached to this skull, a single tooth was found, which most resembles the teeth of birds, especially those of *Ichthyornis.* It is probable that *Laopteryx* possessed teeth, and also biconcave vertebræ.

The specimen here described, and others apparently of the same species, were found in the upper Jurassic of Wyoming Territory, in the horizon of the Atlantosaurus beds.

Yale College, New Haven, March 18, 1881.

ART. XLIII.—*Note on American Pterodactyls;* by O. C. MARSH.

THE Jurassic deposits of this country, up to the present time, have yielded only a single species of *Pterosauria*—*Pterodactylus montanus* Marsh.* The known remains are all fragmentary, but some of them indicate the general characters of the species and genus. Among the remains now in the Yale Museum are portions of the wing bones, including the characteristic wing metacarpal and first phalanx. These bones, although pneumatic, show much thicker walls than the corresponding bones of other Pterodactyls, even those from the same formation in Europe, thus suggesting a less degree of specialization. The size of these specimens indicates a spread of wings about five or six feet. The scapula and coracoid do not appear to have been ankylosed. The vertebræ referred provisionally to this species are procœlian. The teeth found near the remains, and apparently belonging with them, are elongate, and more rounded than in most Pterodactyls.

The genus represented by these remains appears to be distinct from *Pterodactylus*, and may be termed *Dermodactylus*. The only known species will hence be *Dermodactylus montanus*.

AMERICAN CRETACEOUS PTERODACTYLS.

The representatives of the *Pterosauria* from the Cretaceous of this country all appear to be destitute of teeth, and have therefore been placed by the writer in the new order *Pteranodontia*, from the type genus *Pteranodon*. These are mostly of gigantic size, some having a spread of wings of nearly or quite twenty-five feet. These reptiles have one remarkable feature in the skeleton, unknown in any other animals. To aid the

* This Journal, vol. xvi, p. 233, Sept. 1878.

powerful wings in flight, the pectoral arch is strengthened, (1), by the anchylosis of several vertebra: (2) by the robust scapulæ articulating on opposite sides of the common neural spine of these vertebræ.* This is virtually a repetition of the pelvic arch, on a much larger scale. One genus of American Cretaceous Pterodactyls (*Nyctodactylus*) was apparently with out this feature.†

In the same geological horizon with the gigantic forms (Pteranodon beds), the remains of a single small Pterodactyl have been found. This animal was more diminutive than the Jurassic species, having a spread of wings not more than three or four feet. The jaws were proportionally more slender than in the larger Cretaceous species, and no teeth have been found with them. The humerus had a small head, and an enormous radial crest, which curved downward. The scapula and coracoid were firmly ankylosed. Some of the trunk vertebræ have very long transverse processes, or ankylosed ribs, curved backward. Some dimensions of this specimen are as follows:

Length of humerus,	62^{mm}
Greatest diameter of head,	12
Transverse diameter across radial crest,	30
Greatest diameter of distal end,	16
Vertical diameter of humeral glenoid cavity,	13
Transverse diameter,	6

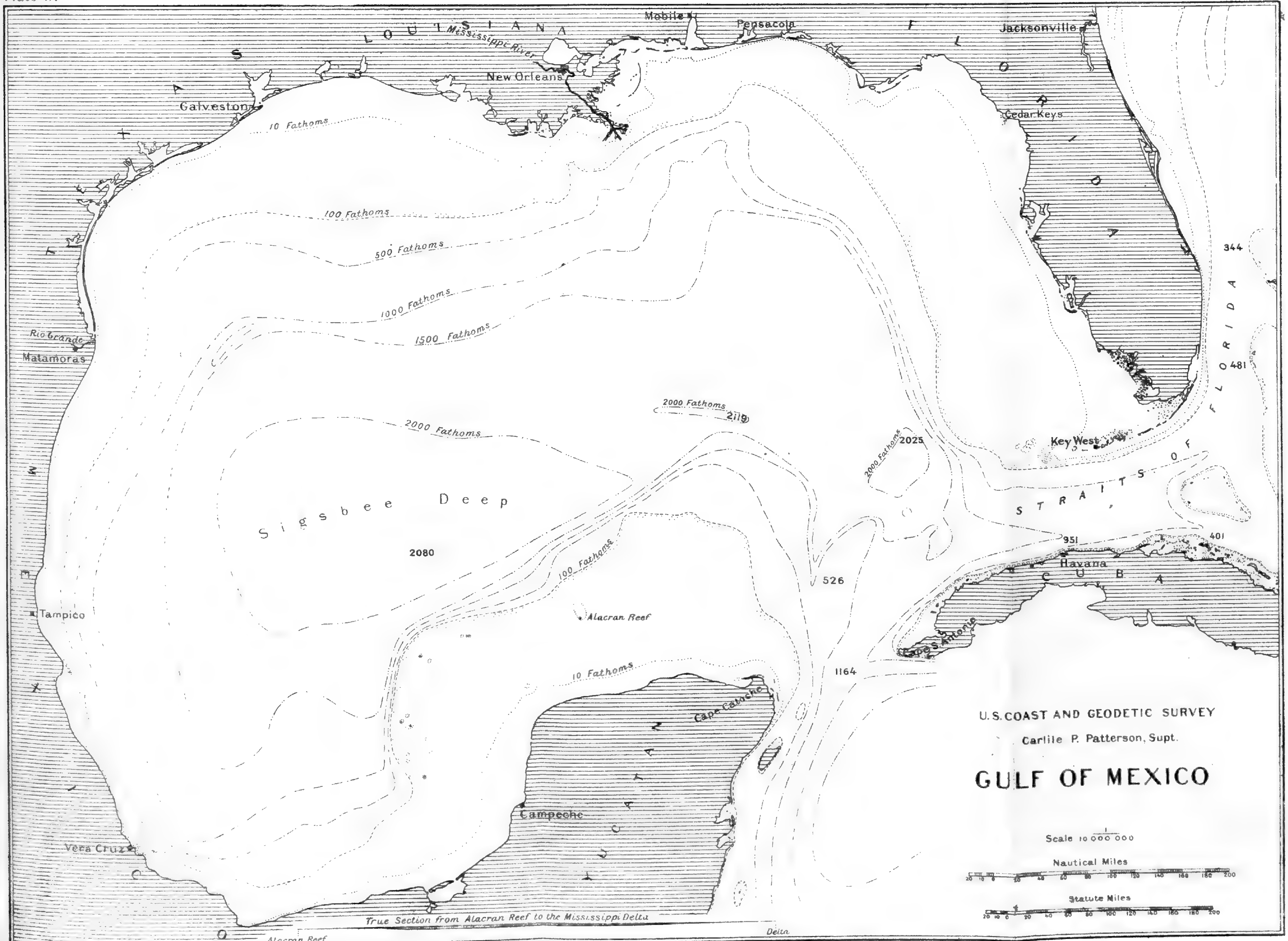
This species may be called *Pteranodon nanus*. Its known remains were found by Mr. S. W. Williston, in the Middle Cretaceous of Western Kansas.

Yale College, New Haven, Conn., March 21st, 1881.

* This peculiar neural spine with its opposite articular facets seems to be present also in some of the English Cretaceous Pterodactyls. Owen figured and described it as a "frontal bone (?)", (Pal. Soc. 1851, Sup. I, p. 12, Plate IV, figs. 6, 7 and 8), and Seeley regarded it as a "? vomer." (Ornithosauria, p. 88, Plate XII, figs. 15 and 16.)

† The name *Nyctosaurus*, applied by the writer to this group, appears to have been preoccupied, and hence may be replaced by *Nyctodactylus*. The only species known is *Nyctodactylus gracilis*.

Plate IX



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AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XLIV.—*On the Action of Frost in the arrangement of superficial earthy material;* by Professor W. C. KERR.

To a foreign geologist, entering the Middle and South Atlantic States for the first time, a hundred miles or more from the coast, the most striking and novel feature of the geology is the great depth of earth which almost everywhere mantles and conceals the rocks. This is readily discovered to be, for the most part, merely the result of the decomposition *in situ* of the exposed edges of the underlying strata. The vertical and highly inclined bedding lines of these strata,—Archæan schists, gneisses and slates,—are distinctly traceable by the eye through this superficial earth-covering, and are seen to pass by insensible gradations into the undecayed rock beneath. Its depth varies from a few feet to twenty or thirty, and sometimes twice that and more, being usually greatest on the slopes of the hills.

So much is obvious, to the most casual observation, in the railroad cuts, and in the gullies by the roadside. But a more minute and systematic study of these superficial earths soon shows that the matter is not nearly so simple and easily explicable. It very soon becomes evident to the careful observer that there are in fact three kinds of earthy layers, each having a different structure and origin. Their usual color is brick-red to brown of various shades, from the oxidation of the iron-bearing minerals.

The banded structure of the original rocks, above referred to as characteristic, being marked by difference in color and composition, according to the varying lithological and chemical constitution of the underlying strata, does not reach the surface, but fails at the depth of four or five to eight or ten feet or more, the materials above this being quite homogeneous.

This thin top layer is well nigh universal, and always recognizable. A little attention suffices to show that it owes its difference in structure and appearance to the penetration and the mechanical and chemical action of the roots of forest trees. The mechanical action of these roots has broken up and obliterated the lines of bedding and commingled the different materials, and their chemical action, living and in decay, has changed their composition and color, sometimes bleaching the whole mass in a degree which decreases with the depth, and not unfrequently in a very irregular manner, so that a section presents a pied surface,—red, of various shades, mingled with splotches of a gray, or pipe-clay color.

A second division of the superficial beds in question underlies (or replaces) the preceding, but is much less extensive, being found chiefly on the hill slopes and occasionally arching, in thinner mass, over the tops of flattish ridges and swells. It is found throughout the hill country and the mountain section of the State, being most conspicuous in the Piedmont, and passing, eastward, insensibly into the Quaternary deposits. The thickness varies from a few inches to twenty, thirty and even fifty feet, and the beds are very irregular in form. These deposits are best developed and may be most successfully studied in the gold gravels or placer beds of the State; but their structural features may be seen in the railroad cuts almost everywhere.

This division is, in general, readily distinguishable from the underlying mass, first, by a complete obliteration of the bedding lines and by a sharp line of separation, and secondly, (from both the other divisions) by a thorough commingling and a more or less obvious (if generally partial) rearrangement of its materials,—an obvious *tendency to restratification*, in an approximately horizontal direction. This generally consists merely in an aggregation of the coarser materials of the beds toward the bottom, or along certain horizontal lines.

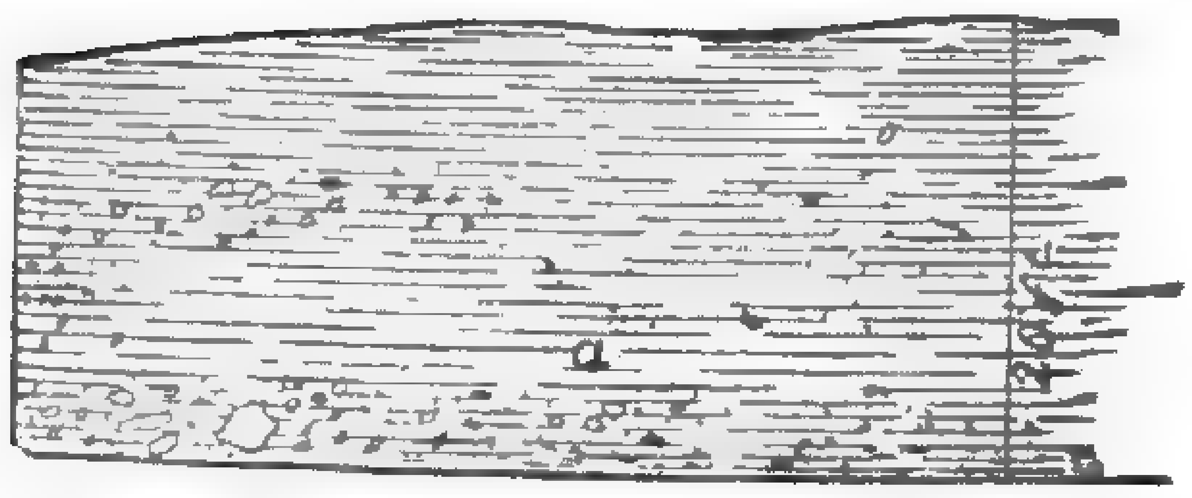
This and other features of these beds will be best understood from a few diagrams. Figure 1 represents a section seen

1.

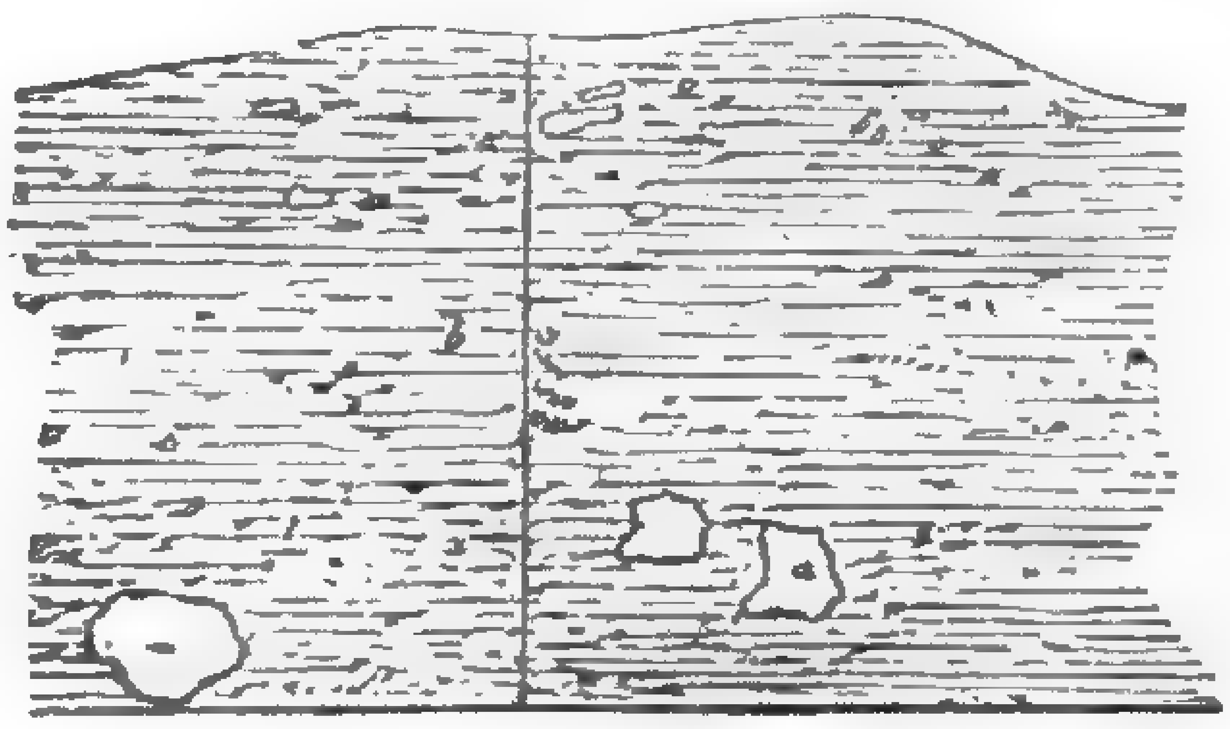
2.

in a railroad cut near Henry Station, not far from the eastern base of the Blue Ridge in McDowell County. We have here a mass of earth with fragments of rock, mostly quartz, of various sizes, in a nearly homogeneous accumulation, with scarcely a discernible arrangement. Figure 2 represents a similar deposit of much less depth, in a railroad cut at Cary, near Raleigh; and figure 3, one near Rockingham, in Richmond

3.



4.



County, the last two near the margin of the Quaternary deposits. In figure 4, from the same locality as figure 1, we have an accumulation of coarser and more heterogeneous materials. In the three former cases, there was simply earth with small fragments of quartz; in the latter, besides quartz fragments and bowlders a yard in diameter, fragments, large and small, of gneiss and hornblende slate and other underlying rocks. In figure 5 the deposit is shown as capping the summit of a hill, a phenomenon of not uncommon occurrence in the Piedmont region: the section here shown is found near Old Fort, in the upper Catawba Valley. In this and in figure 6, two points are illustrated, viz: the partial arrangement of the materials, the accumulation of the larger fragments and pebbles toward the

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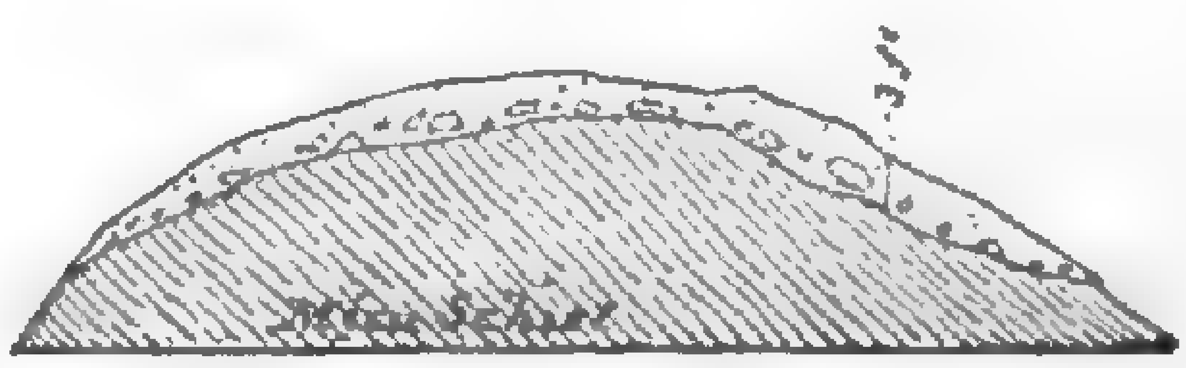

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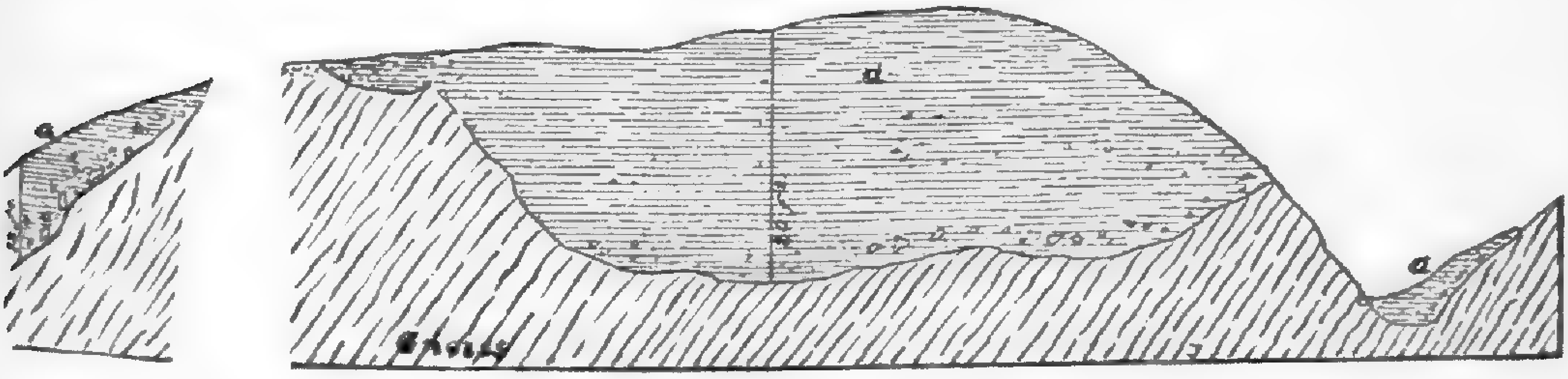

bottom of the beds, and along certain horizontal planes, and the complete independence of these deposits on the form of the surface on which they lie. They also illustrate another important point, viz: that the present topography of the surface is the result of *an extensive erosion, subsequent to the accumulation of these deposits*, so that the hills and valleys of the present and the subjacent topography have often changed places, and these present deposits are mere remnants of much larger and wider accumulations which once filled up the valleys and mantled over the hills and obliterated the features of a former topography. This conclusion is abundantly attested by numerous observations.

Figure 7 brings out another common feature,—the occurrence of periods in the deposits, or of several deposits one upon another. This section is taken from a gold placer in Brindletown, Burke County, near Morganton, at the foot of a little mountain, called the Pilot, the lower slopes of which, next the valleys and streams, are covered with placers of varying depth, up to fifty feet. The same thing is shown in another placer mine on the same side of the mountain, a section of which is given in figure 8. The division between the successive beds at this point is not as sharp as represented in this diagram, although in many cases they are so. The lowest stratum (1) which lies on the decomposed gneiss and mica schist (the slate of the miners), is a four to five foot stratum of slightly rounded quartz fragments of an inch or two to six inches in diameter, the interstices filled with gravel and earth, —a coarse half-compacted conglomerate, which gives place, upward, to a bed of gray, or ash-colored earthy clay (2), six or eight feet thick, above which lies twenty-five to thirty feet of red gravelly earth (3), with a few small scattered quartz fragments.

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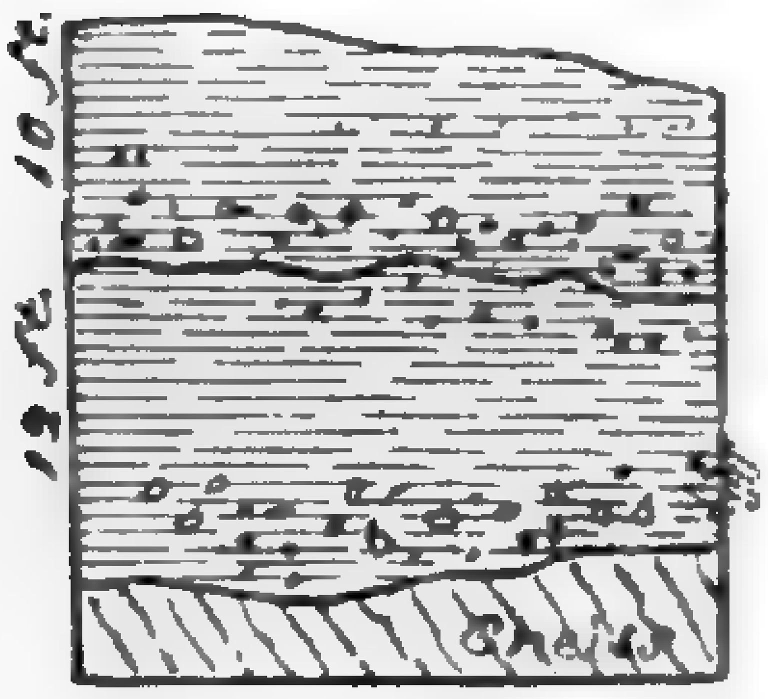

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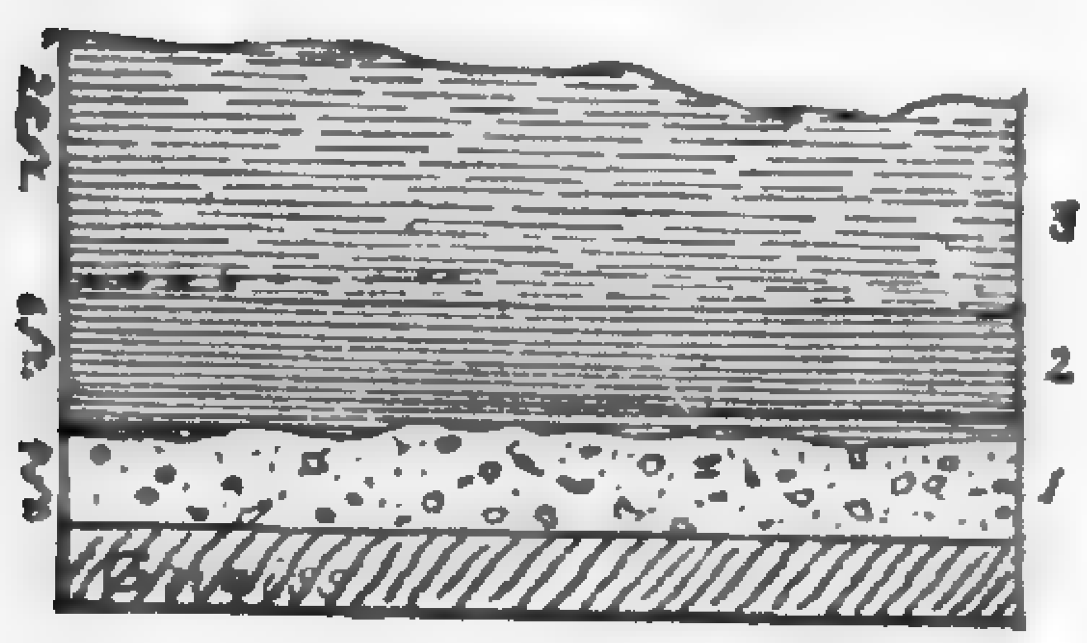

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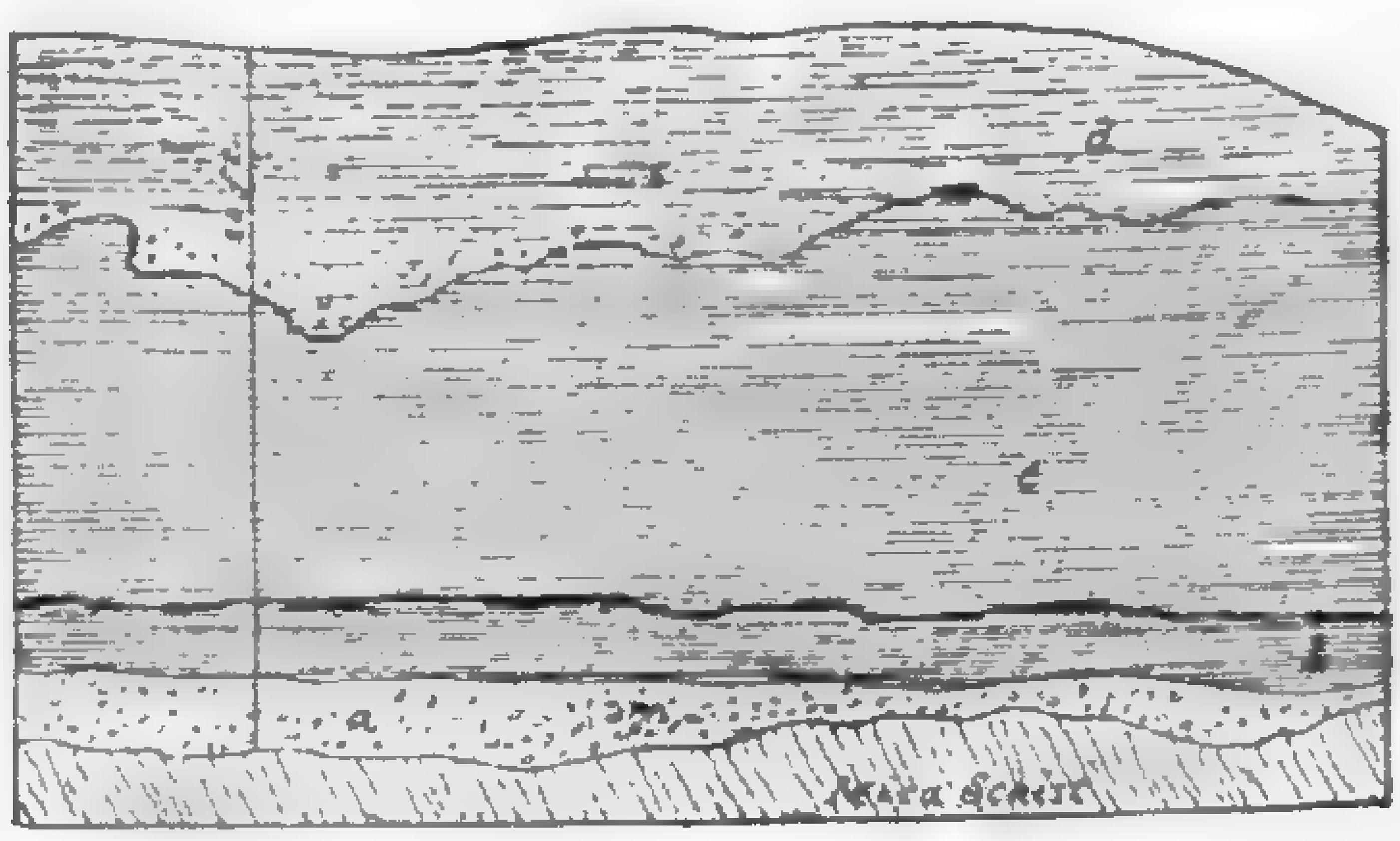

Figure 9 represents another similar deposit half a mile distant from the last, the section being taken, as were the last two, in the gold mines of Col. J. C. Mills, the last at the eastern base of the Pilot, and at a somewhat lower level. The two lower division lines, in this case also, are a little too sharp, the only distinct breach of continuity being found between the strata *c* and *d*: *a* and *b* shading into each other, somewhat abruptly, and so *b* into *c*. In this section *a* and *c* correspond to 1 and 2 of figure 8, *b* being an interpolation, and furnishing the explanation of the bed 2. This interpolated bed is a peaty, black, gravelly soil, with blackened stems and bark of trees and fragments of wood and grass blades, roots and stems. The bleaching of bed 2, figure 8, and of *c*, figure 9, is evidently due to the solvent action of the humous acids from the old soils of the slopes from which this deposit came.

Figure 10 is a section in a railroad cut near Statesville in Iredell County, which shows two muck beds *a*, *a*, in contigu-

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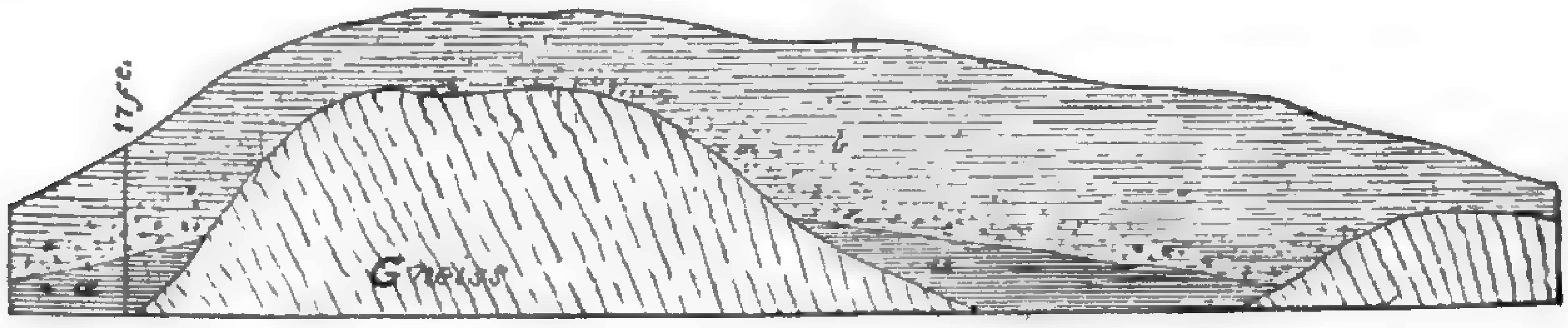

ous depressions which have been buried deeply by earthy accumulations, which show only a slight tendency to stratification, in the apparent *settling* of the quartz fragments.

Now in none of the foregoing sections is there any indication of a proper stratification by the action of water. Indeed it is clear enough that the action of water is excluded by the most obvious features of these deposits. It is proper to say here, however, that there are deposits here and there, which do show traces of such stratification; and occasionally, in certain situations, deposits like those above described, in some parts of them, show slight and partial indications of water action. These, however, are exceptional, and constitute a class by themselves, and need not detain us here.

The diagrams above given represent the general character of hundreds of sections to be seen along any of our railroads. They offer no hint or suggestion as to the origin of these deposits, the cause or mode of their formation. The most frequent and conspicuous of these phenomena are seen, as stated above, in the Piedmont. The railroads of necessity follow the course of the river valleys, and the sections are consequently those of the lower ends of the jutting hills and spurs which slope down into the margins of the plains: that is, they are transverse sections of these ridges and slopes. It goes without saying, that the arrangement of the materials of these deposits, the *settling* of the heavier elements, can only have occurred in consequence of some sort and degree of movement of the mass. It is equally evident that such movement, whatever its cause, must have been in the direction of the slope of the surfaces on which they lie, that is, at right angles to the usual plane of section. And it is only by observing the relation of the arrangement or settling, to the situation on the slope, and by studying this arrangement at different elevations along the line of movement that a clew to their origin could be had. The gold mines, at different elevations near the base of the Pilot, furnished the opportunity for such comparison. It was thus seen that the distribution of the materials of these deposits at their upper portions is represented by figures 1, 2 and 4; at a lower point by figures 3, 6, 7; and still lower by 8, 9. That is to say, a *longitudinal* section, down the slope, would be expressed by figure 11. Above, toward the left of the figure, the angular fragments of rock are distributed

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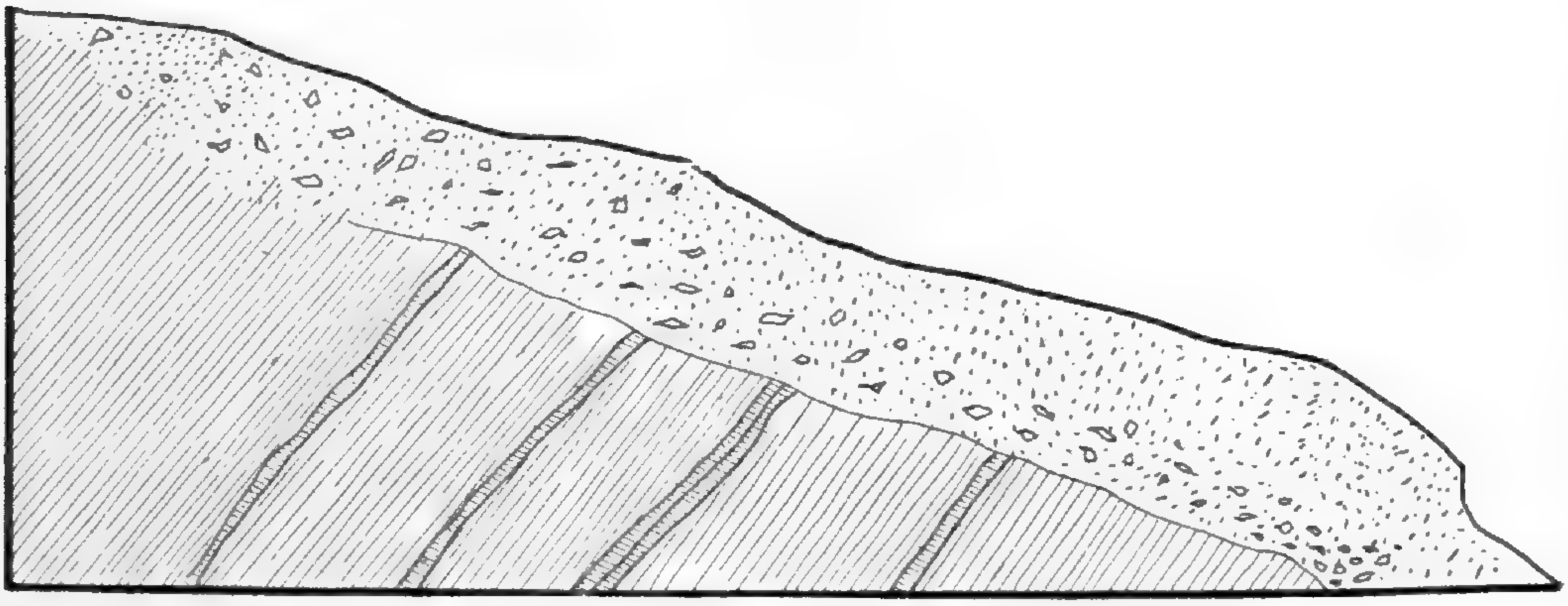

through the mass, but they are seen to descend, and to accumulate with the descent, toward the floor of the deposit and to become more rounded. It may be stated here that the coarse particles of gold in these placers are found with the pebbles,—gravel, and where these have accumulated at the bottom, only this part of the deposit is usually wrought, unless water is abundant; but at higher levels, where the gravel is scattered through the mass, the coarse gold is equally diffused.

The movement down hill then is evident, and the degree of arrangement or settling is proportioned to its amount. Of course the first suggestion that occurs, on this presentation of facts, will be that gravitation may have given rise to the motion. But this theory would not be entertained for a moment by one familiar with the actual sections. These deposits occupy the *lower slopes* of the hills, just where they meet the plains, the inclination varying from two or three to ten and rarely twelve degrees. This is obviously quite insufficient to give rise to any sensible movement from gravitation. Such movements of loose earth and stones do occur, but only on steep slopes of 40° and upward; and such accumulations are not uncommon at the foot of steep declivities; but these are distinguishable at a glance from the deposits in question. And further, instances are not unfrequent of the movement of these deposits on a dead level, and even *up hill*, over local obstructions or irregularities of surface.

The following diagrams illustrate these points, and show the grounds on which the theory adopted for the solution of the problem of the formation of these deposits rests.

Fig. 12 represents a section in a railroad cut near Morganton, which gave the first hint of the true theory of the origin of these beds; and fig. 13 is a similar section ten miles west of the former, near Muddy Creek bridge. In both these cases the vein (shown at *a*) is distinctly seen to be the source of the jointed, rhomboidal quartz fragments which are scattered along the floor of the deposit toward the right hand end of the diagram, a distance of one to several rods.

12.

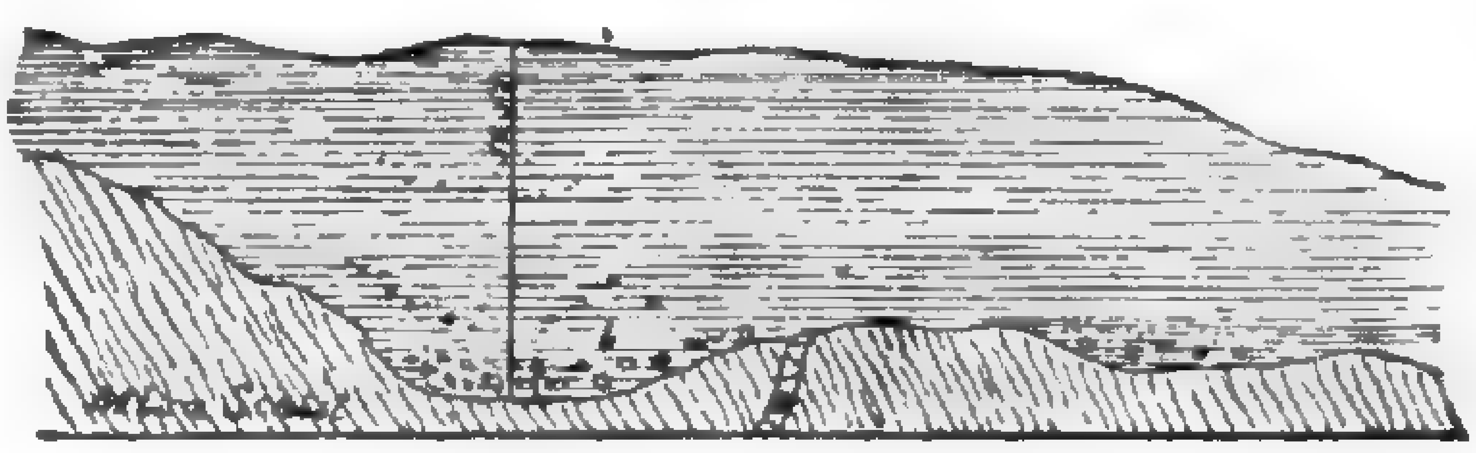

Fig. 14 represents the opposite side of the same railroad cut as fig. 12. In this the fragments are scattered right and left from the vein.

Fig. 15 is a similar section from a railroad cut in Richmond county, near the Peedee river. In this case a large quartz vein in a chloritic argillaceous slate has been broken down by the denudation which the rocks have undergone, and its fragments have been carried to the left and have settled part way through the moved mass, the upper portion of which has been removed by subsequent erosion.

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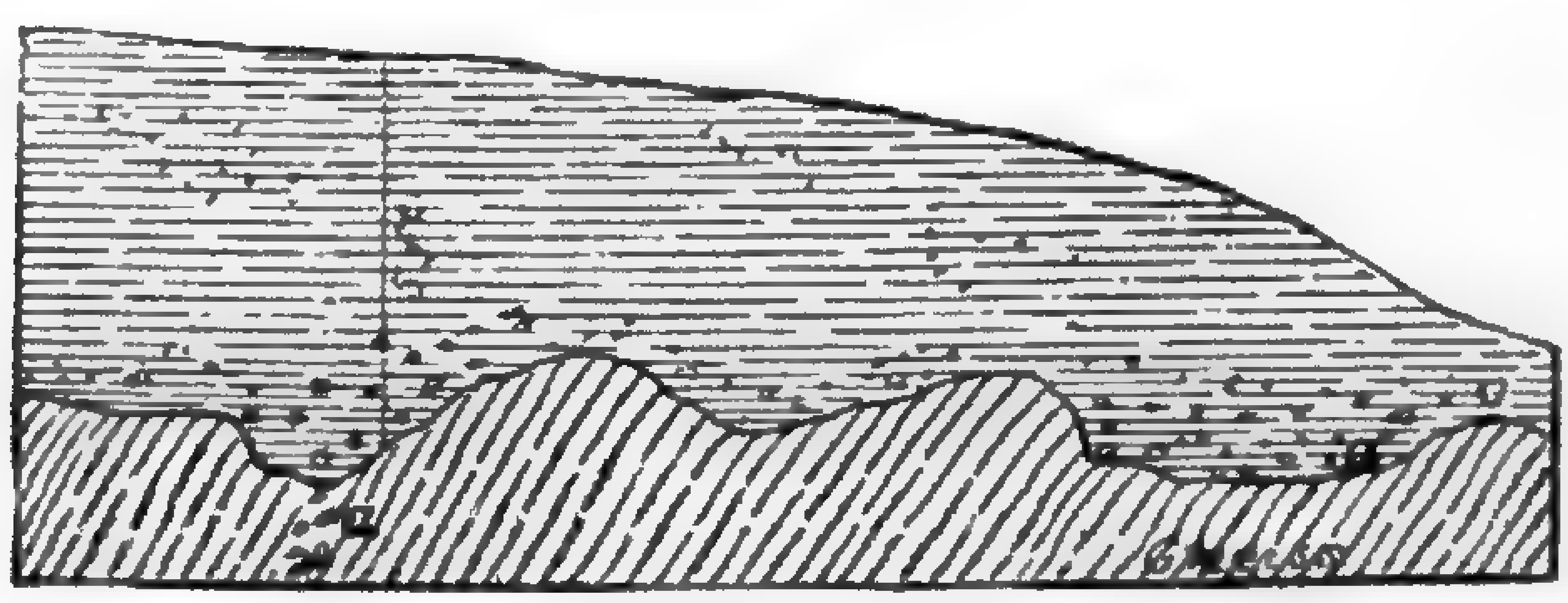

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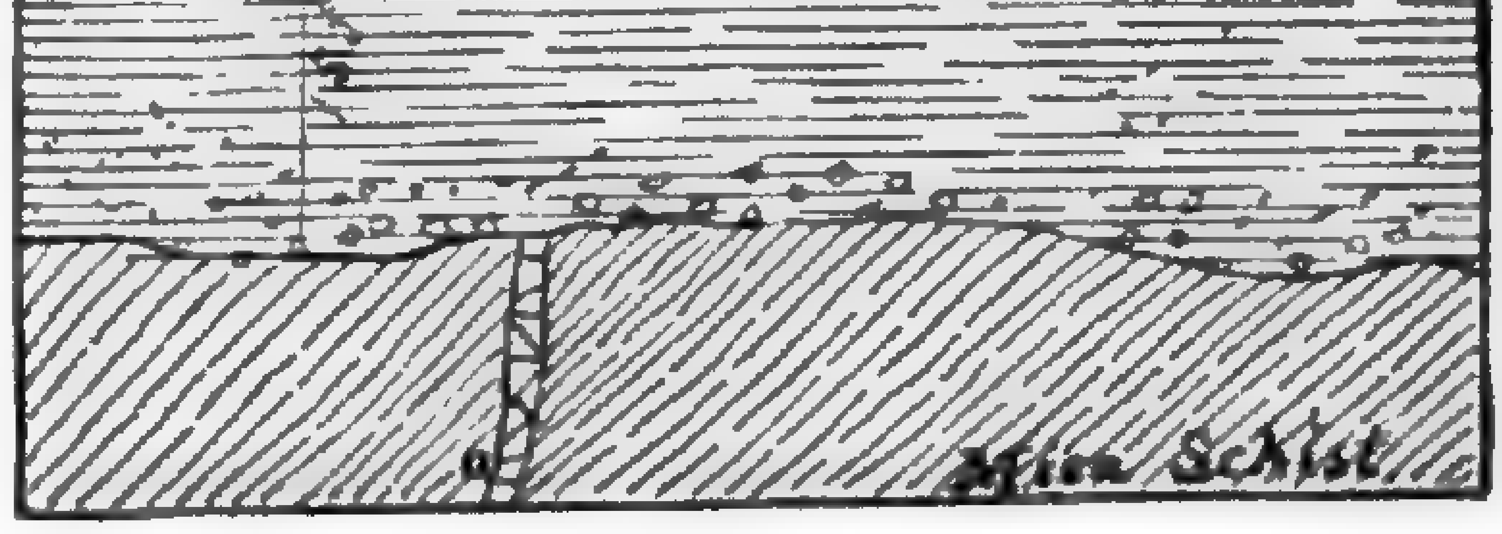

Fig. 16 represents the first stages of movement across a small vein. This is a quartz vein seen in section in a gold mine on the slopes of the South Mountains, near Brindletown. The thin-bedded, soft, decomposed mica schists are intersected by numerous small veins and seams of a granular (saccharoidal) quartz, varying from a usual thickness of one to three inches (occasionally four to six) down to a mere line. These thin veins and seams are so numerous in places, and contain so much free and loose gold in the crevices and on the walls that

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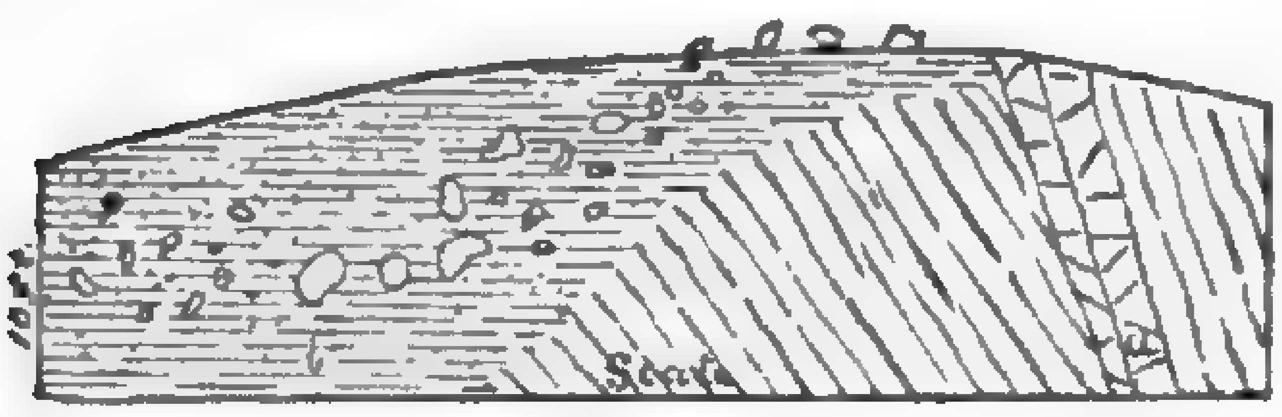

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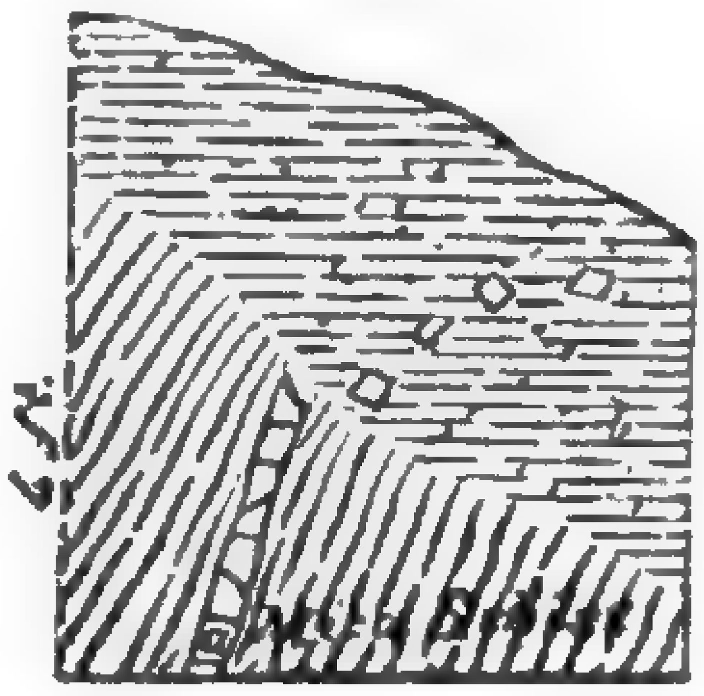

it is profitable to sluice down the whole mass. The quartz is also rich enough for milling, yielding from ten to forty dollars to the ton. Other illustrations of these veins may be seen from the same mine in figs. 19 to 21.

It is clear, then, that these deposits were not accumulated by the action of water, nor by gravitation; and they present none of the features by which glacial deposits are usually recognized. No precisely parallel phenomena seem to have been observed elsewhere, or they are not recorded. And they remained an enigma to me for several years; and until such sections as shown in figs. 12 to 16 were discovered and studied. In these, and in those subsequently found in the gold placers, the character and amount of movement were clearly revealed.

The explanation which these facts have suggested, and which subsequent observation in this State and in other States has fully confirmed, is that the movement in question, to which the gradual settling of the heavier particles and fragments through the mass is due, *was produced by frost*, and that these deposits *are of glacial age.* As the earth is often frozen, in Canada and even in Vermont, during severe winters to a depth of eight or ten feet; and as in Labrador and other sub-arctic regions the frost of the present winters penetrates to a much greater depth, so, it is evident, that during the prevalence of the great ice sheet over the northern end of the continent, as far down as Pennsylvania, and the prevalence of an arctic climate in these middle latitudes, the earth was annually frozen to a depth equal to the maximum thickness of these deposits. The alternate freezing and thawing of the saturated mass of decayed rocks, constituting the pre-glacial surface, would of necessity produce just the movement and settling which are described above. That is, this freezing and thawing would give rise to precisely the same movements of the mass, and of the particles *inter se*, as are seen to occur in the true glacier, *differing only in amount.* In other words, these masses were *earth glaciers*, and these deposits may be denominated *frost drift*, as distinguished from proper glacial drift.

I do not see how these conclusions can be avoided. It seems evident that such phenomena must have occurred during the prevalence of cold of the intensity which an admitted arctic climate must have produced. And, if so, similar effects must be produced in arctic climates, and to some extent in the high latitudes of climates less intense, to-day. And, if so, too, similar phenomena may be expected to be found in regions farther north, produced during the retreat of the ice when these regions were successively subjected to the same degree of cold. Of course these effects would be visible only in exceptional localities, where the surface was not buried under glacial debris, and where the exposed rocks were capable of comparatively rapid disintegration. And, in fact, I have seen in Philadelphia and vicinity, phenomena which plainly come under this class. During the Centennial Exhibition, Market street was extended westward a square above Forty-fourth street, and a hill of some twenty feet was brought to grade in the process. Happening to pass during the excavation, I took a sketch of the exposed section, which is given in fig. 17. The

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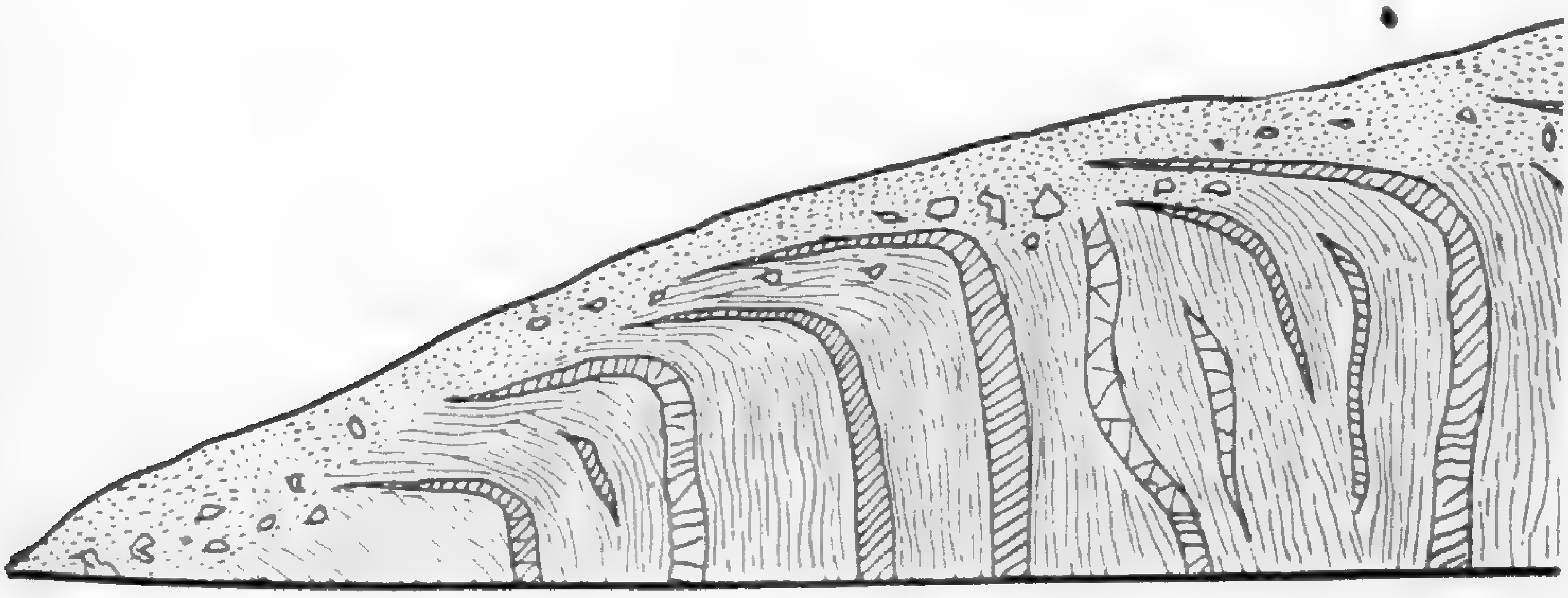

rock is gneiss and mica schist with hornblendic and chloritic strata, inclined at a high angle, and decomposed, for the most part, the entire depth of the cut, presenting a banded section of variously colored earths. The most striking and novel peculiarity of this section is shown in the sketch, viz: the gradual drawing out,—attenuation of these colored bands, as the parts of them in succession were moved down the slope. This section furnishes a new illustration of the character of the relative motion of the different parts of the mass.

As the thickness of the deposit at this point is not more than three to four feet, and there was no reason to suppose any recent or rapid denudation, the probability is strong that it is of recent (*present*) origin, the existing climate of Philadelphia being equal to the production of such effects. Fig. 18 represents a similar section in a drift of a mica mine in Yancey County, this State, near the base of the Black Mountain.

Among the inferences from the above conclusion, in the way of a corollary, is this important one, that the deep decomposition of the rocks of these latitudes has been effected entirely in post-glacial times, since the movement of these earth glaciers would sweep away every thing movable, down to the solid rock; and the frost was sufficient to carry the movement to the greatest depths of previous decomposition. And this conclusion is confirmed by two observations; first, that the force which was sufficient to remove the bowlders and rock fragments which often constitute the lower portion of these deposits—frequently of several tons weight, would abrade and remove every thing but the solid rock; and second, that the irregular form which the floor of these deposits often exhibits, as seen, for example, in fig. 13, corresponds to the unequal decomposition of the different strata of these very variable schistose rocks. This of course excludes any theory like that sometimes broached, which undertakes to account for this phenomenon, by invoking the action of a paleæval atmosphere surcharged with carbonic acid.

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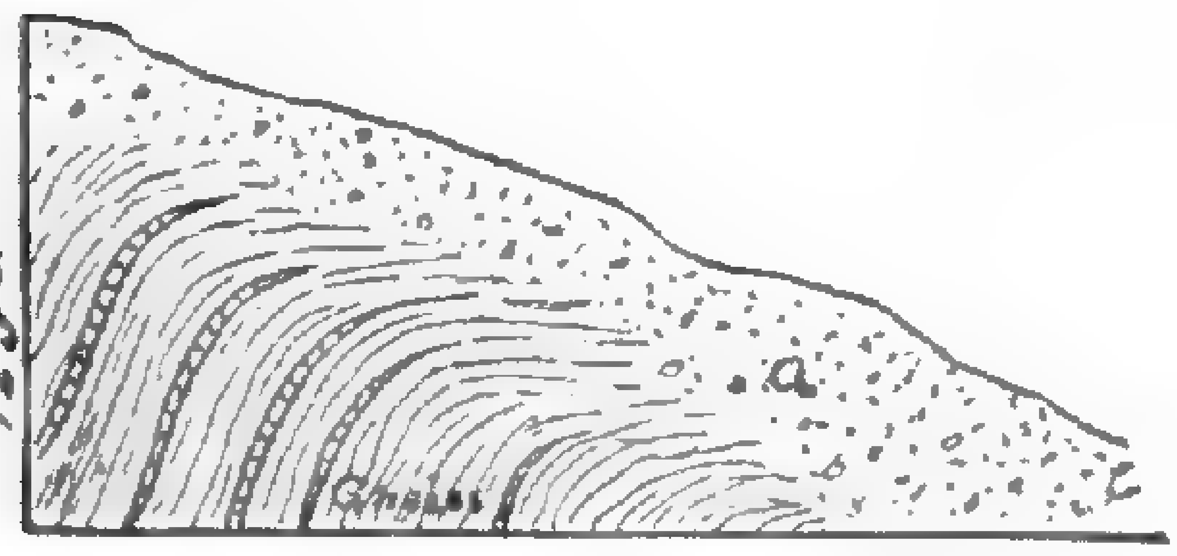

As already stated incidentally, the gold gravels, or placers, of this State, of which there are several hundred square miles, belong to this class of frost drifts. The miners in these deposits usually wash only the lower stratum of "gravel," or pebbles, which lies against the bed rock, or *slate*, together with an inch or two of the surface of this slate on which the coarser gold particles are lodged. The gold and the quartz pebbles are derived, as above indicated, from thin veins and strings which penetrate the more thin-bedded mica schists. As these are disintegrated and broken down and moved, in the manner

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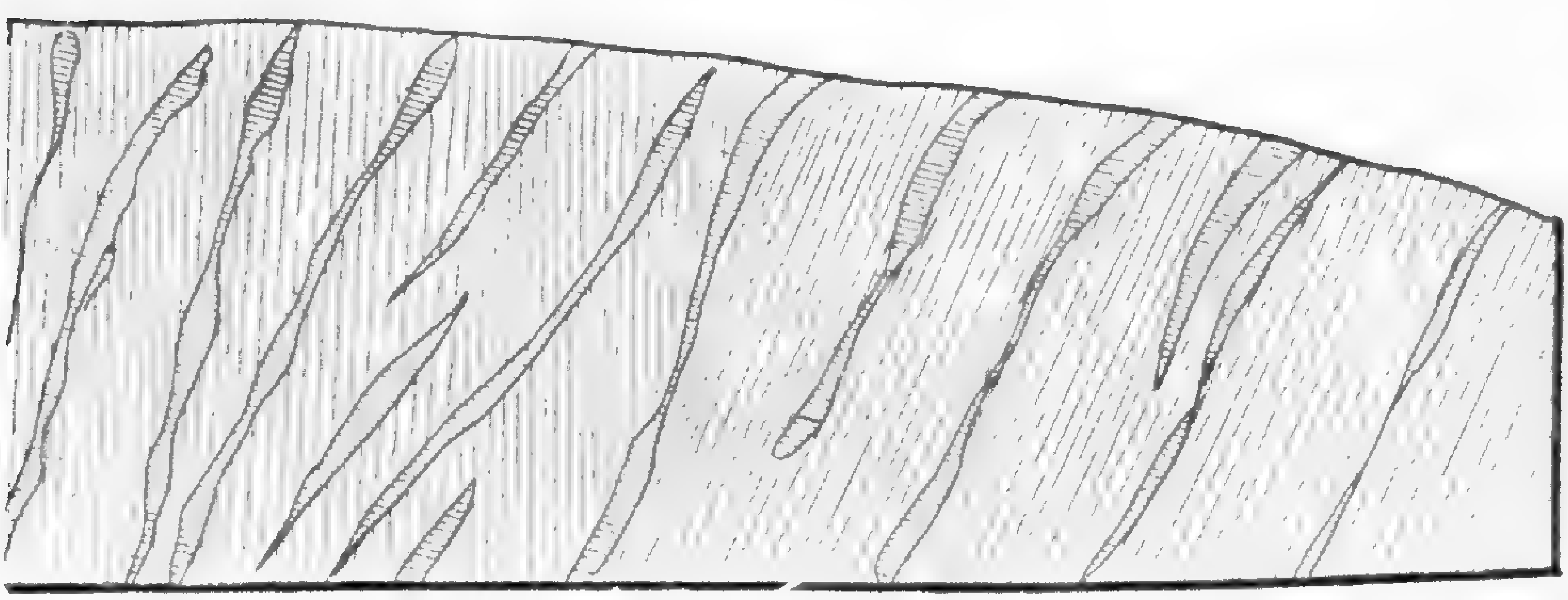

just described, or abraded and swept down by floods, these pebbles with the coarser gold are collected either in the manner described, or in the beds of the streams. Examples of these veins are shown in fig. 19, which represents a common aspect of them in section, in the mines previously alluded to, in which the veins themselves and the including mass of decomposed rock are sluiced down and washed just like a placer. In fig. 20 a vertical section of 20 feet of a single vein of this description which is a thin sheet of quartz, of an inch and less in thickness, yet rich enough to have been followed to a depth of 20 and 30 feet for many rods. Fig. 21 represents the floor of another mine at the same locality, in which several such thin sheet-veins are wrought in one cut, the vein-matter being reduced to nothing at certain points, leaving a mere joint or fissure plane.

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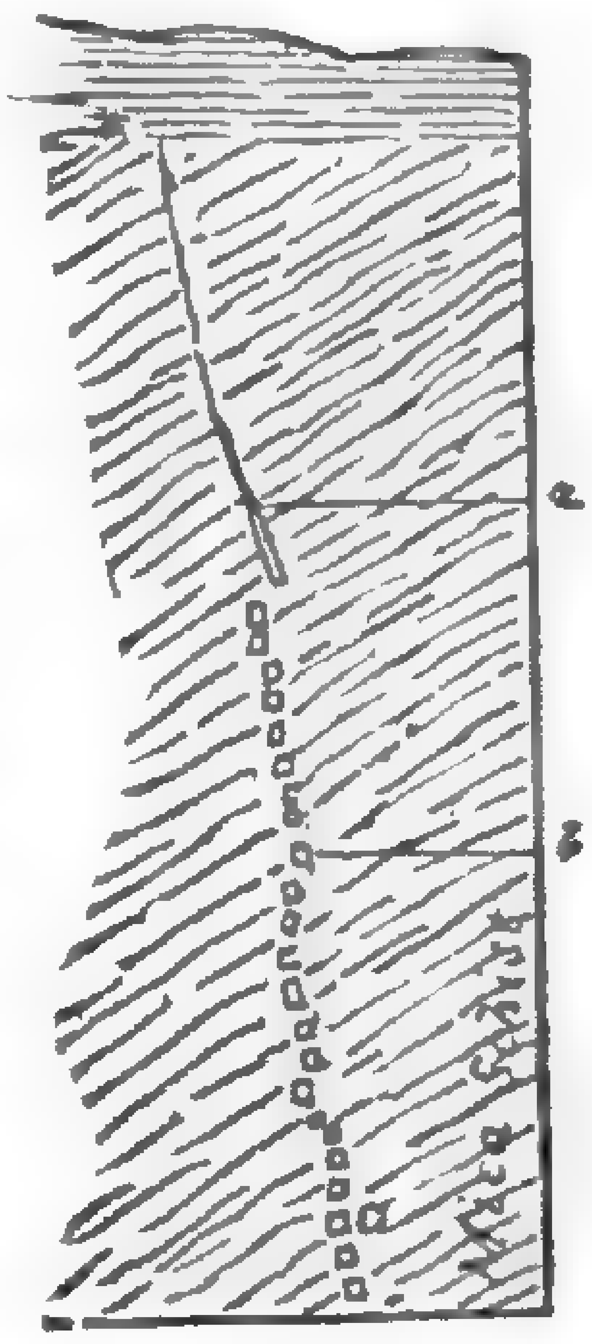

In fig. 22 the relation of the placers to the topography, and of both to the governing geological conditions, are exhibited. This diagram represents an ideal section southeast and northwest, transversely to the strike, across two of the richest and most noted gold valleys, separated by the Pilot, already familiar to us; these are the valleys of Silver Creek and Muddy Creek, known as Brindletown and Brackettown. The Pilot and the ridge of the South Mountains (the left in the section), owe their existence to the harder and heavier bedded gneisses of which they are composed, while the valleys have been scooped out of the softer and thin-bedded mica schists and hydromicaceous rocks, which are also more abundantly veined. It is an old

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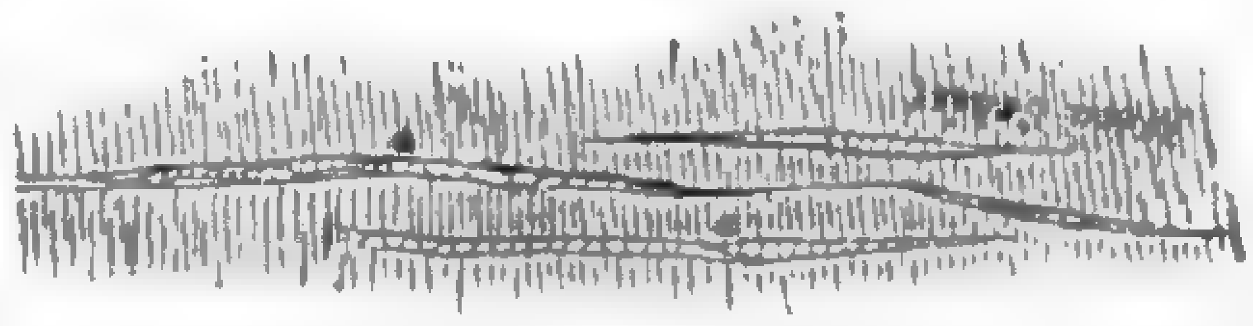

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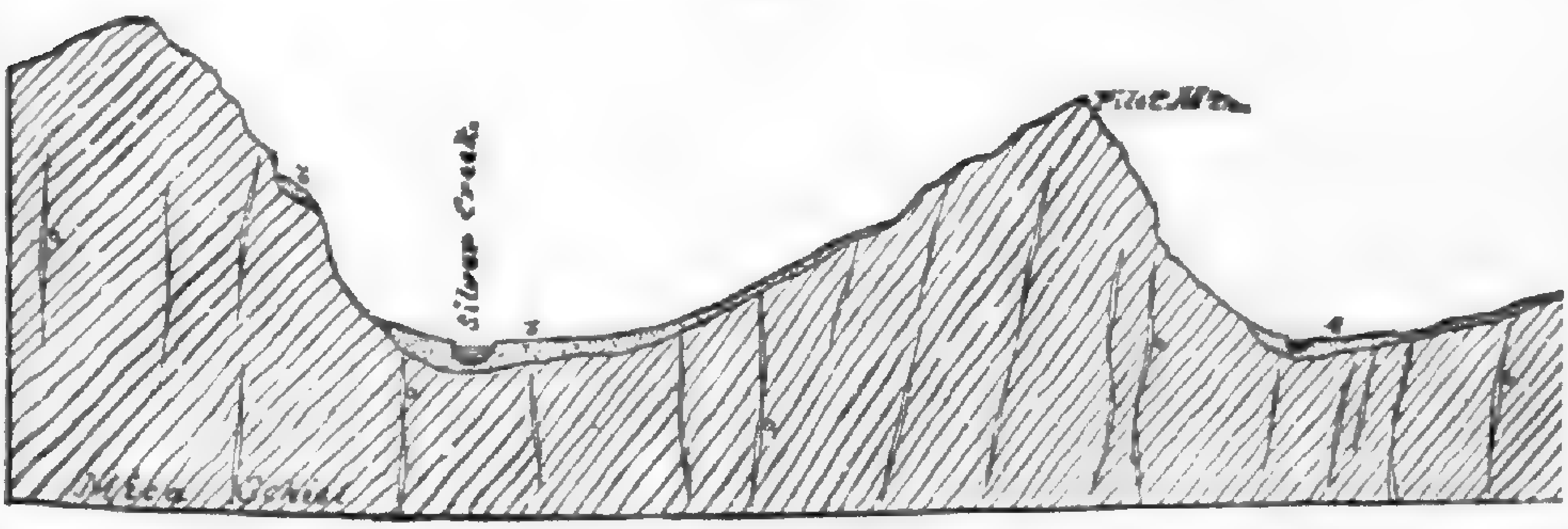

observation of the practical miners, that the gold deposits occur only on the east (and south) slopes of the mountains, while the opposite slopes are comparatively barren. The reason is obvious from an inspection of the diagram. The thicker bedded rocks have fewer veins, and the southeast slopes are the long ones, while those opposite are steep and short; and much the larger part of the abraded vein-bearing masses have been removed from the space above these long slopes.

It has already been stated that, as shown by the most obvious features of these deposits, they have been much more extensive than at present. In some cases, over considerable spaces, the deposit has been entirely removed by denudation, leaving only the floor covered with a layer of quartz pebbles and angular fragments, and the gold in the present soil within

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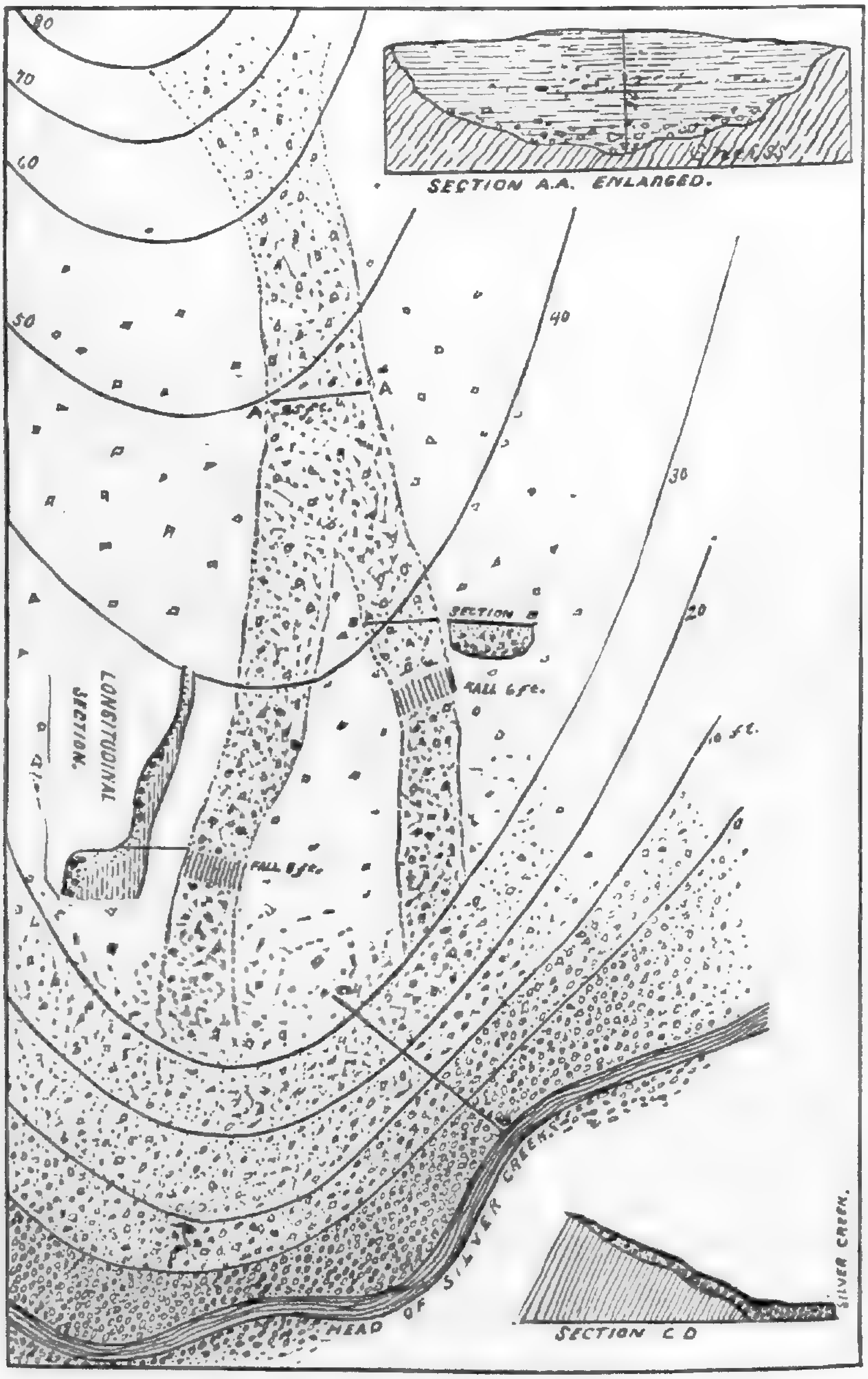


reach of the plowshare. Many of the richest gold washings of this state have been of this description, and farms, gardens, yards and the sites of houses have been sluiced away, and thousands of dollars per acre obtained from soils that had been cultivated for generations, in ignorance of their mineral riches. Large tracts of this character, hundreds of acres in extent, are found in the locality already so often cited, the foot-slopes in the Pilot. The annexed diagram, figure 23, of a placer lying on a swell of land between those represented in figures 8 and 9, illustrates this point. The whole surface of this flat swell, which is nearly half a mile in width, is covered with the quartz fragments of the old bed gravel of an enveloping placer, which has been entirely abraded, leaving its quartz and gold in the soil, with the exception of the fantastic bifurcated strip seen in the figure, which evidently was preserved from abrasion by the furrow which the moving mass had plowed a little deeper along this line. The thickness of this strip increases from a few inches at the top to more than ten feet below the singular golden cascades represented on the two arms. Happening to be present while the last of this curious placer was worked out, I was able to catch and sketch its peculiar features. This small remnant of an extensive deposit preserves, as shown in the sections, at A—A for example, all the characteristics of such drifts,—a dense bed of coarse "gravel," of angular quartz fragments, at bottom, carrying most of the gold, and a thinner and more scattered layer in the middle, with visible gold particles, and the finer gold diffused through the whole ten feet of depth in sufficient richness to justify the excavation and washing of the entire mass.

The diagram (ideal as to its lower portion, and contracted longitudinally), also exhibits the character and origin of the gold deposits in the creek bottoms of the region, which were extremely rich when first wrought, thirty-five to forty years ago, yielding ten dollars a day to the hand, with the rudest apparatus and most unskillful labor. The gold of these creek gravels, as shown in the figure, was derived from the placers swept down from the adjacent slopes.

And it may be of sufficient interest to justify the repetition here of a fact to which I have recently called attention elsewhere, that these gravels are regularly worked over at intervals of eight to ten or twelve years, and at some of the localities, on Silver Creek, for instance, they have been re-worked profitably half a dozen times, only the coarse gold being obtained each time by the rude appliances and methods used. The point of interest is, that the fine and diffused and scale gold which escapes in these rough washings and sluicings, evidently undergoes a process of aggregation: a fact which was noted by Professor Lieber, state geologist of South Carolina, in his geological report of that State, published before the war, but which seems to have escaped due attention. This is readily accounted for by the considerations first, that gold is soluble in alkaline waters;

and second, that these drifts are largely the debris of half-decomposed feldspathic gneisses and schists, of which the feldspathic particles are undergoing kaolinization, liberating the alkaline salts, while the silica attacks such fragments of organic matter as happen to be present, subjecting whole trunks of trees of more than a foot in diameter, to complete silicification even while lying within a few feet of the surface, and facing the drusy rifts of the wood with perfectly terminated quartz crystals.

Raleigh, N. C., March 15, 1881.

ART. XLV.—*Dall's Observations on Arctic Ice, and the bearing of the facts on Glacial phenomena in Minnesota;* by N. H. WINCHELL.

MR. DALL'S observations on the existing perennial ice in northern Alaska are highly interesting and valuable* at this point in the history and progress of glacial theory. He describes the region about Eschscholtz Bay as made of gneissoid rock and volcanic breccia, but without attaining anywhere in the vicinity any greater height than three or four hundred feet above the sea. He also states that the formation of the surrounding country shows no high land or rocky hills suited for the production of a glacier. In this respect it is like the interior of North America, throughout the Western and Northwestern States where there is proof, now rarely questioned, of the former existence of vast fields of glacier ice; and it is highly probable that the field explored by Mr. Dall is an epitome, under peculiar and somewhat inexplicable circumstances of the vaster field which extended from the Rocky Mountains on the west to the Alleghanies on the east, during the latest epoch of continental ice, the only important exception being that over the Continent the southern termination of the ice sheet was everywhere invisible, and abutted nowhere (in the interior) on the ocean shore so as to reveal its existence. The surface covering of the ice was the surface of the country, and over many miles north from its actual termination, it supported a varied and even rank vegetation. Mr. Dall's observations on the "fossil glacier" extending west from Point Barrow and south as far as Kotzebue Sound, seem to prove that the northern slopes of Alaska are now glacier-covered; throughout the most of which distance the margin of the ice is but occasionally revealed by reason of the wave action on the overlying drift.

* This Journal, xx, p. 335 and xxi, p. 104.

In numerous places it seems that the ice is so far attenuated that the drift which it brings forward is the barrier against the ocean, and in other places the ice itself, underlying the drift, is brought into contact with the water of the Arctic Ocean. Without a just conception of the action of the vast continental glacier of glacial times, it is difficult to conceive of this ice in motion, and Mr. Dall believes it has no motion, adducing, however, only the unbroken condition of the mosses and peats on its surface to prove it. It is to be hoped that inland exploration may be made of the glacier at Elephant's Point, in order to ascertain if it is derived from some mountain source. It is almost certain, if our ideas of glacier ice be correct, to have such a source, though its connection unbroken from the coast to the mountains, may be hid from sight for miles, in the same manner as its east and west flanks are hid by the accumulations on its surface. It is also highly probable that it will be found to come in various ways into contact with running water, some of which will bring upon it the fine tough clay described by Mr. Dall, and in other places will precipitate upon it, in stronger current, the gravel and sand, and even some of the stones which he mentions as covering it near Point Barrow.

The facts reported by Mr. Dall throw great light on the manner of formation and deposit of the till, which has been the source of much difference of opinion among glacialists. Some have imagined a *moraine profonde, pushed out from the front margin of the ice-sheet* in its retreat, left as a continuous terminal moraine from north to south after the ice had entirely disappeared. Others contend that it *was not only deposited at the ice-foot but also was formed there.* However satisfactory these theories may be to those who understand them, it is true that to some they are wholly beyond comprehension, and seem to be mythical. Another theory asserts that the ice *died out gradually, and imperceptibly beneath its burden of clay and stone,* and that the till is not a terminal moraine, but instead a surface moraine (to employ a new term) resulting from the same causes, whatever they may be, which bring the drift on to the surface of the ice in northern Alaska and which so frequently hide the surface of the small glaciers that have been described in the Rocky Mountains.

These observations also throw light on the cause and manner of formation of kames. Kames are gravel-ridges, lying in till-covered countries, and occupying the lower portions. They are generally coincident in direction with the direction of the present surface drainage, and often on either side of a kame, which may be several miles in length, there is a swamp or low spot, parallel with the kame, while on the right and left, outside of this valley, the unbroken till spreads out indefinitely.

The gravel of which the kame consists is of the same material as the gravel and stones found in the till that adjoins it, and was undoubtedly brought there at the same time that the till was—but necessarily by some other agent. The kame also sometimes becomes broken up, and fades out, by becoming hummocky and clayey, into the till itself. Now on the supposition that the till before its deposit lay on the surface of the ice, it is plain that surface drainage gathering into small streams and even rivers, would produce deep channels or gorges in the ice-sheet. In the bottom of the stream would be gathered such gravel, stones and sand as the stream had not current enough to carry away. The warmth imparted to it by the water would cause it to sink deeper and deeper into the ice, and in many places to lie on the rocky floor itself, especially in the southerly portions of the gorge where the ice would be thinner. It is easy to see that on the entire withdrawal of the ice, such a kame would lie undisturbed, in its beautiful stratification, where the river produced it; while on either side would be, first, the comparatively low or swampy belt caused by the withdrawal, during the existence of the river, of the clay of the till, and the concentration of its stones and gravel in the bottom of the stream by the sloping sides of the gorge, and secondly, outside of this swampy belt, the unmodified till itself. On the supposition that the stream was sub-glacial, not only can the circumstances not be imagined in accord with the known operations of gravity and momentum; but, if once so formed, the subsequent movements of the ice would inevitably have destroyed the stratification of the kame, and mixed it with the till. On the supposition that the kame was formed by such streams outside the area of the ice, on their debouchure from it, such steep ridges can hardly be explained. Gravel and sand so deposited are spread out more like "alluvial fans," and probably such are the superficial gravels and sands over southern Ohio and Indiana, south of the ice-margin at the time of the last glacial epoch.

University of Minnesota, Feb. 5, 1881.

ART. XLVI.—*On the Projection of Lines of Equal Pressure in the United States, west of the Mississippi River;** by HENRY A. HAZEN.

THE Signal Service Bureau of the United States has published, since 1873, more than 9000 different weather maps, upon which are projected isobars and isotherms for the United States and Canada from a little west of the Mississippi River to the Atlantic. It has been found practically impossible to continue the isobars across the Rocky Mountain plateau to the Pacific, or over more than half the country. The late Chief Signal Officer in his annual reports for 1877, '78 and '79, has stated in substance, that the reduction of pressures, at elevations west of the Mississippi River is greatly to be desired.

The solution of this problem is an exceedingly complicated one for the following reasons:

1st. The elevations of stations are not accurately known. In order to eliminate this error, the method of "isabnormals" or "departures" has been proposed. This system may be briefly described as follows:

We may consider the actual mean pressure for a month or year, at any station, to represent an even flow of air, with a depth indicated by the pressure; if there were no "highs" or "lows," the pressure would remain constant. The algebraic difference between the mean pressure for a month or year and each observation, in other words, the "departure," would indicate if plus, the presence of a "high," if minus, of a "low," and if these "departures" should be plotted on a chart for a series of stations, we should have apparently an exact means of describing a "high" or "low."

This method is open to serious objections and in fact may give results directly contrary to the truth. If all stations were at sea-level the results would be approximately accurate, but it will be seen that this would not be the case at elevations. For example, in winter the atmosphere condensed by the cold sinks and the pressure at a high station diminishes, whereas at the same time at sea-level the pressure increases. Since the temperature is constantly rising and falling it would be impossible to compare "departures" at different altitudes with each other or with those at sea-level.

In Table I are found "departures" as computed from the actual observations and also from the same reduced to sea-level.

* The term *pressure* is used to denote atmospheric pressure. Nearly every daily paper in the country is publishing "Indications" in each issue, in which the expressions "barometer" and "temperature," are almost invariably used. There should be uniformity. Why may not "pressure" and "temperature" be used?

TABLE I.

Departures at North Platte, Neb., elevation 2838 feet, for the observation at 7.35 A. M. Washington time, during January, 1879.

Date.	Temp.	Pressure.				Departure.			
		Actual.	Sig. Serv. Reduction	La Place.	Hazen.	Actual.	S. S.	L.	H.
1	3°	27″·22	30″·08	30″·55	30″·42	9	18	21	15
2	−13	27·27	30·25	30·74	30·55	14	35	40	28
3	− 8	27·44	30·43	30·90	30·71	31	53	56	44
4	− 9	27·31	30·27	30·71	30·57	18	37	37	30
5	4	27·41	30·31	30·65	30·60	28	41	31	33
6	− 1	27·01	29·85	30·30	30·23	−12	− 5	− 4	− 4
7	25	27·03	29·70	30·15	30·12	−10	−20	−21	−15
8	1	27·26	30·14	30·54	30·45	13	24	20	18
9	0	26·98	29·81	30·30	30·19	−15	− 9	− 4	− 6
10	12	26·97	29·72	30·18	30·12	−16	−18	−16	−15
11	3	27·15	29·99	30·49	30·35	2	9	15	8
12	6	27·04	29·84	30·32	30·23	− 9	− 6	− 2	− 4
13	14	26·98	29·72	30·16	30·12	−15	−18	−18	−15
14	6	27·05	29·86	30·31	30·23	− 8	− 4	− 3	− 4
15	10	26·99	29·75	30·23	30·15	−14	−15	−11	−12
16	2	27·08	29·91	30·41	30·28	− 5	1	7	1
17	9	27·06	29·85	30·30	30·22	− 7	− 5	− 4	− 5
18	3	27·23	30·10	30·57	30·43	10	20	23	16
19	8	27·32	30·18	30·56	30·49	19	28	22	22
20	23	27·24	29·97	30·42	30·33	11	7	8	6
21	16	26·97	29·70	30·15	30·10	−16	−20	−19	−17
22	37	26·91	29·50	29·93	29·95	−22	−40	−41	−32
23	27	27·13	29·82	30·22	30·21	0	− 8	−12	− 6
24	36	26·92	29·51	29·94	29·96	−21	−39	−40	−31
25	37	27·31	29·98	30·33	30·34	18	8	− 1	7
26	35	26·65	29·20	29·59	29·69	−48	−70	−75	−58
27	30	26·91	29·54	30·00	29·97	−22	−36	−34	−30
28	26	27·08	29·77	30·20	30·16	− 5	−13	−14	−11
29	15	27·36	30·18	30·58	30·50	23	28	24	23
30	26	27·34	30·08	30·44	30·42	21	18	10	15
31	27	27·27	29·98	30·37	30·34	14	8	3	7
Mean		27·13	29·90	30·34	30·27				

A comparison of the "departures" shows a difference of ±0″·10 between columns 7 and 10, and a still greater difference between 7 and 8 or 9. This discrepancy would be much increased at greater altitudes. No satisfactory projections then can be made with this system.

Having given pressures and temperatures, we may obtain an approximate difference of elevation, of neighboring stations, by applying the formula of LaPlace. In order to obtain some idea of the accuracy of leveling with the barometer the difference of height of the following stations has been computed, see Table II.

TABLE II.

Month.	Difference of Elevation.				
	Mt. Wash'g'n, N. H., & Portland, Me., 6 ys' observations.	Pike's Peak, Col., & Dodge City, Ka., 4 ys' observations.	Dodge C., Ka., & Leavenw'h, Ka., 4 years' observations.	Pioche, Nev., & Visalia, Cal., 1 years' observations.	Boise C., Ida., & Umatilla, Oregon, 1 yrs' observations.
January	6264′	11331′	1665′	5648′	2301′
February	6268	11414	1670	5758	2302
March	6284	11452	1725	5797	2398
April	6242	11485	1718	5821	2485
May	6232	11525	1734	5852	2495
June	6233	11545	1734	5819	2540
July	6225	11567	1752	5867	2522
August	6215	11565	1752	5792	2530
September	6236	11535	1756	5800	2438
October	6249	11426	1722	5722	2381
November	6275	11382	1670	5702	2343
December	6259	11326	1667	5637	2342
Year	6256	11470	1716	5772	2424
Mean of 12 mo's	6248	11463	1714	5768	2424
Mean	6252	11466	1715	5770	2424
True diff. level	6240				

In column 2, Mt. Washington is in latitude 45° north, near the Atlantic coast and sixty miles west of Portland, which is 46′ above the sea. In column 3, Pike's Peak is in the interior in latitude 39° north and 300 miles west of Dodge City, which has an altitude of 2555′. In column 4, Leavenworth is 300 miles east of Dodge City and 840′ high. In column 5, Pioche in latitude 37°·5 north is 300 miles east of Visalia, the latter near the Pacific coast and 370′ high. In column 6, Boise City is in latitude 44° north and about 200 miles southeast from Umatilla, which is 375′ high.

The most noticeable fact is that while the computed elevations on the Atlantic coast gradually diminish from January to July, the opposite effect is observed on the Pacific. The computed difference of elevation between Mt. Washington and Portland is within 12′ of the truth. In the west many of the elevations are in doubt.

Table III gives approximate elevations of most of the stations west of the Mississippi River.

2d. It seems well nigh impossible to determine the law of variation of temperature at most of the high stations in the west. For abrupt elevations, such as Pike's Peak, the law may be fairly well known, but this is not the case in most instances. For example, the mean temperature at Denver, Col., is 49°·1, at Dodge City it is 53°·4 and at Leavenworth it is 53°·5. These temperatures reduced to sea level at the rate of 1° for each 300′ elevation are, 66°·7, 61°·9 and 66°·3 respectively. Again, we frequently find the temperatures ten to fifteen degrees lower at Dodge City than at Denver. At Salt Lake City, on the elevated plateau west of the Rocky Mountains, there is a still greater difficulty, as the temperature seems to run too high.

TABLE III.

Station.	Elevation.		Station.	Elevation.	
	Signal Service.	Barometric.		Signal Service.	Barometric.
Bismarck	1704′	1740′	Leavenworth	813	840
Boerne	1333?	1400	Los Angeles	320	380
Boise City	2877	2799	Mason	1800?	1610
Brackettville	1026?	1140	North Platte	2838	2838
Camp Grant	4823?	4900	Phoenix	1800?	1150
Campo	2500?	2500	Pioche	5779	6148
Cheyenne	6057	6093	Pike's Peak	14151	14021
Concho	1750?	1900	Prescott	5700?	5230
Deadwood		4600	Red Bluff	338	410
Denver	5269	5265	Sacramento	76	100
Dodge City	2486	2555	Salt Lake City	4362?	4365
Fort Buford		1970	St. Paul	796	825
Fort Craig	4622	4570	Santa Fé	6851	7020
Fort Davis	5203	4900	Silver City	6896	5920
Fort Gibson	511	541	Stockton	2000?	3100
Fort Keogh	2536?	2480	Umatilla	461	275
Fort McKavitt	2050?	2230	Virginia City	5480?	5830
Fort Sill	1100?	1198	Visalia	348	378
Fort Stevenson		1760	Winnemucca	4335	4390
Fredericksburg	1614?	1720	Yankton	1275	1210
LaMesilla		4050	Yuma	155?	240

3d. Even if elevations were known, there seems to be no formula of reduction which can be applied to the varying conditions of the temperature and movements of the atmosphere.

In order to obtain a satisfactory method of reduction, the following plan has been adopted, based upon the theory that the fluctuations of pressure are in part dependent upon the temperature at the base and summit of a mountain.

Arrange in a table a column for temperatures running from $-30°$ to $80°$ in a vertical line, and a horizontal row of pressures, limited by the minimum and maximum pressures at the elevated station under consideration.

Take now the difference of pressures at any observation at an upper and lower neighboring station and place it at the intersection of a line passing through the temperature corresponding to the mean temperature of the two stations at the time of the observation, with a vertical line passing through the figure representing the pressure at the elevated station at the same time. By taking a sufficient number of observations, made at all hours of the day, and during all the months of the year, we can construct a table which shall represent the proper reduction of all observations at the upper station.

Tables have been prepared on this system for Mt. Washington, N. H., reducing to sea-level by comparison with Portland, Me., also for nearly all the stations of the Signal Service, above 1000′ in hight, west of the Mississippi River; column 6, Table I, is taken from such a table. For elevations under 3000′ the U. S. Signal Service have adopted a formula of reduction which always gives results too small.

On referring to Table I, we see that during the month of January, 1879, in one instance the reduction in column 4 was 0″·49 less than in column 6, and in two cases the reductions in column 4 were 0″·50 less than in column 5.

In the Annual Report of the Chief Signal Officer for 1876, are published tables computed by Lieut. Dunwoody, for reducing pressures at an elevation not exceeding 7000′ to sea-level. Table IV gives a comparison of reductions by these tables with those by Guyot's tables and also Baily's.

TABLE IV.

Reduction of Mt. Washington to sea-level.

	Actual Difference bet. W. & P.	Baily.	Guyot.	Dunwoody.	Hazen.
Mean annual pressure Mt. W., 23″·626 Mean annual temp'ature Mt. W. & Port., 36°·2	6″·356	6″·316	6″·342	6″·314	6″·356
Pressure Mt. W., 23″·00 Mean temperature Mt. W. & Portland, 20°		6·406	6·429	6·424	6·55
Mean temperature Mt. W. & Portland, −20°		7·142	7·167	7·165	7·13
Pressure Mt. W., 24″·00 Mean temperature Mt. W. & Portland, 60°		6·060	6·082	6·046	6·05
Mean temperature Mt. W. & Portland, 20°		6·685	6·708	6·675	6·61

In column 1 are given pressures on Mt. Washington and the mean temperature between Mt. Washington and Portland. In the remaining columns are found the reductions to sea-level, as computed from various formulæ and tables.

Baily's formula in column 3 has been adopted by Charles Carpmael, Superintendent of the Meteorological Service of Canada, who regards the tables of Dunwoody as unsatisfactory. It would seem that all the results are nearly correct when means are employed; when individual observations are considered, however, the discrepancies are more marked, each of the formulæ in different portions of its range giving the best results. On the whole the reductions by Guyot seem the best and those by Dunwoody are next. These discrepancies are still greater in the case of reductions of pressures at such an altitude as Pike's Peak. This is shown clearly in Table V.

TABLE V.

Reduction of Pike's Peak to sea-level.

Temperature.	Guyot.			Hazen.		
	17″·6.	17″·7.	17″·8.	17″·6.	17″·7.	17″·8.
60°	11″·61	11″·67	11″·74	11″·94	11″·93	11″·92
50	11·92	11·99	12·06	12·11	12·10	12·09
40	12·26	12·33	12·40	12·27	12·26	12·25
30	12·62	12·69	12·76	12·43	12·42	12·41
20	13·00	13·07	13·14	12·59	12·58	12·57
10	13·38	13·46	13·54	12·76	12·75	12·74
0	13·81	13·89	13·97	12·93	12·92	12·91

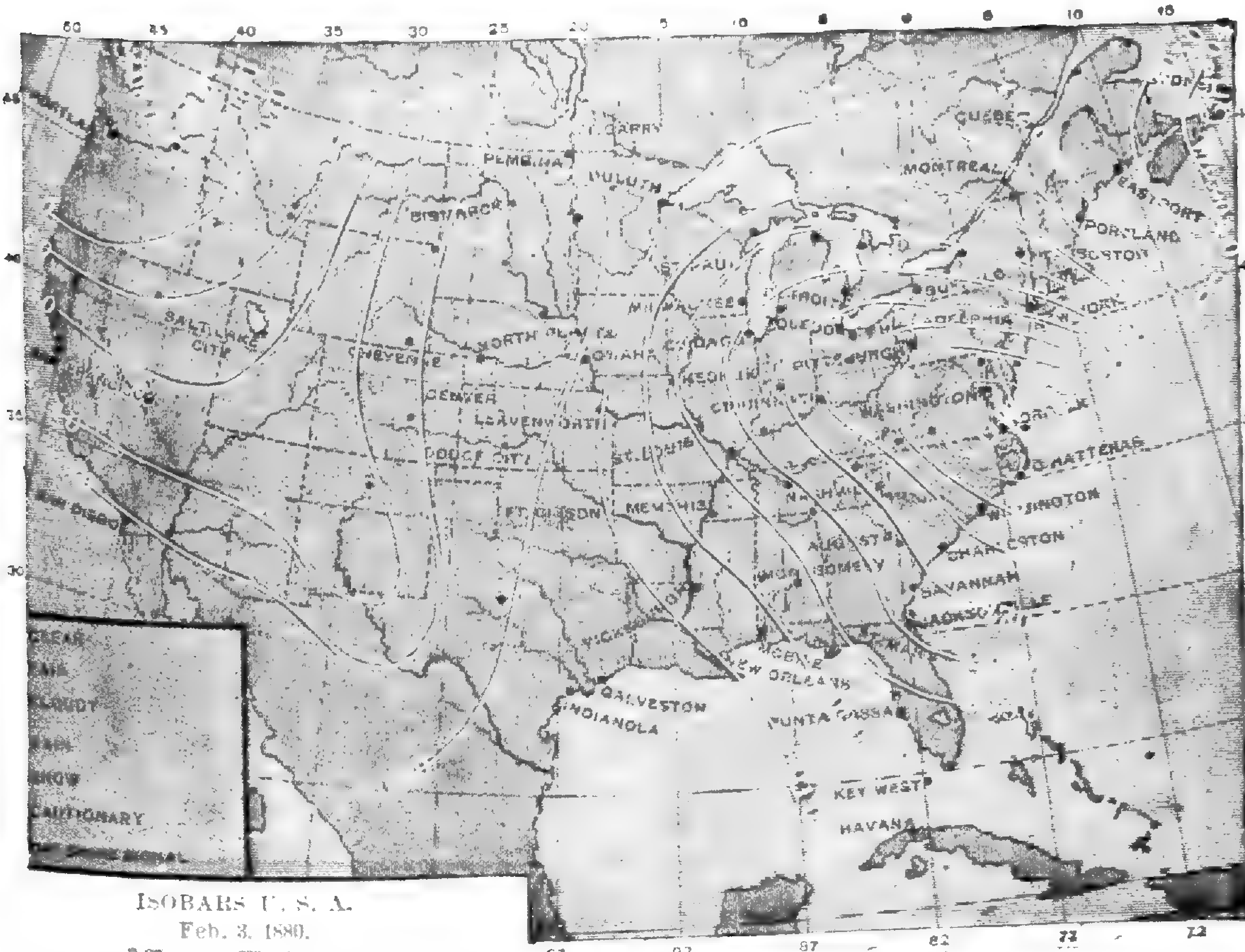
There seems to be a variation by these two methods of reduction of nearly one inch at 0° temperature. If it be objected that no account is taken of pressures at the lower station, and that comparisons made between stations 300 miles apart would differ from those near each other, also that the altitude of Pike's Peak is uncertain. It may be said that the extreme error due to these causes may reach 0″·6 at 0° temperature, and this would diminish with higher temperatures.

The most marked peculiarity in the two tables, however, is that *while the reduction by Guyot increases with an increase of pressure, the actual reduction diminishes.* This fact has been verified by reductions at a large number of stations.

The method proposed then consists in this. All reductions of pressures at altitudes not exceeding 1000′ be made by the use of Guyot's formula. (Table VI, for facilitating this reduction is appended to this paper.) For all other stations reductions be made from tables specially prepared, from a comparison of observations at an elevated and at a lower neighboring station.

Plates are given, showing a projection of isobars over the whole of the United States, for the observation at 7.35 A. M. Washington time, from the 2d to the 7th of February, 1880. In making these reductions, the actual temperature at the station has been used for all except Pike's Peak, at the latter station the mean temperature between Pike's Peak and Dodge City has been employed. The isobars have been projected from the reductions at *all* the stations except Pike's Peak, Salt Lake City, Deadwood, Fort Buford and Fort Stevenson. Observations have not been published to a sufficient extent to give satisfactory tables for reduction in the last three cases; at Salt Lake City the temperatures are troublesome, and Pike's Peak is very high.

ISOBARS U. S. A.
Feb. 2. 1880.
7.35 A. M., Wash. m. t.



ISOBARS U. S. A.
Feb. 3. 1880.
7.35 A. M., Wash. m. t.

ISOBARS U. S. A.
Feb. 4, 1880.
7.35 A. M., Wash. m. t.

ISOBARS U. S. A.
Feb. 5, 1880.
7.35 A. M., Wash. m. t.

ISOBARS U. S. A.
Feb. 6, 1880.
7.35 A. M., Wash. m. t.

ISOBARS U. S. A.
Feb. 7, 1880.
7.35 A. M., Wash. m. t.

Only an approximate solution of the problem is claimed; at the same time it is quite satisfactory and if used will open a wide field for meteorological research, especially if there be a few additional stations established along the 50th and 55th parallels.

An exact determination of elevation of meteorological stations in the west would be of very great importance. Also a series of observations, conducted at elevated and lower stations in the west, for a whole year, as suggested by Lieut. Dunwoody in the preparation of his tables, would be of great assistance in determining a proper formula of reduction to sea-level.

TABLE VI.

For reducing pressures, at elevations not exceeding 1000 feet, to sea-level.

Formula: $\log \beta = \log \beta' + \dfrac{h}{60158{\cdot}6 \times \left(1 + \dfrac{2t - 64}{900}\right) \times \left(1 + \dfrac{h + 52252}{20886860}\right)}$; in this β' and t refer to the pressure and temperature at the upper station, h = altitude of station. Argument, h, β and t, $\beta = \beta'$ + correction from table.

100′.

T.	Press'e 29″·4. C.	Press'e 29″·4. Diff. 100′.	Press'e 29″·9. C.	Press'e 29″·9. Diff. 100′.	Press'e 30″·4. C.	Press'e 30″·4. Diff. 100′.
80°	″·102	·102	·103	·104	·105	·105
75	·103	·103	·104	·105	·106	·106
70	·104	·104	·105	·106	·107	·108
65	·105	·105	·107	·107	·108	·109
60	·106	·106	·108	·108	·109	·110
55	·107	·107	·109	·109	·111	·111
50	·108	·108	·110	·110	·112	·112
45	·109	·109	·111	·111	·113	·113
40	·110	·111	·112	·113	·114	·115
35	·112	·112	·114	·114	·116	·116
30	·113	·113	·115	·115	·117	·117
25	·114	·114	·116	·116	·118	·118
20	·116	·116	·117	·118	·119	·120
15	·117	·117	·119	·119	·121	·121
10	·118	·119	·120	·121	·122	·123
5	·120	·120	·122	·122	·124	·124
0	·121	·122	·123	·124	·125	·126
− 5	·123	·123	·125	·125	·127	·127
−10	·124	·125	·126	·127	·128	·129
−15	·126	·126	·128	·128	·130	·130
−20	·127	·128	·129	·130	·131	·132
−25	·129	·129	·131	·131	·133	·133
−30	·130	·131	·133	·133	·135	·135
−35	·132	·132	·134	·135	·137	·137
−40	·134	·134	·136	·137	·138	·139

200′.

T.	Press'e 29″·3. C.	Press'e 29″·3. Diff. 100′.	Press'e 29″·8. C.	Press'e 29″·8. Diff. 100′.	Press'e 30″·3. C.	Press'e 30″·3. Diff. 100′.
80°	·203	·102	·206	·104	·210	·105
75	·205	·103	·208	·105	·212	·106
70	·207	·104	·211	·106	·214	·108
65	·209	·105	·213	·107	·216	·109
60	·211	·106	·215	·108	·219	·110
55	·214	·107	·217	·109	·221	·111
50	·216	·108	·220	·110	·223	·112
45	·218	·109	·222	·111	·226	·113
40	·221	·111	·224	·113	·228	·115
35	·223	·112	·227	·114	·231	·116
30	·226	·113	·229	·115	·233	·117
25	·228	·114	·232	·116	·236	·118
20	·231	·116	·235	·118	·239	·121
15	·233	·117	·237	·119	·241	·122
10	·236	·119	·240	·121	·244	·123
5	·239	·120	·243	·122	·247	·124
0	·242	·122	·246	·124	·250	·126
− 5	·245	·123	·249	·125	·253	·127
−10	·248	·125	·252	·127	·256	·129
−15	·251	·126	·255	·128	·259	·130
−20	·254	·128	·258	·130	·263	·132
−25	·257	·129	·262	·131	·266	·134
−30	·261	·131	·265	·133	·270	·136
−35	·264	·133	·269	·135	·273	·137
−40	·268	·135	·272	·137	·277	·138

T.	300'.						T.	400'.					
	Press'e 29''·2.		Press'e 29''·7.		Press'e 30''·2.			Press'e 29''·0.		Press'e 29''·5.		Press'e 30''·0.	
	C.	Diff. 100'.	C.	Diff. 100'.	C.	Diff. 100'.		C.	Diff. 100'.	C.	Diff. 100'.	C.	Diff. 100'.
80°	·304	·102	·309	·104	·314	·105	80°	·403	·102	·410	·103	·417	·105
75	·307	·103	·312	·105	·317	·106	75	·407	·103	·414	·105	·421	·107
70	·310	·104	·315	·106	·321	·108	70	·411	·104	·418	·106	·425	·108
65	·313	·105	·319	·107	·324	·109	65	·416	·105	·423	·107	·430	·109
60	·317	·106	·322	·108	·327	·110	60	·420	·106	·427	·108	·434	·110
55	·320	·107	·325	·109	·331	·111	55	·424	·107	·432	·109	·439	·111
50	·323	·109	·329	·110	·334	·112	50	·429	·108	·436	·110	·444	·112
45	·327	·110	·332	·111	·338	·113	45	·434	·109	·441	·111	·449	·113
40	·330	·111	·336	·113	·342	·115	40	·438	·111	·446	·113	·454	·115
35	·334	·112	·340	·114	·346	·116	35	·443	·112	·451	·114	·459	·116
30	·338	·113	·344	·115	·349	·117	30	·448	·113	·456	·115	·464	·117
25	·342	·114	·348	·116	·353	·118	25	·453	·114	·461	·116	·469	·118
20	·346	·116	·352	·118	·357	·120	20	·459	·116	·467	·118	·475	·120
15	·350	·117	·356	·119	·362	·121	15	·464	·117	·472	·119	·480	·121
10	·354	·119	·360	·121	·366	·123	10	·470	·119	·478	·121	·486	·123
5	·358	·120	·364	·122	·370	·124	5	·475	·120	·483	·122	·491	·124
0	·362	·122	·368	·124	·375	·126	0	·481	·121	·489	·124	·497	·126
−5	·367	·123	·373	·125	·379	·127	−5	·487	·122	·495	·125	·503	·127
−10	·371	·125	·377	·127	·384	·129	−10	·493	·124	·501	·127	·510	·129
−15	·376	·126	·382	·128	·389	·130	−15	·499	·126	·507	·128	·516	·130
−20	·381	·128	·387	·130	·394	·132	−20	·505	·128	·514	·130	·523	·132
−25	·385	·129	·392	·132	·399	·134	−25	·512	·129	·520	·131	·529	·133
−30	·390	·131	·397	·134	·404	·136	−30	·518	·131	·527	·133	·536	·135
−35	·396	·133	·402	·135	·409	·137	−35	·525	·133	·534	·135	·543	·137
−40	·401	·135	·408	·137	·415	·139	−40	·532	·135	·541	·137	·550	·139

T.	500'.						T.	600'.					
	Press'e 28''·9.		Press'e 29''·4.		Press'e 29''·9.			Press'e 28''·8.		Press'e 29''·3.		Press'e 29''·8.	
	C.	Diff. 100'.	C.	Diff. 100'.	C.	Diff. 100'.		C.	Diff. 100'.	C.	Diff. 100'.	C.	Diff. 100'.
80°	·503	·102	·511	·103	·520	·105	80°	·602	·102	·613	·103	·623	·105
75	·508	·103	·517	·104	·526	·106	75	·609	·103	·619	·104	·630	·106
70	·513	·104	·522	·106	·531	·107	70	·615	·104	·625	·106	·636	·107
65	·519	·105	·528	·107	·537	·108	65	·621	·105	·632	·107	·643	·108
60	·524	·106	·533	·108	·542	·110	60	·628	·106	·639	·108	·650	·110
55	·530	·107	·539	·109	·548	·111	55	·634	·107	·646	·109	·657	·111
50	·535	·108	·545	·110	·554	·112	50	·641	·108	·653	·110	·664	·112
45	·541	·109	·551	·111	·560	·113	45	·648	·109	·660	·111	·671	·113
40	·547	·111	·557	·112	·566	·114	40	·656	·111	·667	·113	·678	·114
35	·553	·112	·563	·113	·572	·115	35	·663	·112	·674	·114	·686	·115
30	·559	·113	·569	·115	·579	·117	30	·670	·113	·682	·115	·694	·117
25	·566	·114	·576	·116	·585	·118	25	·678	·114	·690	·116	·702	·118
20	·572	·116	·582	·118	·592	·120	20	·686	·116	·698	·118	·710	·120
15	·579	·117	·589	·119	·599	·121	15	·694	·117	·706	·119	·718	·121
10	·586	·119	·596	·121	·606	·123	10	·702	·119	·714	·121	·726	·123
5	·593	·120	·603	·122	·613	·124	5	·710	·120	·723	·122	·735	·124
0	·600	·122	·610	·124	·621	·126	0	·719	·122	·732	·124	·744	·126
−5	·607	·123	·618	·125	·628	·127	−5	·728	·123	·741	·125	·753	·127
−10	·615	·125	·625	·127	·636	·129	−10	·737	·125	·750	·127	·763	·129
−15	·623	·126	·633	·128	·644	·130	−15	·746	·126	·759	·128	·772	·130
−20	·631	·128	·641	·130	·652	·132	−20	·756	·128	·769	·130	·782	·132
−25	·639	·129	·650	·131	·661	·134	−25	·765	·129	·779	·132	·792	·134
−30	·647	·131	·658	·133	·669	·136	−30	·775	·131	·789	·133	·802	·136
−35	·656	·133	·667	·135	·678	·137	−35	·786	·133	·799	·135	·813	·137
−40	·664	·135	·676	·137	·687	·139	−40	·796	·135	·810	·137	·824	·139

700′.

T.	Press'e 28''·7.		Press'e 29''·2.		Press'e 29''·7.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·702	·102	·714	·103	·726	·105
75	·709	·103	·721	104	·733	·106
70	·716	·104	·729	·106	·741	·107
65	·724	·105	·736	·107	·749	·108
60	·731	·106	·744	·108	·757	·110
55	·739	·107	·752	·109	·765	·111
50	·747	·108	·760	·110	·773	·112
45	·755	·110	·768	·111	·782	·113
40	·764	·111	·777	·113	·790	·115
35	·772	·112	·786	·114	·799	·116
30	·781	·113	·795	·115	·808	·117
25	·790	·115	·804	·117	·817	·119
20	·799	·116	·813	·118	·827	·120
15	·808	·117	·822	·119	·836	·121
10	·818	·119	·832	·121	·846	·123
5	·828	·120	·842	·122	·857	·124
0	·838	·122	·852	·124	·867	·126
− 5	·848	·123	·863	·125	·878	·127
−10	·859	·125	·874	·127	·889	·129
−15	·870	·126	·885	·128	·900	·130
−20	·881	·128	·896	·130	·911	·132
−25	·892	·130	·907	·132	·923	·134
−30	·904	·131	·919	·134	·935	·136
−35	·915	·133	·931	·135	·947	·138
−40	·928	·135	·944	·137	·960	·140

800′.

T.	Press'e 28''·6.		Press'e 29''·1.		Press'e 29''·6.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·800	·102	·814	·103	·828	·105
75	·809	·103	·823	·104	·837	·106
70	·817	·104	·831	·105	·845	·107
65	·826	·105	·840	·107	·854	·108
60	·834	·106	·849	·108	·863	·110
55	·843	·107	·858	·109	·873	·111
50	·852	·108	·867	·110	·882	·112
45	·862	·109	·877	·111	·892	·113
40	·871	·111	·887	·113	·902	·115
35	·881	·112	·896	·114	·912	·116
30	·891	·113	·907	·115	·922	·117
25	·901	·115	·917	·117	·933	·119
20	·912	·116	·928	·118	·944	·120
15	·922	·117	·939	·119	·955	·121
10	·934	·119	·950	·121	·966	·123
5	·945	·120	·961	·122	·978	·124
0	·956	·122	·973	·124	·990	·126
− 5	·968	·123	·985	·125	1·002	·127
−10	·980	·125	·997	·127	1·014	·129
−15	·992	·126	1·010	·129	1·027	·131
−20	1·005	·128	1·023	·130	1·040	·132
−25	1·018	·130	1·036	·132	1·053	·134
−30	1·031	·131	1·049	·134	1·067	·136
−35	1·045	·133	1·063	·136	1·081	·138
−40	1·059	·135	1·078	·138	1·096	·140

900′.

T.	Press'e 28''·5.		Press'e 29''·0.		Press'e 29''·5.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·899	·102	·915	·103	·930	·105
75	·908	·103	·924	·104	·940	·106
70	·917	·104	·934	·105	·950	·107
65	·927	·105	·943	·107	·960	·108
60	·937	·106	·953	·108	·970	·110
55	·947	·107	·964	·109	·980	·111
50	·957	·108	·974	·110	·991	·112
45	·968	·110	·985	·111	1·002	·113
40	·979	·111	·996	·113	1·013	·115
35	·990	·112	1·007	·114	1·024	·116
30	1·001	·113	1·018	·115	1·036	·117
25	1·012	·115	1·030	·117	1·048	·119
20	1·024	·116	1·042	·118	1·060	·120
15	1·036	·117	1·054	·119	1·072	·121
10	1·048	·119	1·067	·121	1·085	·123
5	1·061	·120	1·080	·122	1·098	·124
0	1·074	·122	1·093	·124	1·112	·126
− 5	1·087	·123	1·106	·125	1·125	·127
−10	1·101	·125	1·120	·127	1·140	·129
−15	1·115	·126	1·134	·129	1·154	·131
−20	1·129	·128	1·149	·130	1·169	·132
−25	1·144	·130	1·164	·132	1·184	·134
−30	1·159	·131	1·179	·134	1·199	·136
−35	1·174	·133	1·195	·136	1·215	·138
−40	1·190	·135	1·211	·138	1·232	·140

1000′.

T.	Press'e 28''·4.		Press'e 28''·9.		Press'e 29''·4.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·997	·102	1·014	·103	1·032	·105
75	1·007	·103	1·025	·104	1·043	·106
70	1·018	·104	1·036	·105	1·053	·107
65	1·028	·105	1·046	·107	1·065	·109
60	1·039	·106	1·058	·108	1·076	·110
55	1·050	·107	1·069	·109	1·087	·111
50	1·062	·108	1·081	·110	1·099	·112
45	1·074	·110	1·093	·111	1·111	·113
40	1·086	·111	1·105	·113	1·124	·115
35	1·098	·112	1·117	·114	1·136	·116
30	1·110	·113	1·130	·115	1·149	·117
25	1·123	·115	1·143	·117	1·163	·119
20	1·136	·116	1·156	·118	1·176	·120
15	1·149	·117	1·170	·120	1·190	·122
10	1·163	·119	1·184	·121	1·204	·123
5	1·177	·120	1·198	·122	1·219	·125
0	1·192	·122	1·213	·124	1·233	·126
− 5	1·206	·123	1·228	·125	1·249	·128
−10	1·221	·125	1·243	·127	1·264	·129
−15	1·237	·126	1·259	·129	1·280	·131
−20	1·253	·128	1·275	·131	1·297	·133
−25	1·269	·130	1·291	·132	1·314	·135
−30	1·286	·132	1·308	·134	1·331	·136
−35	1·303	·133	1·326	·136	1·349	·138
−40	1·321	·135	1·344	·138	1·367	·140

ART. XLVII.—*Neumann's Method of calibrating Thermometers, with ways of getting columns for calibration;* by T. RUSSELL, U. S. Lake Survey.

NEUMANN'S method of calibrating thermometers has very considerable advantages over those of Bessel and of Hällström, which are the ones in common use. In the computations of the corrections by this method the numbers used are always small, and there is entire freedom from arbitrary assumptions. Without at all increasing the work of reduction, the calibrating columns can be used to the greatest advantage, and even when all the regular observations required by the method are not obtained, the corrections can nevertheless be derived in a definite manner. The method combines, in short, the greatest simplicity, elegance and exactness.

An essential feature of the method is that the columns used must be as nearly as possible equal in length to a whole number of intervals between the points for which the corrections are required; if, for instance, for every ten degrees, the lengths of the columns used must then be about ten, twenty, thirty, etc. degrees. Although it is not necessary to have all the possible columns of this kind, yet the greater the number obtained the simpler becomes the reduction. Calling the points for which the corrections are required principal points, the columns obtained are to be measured with the lower ends near all of the principal points, as far as the lengths of the columns will permit. The lengths of the columns being as stated above, the upper ends will also be in the vicinity of principal points.

For a knowledge of this method the writer is indebted to an article by M. Thiesen, in the November number for 1879, of the Zeitschrift der österreichischen Gesellschaft für Meteorologie. The notation given there is followed here. Denote the calibration corrections at the principal points of a thermometer by $\Delta_0\ \Delta_1\ \Delta_2 \ldots .\ \Delta_n$, and the corrections to the intervals between successive principal points by $\delta_0\ \delta_1\ \delta_2$, etc., then we have in general:

$$\delta_i = \Delta_{i+1} - \Delta_i$$

Let the general designation of principal points near the upper ends of columns be k, and that of points near the lower ends be i. Denote the volume of any column by $f_{(k-i)}$ and its apparent length, that is the difference of the readings of the upper end and lower end in a given position, by (k, i). If the corrections of the small spaces which lie between the ends of the column and the principal points i, and k, be neglected, the following relation holds:

$$f_{(k-i)} = (k, i) + \Delta_k - \Delta_i$$

If the column is moved and placed with the ends near other principal points, other similar equations will be obtained, in which the left side will be the same, but on the right side in place of i and k, there will be in succession $i+1$ and $k+1$, $i+2$ and $k+2$, etc. If each of these equations is subtracted from the equation following it, a new set of equations will result of the form:

$$\delta_i - \delta_k = (k+1, i+1) - (k, i)$$

The further development of the method can best be shown in the course of the example of calibration which follows:

Thermometer, Green, 4470, is divided to fifths of a degree, Fahrenheit. The apparent lengths of columns given below are from estimated readings of the ends to the nearest tenth of a division, or 0°·02. As it is not intended to use this thermometer at temperatures above 122°, no special effort was made to get the corrections above that point. On account of this the calibration falls into two parts, which illustrate both branches of the method; the one where all requisite columns are used, and the other where some of the columns are wanting. Part first consists in the derivation of the corrections at 77°, 122° and 167°, with columns of 45°, 90° and 135°. Part second consists in the derivation of the corrections for every tenth degree up to 122°, by the use of columns which are in length multiples of ten degrees.

Table I contains the measured lengths of columns for the first part of the work.

TABLE I.

Apparent lengths of columns.

45° column.			90° column.			135° column.		
32·77	44·68		32·122	90·07		32·167	134·61	
		+0·03			+0·02			+0·07
77·122	44·71		77·167	90·09		77·212	134·68	
		+0·01			+0·02			
122·167	44·72		122·212	90·11				
		+0·03						
167·212	44·75							

Table II is formed by placing vertically the first horizontal line of differences of table I, and parallel to it the other lines of differences, beginning one line lower each time. This being done the numbers in the vertical lines are copied horizontally, with the signs changed. These two parts of the table are separated by a diagonal line of double zeros.

TABLE II.

Values of $\delta_i - \delta_k$ in 0°·01 F.

	32	77	122	167
32	00	−03	−02	−07
77	+03	00	−01	−02
122	+02	+01	00	−03
167	+07	+02	+03	00
Sums	+12	00	00	−12

The first column is composed of the following values, in which δ_{32}, is the correction of the interval 32° to 77°, δ_{77}, that of 77° to 122° and so on:

$$\begin{aligned} \delta_{32} - \delta_{32} &= \ 00 \\ \delta_{32} - \delta_{77} &= +\ 03 \\ \delta_{32} - \delta_{122} &= +\ 02 \\ \delta_{32} - \delta_{167} &= +\ 07 \end{aligned}$$

by summing there results: $4\delta_{32} - (\Delta_{212} - \Delta_{32}) = +12$.

The second column of table II is made up as follows:

$$\begin{aligned} -\delta_{32} + \delta_{77} &= -\ 03 \\ \delta_{77} - \delta_{77} &= \ 00 \\ \delta_{77} - \delta_{122} &= +\ 01 \\ \delta_{77} - \delta_{167} &= +\ 02 \end{aligned}$$

and by summing, as before; $4\delta_{77} - (\Delta_{212} - \Delta_{32}) = 00$. In like manner the other columns give similar equations, and since Δ_{212} and Δ_{32} are zero, we have:

$$\begin{aligned} 4\,\delta_{32} &= +\ 12 \quad \therefore \quad \delta_{32} = +\ 0^\circ{\cdot}03 \\ 4\,\delta_{77} &= \ 00 \quad \therefore \quad \delta_{77} = \ 00 \\ 4\,\delta_{122} &= \ 00 \quad \therefore \quad \delta_{122} = \ 00 \\ 4\,\delta_{167} &= -\ 12 \quad \therefore \quad \delta_{167} = -\ 0^\circ{\cdot}03 \end{aligned}$$

by adding these values of δ, the corrections at 77°, 122° and 167° are found to be alike, and equal to $+0^\circ{\cdot}03$.

In the second part of the work no measurements were made with a ten-degree column, and therefore the symmetry of the first part will be wanting. The lengths of the columns as measured are given in table III. Before each line of lengths is given the approximate scale-reading of the lower ends of the columns.

TABLE III.

Apparent lengths of columns.

Lower end.							
32.	20·36	29·80	39·77	49·55	59·94	69·65	80·55
42.	20·38	29·82	39·78	49·57	59·90	69·65	80·47
52.	20·45	29·91	39·87	49·61	60·02	69·75	
62.	20·47	29·88	39·81	49·62	59·98		
72.	20·46	29·88	39·84	49·60			
82.	20·42	29·90	39·81				
92.	20·49	29·86					
102.	20·44						

Table IV is formed in the same way as table II. It will be noticed that there are two series of blanks corresponding to the 10° column of which the observations are wanting.

TABLE IV.

Values of $\delta_i - \delta_k$ and residuals in 0°·01 F.

	32	42	52	62	72	82	92	102	112
32	00		−02	−02	−01	−02	+04	00	+08
42		00		−07	−09	−09	−04	−12	−10
52	+02 − 1		00		−02	+03	+06	−01	+04
62	+02 − 3	+07 + 1		00		+01	00	−03	+02
72	+01 0	+09 + 1	+02 − 2		00		+04	−02	+03
82	+02 − 3	+09 − 1	−03 + 1	−01 + 1		00		−07	+04
92	−04 + 1	+04 + 2	−06 + 2	00 − 2	−04 0		00		+05
102	00 + 2	+12 0	+01 0	+03 + 1	+02 0	+07 − 3		00	
112	−08 + 3	+10 − 5	−04 − 2	−02 − 2	−03 − 2	−04 + 1	−05 + 3		00
Sums	−05	+51	−12	−09	−17	−04	+05	−25	+16

The sum of the numbers in the last horizontal line must be zero. This gives a check on the summing of the columns and the copying with signs changed. Another check on the work is this: that the differences of any two quantities in the same horizontal line should be the same, within the limits of the errors of observation.

Analyzing by a process similar to that used for table II, the following equations will be found, in which δ_{32} is the correction of the interval 32° to 42°; δ_{42}, that of 42° to 52° and so on.

			Approximations. First.	Second.	Third.
$8\,\delta_{32} = \Delta_{122} - \Delta_{32} - \delta_{42}$	−05	$\delta_{32} =$	−·003	−·013	−·013
$7\,\delta_{42} = \Delta_{122} - \Delta_{32} - \delta_{32} - \delta_{52}$	+51	$\delta_{42} =$	+·077	+·080	+·082
$7\,\delta_{52} = \Delta_{122} - \Delta_{32} - \delta_{42} - \delta_{62}$	−12	$\delta_{52} =$	−·013	−·023	−·024
$7\,\delta_{62} = \Delta_{122} - \Delta_{32} - \delta_{52} - \delta_{72}$	−09	$\delta_{62} =$	−·009	−·004	−·003
$7\,\delta_{72} = \Delta_{122} - \Delta_{32} - \delta_{62} - \delta_{82}$	−17	$\delta_{72} =$	−·020	−·019	−·019
$7\,\delta_{82} = \Delta_{122} - \Delta_{32} - \delta_{72} - \delta_{92}$	−04	$\delta_{82} =$	−·001	·000	−·001
$7\,\delta_{92} = \Delta_{122} - \Delta_{32} - \delta_{82} - \delta_{102}$	+05	$\delta_{92} =$	+·011	+·016	+·017
$7\,\delta_{102} = \Delta_{122} - \Delta_{32} - \delta_{92} - \delta_{112}$	−25	$\delta_{102} =$	−·031	−·037	−·038
$8\,\delta_{112} = \Delta_{122} - \Delta_{32} - \delta_{102}$	+16	$\delta_{112} =$	+·024	+·031	+·032

The values of δ, are derived from these equations by approximation. As seven times the correction of any interval may be reasonably assumed to be large as compared with the sum of the corrections of two adjoining intervals, approximate values can be derived from these equations by neglecting the δ on the right hand side. Δ_{122} is known from the first part of the work to be +0°·03, and Δ_{32} is zero. When the first approximation is made, the values found can be substituted on the right hand side of the equations and another set of values derived more accurate than the first. A few such processes will give the values of δ with sufficient accuracy. From these final values of δ, the calibration corrections $\varDelta_i$ given below are obtained by the formula $\varDelta_{i+1}=\varDelta_i+\delta_i$.

Correction. Δ_i	
32 =	0·00
42 =	−0·01
52 =	+0·07
62 =	+0·04
72 =	+0·04
82 =	+0·02
92 =	+0·02
102 =	+0·04
112 =	0·00
122 =	+0·03

To get some idea of the accuracy of the determination, the differences of observed and computed values of $\delta_i-\delta_k$ are given in table IV, in small figures, under each of the values. These residuals correspond to a probable error in any observed $\delta_i-\delta_k$ of about $\pm 0^\circ{\cdot}013$: and the probable error of any calibration correction will not exceed $\pm 0^\circ{\cdot}01$.

The calibration of a thermometer by this method where any of the observations with a particular column are lacking offers no special difficulty. When the observations are far from being as nearly complete as in the example just presented, good results can nevertheless be obtained, but the computation then becomes more tedious. In calibrating, every series of measurements with a column ought to be repeated in the reverse of the order first made. This will be a guard against large errors; and moreover the means of the two measurements will be free of errors arising from change of temperature of the column, provided its temperature is rising or falling uniformly.

Thermometers with reservoirs at the top of the tube are the easiest and safest to calibrate. This reservoir should be pear-shaped and of a capacity sufficient to hold at least as much mercury as the tube from freezing to boiling points. To obtain columns for calibrating, hold the thermometer vertical, with the bulb up, and give it a slight shock by the sudden stopping of a downward motion. This will be apt to detach a column of indefinite length or cause the mercury to run from the bulb. In case this does not occur in a few trials heat the thermometer so as to bring more mercury into the tube, and try it again. It will finally succeed with some greater length of column. In case the mercury runs from the bulb let it go until it enters the reservoir and partially occupies it. Then invert the thermometer quickly and the connection between the mercury in the bulb and that above will be broken. In case the portion detached is not the length of a column required move the mercury until it partially occupies the reservoir again. Then take the thermometer in the right hand, tap the index finger of the left hand with the reservoir-end, holding the instrument about horizontal. This will detach a greater or less portion of the mercury, depending on the intensity of the shock. If what is left is not of the required length bring back the mercury to the entrance of the reservoir; a few taps on the finger, as before, will cause the mercury to reunite. This process can be done over and over until a column of the required length is obtained.

In this way within half an hour a person can usually obtain a working column to a few tenths of a degree without any risk to the thermometer. Care should be taken in deriving the columns not to let all the detached mercury run into the reservoir, but to have a portion always projecting into the tube. If it does get into the reservoir, or there is not enough in the tube to cause it to run down by a sharp, quick motion when the thermometer is held vertical, the reservoir must be heated. An alcohol lamp is preferable for this purpose. The expansion of what little air there is in the reservoir will almost always drive down the mercury, but sometimes it requires the volatilization of the mercury itself. This difficulty of getting the mercury to run down the tube is in the way of obtaining short columns, especially in very capillary tubes.

Short columns can best be obtained from the bulb, in case the thermometer has but little tubing below freezing point so as to allow the mercury to sink into the bulb when put in a cooling mixture, as of salt and pounded ice. To obtain columns in this way, bring down the detached portion of mercury from the reservoir and let it join the main body of mercury in the bulb. It will be found that this junction will not be perfect, a slight bubble always remaining at the place of joining. Place the bulb in a cooling mixture until the top of the column is about as far above the bulb as the length of column desired; in the meantime the bubble, of which mention has been made, will have entered the bulb. Now take the thermometer in the right hand and hold it inclined, with the bulb down. A few light shocks by the sudden stopping of a rapid motion in the direction of the thermometer stem will bring the bubble to the entrance of the tube. The expansion of the mercury as the temperature rises will drive the short column before it. By this process also the mercury may be perfectly reunited after the calibration is completed, by cooling until all the mercury runs into the bulb, when a little jarring of the thermometer, as before, will cause the bubble to disappear.

Another method of getting columns of definite length is described in *Fischer's Geodäsie*, credited to Hansteen. The pinciple consists in getting a small bubble of air in the column of mercury, but not large enough to occupy the whole cross-section of the tube; then by very slow heating or cooling when the desired length of column is above the bubble it may be detached by a sudden jar. To operate successfully, according to this method, a thermometer of large bore is required. In the case of a thermometer without a reservoir at the top these latter methods are the only ones that can be safely used. Egen's method of directing the flame of a blowpipe on the tube should never be followed.

In selecting a thermometer some idea of the nature of the bore, whether regular or not, can be formed by inspection without the aid of detached columns. If examination with a reveals a straight smooth exterior it generally denotes the same interior qualities.

Art. XLVIII.—*Notice of William Hallowes Miller;* by J. P. Cooke.*

William Hallowes Miller, who was elected Foreign Honorary Member of this Academy in the place of C. F. Naumann, May 26th, 1874, died at his residence in Cambridge, England, on the 20th of May, 1880, at the age of 79, having been born at Velindre in Wales, April 6th, 1801. His life was singularly uneventful even for a scholar. Graduating with mathematical honors at Cambridge in 1826 he became a fellow of his College (St. Johns) in 1829, and was elected Professor of Mineralogy in the University in 1832. Amidst the calm and elegant associations of this ancient English University, Miller passed a long and tranquil life,—crowded with useful labors, honored by the respect and love of his associates and blessed by congenial family ties. This quiet student life was exactly suited to his nature, which shunned the bustle and unrest of our modern world. For relaxation even he loved to seek the retired valleys of the Eastern Alps; and the description which he once gave to the writer, of himself sitting at the side of his wife amidst the grand scenery, intent on developing crystallographic formulæ while the accomplished artist traced the magnificent outlines of the Dolomite Mountains, was a beautiful idyl of science.

Miller's activities, however, were not confined to the University. In 1838 he became a Fellow of the Royal Society, and in 1856 he was appointed its Foreign Secretary,—a post for which he was eminently fitted and which he filled for many years. In 1843 he was selected one of a committee to superin-

* Read before the American Academy of Arts and Sciences, Boston, and to appear in the Proceedings.

tend the construction of the new Parliamentary standards of length and weight to replace those which had been lost in the fire which consumed the Houses of Parliament in 1834, and to Professor Miller was confided the construction of the new standard of weight. His work on this important committee, described in an extended paper published in the Philosophical Transactions for 1856, was a model of conscientious investigation and scientific accuracy. Professor Miller was subsequently a member of a new Royal Commission for "examining into and reporting on the state of the secondary standards, and for considering every question which could affect the primary, secondary and local standards"; and in 1870 he was appointed a member of the "Commission Internationale du Mètre." His services on this commission were of great value and it has been said that "there was no member whose opinions had greater weight in influencing a decision upon any intricate and delicate questions."

Valuable, however, as were Professor Miller's public services on these various commissions his chief work was at the University. His teacher, Dr. William Whewell, afterwards the Master of Trinity College, was his immediate predecessor in the Professorship of Mineralogy at Cambridge. This great scholar, whose encyclopædic mind could not long be confined in so narrow a field, held the Professorship only four years, but during this period he devoted himself with his usual enthusiasm to the study of crystallography, and he accomplished a most important work in attracting to the same study young Miller, who brought his mathematical training to its elucidation. It was the privilege of Professor Miller to accomplish a unique work, for the like of which a more advanced science, with its multiplicity of details, will offer few opportunities.

The foundations of crystallography had been laid long before Miller's time. Haüy is usually regarded as the founder of the science; for he first discovered the importance of cleavage, and classed the known facts under a definite system. Taking cleavage as his guide and assuming that the forms of cleavage were not only the *primitive forms* of crystals as a whole, but also the forms of their *integrant molecules*, he endeavored to show that all secondary forms might be derived from a few primary forms, regarded as elements of nature, by means of *decrements* of molecules at their edges. In like manner he showed that all the forms of a given mineral, like fluor spar or calcite, might be built up from the integrant molecules by skilfully placing together the primitive forms. Haüy's dissection of crystals in a manner which appeared to lead to their ultimate crystalline elements gained for his system great popular attention and applause. The system was developed with great perspicuity and completeness in a work remarkable for the vivacity of its style and the felicity of its illustration. Moreover, a simple mathematical expression was given to the system, and the notation which Haüy invented to express the relation of the secondary to the primary forms, as modified and improved by Lèvy, is still used by the French mineralogists.

The system of Haüy, however, was highly artificial and only prepared the way for a simpler and more general expression of the facts. The German crystallographer Weiss seems to have been the first to have recognized the truth that the decrements of Haüy were merely a mechanical mode of representing the fact that all the secondary faces of a crystal make intercepts on the edges of the primitive form which are simple multiples of each other; and this general conception once gained it was soon seen that these ratios could be as simply measured on the axes of symmetry of the crystal as on the edges of the fundamental forms; and, moreover, that when crystal forms are viewed in their relation to these axes a more general law becomes evident, and the artificial distinction between primary and secondary forms disappears.

Thus became slowly evolved the conception of a crystal as a group of similar planes symmetrically disposed around certain definite and obvious systems of axes, and so placed that the intercepts, or parameters, on these axes bore to each other a simple numerical ratio. Representing by $a : b : c$ the ratio of the intercepts of a plane on the three axes of a crystal of a given substance, then the intercepts of every other plane of this, or of any other crystal of the same substance, conform to the general proportion $m\,a : n\,b : p\,c$, in which m, n, p are three simple whole numbers. This simple notation devised by Weiss expressed the fundamental law of crystallography, and the conception of a crystal as a system of planes symmetrically distributed according to this law was a great advance beyond the decrements of Haüy, an advance not unlike that of astronomy from the system of vortices to the law of gravitation. Yet, as the mechanism of vortices was a natural prelude to the law of Newton, so the decrements of Haüy prepared the way for the wider views of the German crystallographers.

Whether Weiss or Mohs contributed most to advance crystallography to its more philosophical stage, it is not important here to inquire. Each of these eminent scholars did an important work in developing and diffusing the larger ideas, and in showing by their investigations that the facts of nature corresponded to the new conceptions. But to Carl Friedrich Naumann, Professor at the time in the "Bergakademie zu Freiberg," belongs the merit of first developing a complete system of theoretical crystallography based on the laws of symmetry and axial ratios. His "Lehrbuch der reinen und angewandten Krystallographie," published in two volumes at Leipzig in 1830, was a remarkable production, and seemed to grasp the whole theory of the external forms of crystals. Naumann used the obvious and direct methods of analytical geometry to express the quantitative relations between the parts of a crystal; and although his methods are often unnecessarily prolix and his notation awkward, his formulæ are well adapted to calculation, and easily intelligible to persons moderately disciplined in mathematics.

But, however comprehensive and perfect in its details, the system of Naumann was cumbrous, and lacked elegance of mathematical form. This arose chiefly from the fact that the old methods of analytical geometry were unsuited to the problems of crystallography; but it resulted also from a habit of the German mind to dwell on details and give importance to systems of classification. To Naumann the six crystalline systems were as much realities of nature as were the forms of the integrant molecules to Haüy, and he failed to grasp the larger thought which includes all partial systems in one comprehensive plan.

Our late colleague, Professor Miller, on the other hand, had that power of mathematical generalization which enabled him to properly subordinate the parts to the whole, and to develop a system of mathematical crystallography of such simplicity and beauty of form that it leaves little to be desired. This was the great work of his life and a work worthy of the University which had produced the "Principia." It was published in 1839 under the title "A Treatise on Crystallography," and in 1863 the substance of the work was reproduced in a more perfect form, still more condensed and generalized, in a thin volume of only eighty-six pages, which the author modestly called "A Tract on Crystallography."

Miller began his study of crystallography with the same materials as Naumann; but in addition he adopted the beautiful method of Franz Ernst Neumann of referring the faces of a crystal to the surface of a circumscribed sphere by means of radii drawn perpendicular to the faces. The points where the radii meet the spherical surface are the poles of the faces, and the arcs of great circles connecting these poles may obviously be used as a measure of the angles between the crystal faces. This invention of Neumann's was the germ of Miller's system of crystallography; for it enabled the English mathematician to apply the elegant and compendious methods of spherical trigonometry to the solution of crystallographic problems; and Professor Miller always expressed his great indebtedness to Neumann not only for this simple mode of defining the position of the faces of a crystal, but also for his method of representing the relative position of the poles of the faces on a plane surface by a beautiful application of the methods of stereographic and gnomonic projection. This method of representing a crystal shows very clearly the relations of the parts, and was undoubtedly of great aid to Miller in assisting him to generalize his deductions.

From the outset Professor Miller apprehended more clearly than any previous writer the all-embracing scope of the great law of crystallography. He opens his Treatise with its enunciation, and from this law as the fundamental principle of the subject the whole of his system of crystallography is logically developed. Beyond this all that is peculiar to Miller's system is involved in two or three general theorems. The rest of his "Treatise" consists of deductions from these theorems and their application to particular cases. These given and the rest could be at once developed by any scholar who was familiar with the facts of crystallography; and the circumstance that its essential features can be so briefly stated is sufficient to show how exceedingly simple the system is. At the same time, it is wonderfully comprehensive, and the student who has mastered it feels that it presents to him in one grand view the entire scheme of crystal forms, and that it greatly helps him to comprehend the scheme as a whole, and not simply as the sum of certain distinct parts. So felt Professor Miller himself; and, while he regarded the six systems of crystals of the German crystallographers as natural divisions of the field, he considered that these divisions were bounded by artificial lines which have no deeper significance than the boundary lines on a map. How great the unfolding of the science from Haüy to Miller, and yet now we can see the great fundamental ideas shining through the obscurity from the first. What we now call the parameters of a crystal were to Haüy the fundamental dimensions of his "integrant molecules," our indices were his "decrements," and our conceptions of symmetry his "fundamental forms." There has been nothing peculiar, however, in the growth of crystallography. This growth has followed the usual order of science, and here as elsewhere the early gross material conceptions have been the stepping stones by which men rose to higher things. In sciences like chemistry, which are obviously still in the earlier stages of their development, it would be well if students would bear in mind this truth of history, and not attach undue importance to structural formulæ and similar mechanical devices, which, although useful for aiding the memory, are simply hindrances to progress as soon as the necessity of such assistance is passed. And when the life of a great master of science has ended, it is well to look back over the road he has traveled, and while we take courage in his success consider well the lesson which his experience has to teach; and, as progress in this world's knowledge has ever been from the gross to the spiritual, may we not rejoice as those who have a great hope.

Although the exceeding merit of the "Treatise on Crystallography" casts into the shade all that was subordinate, we must not omit to mention that Professor Miller published an early work on Hydrostatics and numerous shorter papers on Mineralogy and Physics, which were all valuable, and constantly contained important additions to knowledge. Moreover, the "New Edition of Phillips' Mineralogy" which he published in 1852 in connection with H. J. Brooke, owed its chief value to a mass of crystallographic observations which he had made with his usual accuracy and patience during many years and there tabulated in his concise manner. As has been said by one of his associates in the Royal Society, "it is a monument to Miller's name although he almost expunged that name from it.* It is due to Professor Miller's memory that his works should be collated, and especially that by a suitable commentary his "Tract on Crystallography" should be made accessible to the great body of the students of physical science, who have not as a rule the ability or training which enables them to apprehend a generalization when solely expressed in mathematical terms. The very merits of Professor Miller's book as a scientific work renders it very difficult to the average student, although it only involves the simplest form of algebra and trigonometry.

Independence, breadth, accuracy, simplicity, humility, courtesy are luminous words which express the character of Professor Miller. In his genial presence the young student felt encouraged to express his immature thoughts, which were sure to be treated with consideration, while from a wealth of knowledge the great master made the error evident by making the truth resplendent. It was the greatest satisfaction to the inexperienced investigator when his observations had been confirmed by Professor Miller, and he was never made to feel discouraged when his mistakes were corrected. The writer of this notice regards it as one of the great privileges of his youth, and one of the most important elements of his education, to have been the recipient of the courtesies and counsel of three great Englishmen of science, who have always been "his own ideal knights," and these noble knights were Faraday, Graham and Miller.

* Obituary Notices from the Proceedings of the Royal Society, No. 206, 1880, to which the writer has been indebted for several biographical details.

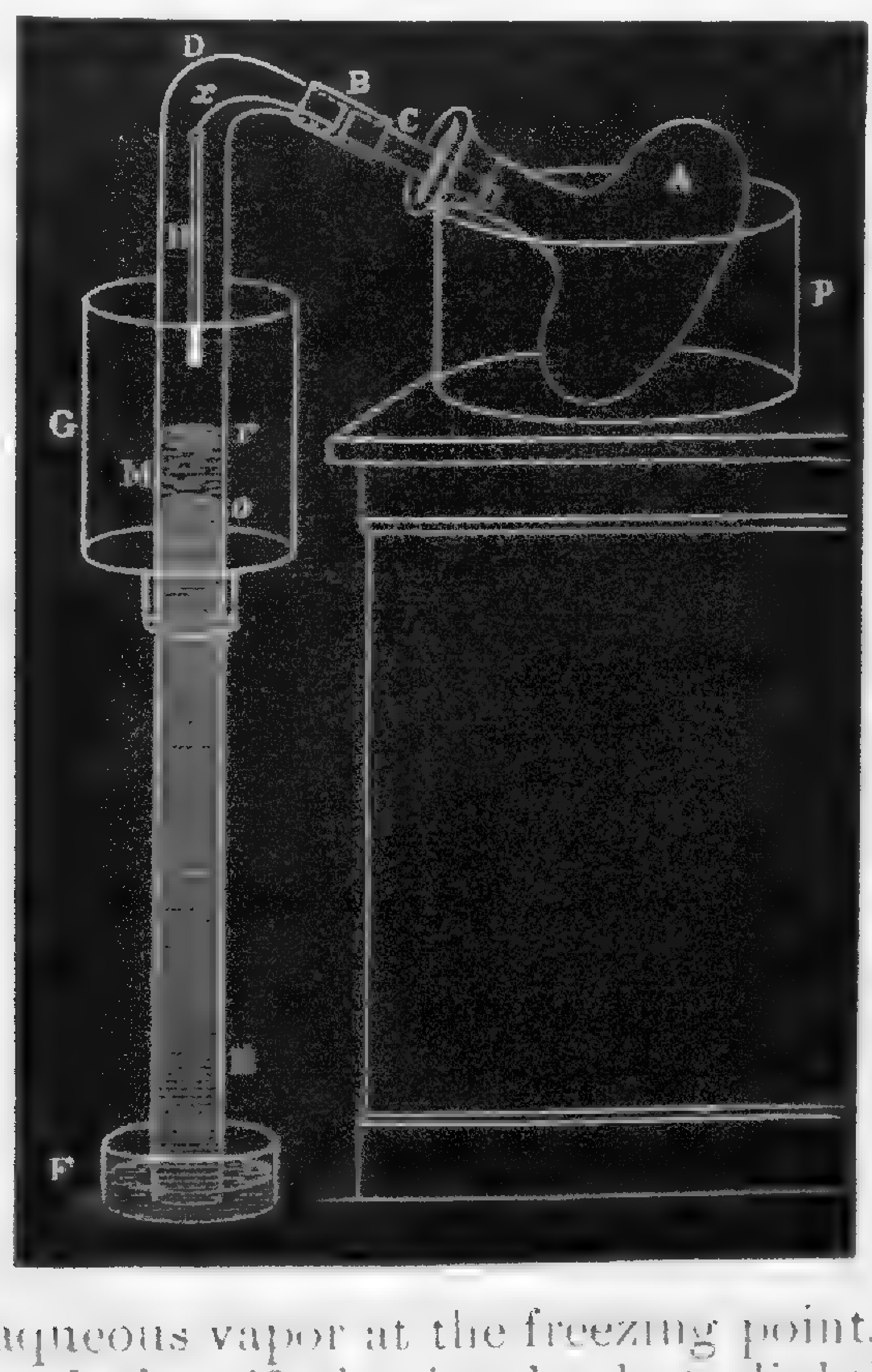
ART. XLIX.—*Preliminary Note on the Existence of Ice and other Bodies in the Solid State at Temperatures far above their ordinary Melting Points;* by THOMAS CARNELLEY, D.Sc., Professor of Chemistry in Firth College, Sheffield.*

IN the present communication I have the honor to lay before the Royal Society a detailed description of experiments, proving that under certain conditions it is possible for ice and other bodies to exist in the solid state at temperatures far above their ordinary melting points. On a future occasion I hope to submit to the Society a full account of the investigation of which these experiments form a part, together with the conclusions to be drawn therefrom. The bodies whose behavior I propose to discuss at present are ice and mercuric chloride.

Ice.

In the case of ice the great difficulty to be overcome is to maintain the pressure in the containing vessel below $4{\cdot}6^{mm}$, i. e.,

1.



the tension of aqueous vapor at the freezing point, for it will be easily understood that if the ice be but slightly heated the quantity of vapor given off would soon be sufficient to raise the pressure above that point. After several fruitless attempts the

* From the Proceedings of the Royal Society, January 6, 1881.

following plan, involving the principle of the cryophorus, was adopted.

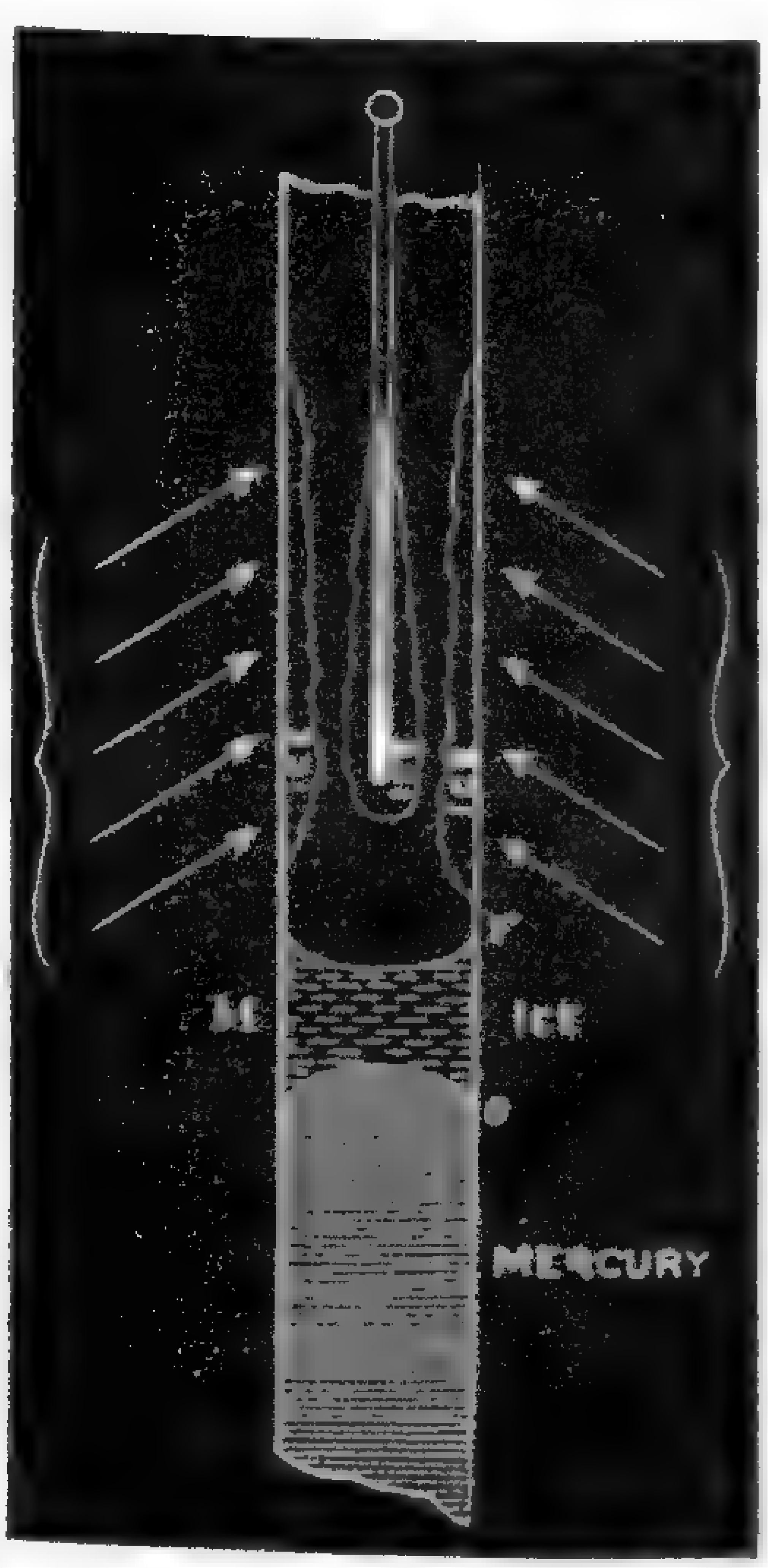
A strong glass bottle, such as is used for freezing water by means of Carré's pump, was fitted with a cork and glass tube C (fig. 1), and the cork well fastened down by copper wire and paraffin wax. A and C were then filled with mercury, and C connected with the end of the tube DE by means of the piece of stout india-rubber pump tubing B, a thermometer having been previously attached by the wire x to the lip of the tube at B. The connection at B was made tight by fine copper wire. The tube DE was about one inch in diameter, and about four feet long from the bend to the end E; after connection with C it was completely filled with mercury, care being taken to expel the air from A, C and DE as completely as possible; the whole was then inverted over the mercurial trough F, as shown in the figure, when the mercury fell to o, the ordinary height of the barometer. The mercury was run out of A by tilting up the bottle and inclining the tube DE. By this means a Torricellian vacuum was obtained from A to o. DE was next brought to the vertical, and the bottle A placed in the trough P. A tin bottle G without a bottom was fitted with a cork, so that it might slide somewhat stiffly along DE.

To begin with, the tin bottle was placed in the position G and filled with a freezing mixture of salt and ice. Some boiled water was then passed up the tube DE, sufficient to form a column at M about two inches deep. The thermometer H had been previously arranged, so that its bulb might be one or two inches above the surface of the water M. The bottle A was next surrounded by a good quantity of a freezing mixture of salt and ice, in order that any vapor given off from the water at M might be condensed in A as fast as it was formed, and the internal pressure might never be more than about 1·0 to 1·5^{mm}. When A had been sufficiently cooled, which required about fifteen minutes, the tin vessel G was slid down the tube DE, and its freezing mixture removed. The water at M had then solidified to a mass of ice, which on heating with the flame of a Bunsen's burner melted either wholly or partially, and the liquid formed began at once to boil. The fusion commenced first at the bottom of the column of ice, whereas the upper part fused only with difficulty, and required rather a strong heat. The fusion in this case was probably due to the steam evolved from the lower portions of the ice column being imprisoned and unable to escape, and hence producing pressure sufficient to cause fusion.

When the greater part of the ice had been melted the tube was tightly clasped by the hand, the heat of which was sufficient to produce a somewhat violent ebullition. The liquid in boiling splashed up the side of the tube and on to the bulb of the thermometer, where it froze into a solid mass, as represented in fig. 2. By this means the ice was obtained in moderately thin layers. The tube at the points indicated by the arrows was then strongly heated by the flame of a Bunsen's burner, with the following results:—

The ice attached to the sides of the tube at first slightly fused, because the steam evolved from the surface of the ice next the glass being imprisoned between the latter and the overlying strata of ice, could not escape, and hence produced pressure sufficient to cause fusion, but as soon as a vent-hole had been made fusion ceased, and the whole remained in a solid state, and neither the ice on the sides of the tube nor that on the bulb of the thermometer could be melted, however great the heat applied, the ice merely volatilizing without previous melting. The thermometer rose to temperatures varying between 120° and 180° in different experiments, when the ice had either wholly volatilized or had become detached from the bulb of the thermometer. The ice attached to the latter did not partially fuse at the commencement of the heating because, the heat reaching

2.



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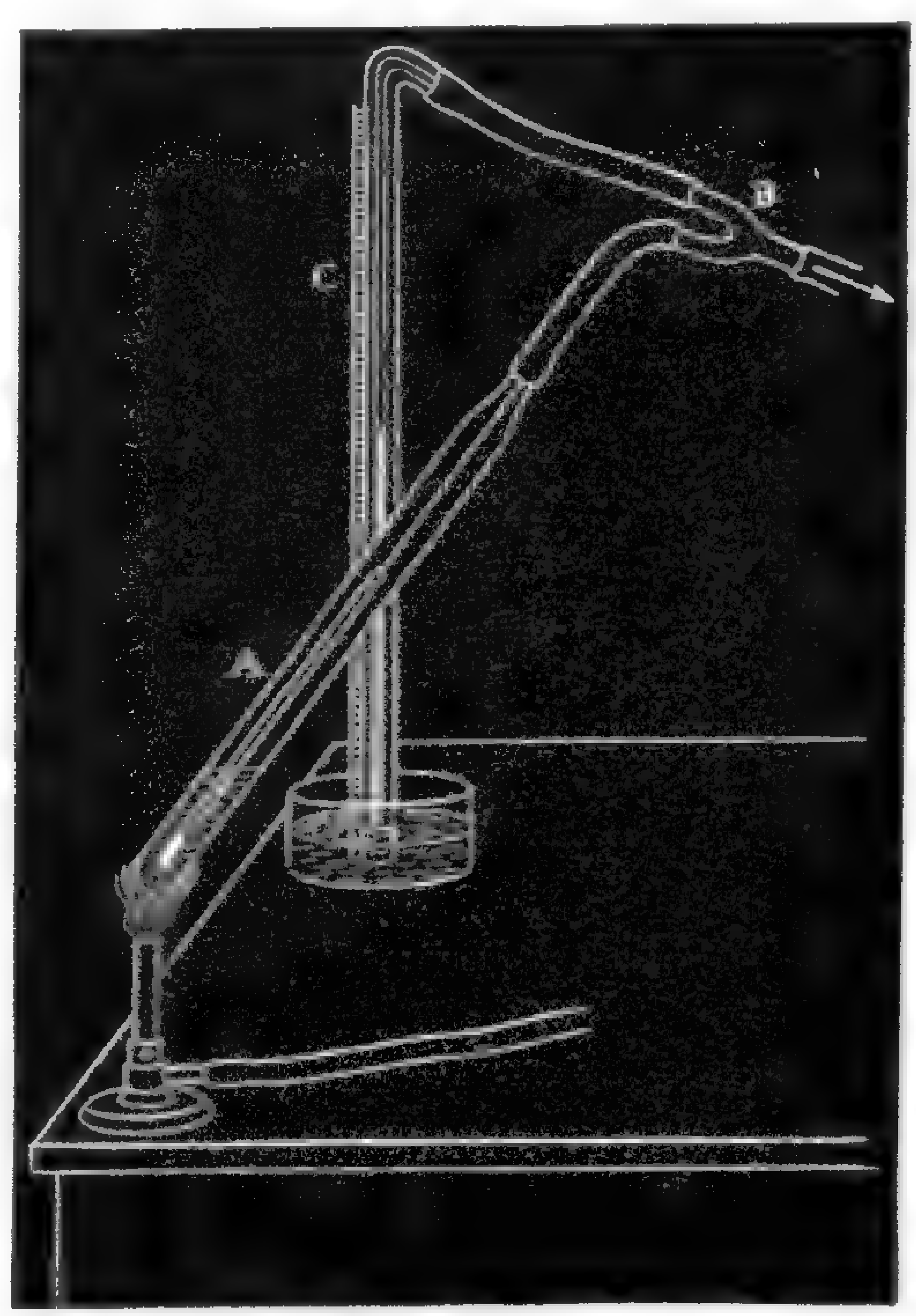


the outer surface of the ice first, evaporation could take place from a free surface and the vapor not become imprisoned, as was the case with the ice attached to the sides of the tube.

These experiments were repeated many times and always with the same result, except in one case in which the heat applied had been very strong indeed and the ice attached to the sides of the tube fused completely. On removing the lamp, however, for a few seconds the water froze again, notwithstanding that the portion of the glass in contact with it was so hot that it could not be touched without burning the hand.

The chief conditions necessary for success appear to be—(1) That the condenser (A, fig. 1) is sufficiently large to *maintain* a good vacuum. In the present case the capacity was about three-quarters of a liter; (2) That the ice is not in too great mass, but arranged in thin layers. Further, in the case where the heat is applied to the under surface of the layers of ice, the latter must be sufficiently thin to allow of a vent-hole being formed for the escape of the steam coming from below, otherwise fusion occurs. When the heat is applied to the free surface of the ice, the layers may be much thicker.

Mercuric Chloride,

m. p.=288°, re-solidifies at 270–275°, b. p.=303°.

About 40 grs. of pure mercuric chloride were placed in the tube (A, fig. 3), and a thermometer arranged with its bulb imbedded in the salt. The drawn-out end of the tube was connected by a stout india-rubber tubing with one branch of the three-wayed tube B, while the other was attached to the manometer C. B was connected with a Sprengel pump, fitted with an arrangement for regulating the pressure.

When the pressure had been reduced by means of the pump to below 420^{mm}, the mercuric chloride was strongly heated by the flame of a Bunsen's burner, with the following results:

Not the slightest fusion occurred, but the salt rapidly sublimed into the cooler parts of the tube, while the unvolatilized portion of the salt shrank away from the sides of the tube and clung tenaciously in the form of a solid mass to the bulb of the thermometer, which rose considerably above 300° C., the mercury of the thermometer shooting up to the top of the stem. After slight cooling the air was let in, and under the increased pressure thus produced the salt attached to the bulb of the thermometer at once melted and began to boil, cracking the tube at the same time.

The experiment was next varied as follows:—

About the same quantity of chloride was placed in the tube A, fig. 3, as before, and heated by the full flame of a Bunsen's burner. The lamp was applied during the whole of this experiment, and the size of the flame kept constant throughout. The mercuric chloride first liquefied and then boiled at 303° under ordinary pressure, and while the salt was still boiling the pressure was gradually reduced to 420^{mm}, when the boiling point slowly fell to 275°, at which point the mercuric chloride suddenly began to solidify, and at 270° was completely solid, the pressure then being 376^{mm}. When solidification was complete the pump was stopped working, but the heat still continued to the same extent as before. The salt then rose rapidly to temperatures above that at which a thermometer could be used, but not the least sign of fusion was observed. From the completion of the solidification to the end of the experiment the pressure remained at about 350^{mm}.

The above experiment, which was repeated three times, shows, therefore, that when the pressure is gradually reduced from the ordinary pressure of the atmosphere to 420^{mm}, and the boiling point simultaneously from 303° to 275°, the salt solidifies while it is still boiling and in contact with its own hot liquid notwithstanding that it is being strongly heated at the same time; and that, after solidification is complete at 270°, the temperature then rises far above the ordinary boiling point (303°) of the substance without producing any signs of fusion. Under ordinary circumstances, mercuric chloride melts at 288° and re-solidifies at 270°–275°, i. e., at a temperature identical with that at which it solidifies under diminished pressure, as above described.

The solid mercuric chloride obtained on solidification under the combined influence of diminished pressure, and the application of a strong heat had a peculiar appearance, quite different to that produced when the substance is allowed to solidify in the ordinary way. It appeared to consist of a mass of pearly leaflets closely packed together round the bulb of the thermometer.

Any final explanation of these phenomena is reserved until further experiments have been made.

Appendix.

Since writing the foregoing, it has been said in explanation of the phenomena therein described, that the thermometer, though embedded in the mass of ice, did not really indicate the true temperature of the latter. With the object, therefore, of proving whether the ice is hot or not, I have, at the suggestion of Professor Roscoe, made the following calorimetrical determination.

The arrangement of the apparatus was so modified, that the ice, after being strongly heated, could be suddenly dropped into a calorimeter containing a known quantity of water of known temperature. The resulting temperature, after the ice had been dropped in, was read off by a thermometer graduated so as to indicate a difference of 0°·05 C. The weight of the ice was found by re-weighing the calorimeter.

So far, I have only had the opportunity of completing the two following determinations, and in the second of these the weight of the ice could not be found, as a small quantity of water was lost out of the calorimeter, owing to a sudden jerk at the moment the ice entered it:—

(1.) Weight of water in calorimeter, including the value of the latter =185 grms.

Weight of ice dropped in =1·3 grms.

$$\begin{array}{lr} \text{Temperature of calorimeter before} = & 13^\circ\!\cdot4 \\ \text{“} \qquad\qquad \text{“} \qquad \text{after} = & 13\cdot6 \\ \hline \text{Rise in temperature} = & 0\cdot2 \end{array}$$

$$M(\theta - t) \quad + \quad 80W \quad = W(T-\theta)$$

$$(185)\times 0\cdot2) + (80\times 1\cdot3) = 1\cdot3(T-13\cdot6)$$

$$\therefore \quad T = 122^\circ \text{ C.} \quad \text{Where } T = \text{temperature of ice.}$$

(2.) Weight of water in calorimeter, &c.= 185 grms.

$$\begin{array}{lr} \text{Temperature of calorimeter before} = & 12^\circ\!\cdot7 \\ \text{“} \qquad\qquad \text{“} \qquad \text{after} = & 12\cdot8 \\ \hline \text{Rise in temperature} = & 0\cdot1 \end{array}$$

On weighing the calorimeter after the experiment, the increase in weight was only 0·15 grams, but as a portion of the water had been jerked out during the operation, the true weight of the ice and therefore its temperature could not be found. But since the calorimeter had slightly risen in temperature, the ice must have been above 80° C.

From the nature of the experiment, as carried out on the present scale, the weight of the ice which can be dropped into the calorimeter is only small, and therefore the rise in temperature is but slight. But since a fall in temperature of a much larger amount ought to have been obtained had the ice been at 0°, it is considered that the above experiments are conclusive. Great care was taken, in order to obtain correct temperatures in the calorimeter. The latter was inclosed in several casings, and the water was allowed to stand in it for several hours before the experiment, so that it might first attain the temperature of the room, while the time which elapsed between the readings of the thermometer before and after the ice was dropped in would not be more than from 10 to 15 seconds.

In the course of the next few weeks I intend to make one or two more determinations, and if possible, on a larger scale.

ART. L.—*Note on the Geology of the Peace River Region*; by GEORGE MERCER DAWSON, Assistant Director Geological Survey of Canada.

THE first definite knowledge of the geological features of the Peace River basin was obtained in 1875. In that year Mr. Selwyn, Director of the Geological Survey of Canada, setting out from McLeod's Lake, in British Columbia, descended the Parsnip and Peace Rivers to the confluence of the Smoky with the latter, returning by the same route. The geographical and geological notes published in the report of the expedition have constituted the basis of subsequent work. In 1879 the Canadian government decided to ascertain more completely than had previously been possible, the character of the Peace and Pine Passes through the Rocky Mountains as prospective railway routes, and the economic value, agriculturally and geologically, of the Peace River basin. The writer represented the geological survey on the expedition of that year, and the information now obtained, with that previously alluded to, enables a clear general idea of the geological features of the district to be formed. The geology of this region is of interest as representing the farthest northern portion of the Mesozoic interior continental basin yet known with any precision, the country examined lying chiefly between the 54th and 57th parallels of north latitude. The general geological result of the exploration is the preliminary examination of a section extending from the Pacific Coast to Edmonton, on the Saskatchewan, including the entire Cordillera belt, between the parallels above mentioned, with a length in all of about 700 miles. The remarks here following refer to the eastern portion of this section only.

The Rocky Mountain Range about the sources of the Peace is narrow and comparatively low, the higher peaks seldom exceeding 6,000 feet. It is chiefly composed of limestones in massive beds, which are underlain by saccharoidal quartzites, and overlain on the west by micaceous and plumbaginous schists. In some of the limestone beds, fossils of Devonian age have been found, the most abundant form being *Atrypa reticularis*, a shell widely distributed over the Mackenzie River district farther to the north. The beds of the mountains have general westerly dips, and overturned folds probably occur. On the east side of the range, on both Peace and Pine Rivers, hard dark calcareous beds are found holding *Monotis subcircularis*, a form characteristic of the "Alpine Trias" of Nevada and California, and found also in several places on the British Columbian Coast.

To the east of these beds of the mountains, and resting quite unconformably on them, are the Cretaceous rocks, which, between the mountains and the eastern outcrop of the Devonian rocks on the Lower Peace, occupy a basin with a width of nearly 350 miles, implying a Cretaceous sea of that width.

The Rocky Mountains have here formed a shore-line in Cretaceous times,—though probably not a continuous one—and the Cretaceous rocks along their eastern base are almost entirely sandstones and conglomerates, the constituent fragments of which can be traced to the cherts and quartzites accompanying the limestones of the mountains. The mountains are bordered to the east by foot-hills, in which, on the upper part of Pine River, for a distance of about fifteen miles from the older rocks, the Cretaceous sandstones are folded and disturbed. The disturbance, however, gradually diminishes on receding from the mountains, and the beds at length become flat, or are affected by very slight and broad undulations only. Slaty materials increase in importance eastward, and the Cretaceous series eventually resolves itself into the following subdivisions—clearly shown on Smoky River—which in the annexed table are placed opposite their supposed equivalents in Meek and Hayden's and the Southern Rocky Mountain sections.

Upper, or Wapiti River Sandstones,	Fox Hill (and Laramie ?)	
Upper, or Smoky River Shales,	Pierre.	
Lower, or Dunvegan Sandstones,	Niobrara.	Colorado Group.
Lower, or Ft. St. John Shales,	Benton.	
	Dakota.	

The correlation, as above shown, is based partly on paleontological evidence, and partly on lithological resemblance. That the upper Shales represent the Pierre group is quite clear, as a large number of characteristic fossils of this stage have been obtained on Smoky River. No fossils have been found in the overlying sub-division. The fossils of the lower Sandstones are peculiar, consisting chiefly of fresh-water and estuarine mollusks and land plants. In the lower Shales the most characteristic form is a large Ammonite resembling *Ammonites* (*Prionocyclus*) *Woolgari*, but, according to Mr. Whiteaves, specifically distinct. The Peace River country being so remote from the typical region of the Cretaceous sub-divisions, it is not intended to insist on their precise synchronism with the groups here mentioned, but merely to point out a probable general equivalency. No beds so low as the Dakota group have yet been found in this region, though it is probable that they occur on the Peace below the confluence of the Smoky.

The lithological resemblance of the shales of the Upper and Lower sub-divisions to those of the Pierre and Benton sub-divisions is exceedingly close. It is probable that these mark periods of general submergence, when sediment-bearing currents passed freely through the interior continental valley. Elevation is known to have been in progress during the Niobrara period in the Rocky Mountain region to the south, and in the Dunvegan Sandstones, we may see an indication of the elevation of land surfaces to the north and west, which interrupted these currents and allowed the undisturbed deposition of the calcareous Niobrara beds of the south and east of the interior continental region.

The fossils of the Lower or Dunvegan sandstones are of especial interest, giving us a number of fresh-water mollusks and land-plants of a stage of the Cretaceous, previously almost unrepresented in these respects. The fresh-water mollusks closely resemble those of the Laramie group, and the plants, while showing a close analogy with those of the Dakota group, help to fill a gap in time between these and those of the Vancouver (Chico) Cretaceous, and the Laramie and Fort Union. They include species of *Cycadites*, *Magnolia*, *Protophyllum*, *Sequoia*, *Glyptostrobus gracillimus*, etc., which will be described in the forthcoming Report of Progress of the Geological Survey.

In 1872, Professor Meek described a series of beds at Coalville, Utah, which appear to have been formed at the edge of the Cretaceous sea, at the mouth of a small river, and hold fresh-water mollusks. The fossils from these beds represent a stage somewhat higher in the Cretaceous than those of the Dunvegan rocks, but closely resemble them and those of the overlying Laramie series. *Brachydontes multilinigera* of the Coalville section, is found in several places in the Dunvegan beds. After remarking on the peculiar character of this fauna, Meek writes:* "Here we have, from beds certainly overlaid by one thousand feet of strata containing Cretaceous types of fossils, a little group of forms, presenting such modern affinities that, if placed before any paleontologist unacquainted with the facts, they would be at once referred to the Tertiary."

In the Peace River district we find, instead of a merely local intercalation of this kind, a widely-extended series of beds of Cretaceous age, persistently holding fresh-water and estuarine types of mollusks and land plants.

The chief evidence going to prove the Tertiary age of the Laramie and Fort Union beds, after that afforded by the plants,

* U. S. Geol. Survey of Territories, 1872, p. 435.

has been found in the Tertiary aspect of the mollusks, most of which are fresh or brackish-water forms. Hitherto little has been known of the fresh-water fauna of the undoubted Cretaceous, but if this should prove to have, as now appears probable, a "Tertiary" aspect throughout, it will tend to break down the molluscan evidence of the Tertiary age of the Laramie, and unite this formation still more closely with the underlying beds.

Montreal, March 1, 1881.

ART. LI.—*On the Shadows obtained during the Glow Discharge*; by H. B. FINE and W. F. MAGIE.

IT is well known that a body interposed between the poles of a Holtz machine causes a so-called *electrical shadow* to appear upon the positive glow. We believe, however, that the fact that a similar shadow can be obtained upon the negative glow has not yet been published. These appearances seemed of some importance as offering a further proof of the essential similarity of the positive and negative discharges. The following points with reference to them may be of some interest.

The glow was best obtained on either electrode when the other terminated in a point, the positive glow showing to better advantage on the smaller, and the negative glow on the larger of the two balls usually employed as terminals. Whenever either the positive or negative glow was established, a well defined shadow was cast upon it by any body, preferably a non-conductor, interposed between the electrodes. By careful manipulation, the smaller ball being used as positive, the larger as negative terminal, both glows were obtained at the same time, and shadows could be made to appear upon them simultaneously. The observations of Professor Wright* on the positive shadow were verified and found to hold for the negative also; and, in fact, all the phenomena obtainable with the one were likewise characteristic of the other.

These shadows, in general, whether positive or negative, represent closely the outline of the interposed object. If, however, the lines of electrical action be deflected by the presence of a conductor, the form of the shadow is altered. We could not effect any such alteration by merely blowing across the field.

The size of the shadow varies with the tension on the electrode, becoming smaller as this is heightened. This fact is

* This Journal, II, xlix, 381.

easily illustrated by touching the electrode upon which the glow appears, and then removing the hand. The shadow, which at first covers almost the whole surface of the ball, rapidly diminishes as the tension rises. The size of the shadow further depends on the distance of the interposed object from the glowing electrode, though the relations of size and distance could not be very definitely determined. When the point and ball were used as terminals, the shadow appeared greatest when the interposed object was near either electrode and least when it was half way between them. When the two balls were used and both glows established at once, and generally when the discharge opposite the glow came from several points, the shadow decreased regularly as the interposed object was further removed.

It would not be proper for us to omit mention of the fact that Professor C. A. Young has since informed us that he noticed the existence of the negative shadow several years ago.

J. C. Green School of Science, Princeton, N. J.

ART. LII. — *Note on a New Form of Galvanometer for Powerful Currents;* by Professor C. F. BRACKETT, College of New Jersey.

THE very powerful currents produced by large dynamo-machines are not easily estimated by the appliances usually found in the physical laboratory.

The various forms of the electro-dynamometer, the cosine galvanometer and some other special forms of apparatus may of course be employed with satisfactory results. None of these instruments being in the collection at Princeton, it was determined to construct a galvanometer which should obey the law of tangents and yet not be so large as to be unwieldy. In order to this, recourse was had to the differential principle. The construction is as follows:

Two stout hoops of copper or brass of different diameters are very exactly turned in the lathe. They are then each cut open at one point and joined to each other concentrically, by soldering, with hard solder, between the ends on one side of the cut, a piece of metal having the same cross section as that of the hoops, and of suitable length. At several other points are inserted between the hoops pieces of hard rubber of proper thickness, which serve to keep them truly concentric.

The three ends of the system thus arranged and set upright on a proper base board are joined to binding screws.

It will be seen that the differential action on a needle placed at the center, or on the axis of the hoops passing through their center, depends on the different distances of two equal and opposite currents. It is evident also that the instrument may be used as a simple tangent galvanometer.

Thus if we call the free ends of the hoops A and B respectively, and the point of juncture C, by joining up a circuit through A and B we get the differential action; but by joining up through C and A or B, the action is that of a simple tangent galvanometer. If r and r' represent the radii of the outer and inner hoops respectively, the ordinary formula becomes

$$I = \frac{r\,r'}{2\pi(r-r')} \times H \tan d$$

when the instrument is used differentially.

An instrument has been constructed at the J. C. Green School of Science for its Physical Laboratory of dimensions as follows:

Diameter of outer hoop................	10·9 cm
Diameter of inner hoop................	9·96cm
Width of each hoop....................	2·3 cm
Thickness of each hoop...	0·35cm

The theoretical constant of this instrument agrees very closely with that ascertained experimentally by means of the voltameter. The needle which is usually suspended in the center of the hoops, may, if desired, in order to measure exceedingly powerful currents, be moved along their axis to any required distance on one side. The constant is, in that case, easily found by an obvious modification of the formula.

Princeton, March 10, 1881.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Chlorhydrates of Metallic Chlorides.*—Compounds formed by the union of hydrochloric acid with metallic chlorides have been described, but they have been very imperfectly studied. Since these bodies appear to perform an important part in certain reactions, Berthelot has investigated them, both chemically and thermally. By the prolonged action of hydrochloric acid gas upon a solution of cadmium chloride saturated in the cold, a well defined and crystallized body $CdCl_2(HCl)_2(H_2O)_7$ is obtained, which fumes in the air and loses hydrochloric acid; but since cadmium chloride absorbs this gas even when fused the dissociation is not complete at a red heat. Thermally $CdCl_2+(HCl)_2$ gas $+(H_2O)_7$ liquid, evolves $+40·2$ calories; with solid water, $+30$ calories. Bromhydrate of bromide of cadmium and the iodhydrate of iodide of cadmium were also obtained in beautiful

crystals. Iodhydrate of lead iodide, and iodhydrate of silver iodide, the former $PbI_2(HI)_2(H_2O)_5$ and the latter $(AgI,HI)_3(H_2O)_7$, were prepared by dissolving the iodides in hydriodic acid. The first of these evolves 23·3 calories, the second 21·6 calories. The actual existence of such bodies is therefore beyond question. By reason of the heat of their formation, and their conditions of dissociation, they determine many reactions hitherto inexplicable; such for example as the decomposition of mercurous chloride by hydrochloric acid: $Hg_2Cl_2+nHCl=HgCl_2nHCl+Hg$. Now it appears that $Hg_2Cl_2=HgCl_2$ solid $+Hg$ liquid absorbs 19 calories; and hence the reaction results from the formation of a chlorhydrate of mercuric chloride which evolves more heat than 19 calories. The production of these compounds also plays an important part in the reduction of metallic chlorides by hydrogen. —*Bull. Soc. Ch.*, II, xxxv, 291, March, 1881. G. F. B.

2. *On a Characteristic color-reaction of the Sulph-hydrates.*—CLAESSON has confirmed the reaction observed by Andreasch, i. e., the production of a deep red color when ferric chloride is added to a solution of a thioglycolate, and has considerably extended it, by showing that it belongs not to thioglycolic acid alone but is a general reaction characterizing all sulphhydrates both inorganic and organic, including the well known sulphocyanate test. Sulphides and disulphides give no color with ferric chloride. The following sulphhydrates react with it to produce the colors given: sulphhydrate of methyl, of ethyl, of amyl, of benzene, of toluene, toluene disulphhydrate, and thiacetic acid give a dark red-brown color; thioglycolic and thiolactic acids a dark red-violet; sulphocyanates a dark red; hyposulphites the same; alkali and alkali-earth sulphhydrates a green color. The test is applied by dissolving the substance in water or alcohol, adding some ammonia, and then a few drops of a very dilute ferric chloride solution. The color appears immediately, but owing to reduction of the iron, it disappears in a short time.—*Ber. Berl. Chem. Ges.*, xiv, 411, March, 1881. G. F. B.

3. *On the Composition of Sodium Hyposulphite.**—BERNTHSEN some time ago proposed a quantitative method for the determination of hyposulphite of sodium founded on the decolorization of an ammoniacal solution of copper sulphate, indigo-carmine being used as an indicator. He has now examined this body anew and has sought to determine its composition by a method different from that used by Schützenberger. To the solution obtained by the action of zinc on hydro-sodium sulphite, chloride of barium was added to precipitate the sulphurous and sulphuric acids. The filtered solution contained sodium, barium and zinc hyposulphites, with only a trace of thiosulphate. By converting the hyposulphite into sulphate by means of iodine, determining carefully both the iodine used and the sulphuric acid formed, it appeared that each sulphur atom in the hyposulphite required three

* The author, following Roscoe, uses the name "hyposulphite" for the hydrosulphite of Schützenberger, and gives the name "thiosulphate" to the old hyposulphite.

iodine atoms to convert it into sulphuric acid. Hence the state of oxidation in the hyposulphite is represented by the formula S_2O_3. So from the cuprous salt resulting from the reduction of ammoniacal cupric sulphate by which the hyposulphite is converted into sulphite, it appears that to every two atoms of sulphur in the hyposulphite one atom of oxygen is necessary: $S_2O_3+O=(SO_2)_2$. Estimating now the ratio of bases to sulphur in the solution, there appeared one of base to one of sulphur. The simplest formula would therefore be $NaSO_2$. But from the dibasic character of the sulphur acids this should probably be doubled $Na_2S_2O_4$. Its formation is given in the equation:

$$Zn+(HNaSO_3)_4=ZnSO_3+Na_2SO_3+Na_2S_2O_4+(H_2O)_2$$

—*Ber. Berl. Chem. Ges.*, xiv, 438, March, 1881. G. F. B.

4. *On the Ignition of Combustibles by Nitric Acid.*—The impression is a very general one that nitric acid, even of 1·52 gravity, will not inflame ordinary combustibles. KRAUT, however, having made some experiments on the subject, gives a method by which sawdust, straw, hay, tow or shavings may be easily ignited by means of nitric acid. A wooden box 25^{cm} square and 40^{cm} high is filled to a height of 15 to 20^{cm} with one of the above mentioned combustibles. On this a beaker or flask is placed containing 25 to 100^{cm} of nitric acid of at least 1·5 sp. gr. and the box is then filled with the material. The glass is now broken and a wooden cover placed on the box. In one or two minutes, vapors are visible. A thick white smoke appears a little later and then the odor of the burning material is observed. If after five or ten minutes the box be opened, the interior is filled with a burning mass which bursts into flame on the access of air.—*Ber. Berl. Chem. Ges.*, xiv, 301, Feb. 1881. G. F. B.

5. *On Pernitric Oxide.*—In experimenting upon the silent electrical discharge and the effects produced by it, BERTHELOT observed that a mixture of oxygen and nitrogen tetroxide became decolorized under its action; but that the resulting compound was slowly decomposed, reproducing the orange vapor. That the new compound of nitrogen and oxygen thus obtained was not nitric oxide (N_2O_5) was proved by exposing it to a freezing mixture; no crystals were formed as would have been the case had it been N_2O_5. At St. Claire Deville's suggestion Hautefeuille and Chappuis have repeated Berthelot's experiment and have examined the product with the spectroscope. They find in the decolorized mixture characteristic bands, which seems to confirm the supposed existence of pernitric oxide.—*Ann. Chim. Phys.*, V, xxii, 432, March 1881. G. F. B.

6. *On the Atomic Weight of Platinum.*—The atomic weight generally assumed for platinum varies between 196 and 198 and rests upon the determinations of Berzelius (1826) and Andrews (1852). The former decomposed potassium-platinum chloride by igniting it in a stream of hydrogen. From the ratio of Pt to KCl, the at. wt. 196·705 was obtained; from the amount of Pt in the salt, 196·98; and from the loss of weight by reduc-

tion, 197·234. Andrews digested the potassium-platinum chloride with zinc; weighed the platinum precipitated and determined the chlorine in the solution. He obtained 197·88 as a mean. SEUBERT, observing that in the periodic systems of classification of Lothar Meyer and Mendelejeff platinum comes before gold while the above atomic weight puts it after this metal, has undertaken a revision of the atomic weight of platinum. The pure metal was prepared by Schneider's method, which depends on the fact that when warmed with excess of sodium hydrate, the tetrachlorides of all the platinum metals except platinum itself, are converted into lower chlorides not precipitable by alkali chlorides. The solution in aqua regia was therefore evaporated to expel excess of nitric acid, mixed with sodium hydrate solution and boiled for a long time. On addition of HCl, an olive green precipitate of iridium sesquichloride fell down, and the filtered solution treated with a hot solution of ammonium chloride, gave a heavy precipitate of ammonium-platinum chloride. By ignition, this precipitate left 127 grams of a bright gray platinum sponge, which was dissolved in aqua regia and the solution evaporated and then diluted to 400^{cc}. Pure potassium chloride was prepared from pure crystallized hydro-potassium carbonate by solution in hydrochloric acid; recrystallization and fusion. The ammonium chloride was purified by the method of Stas. For preparing the double salts four successive operations were used: In the first, the concentrated solution of the alkali chloride was poured into the moderately dilute Pt solution containing the calculated quantity of metal, and the precipitate thoroughly washed and dried, at 150° to 160° for the potassium, and 100° to 110° for the ammonia salt. The double salts were reduced by hydrogen and the platinum washed. In the second, this platinum sponge was dissolved in dilute aqua regia, evaporated with HCl, dissolved in acidulated water, concentrated to crystallization while a current of chlorine was passed through it, the drained crystals dissolved in acidulated water, diluted to a definite volume and divided into halves. Each was diluted to a liter, cooled and poured into a liter of alkali chloride solution also cooled, containing 50 grams of the ammonium and 60 of the potassium salt. Both salts were recrystallized and reduced by hydrogen. In the third, the sponge was dissolved in HCl, chlorine being continuously passed into the solution, the platinum precipitated as double salt, recrystallized and ignited. In the fourth, the solutions were more dilute and the alkali chlorides were in excess. The final yield of double chlorides was analyzed by heating the salt placed in a boat of porcelain, in a current of hydrogen. The final values obtained were (A) for the ammonium salt (*a*) by the platinum determination 194·68495, 194·03928, 194·66507, 195·03374, in four experiments; (*b*) by chlorine estimation 195·33013; (B) for the potassium salt (*a*) by platinum 194·39190; (*b*) Pt: KCl, 194·49368; (*c*) Pt: Cl_4 194·63088; or as a mean 194·62003. After introducing corrections and reducing to a vacuum the mean value obtained is 194·34050; which the author regards as the atomic weight of Platinum.—*Liebig's Ann.*, ccvii, 1, Feb., 1881. G. F. B.

7. *On a Compound formed by Camphor with Alcohol.*—The production of a liquid compound by the union of camphor with hydrochloric, nitric or sulphurous acid, is well known. BALLO has observed the same phenomenon with alcohol. When an excess of camphor is heated with alcohol of a certain concentration, the portion remaining undissolved fuses and collects above or below the solution, according to the gravity of the alcohol. With alcohol of 0·8844 the camphor solution boils at 83·7° and the camphor fuses above this point; the fused camphor is heavier than the solution. At 0·8927, the solution boils at 85°, and the camphor fuses at 85°. At 0·9055, the boiling point is 82° and the fusing point 71°, the specific gravity of the solution and the melted camphor being nearly equal. At 0·9277, the boiling point is 85° and the fusing point 69°, the melted camphor now floating on the solution. At 0·9598 the boiling point is 86°–87°, the fusing point 66°–67°. At 0·9763, both points are at 89°. Hence it appears that the limits between which camphor fuses in common alcohol are comprised between 36 and 65 per cent of absolute alcohol. There appears to be more than one definite compound of camphor and alcohol formed, since the fusing point varies from 66° to 71°. After cooling, the camphor which has been thus liquefied is scarcely to be distinguished from ordinary camphor. Dried between folds of paper it contains only traces of alcohol.—*Ber. Berl. Chem. Ges.*, xiv, 334, Feb., 1881. G. F. B.

8. *On the Naturally-occurring Mydriatic Alkaloids.*—LADENBURG has given in a complete form the results of his researches upon the naturally-occurring mydriatic alkaloids. These bodies are three in number: 1st, Atropine $C_{17}H_{23}NO_3$, occurring in *Atropa belladonna*, and *Datura stramonium*, and splitting into tropic acid $C_9H_{10}O_3$, and tropine $C_8H_{15}NO$. 2d, Hyoscyamine, $C_{17}H_{23}NO_3$, occurring in *Atropa belladonna*, *Datura stramonium*, *Hyocyamus niger*, and *Duboisia myoporoides*, and splitting also into tropic acid $C_9H_{10}O_3$ and tropine $C_8H_{15}NO$. 3d, Hyoscin, $C_{17}H_{23}NO_3$, occurring in *Hyoscyamus niger*, and splitting into tropic acid $C_9H_{10}O_3$ and pseudo-tropine $C_8H_{15}NO$. It appears then that the mydriatic alkaloids occurring in nature are only three in number and that they are all isomeric with one another.—*Liebig's Ann.*, ccvi, 274, Feb., 1881. G. F. B.

9. *On the Synthesis of Tropic acid.*—SPIEGEL has effected a new synthesis of tropic acid by acting on acetophenone with hydrocyanic acid, producing the cyanhydrin of acetophenone. This heated to 130° with strong hydrochloric acid gives chlorhydratropic acid. By the action of soda on this for a short time atropic acid is produced, and for a longer time tropic acid. To this the author assigns the formula $C_6H_5\left\{\begin{array}{l}CH_3\\ COH\\ COOH\end{array}\right.$ — *Ber. Berl. Chem. Ges.*, xiv, 235, Feb., 1881. G. F. B.

10. *Photographs of Nebulæ.*—M. J. JANSSEN calls attention to the effect of short and long exposures upon the negatives which are obtained. Photographs of the same nebula will not agree unless the same conditions of exposure are narrowly observed. In proof of this the photographs of the solar corona taken at Siam in the eclipse of 1875 are referred to: the nebulosity, so to speak, of the corona gave different impressions upon sensitive plates which were exposed during times expressed by the numbers 1, 2, 4, 8: and it must be inferred that the changes in the height of the corona are to be attributed to the times of exposure, instead of to actual variations in the extent of the phenomenon. It is then indispensable that the photographs of nebulæ should be accompanied by some evidence of the conditions under which they are taken, in order that subsequent observers may study the changes in the nebula. M. Janssen proposes to take the photograph of the image of a star, or nebula, a little out of focus. In this case the photograph is a little circle of sensibly uniform opacity, and one can compare the opacity of the photographs of different stars and connect the degrees of opacity with the photometric power.—*Comptes Rendus*, Feb. 7, 1881. J. T.

11. *New form of Mercury-pump.*—H. ERNST BESSEL-HAGEN describes a modification of Töpler's quicksilver pump (Töpler, Dingler polyt. I, clxiii, p. 426, 1862). The pump is much simpler than the Gimingham pump which was used by Crookes and is not so liable to break. It allows the vessel which is to be exhausted to be connected to the pump without the intervention of stop cocks or metallic joints. Nothing but a continuous glass tube connecting with the pump by a mercury packing is employed. The importance of heating the tube which is to be exhausted in order to drive off the layer of air which adheres to the sides of the vessel is insisted upon. H. Hagen has obtained an exhaustion of $0·000012^{mm}$, while Crookes has obtained only $0·000046^{mm}$. Besides heating the vacuum tube to expel the air rom its sides, H. Hagen passed electric discharges through the tube and found these discharges efficacious in dislodging the air from the sides of the tube. He also disproves the statement that a vacuum has been obtained through which electrical discharges will not pass. At the pressure of $0·000012^{mm}$ electrical discharges through the vacuum tube were made apparent by loud sparks in the outer circuit and by a phosphoresent glow within the tube. The influence of mercury vapor upon Crookes' phenomena is also shown. The endeavor to detect the passage of aqueous vapor through the sides of the vacuum tube by spectrum analysis gave a negative result.—*Annalen der Physik und Chemie*, No. 3, 1881. J. T.

12. *Absorption of the Sun's rays by the Carbonic Acid of the Atmosphere.*—H. ERNST LECHER, by means of observations with a thermo-electrical apparatus in connection with observations with a pyrheliometer, arrives at the conclusion that the amount of carbonic acid which has been proved to exist in the air is sufficient

to cause the absorption which has generally been attributed to aqueous vapor alone. He believes also that his method is better adapted for obtaining the amount of carbonic acid in different layers of the atmosphere than the chemical methods hitherto adopted.—*Annalen der Physik und Chemie*, No. 3, 1881.

J. T.

13. *Conversion of Radiant Energy into Sonorous Vibrations.*—Mr. WILLIAM HENRY PREECE, in a paper read at the Royal Society, March 10th, gives the details of numerous experiments upon the effect of intermittent beams of light in producing sonorous vibrations. It was found that their vibrations were not produced by the disc which received the intermittent beam, but were due to the motion of the air contained in the hearing tube, for the sounds were louder without the disc than with it. These sounds were increased when the sides of the tube were covered with lampblack, and were cut off by an athermanous diaphragm. A spiral of fine platinum wire was enclosed in a blackened tube and an intermittent current was sent through it. The sounds produced by this apparatus were excellent and proved that the sound vibrations were due to the motion of the air. A microphone was then substituted for the interrupter, and it was found that the apparatus served as a telephone receiver and articulate speech was reproduced.—*Nature*, March 24, 1881. J. T.

14. *On the Tidal Friction of a Planet attended by several Satellites, and on the Evolution of the Solar System;* by G. H. DARWIN, F.R.S. (Abstract of a paper read before the Royal Society, Jan. 20, 1881.)—The first part of the paper contains the investigation of the changes produced by tidal friction in a system consisting of a planet with any number of satellites revolving round it in circular orbits. The planet's equator and the satellites' orbits are all supposed to be in one plane. The planet is formed of homogeneous viscous fluid, but a large part of the results, due to the particular sort of tidal friction which arises in this special case, would be equally true under a more general hypothesis as to the nature of the planet. The mutual perturbations of the satellites are neglected, so that only the rotation of the planet and the distances of the satellites have to be considered.

It is then proved that if E be the whole energy, both kinetic and potential, of the system, and if ξ be a function of the distance of any one of the satellites from the planet (which function, when the mass of the satellite is small compared with that of the planet, is the $\frac{1}{2}$ power of the distance), the equation expressive of the rate of change of ξ is

$$\frac{d\xi}{dt}=-A\frac{\delta E}{\delta \xi}$$

where t is the time, A a certain constant, and δ expresses partial differentiation.

A similar equation applies to each satellite, and the whole of the equations form a system of simultaneous differential equations which have to be solved in order to trace the changes in the system of satellites.

Expressions are also found for the rotation of the planet, and for the energy E, in terms of the resultant moment of momentum of the system and of the $\mathcal{E}$'s.

It is then shown how these equations may be solved by series, proceeding by powers of the time. As, however, the series are not rapidly convergent, they are not appropriate for tracing extensive changes of configuration.

The case where there are only two satellites is then considered in detail, and it is shown that, if a surface be constructed, the points on which have E and the two $\mathcal{E}$'s as their three rectangular coördinates (E being drawn vertically upward and the $\mathcal{E}$'s being horizontal), then the solution of the problem is expressed by the statement that the point, representing on the surface the configuration of the system, travels down the steepest path.

The contour-lines on this "surface of energy" are illustrated by figures, and the graphical solution found therefrom is interpreted and discussed.

The second part of the paper contains a discussion of the part played by tidal friction in the evolution of the solar system.

It is proved that the rate of expansion of the planetary orbits which arises from the friction of the tides raised by the planets in the sun must be exceedingly small compared with that which arises from the friction of the tides raised by the sun in the planets. Thus the investigation in the first part of the paper, where the satellites are treated as particles, is not applicable to the solar system.

Although the problem of finding the changes in a system, formed by a rigid or perfectly fluid sun attended by tidally disturbed planets, is easy of solution, yet it seemed inexpedient to attempt a numerical solution which should be applicable to the solar system.

It appeared, however, likely that a knowledge of certain numerical values would throw light on the question. Accordingly the moments of momentum of the orbital motion of the planets round the sun, of the sun's rotation round his axis, of the orbital motion of the satellites round their planets, and of the rotation of the planets about their axes are evaluated with such degree of accuracy as the data permit.

From a comparison between the orbital momenta of the planets and their rotational momenta, it is concluded that tidal friction can scarcely sensibly have enlarged the planetary orbits since the planets had a separate existence.

By parallel reasoning (although the argument has much less force) it also seemed improbable that the orbits of the satellites of Mars, Jupiter, and Saturn have undergone very large extensions since the satellites had separate existences, and it seemed nearly certain that they cannot be traced back to an origin almost in contact with the present surfaces of their planets, as was shown in previous papers to be probably the case with the moon and earth.

The numerical values spoken of above exhibit a very striking difference between the condition of the earth and the moon and that of these other planets, and it may therefore be admitted that their modes of evolution have also differed considerably.

The part played by tidal friction in the evolution of planetary masses is then discussed.

A numerical comparison is made of the relative efficiency of solar tidal friction in reducing the rotational momentum and the rotation of the several planets. It is found that the efficiency as regards the rotation is nearly the same for Mars and for the earth, notwithstanding the greater distance of the former from the earth. This point is important with reference to the rapid revolution of the inner satellite of Mars, and confirms the explanation of this fact, which has been offered in a previous paper.

The numbers expressive of the relative efficiency of solar tidal friction are of course very much smaller for the more remote planets than for the nearer ones, but they must not be supposed to represent the total amount of rotation destroyed by solar tidal friction, because the exterior planets must be presumed to have existed much longer than the interior ones. Nevertheless the disproportion between the numbers is so great that it must be held that the influence of solar tidal friction on Jupiter and Saturn has been considerably less than on the nearer planets.

The manner in which tidal friction and the contraction of a planetary mass would work together is then considered, and it is found to be probable that tidal friction was a more important cause of change when the masses were less condensed than it is at present; thus the present rate of action of solar tidal friction is not to be taken as a measure of what has existed in all past time.

This discussion leads the author to assign a cause for the observed distribution of satellites in the solar system. For if, as the nebular hypothesis supposes, satellites are formed when instability is produced by the acceleration of rotation accompanying contraction, then the epochs of instability would recur more rarely if tidal friction were operative than without it; and if tidal friction were sufficiently powerful, an epoch of instability would never occur.

The efficiency of solar tidal friction diminishes as we recede from the sun, and therefore planets near the sun should have no satellites, and the number of satellites should increase for the remoter planets. This is the observed condition of the solar system.

This theoretical view is also shown to explain how the earth and moon came to differ from the other planets in such a manner as to permit tidal friction to be the principal feature in their evolution, while its effects are less striking in the other planets.

Among other points discussed are the comparative speeds of rotation of the several planets, and the probable effects of the genesis of a satellite on the course of change afterwards followed by a planet.

The paper ends with a review of the solar system, in which it is shown that the tidal hypothesis is a means of coördinating many apparently disconnected phenomena, besides giving a history of the earth and moon since the origin of the latter.

These investigations afford no grounds for the rejection of the nebular hypothesis, but while they present evidence in favor of the main outlines of that theory, they introduce modifications of considerable importance. Tidal friction is a cause of change of which Laplace's theory took no account, and although the activity of that cause is to be regarded as mainly belonging to a later period than the events described in the nebular hypothesis, yet its influence has been of great, and in one instance of even paramount importance, in determining the present condition of the planets and of their satellites.

15. *Sight: An Exposition of the Principles of Monocular and Binocular Vision;* by JOSEPH LECONTE, LL.D. 275 pp. 8vo. New York, 1881. (D. Appleton & Co. International Scientific Series.)—Professor LeConte has given a popular and readable, and at the same time scientific, exposition of the subject of vision. Two-thirds of the volume are devoted to binocular vision, a subject to which the author has contributed much by his own researches (see numerous articles in this Journal). The development of this subject is a feature of the volume, and gives it especial value, although it may perhaps seem to some that other topics of no less interest are sacrificed to it.

II. GEOLOGY AND MINERALOGY.

1. *Jurassic and underlying strata in the Section of the Alps along the St. Gothard Tunnel.*—A brief notice of this section by M. Renevier, is given in vol. xvi of this Journal (1878). During the past year an account of the rocks has been published by M. Stapff, as an Appendix to the Report of the Swiss Federal Council. A few facts are here cited from Professor Favre's Review of Swiss Geology, for 1880, published in the Geneva Archives des Sciences, Feb., 1881.

The section is 14,920 meters long. The northern, 2010 meters, are through the mass of the Finsteraarhorn; from 2010 to 4325 meters through the fold of Ursern; from 4325 to 11,742 meters through the mass of St. Gothard; and the remaining 3178 meters through the fold of Tessin. The rock of the mass of the Finsteraarhorn is a gneissoid granite (made of quartz, orthoclase, some triclinic feldspar and black and white mica), with gneiss between 1100 and 1525 meters. There are many faults, especially in the region of the gray gneiss. In the fold of Ursern, made up of several secondary folds, the center consists of cipolin or calcareous beds containing traces of fossils, probably of Jurassic age, and accompanying it are black schists of the Lias and older formations. More to the south there is another corresponding fold, in which occur schists, apparently the equivalent of the cipolin beds, flanked, like them, with black schists. These beds are enclosed by the gneiss of Ursern, having some quartzose and green beds, constituting the borders, so that the whole has the form of a ω.

In the Gothard mass, which next follows, there is gneiss varying to mica schist and to granite, with some serpentine (between 4870 and 5310 meters), and, subordinate to the gneiss, hornblendic beds. The rocks are closely related to those of the fold of Ursern, passing into them by an insensible gradation. The fan-like position of the beds of Gothard is much more distinct to the south than on the northern side. These Gothard rocks are sedimentary metamorphic terranes, joining without interruption to the most recent beds of the folds of Ursern on the north and of Tessin on the south.

In the fold of Tessin, the rock, to within ninety meters of the south end, is mica schist, often garnetiferous; in part hornblendic; partly calcareous mica schist; and then there are fifty-three feet of dolomite. These rocks have close analogies to those of the Ursern fold, the cipolins of Altekirch corresponding to the dolomite of Tessin, the sericite schists to the gray garnetiferous mica schist, and so on. The group then in the valley of Tessin represents also altered sedimentary strata from the Jurassic to the Carboniferous. The beds plunge under Gothard with a marked curve, the dip being greater at the surface than in the tunnel.

Thus, the author observes, the mass of Gothard consists of a series of metamorphic sediments, and the folds of Ursern and Tessin, on the opposite sides, correspond to one another. The gneissoid granite of the Finsteraarhorn is the oldest of the series, and a break exists between it and the Ursern fold.

The serpentine of the Gothard mass is considered by M. Stapff as formed by the alteration of olivine, some grains of which still remain. M. Cossa has shown that part of the rock, though of a kind capable of changing to serpentine, is not true serpentine, but consists of talc, pyroxene (not lamellar) and olivine, with the pyroxene sometimes predominating. Gümbel has found fragments of *Crinoids* in the limestones of Andermatt, confirming the view of M. Stapff as to the origin of the limestones.

2. *The great fault in the Alps after the Carboniferous era.*—According to M. Lory (Observations sur la structure des Alpes, in C. R. du Congr. Internationale de Geol. of 1878), the dislocation which raised the crystalline schists in the zone of Mount Blanc, between the Bernese Alps on the east and Maritime Alps on the southwest, took place after the deposition of the Carboniferous beds which are conformable to these schists, and before the Triassic era, the Mesozoic beds being laid down unconformably on the schists, and sometimes now overlying them in horizontal

masses (Aiguilles Rouges, Oisans). There were also other movements after the deposit of the Mesozoic strata, but of less extent.

3. *Radiolarians* (*Polycystines*), *making for the most part the Jasper beds of Tuscany.*—Dr. D. PANTANELLI has published a paper on the Tuscan jaspers in the Transactions of the R. Accademia dei Lincei (Rome), 1880, giving the results of the microscopic study of the Tuscan beds of jaspers in the Eocene, Cretaceous and the Upper Lias. The author gives a double quarto plate of figures of the fossils, and shows that the beds are marine deposits, and were probably formed at some considerable depth, since Radiolarians are most abundant in the deeper waters, the number being proportionately largest, according to observations hitherto made, between 5000 and 10,000 feet.

4. *Fossil Sponge-Spicules from the Upper Chalk, found in the interior of a single flint-stone from Horstead in Norfolk*; by GEORGE JENNINGS HINDE, F.G.S. 84 pp. 8vo, with 5 plates. Inaugural Dissertation. Munich, 1880.—The material examined was from an interior closed cavity of a mass of flint and resembled fine meal. The author describes, from it, 160 forms of spicules, which he refers to 38 species and 32 genera of Sponges, 14 of the species belonging to the Lithistids and Hexactinellids. Besides the spicules of sponges, the cavity afforded remains of Foraminifers, Ostracoids, Echinoderms, Annelids, Cirripeds, Bryozoans, Brachiopods, Lamellibranchs and Fishes, the first two kinds, with the sponges, being far the most abundant. The abundance of the sponge spicules sustains the author's conclusion that flint nodules of the Chalk have resulted from the aggregation of the siliceous spicules or skeletons of the sea-bottom sponges, as the chalk from an aggregation of the shells of foraminifers, ostracoids and other calcareous secretions of the same seas. The author remarks that only two or three Radiolarians are yet known from the Chalk formation. The plates are crowded with excellent figures of the spicules.

5. *Vertebrates of the Permian of Texas.*—Professor E. D. COPE has a second paper on this subject in the Proceedings of the American Philosophical Society, xix, 38 (1880). Professor Cope describes in this memoir two species of *Theropleura* Cope (near the Rhynchocephalia), one of *Dimetrodon* Cope, one of *Diadectes*, two of *Helodectes* Cope, defines anew the genera of Ganocephala, *Eryops* Cope and *Trimerorhachis* Cope, and describes one fish of the tribe Crossopterygia, *Ectosteorhachis nitidus* Cope.

6. *Report of the Professor of Agriculture of the University of California*, 1880. 108 pp. 8vo. Sacramento, 1881.—Professor E. W. HILGARD presents, in his report, besides other discussions of importance, some interesting facts with regard to the reclamation of alkali lands. As ordinary surface irrigation tends to concentrate the alkali at the surface—"the more water evaporates from the surface within a season, the more alkali salts will be drawn to the surface." The chief remedy proposed is underdraining, which "may so far lower the water-table from which the

saline matters are derived, and may so far favor the washing out of the salts during the rainy season, that the latter will thereafter fail to reach the surface so as to accumulate to an injurious extent with reasonable tillage." In his illustrations of the subject analyses are given of the waters of Kern and Tulare lakes, and of some rivers of California. In that of Kern Lake, March, 1880, the total residue obtained was 211·50 grains per gallon (about 26 times more than in an average river water), which consisted of Carb. soda 64·37, common salt, glauber salt, etc. 115·41, carb. Ca, Mg and silica 9·29, vegetable matter 22·43. The water from the middle of Tulare Lake, at surface, afforded 81·95 for the total residue, consisting of Carb. soda 35·30, common salt, glauber salt, etc. 35·96, carb. Ca and Mg, and silica 5·37, vegetable matter 5·32.

Water of the Cañon of Kern River afforded 9·49 of total residue; but the proportion between the sodium carbonate and the other salts is almost exactly that in the water of Tulare Lake, or 1 to 22; so that, if 22 gallons were boiled down to 1, the water would have the same alkali in quantity and quality as that of the lake; and if further reduced to 3½ pints, it would have about the composition of that of Kern Lake. Professor Hilgard remarks as follows respecting the use of the Kern River waters in irrigation:

"Those using its waters should keep in mind that their evaporation adds annually to the alkali in the soil;" and that "tillage after irrigation, the planting of deep-rooted crops instead of grain, and the use of gypsum as a neutralizer of the worst ingredient—the carbonate of soda—are the measures that suggest themselves as the most feasible; while subirrigation, and especially the leaching out of the alkali from time to time by long-continued flooding, and underdrainage are more radical remedies for future use." After a further discussion of the facts he adds: "There are, probably, few river-waters in the world of such composition, or natural purity, that continued irrigation without correlative underdrainage can be practiced without in the end causing an injurious accumulation of soluble salts in the soil. In India, according to the testimony of Professor George Davidson, the evil effects of such practice have become painfully apparent, and, to such an extent, that after the expenditure of enormous sums for bringing the water upon the fields, the government now finds itself face to face with the costly problem of its economical removal by drainage, so as to relieve the soil of its accumulated alkali which has rendered it unfit for cultivation. An early attention to this matter, with such foresight as will prevent the occurrence of similar difficulties cannot be too earnestly recommended to all interested in the irrigated lands of California."

7. *Biennial Report of the State Geologist of the State of Colorado*, for the term ending December 31, 1880. 75 pp. 8vo. Denver, 1881.—Professor J. Alden Smith, appointed geologist of Colorado in 1872, gives in this report a general description of the gold and silver mines of the State, with remarks on the other

sources of mineral and agricultural wealth. He gives also a very full catalogue, arranged alphabetically, of the mineral species found in the State. This is a revision and extension of a catalogue published by him in 1870, and it includes notices of the recent work by Dr. Genth, Dr. Lœw and others on Colorado minerals. To complete the long list of Colorado species the work by Allen and Comstock on bastnäsite, and the new species tysonite, should properly be mentioned.

8. *Grundlinien der Geologie von Bosnien-Hercegovina.*—Erläuterungen zur geologischen Uebersichtskarte dieser Länder, von Dr. Ed. v. Mojsisovics, Dr. E. Tietze and Dr. A. Bittner, Mit Beiträgen von Dr. M. Neumayr und C. v. John und einem Vorworte von Fr. v. Hauer. 322 pp. 8vo, with a colored geological chart and three lithographic tables. Vienna, 1880.—This work treats of the stratified formations of the region, from the Paleozoic to the Quaternary, the local geology of the different parts, the crystalline rocks, and closes with a chapter on the "Tertiary Inland Mollusks," by Dr. Neumayr.

9. *Journal of the Cincinnati Society of Natural History*, for Jan., 1881.—This number of the Journal has a descriptive bibliographic paper on the N. A. Tertiary, by S. A. Miller; descriptions of new Tineina, by V. T. Chambers; papers on the Geographical distribution of certain N. A. fresh-water mollusks and the probable causes of their variation, and on new Upper Subcarboniferous Crinoids, by A. G. Wetherby, besides other papers. In Mr. Miller's paper, the earliest paper referred to on Martha's Vineyard Tertiary, in vol. vii, 1824, is stated to be by Professor Silliman. In the title of this paper no name of author is given, but the index inserts the article under the name of Edward Hitchcock. The same volume contains, on pp. 31–43, an article entitled "Geological essay on the Tertiary formations in America," by John Finch (read before the Acad. Nat. Sci. of Philadelphia, in 1823), which well deserves to be noticed: it recognizes as Tertiary the deposits of the Atlantic border from Gay Head and New York to the Gulf of Mexico, and gives many important details.

10. *Geological Reports recently issued.* (Received too late for notice in this place.)

Geological Survey of Pennsylvania.—(1) The Geology of the Oil Regions of Warren, Venango, Clarion and Butler Counties, by John F. Carll. No. III. 482 pp. 8vo., with 23 plates and an atlas of 22 sheets of maps, oil-well sections, and working drawings of oil-well rig and tools. Harrisburg, 1880. (2) Report of Progress of Armstrong County, by W. G. Platt. No. H[5]. 338 pp. 8vo, with a colored map of the county. Harrisburg, 1880. (3) The Geology of Clinton County, Part II, containing a special study of the Carboniferous and Devonian strata along the west branch of the Susquehanna River, by H. Martin Chance, with a description of the Renovo Coal Basin by C. A. Ashburner, and notes on the Tangascootack Coal Basin in Centre and Clinton Counties, by F. Platt. 174 pp. 8vo, with a colored map, sheet of sections, topographical map of the Renovo Basin, 6 plates and 21 sections in the text. Harrisburg, 1880. The volume by L. Lesquereux on Coal plants, briefly noticed on page 329, has also been issued.

Geological Survey of New Jersey: Annual Report for the year 1880, by the State Geologist, Prof. G. H. Cook. 220 pp. 8vo, with a colored map.

State of Indiana.—Report of the Department of Statistics and Geology, 1880, by JOHN COLLETT. 544 pp. 8vo, with plates.

Geological Survey of Canada.—Report of the Geology of Southern New Brunswick, 1878–79, by Prof. L. W. BAILEY, G. F. MATTHEWS, and R. W. ELLS. 261 pp. 8vo, with a large geological map and 6 plates of sections. Montreal, 1880. (Dawson Brothers.)

11. *Lazulite from Canada.*—The occurrence of lazulite in the District of Keewatin, near the mouth of the Churchill River, is described by C. Hoffmann (Geology of Canada, Report of Progress for 1878–9). The mineral occurs massive in narrow veins in quartz. It has a deep azure blue color; its specific gravity is 3·0445. An analysis afforded the following results (after the deduction of 3·81 p. c. silica, as impurity):

P_2O_5	Al_2O_3	FeO	MgO	CaO	H_2O
46·39	29·14	2·09	13·84	2·83	6·47=100·76

The Chemical Contributions to the Geology of Canada (25 pp.) by Mr. Hoffmann, from which the above analysis is quoted, contain also an analysis of cyanite from North Thompson River, British Columbia, others of graphite, kaolin, alunogen, also analyses of various natural waters, coals, iron, copper and manganese ores, gold and silver assays, etc.

12. *The Minerals and Mineral Localities of North Carolina;* being chapter I of the second volume of the Geology of North Carolina. 122 pp. 8vo. Raleigh, 1881.—This volume opens with a general statement by the State Geologist, Prof. Kerr, and following this is the extended report by Dr. F. A. Genth. A description is given of each of the species discovered in the State, embracing not only whatever has been previously published, but also numerous new analyses, mostly by Dr. Genth or his assistants; and many facts made known by the recent explorations of Prof. J. T. Humphreys, Mr. J. A. D. Stephenson, Mr. W. E. Hidden, and others. The list of species is a long one (178) and includes, more especially from the mica mines in the western part of the State, many very rare and interesting minerals, among which may be mentioned the samarskite and related species, as also the uranium minerals. A full synopsis of minerals and localities by counties will be found of value, especially by collectors. To the body of the report Mr. Hidden adds several pages in which he describes the discoveries recently made by him (see this Journ., Feb., 1881, p. 159); he figures a series of highly modified and interesting quartz crystals, and also several crystals of beryl, one of them showing the planes I, i-2, O, 1, 2, 2-2, 3-$\frac{3}{2}$, 4-$\frac{4}{3}$.

13. *Durability of Building Stones.*—Dr. HIRAM A. CUTTING, of Vermont, has made examinations as to the degree of heat sufficient to cause the destruction of different building stones and has extended his experiments to 22 kinds of granite, 23 of sandstone, 7 of limestone, 7 of marble, 3 of conglomerate, 1 of slate, 1 of soapstone, and 1 of artificial stone. Under the application of the heat, the granite (1) began to yield at a temperature between 700° and 800° F.; (2) became cracked between 800° F. and 900° F.; (3) became generally cracked between 800 and 950° F.

and (4) was made worthless by or before reaching a temperature of 1000° F.

The following table contains these results under the headings (1), (2), (3), (4), and those also for the other kinds of stones.

	(1)	(2)	(3)	(4)
Granites	700°– 800°	800°– 900°	800°– 950°	at or below 1000°
Sandstones	800°– 900°	850°–1000°	900°–1000°	1000°–1200°
Massive limestones	850°– 950°	900°–1000°	900°–1100°	mostly 1200°
Marbles	900°–1000°	950°–1000°	1000°–1200°	1200°
Conglomerates	600°– 700°	700°– 800°	800°– 900°	900°–1000°

The granites had a specific gravity between 2·600 and 2·727, excepting one from Stanstead, Canada, of 2·833; and immersion in water added to their weight, through absorption, from 1-280th of their weight to 1-818th. In the case of sandstones, sp. gr.= 2·168 to 2·661, but mostly under 2·400; and the absorption was 1-17th to 1-80th excepting two giving 1-240th (a freestone from Nova Scotia), and 1-314th (the Montrose stone, Ulster Co., N. Y.) For the marble, sp. gr.=2·666 to 2·848, and the absorption 1-300th to 1-380th; for the more solid of the pure massive limestones, sp. gr.=2·478 to 2·706, and absorption 1-280th to 1-480th.

The least absorbent of the granites (its ratio of absorption 1-818th) was one of the most destructible by heat, and the most absorbent (1-280th) was equally destructible. The limestones and marbles are stated to change to quicklime at about 1200° F.

14. *Brief notices of some recently described minerals.*—Begeerite. Occurs massive and in small isometric crystals, showing octahedral and dodecahedral planes. Specific gravity 7·273. Luster metallic, on the crystals brilliant. Color light to dark-gray. An analysis gave (after deducting quartz) S 14·97, Bi 20·59, Pb 64·23, Cu 1·70=101·49. This corresponds nearly to the formula $Pb_6Bi_2S_9$ or $6PbS+Bi_2S_3$. Found at the Baltic Lode, near Grant P. O., Park Co., Colorado. Named after Mr. H. Begeer of Denver. Described by Dr. G. König.—*Amer. Chem. Journ.*, vol. ii, No. 6.

Eleonorite. Occurs in small crystals belonging to the monoclinic system, resembling in habit the lazulite from Georgia; the crystals often forming drusy surfaces. Hardness 3–4. Color reddish-brown to dark hyacinth-red and streak-yellow. Luster vitreous inclining to pearly. An analysis gave P_2O_5 31·88, Fe_2O_3 51·94, H_2O 16·37=100·19, corresponding to $2Fe_2P_2O_8+H_6Fe_2O_6+5H_2O$. It is very near beraunite, if not identical with it. Found with other phosphates at the Eleonore mine near Bieber, also from Waldgirmes near Giessen. Named by Nies, and described by Streng.—*Jahrb. Min.*

Picite is a second phosphate from the same localities as *Eleonorite.* It is a glassy, apparently amorphous, mineral. Hardness 3–4. Specific gravity 2·83. Luster greasy to vitreous. Color dark-brown, streak yellow. Fracture semi-conchoidal. An analysis gave: P_2O_5 24·47, Fe_2O_3 46·50, Al_2O_3 1·00, H_2O 28·03=100. The formula corresponds to $4Fe_2P_2O_8+3H_6Fe_2O_6+27H_2O$, on the uncertain assumption that the mineral is homogeneous.—*Jahrb. Min.*, 1881, i, p. 16 *ref.* and p. 102.

NEOCYANITE. A recent sublimation product at Vesuvius, in composition essentially an anhydrous silicate of copper. It occurs in minute crystals of an azure blue color. Described by Scacchi; *Rend. Accad. Sc. Napoli*, Dec. 4, 1880.

15. *Analysis of Columbite;* by E. J. HALLOCK, Ph.D. (Communicated.)—The sample analyzed was from Middletown, Conn., and was kindly furnished to the writer by Professor Charles A. Joy. The specific gravity of the crystals freed from gangue was found to be 6·14. Two analyses afforded:—

	I.	II.
Mixed acids	82·64	82·56
Iron protoxide	11·77	12·08
Manganese protoxide	4·95	4·93
Lime	0·50	0·45
	99·86	100·02

The columbic and tantalic acids were not separated, but the specific gravity of the ignited mixed acids from No. 2 was 7·48, indicating a large proportion of tantalic acid.

Southern Medical College, Atlanta, Ga., Feb., 1881.

III. BOTANY AND ZOOLOGY.

1. *Notes on Orchideæ*, and *Notes on Cyperaceæ;* by GEORGE BENTHAM, F.R.S.—Two notable papers extracted from the (still unpublished) eighteenth volume of the Journal of the Linnean Society, and important as forerunners, being a sketch of the arrangement adopted for these orders in the forthcoming and concluding portion of the Genera Plantarum, and containing also some historical and critical details which could find no place in that condensed systematic work. It must suffice to direct attention to these papers, as we cannot now give an analysis of them. That on the *Orchideæ* is naturally far the most considerable; it occupies the pages of the volume from 281 to 360, and is a succinct exposition of a complete re-arrangement of this vast and difficult order, as to the tribes, sub-tribes, and the limitation of many genera. That on the *Cyperaceæ*, pp. 360–367, is comparatively a small affair; this family exhibiting small diversity of structure. The genera are grouped under two principal divisions (after Bœckler), each containing three tribes. The history of some of the early genera, and of the way they have been mistaken or confused, forms a curious part of Mr. Bentham's notes.

A. G.

2. *On the Germination and Histology of the Seedling of Welwitchia;* by F. ORPEN BOWER, B.A., Camb. Reprinted from the Quarterly Journal of Microscopical Science, n. ser. xxi, pp. 15–22, with two plates.—We have had the pleasure of inspecting from time to time the seedlings of *Welwitchia* which germinated early last autumn at Kew Gardens, and of which several have survived through the winter and are still thriving, although the larger portion was lost. This paper by a promising phytotomist inves-

tigates the structure and development of the mature embryo and of the seedling, and is to be followed by a research into the histology of the more advanced plant from good specimens in spirit. An important intermediate stage between these preserved young plants and the growing seedlings remains to be supplied, and may be expected from the further development of these precious living plants. Without referring here to the details of germination and of the minute anatomy, we will only refer to the two points brought to view by Mr. Bower of much interest to the morphologist. One is the production from the caulicle or hypocotyledonary stem, at the beginning of germination, of a fleshy outgrowth, which remains in the axis of the seed, enveloped by the endosperm, long after the development and liberation of the cotyledons and their elevation by the elongating growth of the caulicle. This process, of which no trace is seen before germination, either internally or externally, develops in proximity to the cotyledons, just below the constricted apex of the caulicle, and in the same plane with these, being therefore incumbent upon the back of one of them, which at one time it almost equals in length and at the base exceeds in thickness, while the apex tapers to a blunt point. The development of the caulicle, which carries up the soon foliaceous cotyledons well above ground, is almost wholly above this process, which, as already stated, remains in the seed; and the surrounding endosperm being still capable of furnishing considerable nutriment, Mr. Bower infers that the process serves as a feeder to the seedling, for the appropriation of this residual store of food. He therefore calls it "the feeder" in his description, speaking physiologically; while morphologically it is of course likened to the "peg" of germinating squashes, the very different use of which, in riving the seed-coat and freeing the cotyledons, has recently been so well described by Darwin.

The second point is that the seedling of *Welwitchia* promptly produces a two-leaved plumule, decussating with the cotyledons, and it is inferred that this pair of leaves (and not the cotyledons as had been supposed) makes the permanent foliage of this strange plant. The living seedlings give as yet no external evidence that the cotyledons are to die off; but developed young plants in spirit show apparent scars and vestiges which indicate such disappearance, and the arrangement of vascular bundles within well accords with this view. It is almost certain that the two leaves of these plants represent the permanent foliage; and the fact that they stand in the plane at right angles with that of the "peg" or process, while this in the seedling is directly under one of the cotyledons, convinces us that the permanent foliage belongs to the plumular pair of leaves. A. G.

3. *J. Freyn, of Prague, Austria*, is engaged in the preparation of a monograph upon the genus Ranunculus. He is desirous of obtaining specimens of American species and varieties, together with notes relative to their numerical distribution, their habit and habitat. For good specimens exhibiting flowers, leaves and ripe fruit, he will be glad to exchange specimens of European desiderata.

4. *Geographical distribution of certain Freshwater Mollusks of North America, and the probable causes of their variation;* by A. G. WETHERBY.—The January number of the Journal of the Cincinnati Society of Natural History contains the first part of this important memoir. A notice is deferred until the promised future paper is published.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Distribution of Time Signals.*—The American Meteorological Society has issued two circulars relating to the public distribution of time signals. The first calls attention to the convenience of having the country divided into districts which keep a time differing one hour from the times in neighboring districts, after the manner explained in the first volume of the Proceedings of the Society, and subsequently commented on in the *North American Review* for December, 1880.

The second circular includes a letter from the chief signal officer of the army, Gen. W. B. Hazen, to the president of the society, Dr. F. A. P. Barnard. In this letter the chief signal officer expresses the interest the Signal Service would naturally have in performing the important duty of dropping time balls in the various parts of the country, wherever competent local authority will furnish an accurate standard of time, and the cost of erection of the signal be assumed by those interested.

That the public is getting to be fully aware of the economic value of having large sections of country living under the same clock time has been shown by the readiness with which communities have united in such a common time when it has been proposed to them. For example, the bill establishing a common State time for Connecticut, introduced during the present session, passed both houses of the legislature without a dissenting vote: and there is no doubt that the Signal Service and the Meteorological Society will confer a greatly recognized benefit upon the public, should they be successful in introducing public time signals to the country at large. Time balls are costly, though accurate; it might be worth the while to enquire into the feasibility of also establishing time guns—which, though under some conditions less accurate than time balls, yet are generally more convenient to the public. Possibly some of the artillery of the Ordnance Department which has outlived its usefulness in warfare might be used for the purpose. We give the memorandum accompanying Gen. Hazen's letter in the foot note.

MEMORANDUM No. 1.

Conditions on which the Chief Signal Officer coöperates with others in the maintenance of a public Standard Time Ball :—

1*st.*—At any Signal Service Station already established for the benefit of commerce and agriculture, and at which two (2) or more men are necessarily stationed, the Chief Signal Officer will contribute such portion of the time of one man as will be necessary, in order to keep in perfect working order the ball, mast, electrical and other apparatus at the station, and will have the ball hoisted daily at the proper time, and the electric connections properly made; provided this does not, on the average, require more of the time of the man on duty than one-half hour per day.

2d.—The expense of battery and battery-room, and of purchasing, installing and repairing the apparatus, as also the expense attending the astronomical determination of time and the necessary telegraphy, must be borne by other parties, and must not in any way be imposed upon the Signal Service.

3d.—The Chief Signal Officer will not undertake such coöperation for the benefit of special individuals, nor unless there is satisfactory evidence that the "time signals" will be in charge of such astronomers and institutions as can guarantee a high standard of accuracy, and the uniform maintenance of their part of the time service from year to year.

4th.—The signal, which consists in dropping the "time ball", must be given automatically by telegraphy from the Astronomical Observatory, which shall alone be responsible for the accuracy thereof.

5th.—The Chief Signal Officer will be pleased to publish such portions of the annual reports of the observatories in charge of time balls as relate to the accuracy of the signals.

6th.—Without presuming to prescribe, the Chief Signal Officer would suggest, that the interests of navigators as well as of railroad travelers, and of the community at large, will probably be best subserved by causing the respective time balls to be dropped simultaneously throughout large sections of the country, and especially at noon of the meridians of 75°, 90°, 105° or 120° of longitude west of Greenwich, in accordance with the following schedule:

Atlantic Coast	time balls	all drop	at noon	on the	75th	meridian.
Gulf Coast	"	"	"	"	90th	"
Lake Coast	"	"	"	"	90th	"
Mississippi Valley	"	"	"	"	90th	"
Pacific Coast	"	"	"	"	120th	"

Thus, for instance, at Washington, the time ball will be dropped at exactly five hours of Greenwich mean time, which will be eight minutes earlier than Washington mean noon, and three minutes later than New York mean noon.

7th.—The Chief Signal Service Officer will take action in reference to time balls at any station, so soon as Chambers of Commerce, or Observatories, or other local organizations communicate their desires to him.

2. *Changes in water-level of lakes on the borders of Oregon and California.*—A letter to the editors from Mr. B. F. Dowell, of Jacksonville, Oregon, states that Goose Lake, 30 miles long and two-thirds of it in Oregon, the rest in California, was almost dry in 1853 and 1854 while in 1869 and 1870 there were ten feet of water; its depth has been increasing since 1870, and there is a probability of its discharging, as at some former time, into Pitt River. Clear Lake also, about two miles farther south, is ten feet deeper than it was in 1853–4; and Tulie Lake, in the same region (the locality of the lava beds where were the hiding places of the Modoc Indians) is 10 or 15 feet higher to-day than then.

3. *Bibliographie Astronomique.*—The second fascicule of this valuable work of Messrs. Houzeau and Lancaster has been distributed. It is devoted to Spherical Astronomy (110 columns); Theoretic astronomy (80 columns); Celestial Mechanics (100 colums); and *Astronomie Physique* (212 columns). This last subject covers not Physical Astronomy as usually understood, but cosmogony, satellites, comets, meteors, photometry, spectroscopy, etc. The references are to memoirs, not to complete works, nor

observations; these are to appear in other volumes. The work seems to be very complete, and will be invaluable to astronomers.

4. MAJOR J. W. POWELL has been appointed Director of the Geological Survey of the National Domain in place of Clarence King resigned. His various reports on the Rocky Mountain region, geological, ethnographic and economical, show that he is well fitted for the position.

5. *Report of the Superintendent of the United States Coast Survey*, showing the progress of the work for the fiscal year ending with June, 1877. 192 pp., with 25 maps. Among the Appendices are the following: Notes concerning alleged changes in the relative elevations of land and of sea, by HENRY MITCHELL; Description of an apparatus devised for observing currents in connection with the physical survey of the Mississippi River, by H. L. MARINDIN; Description of an optical densimeter for ocean water, by J. E. HILGARD; Comparison of American and British standard yards, by J. E. HILGARD; Description of an improved open vertical clamp for the telescopes of theodolites and meridian instruments, by G. DAVIDSON; Observations of the density of the waters of Chesapeake Bay and its principal estuaries, by Lieut. COLLINS; A quincuncial projection of the sphere, by C. S. PEIRCE.

Exercises in Practical Chemistry. Vol. I, Elementary Exercises, by A. S. Vernon Harcourt and H. G. Madan. Third edition, revised by H. G. Madan. 480 pp. 8vo. Oxford, 1880 (Clarendon Press).

A Memorial of Joseph Henry. 528 pp. Washington, 1880. Contents: Introduction, Proceedings in Congress relative to a public commemoration; Part I, Obsequies of Joseph Henry, pp. 7–27; Part II, Memorial services at the Capitol, pp. 37–121; Part III, Memorial Proceedings of Societies, pp. 125–475; Appendix.

A Lecture on the progress of the work of completion of the new improved bed of the Danube at Vienna, and the lessons taught thereby, together with a description of the catastrophe produced by the ice gorge of 1880, by Sir Gustave Wex. 33 pp., with five sheets of drawings. (Extract from the Journal of the Society of Austrian Engineers and Architects, No 3, 1880). Translated by Major G. Weitzel, U. S. A. Washington, 1881.

Meteorological Researches for the use of the Coast Pilot. Part II, On Cyclones, Waterspouts and Tornadoes by William Ferrel. 95 pp. 4to, with 6 plates. (U. S. Coast and Geodetic Survey, Carlile P. Patterson, Superintendant). Methods and Results. Appendix No. 10 of Coast Survey Report for 1878.

Report of the Director of the Detroit Observatory of the University of Michigan to the Board of Regents for the period beginning Oct. 1, 1879 and ending Jan. 1, 1881. 20 pp. 8vo. Ann Arbor, 1881.

Annual Report upon the Surveys of Northern and Northwestern Lakes in charge of Gen. C. B. Comstock, U. S. A., being Appendix OO of the Annual Report of the Chief of Engineers for 1880. 93 pp. 8vo, with a map and several plates.

Annual Report of the Superintendent of the Yellowstone National Park to the Secretary of the Interior for the year 1880. 64 pp. 8vo. Washington, 1881.

Notes on North American Microgasters with descriptions of a new species by C. V. Riley, Ph.D., 20 pp. From the Transactions of the Academy of Sciences of St. Louis, vol. iv, No. 2.

Parasites of the Termites, by Joseph Leidy, M.D. 25 pp. with two plates. From the Journal of the Academy of Natural Sciences of Philadelphia, vol. viii.

OBITUARY.

M. ACHILLE DELESSE, Inspector General of Mines in France, and well known for his able researches in geology and mineralogy, died at Paris near the close of March.

APPENDIX.

ART. LIII.—*Principal Characters of American Jurassic Dinosaurs;* by O. C. MARSH. Part V. With seven Plates.

IN previous articles, the writer has described the main characters of *Morosaurus*, *Apatosaurus*, *Diplodocus*, and *Atlantosaurus*, the best known genera of the *Sauropoda* hitherto found in American deposits.* The fortunate discovery of a nearly complete skeleton of *Brontosaurus* has added many new points to our knowledge of this group, and some of these are given in the present communication. A second species, equally gigantic in size, has since been found, and its distinguishing features are also here recorded.

Two new genera from the same formation are noticed, and an outline of classification of the best known American Jurassic Dinosaurs is proposed.

Brontosaurus excelsus Marsh.†

The present genus may readily be distinguished from all the other *Sauropoda* by the sacrum, which is composed of five ankylosed vertebræ, none of the other genera in this group having more than four. The sternum, moreover, consists of two separate bones, which are parial, and were united to each other on the median line apparently by cartilage only. In many other respects the genus resembles *Morosaurus*.

The present species, aside from its immense size, is distinguished by the peculiar lightness of its vertebral column, the cervical, dorsal, and sacral vertebræ all having very large cavities in their centra. The first three caudals, also, are lightened by excavations in their sides, a feature not before seen in this group, and one not shared by the other species of this genus.

* This Journal, xvi, 411, Nov., 1878, and xvii, 86, Jan., 1879.
† This Journal, xviii, 503, Dec., 1879, and xix, 395, May, 1880.

The Scapular Arch.

The scapular arch in the present species is fortunately better known than that of any other Dinosaur hitherto discovered. In Plates XII and XIII the various bones are represented separately, and in figure 1 of the latter plate they are in position. The scapula resembles in general form the corresponding bone in *Morosaurus*, but the shaft is longer, and the upper end less expanded. The coracoid, on the other hand, differs materially from that of *Morosaurus*, and approaches more nearly that of *Apatosaurus*, which is sub-quadrate in outline. In Plate XII the scapula and coracoid of the present species are placed nearly in the same plane, and the space between them probably represents about the amount of cartilage which originally separated them. Both scapulæ were found in apposition with their respective coracoids.

The two sternal bones lay side by side between the two coracoids, and in Plate XIII they are represented nearly as found. They are sub-oval in outline, concave above, and convex below. They are parial, and when in position nearly or quite meet on the median line. Each bone is considerably thickened in front, and shows a distinct facet for union with the coracoid. The posterior end is thin and irregular.

The Presacral Vertebræ.

The cervical vertebræ of the present species are quite numerous, thirteen at least belonging in this part of the column. All are strongly opisthocœlian. The anterior cervicals are very small in comparison with those near the dorsal region. From the third vertebra to the middle of the neck, the centra increase in length and especially in bulk, but the posterior cervicals gradually become shorter. In Plate XIV the sixth cervical is represented, and this is typical for the anterior half of the neck. All the anterior cervicals have coössified ribs, as in Birds. In the posterior cervicals, the ribs become free. The articular facet for the head of the rib rises gradually on the side of the centrum, the tubercular articulation remaining on the diapophysis. None of the cervicals have a neural spine. The neural canal is comparatively small. The centra of all the cervicals have deep excavations in the sides, and the transverse processes are more or less cavernous. The posterior cervicals which bear free ribs are remarkable for the great size of the zygapophyses, which are here much larger than elsewhere in the series. The anterior cervicals have several lateral cavities, while those farther back have only one large foramen in each side of the centrum, as in the dorsals.

The dorsal vertebræ of this species have short centra, more or less opisthocœlian. There is a very large cavity in each side which is separated from the one opposite by a thin vertical partition. The neural canal is much larger than in the cervicals. The anterior dorsals are distinctly opisthocœlian. The neural spine has no prominence in this region, but rises rapidly further back. In Plate XV, figures 1 and 2, a posterior dorsal is represented which shows the peculiar character of the vertebræ in this part of the series. The neural spine is greatly developed and has its summit transversely expanded. The vertebræ in this region, as in all the known *Sauropoda*, have the peculiar diplosphenal articulation. This is shown in figure 2. In the vertebra figured, at the base of the neural spine, there is a strong anterior projection, which was inserted into the cavity between and above the posterior zygapophyses of the vertebra in front. There appear to be no true lumbar vertebræ, as those near the sacrum supported free ribs of moderate size. These vertebræ have both faces of the centrum nearly flat or biconcave.*

The Sacrum.

The sacrum in the present species consists of five well coössified vertebræ, and in the type specimen the centrum of the last lumbar is firmly united with it, as shown in Plate XVI. The striking feature about this sacrum is the large general cavity it contained. This was divided in part by a median longitudinal partition, as shown in Plate XV, figure 3. This septum, however, was not continuous the whole length of the sacrum, so that the two lateral cavities were virtually one. This extended even into the lateral processes. The transverse partitions formed by the ends of the respective centra were also perforate, so that the sacrum proper was essentially a hollow cylinder. This cavernous character of the sacrum is one of the peculiar features of the suborder *Sauropoda*, and was described by the writer, when the first species of this group was discovered in this country.† The statement that any of the group have the sacrum solid, like the caudals, is evidently based on erroneous observation.

Another peculiar character of the sacrum in the present genus is its lofty neural spine. This is a thin vertical plate of bone with a thick massive summit, evidently formed by the

* Prof. Cope, mistaking the character of these vertebræ in an allied form, described them as representing a new genus, *Amphicœlias*, and even a new family, *Amphicœliidæ*. (Proc. Am. Phil. Soc., xvii, 243.) All the known *Sauropoda*, however, have similar vertebræ, with opisthocœlian centra in the cervical and anterior dorsal regions.

† This Journal, xiv, 87, July, 1877.

union of the spines of several vertebræ. In front, it shows rugosities for the ligament uniting it to the adjoining vertebra, and its posterior margin likewise indicates a similar union with the first caudal. In this genus, as in all the *Sauropoda*, each vertebra of the sacrum supports its own transverse processes. As shown in Plate XVI, the articulation for the ilium is formed by the coössification of the distal ends of the transverse processes. The neural canal is much enlarged in the sacrum, but proportionally less than in *Stegosaurus*.

The Caudal Vertebræ.

In the present species, the three vertebræ next behind the sacrum have moderate sized cavities between the base of the neural arch and the transverse processes. These shallow pockets extend into the base of the processes, but the centra proper are solid. All the other caudals have the centra, processes, and spines composed of dense bone. The fourth caudal vertebra, represented in Plate XVII, figures 1 and 2, is solid throughout, and the same is true of the chevron, figures 3 and 4. The neural spines of the anterior caudal vertebræ are elevated and massive. The summit is cruciform in outline, due to the four strong butresses which unite to form it.

The median caudals all have low weak spines, and no transverse processes. The posterior caudals are elongate, and without spines or zygapophyses.

The Pelvic Arch.

The pelvic bones in the present species are shown in Plate XVIII. The ilium represented is not perfect on its upper margin, which extended higher originally than shown in the figure. Its anterior process for the support of the pubis is much larger than the posterior one which meets the ischium. The pubis is elongate and massive. It sends down a strong wing for union with the ischium, and has in front of this the usual foramen. The distal end is expanded, and has on the inner surface a rugose facet for union with its fellow by cartilage. The ischium is more slender than the pubis, and has its lower end expanded for symphysial union with the one on the other side. This pelvis is more like that of *Atlantosaurus* than any other of the known genera of the *Sauropoda*. The three bones shown in Plate XVIII were found nearly in the position represented.

Brontosaurus amplus, sp. nov.

A second species of this genus is from the same horizon, and is represented by the greater portion of the skeleton. In size, the two were very nearly equal, but they may be distinguished readily by the vertebræ. In the present species, the dorsal vertebræ are less massive, the differences being especially noticeable in the zygapophyses. The anterior caudals, moreover, are without the cavities noticed in the type species, and are likewise proportionally longer. The single sternal bone found near its coracoid is thinner, and has its anterior border less developed than the corresponding part in *Brontosaurus excelsus*. The metacarpals of the present species are more elongate than in the other known members of the group.

Diracodon laticeps, gen. et sp. nov.

A new Jurassic Dinosaur of moderate size is indicated by various remains, among which are the two maxillary bones. These are unusually slender, and peculiar in the large number of teeth they contained. These teeth resemble in form those of *Echinodon*, Owen. They have compressed serrated crowns, sculptured on both sides. The base of the crown is expanded, and below this is a distinct neck, which will readily distinguish these teeth from any hitherto found in this country. The teeth are implanted in distinct sockets, and there were twenty-two in each maxillary. There is a foramen on the inner side, just below each tooth, and some large cavities on the outer side of each jaw. The teeth are very small.

The front of these jaws is edentulous, and this part curves inward so far that the snout must have been a broad one, almost batrachoid in form.

The following measurements indicate the size of these specimens:

Entire length of maxillary bone	170·mm
Space occupied by teeth	104·
Space occupied by eleven anterior teeth	50·
Length of anterior edentulous portion	62·
Vertical diameter of jaw, above eleventh tooth	27·

The present species was probably ten or twelve feet in length. The vertebræ referred to this animal are biconcave, and the other characters known make it probable that the genus is most nearly related to *Laosaurus*. The known remains are from the Atlantosaurus beds of Wyoming.

Hallopus, gen. nov.

The specimen described by the writer as *Nanosaurus victor*,* proves, on investigation, to be distinct from the type of the genus to which it was referred, and presents some peculiar characters. Some of these characters are as follows:

(1) There are but two vertebræ in the sacrum.
(2) The femur is shorter than the tibia.
(3) The metatarsals are one-half the length of the tibia.
(4) The calcaneum is much produced backward.

The last character has not before been seen in Dinosaurs, and indicates a foot especially adapted for leaping. The species representing this group may be called *Hallopus victor*. The animal was about as large as a fox. The geological horizon of this specimen is near the base of the Atlantosaurus beds, in Colorado, and perhaps below them.

The collection of American Jurassic Dinosaurs now in the museum of Yale College includes the remains of several hundred individuals, many of them in excellent preservation. The completeness of this series renders it valuable as a basis of classification for the known American forms, and an outline of this classification may appropriately be presented in the present article. Most of the many genera and species represented in this series can be readily grouped in five suborders, as given below, two of which have already been defined by the writer. The details of the present classification, and its application to the Dinosauria from other formations in this country, as well as to those of Europe, will be reserved for a future communication. The outline of classification now proposed is as follows:

* This Journal, xiv, 255, Sept. 1877.

Order DINOSAURIA, Owen.

(1.) Suborder SAUROPODA (Lizard foot.) Herbivorous.
Feet plantigrade, ungulate; five digits in manus and pes.
Pubes united in front by cartilage. No post-pubis.
Precaudal vertebræ hollow. Limb bones solid.

Family *Atlantosauridæ*.
Genera *Atlantosaurus*, *Apatosaurus*, *Brontosaurus*, *Diplodocus*, and *Morosaurus*.

(2.) Suborder STEGOSAURIA (Plated lizard.) Herbivorous.
Feet plantigrade, ungulate; five digits in manus and pes.
Pubes free in front. Post-pubis present.
Vertebræ and limb bones solid.

Family *Stegosauridæ*.
Genus *Stegosaurus*.

(3.) Suborder ORNITHOPODA (Bird foot.) Herbivorous.
Feet digitigrade; four functional digits in manus and three in pes.
Pubes free in front. Post-pubis present.
Vertebræ solid; limb bones hollow.

Family *Camptonotidæ*.
Genera *Camptonotus*, *Diracodon*, *Laosaurus*, and *Nanosaurus*.

(4.) Suborder THEROPODA (Beast foot.) Carnivorous.
Feet digitigrade; digits with prehensile claws.
Pubes coössified in front. Post-pubis present.
Vertebræ more or less cavernous; limb bones hollow.

Family *Allosauridæ*.
Genera *Allosaurus*, *Creosaurus*, and *Labrosaurus*.

(5.) Suborder HALLOPODA (Leaping foot.) Carnivorous?
Feet digitigrade, unguiculate; three digits in pes.
Metatarsals much elongated; calcaneum much produced backward.
Two vertebræ in sacrum. Limb bones hollow.

Family *Hallopodidæ*.
Genus *Hallopus*.

DINOSAURIA?

(6.) Suborder CŒLURIA (Hollow tail.) Carnivorous?
Family *Cœluridæ*.
Genus *Cœlurus*.

Yale College, New Haven, April 15, 1881.

Left scapula and coracoid of *Brontosaurus excelsus*, Marsh; one-twelfth natural size. *a*, scapular face of glenoid cavity; *b*, rugose surface for union with coracoid: *a′*, coracoidean part of glenoid cavity.

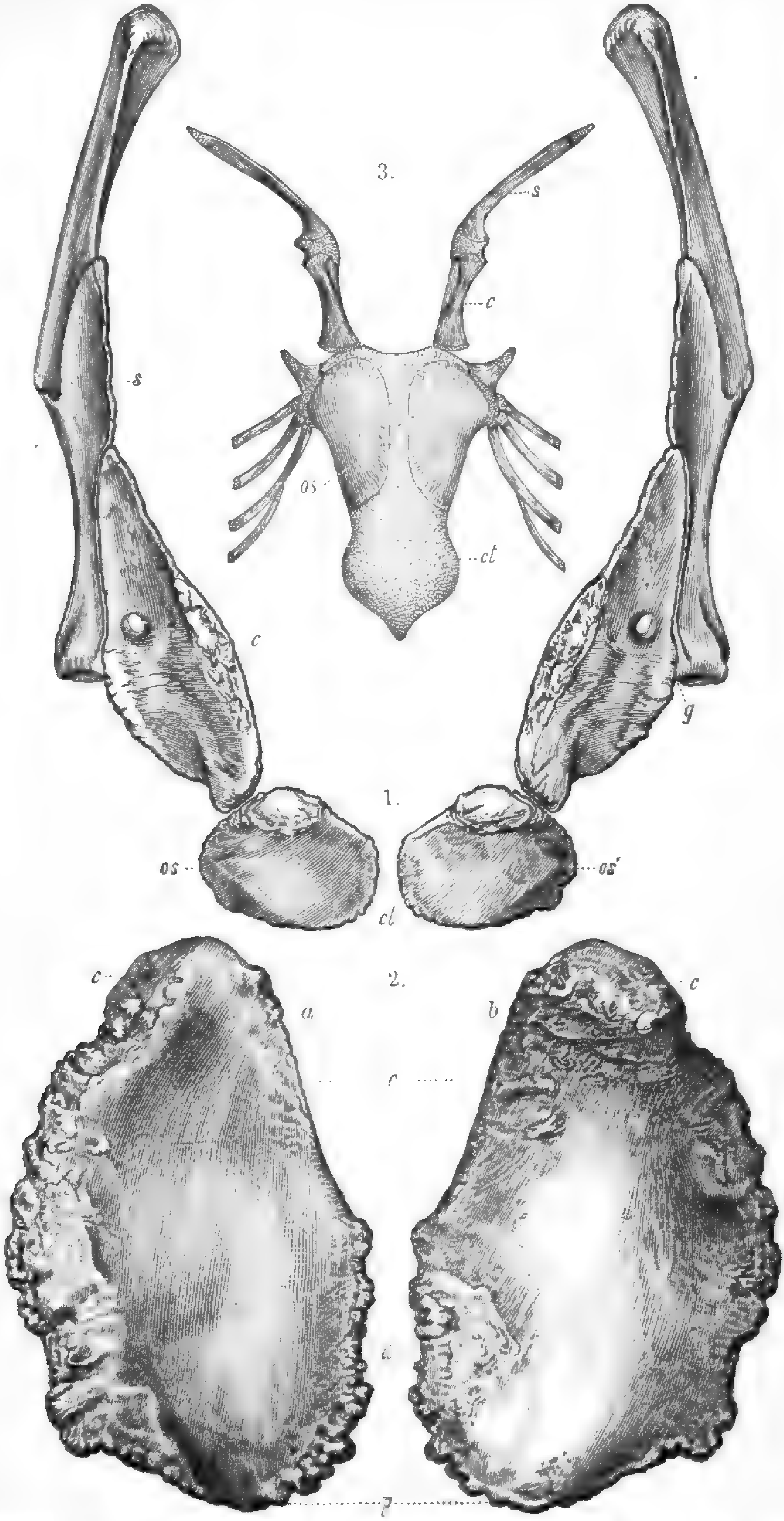
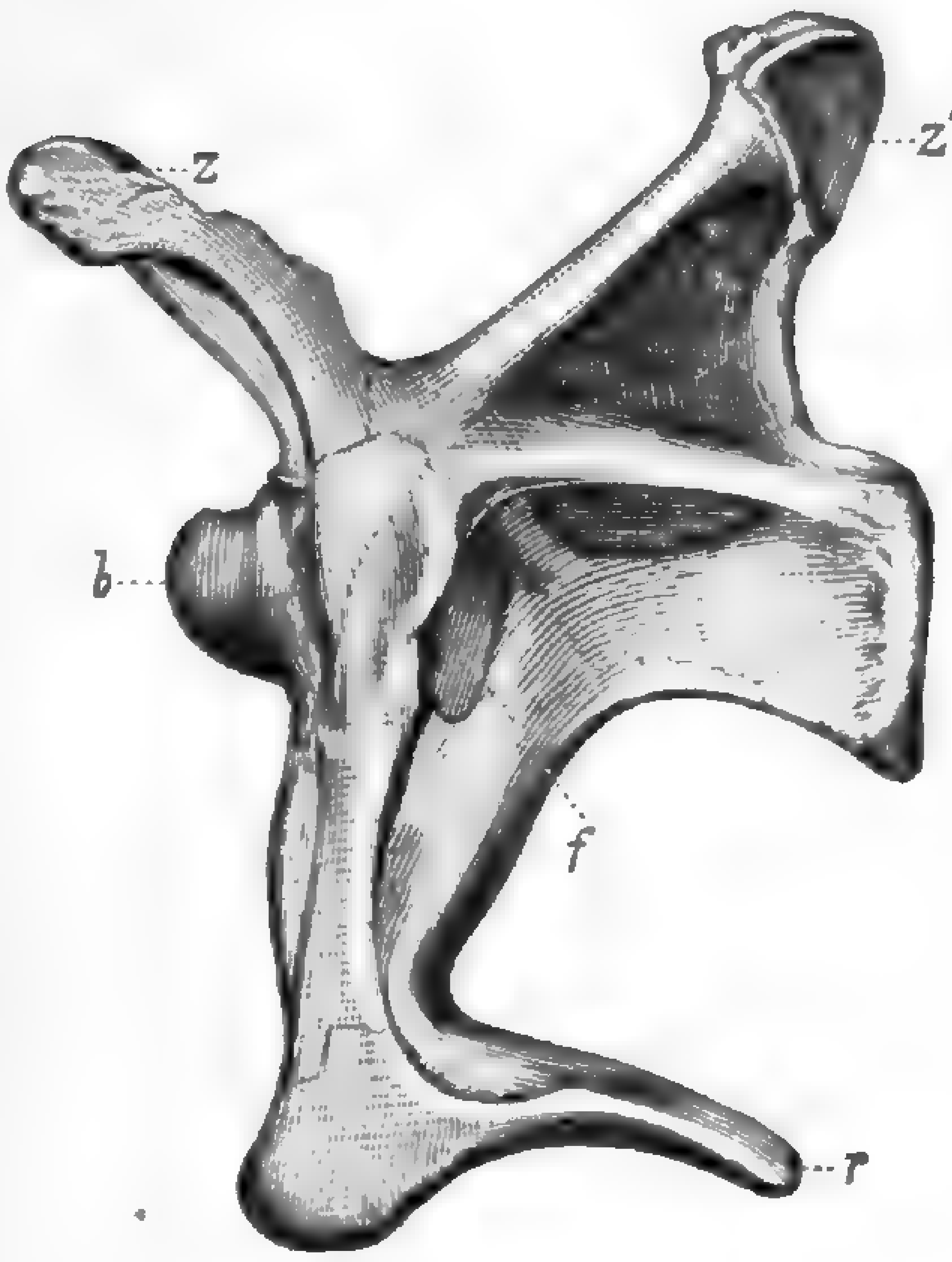


FIGURE 1.—Scapular arch of *Brontosaurus excelsus*, Marsh, front view; one-sixteenth natural size; *s*, scapula; *c*, coracoid; *g*, glenoid cavity; *os*, right sternal bone; *os'*, left sternal bone; *ct*, cartilage.

FIGURE 2.—Left sternal bone, one-eighth natural size; *a*, superior view; *b*, inferior view; *c*, face for coracoid; *d*, margin next to median line; *e*, inner front margin; *p*, posterior end.

FIGURE 3.—Scapular arch of young *Rhea Americana*, Lath; (after Parker); three-fourths natural size; seen from below. Letters as above.

1.



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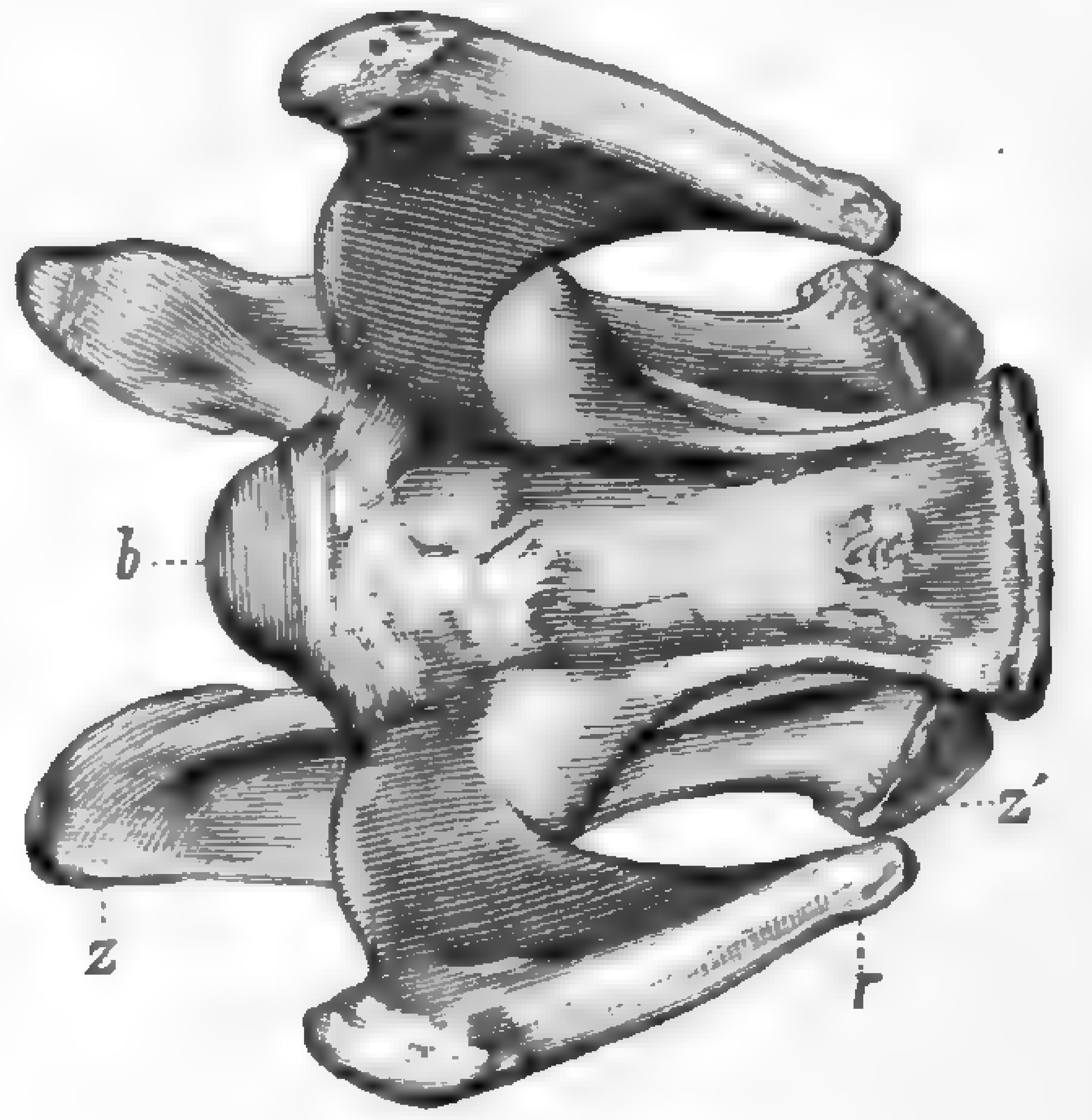

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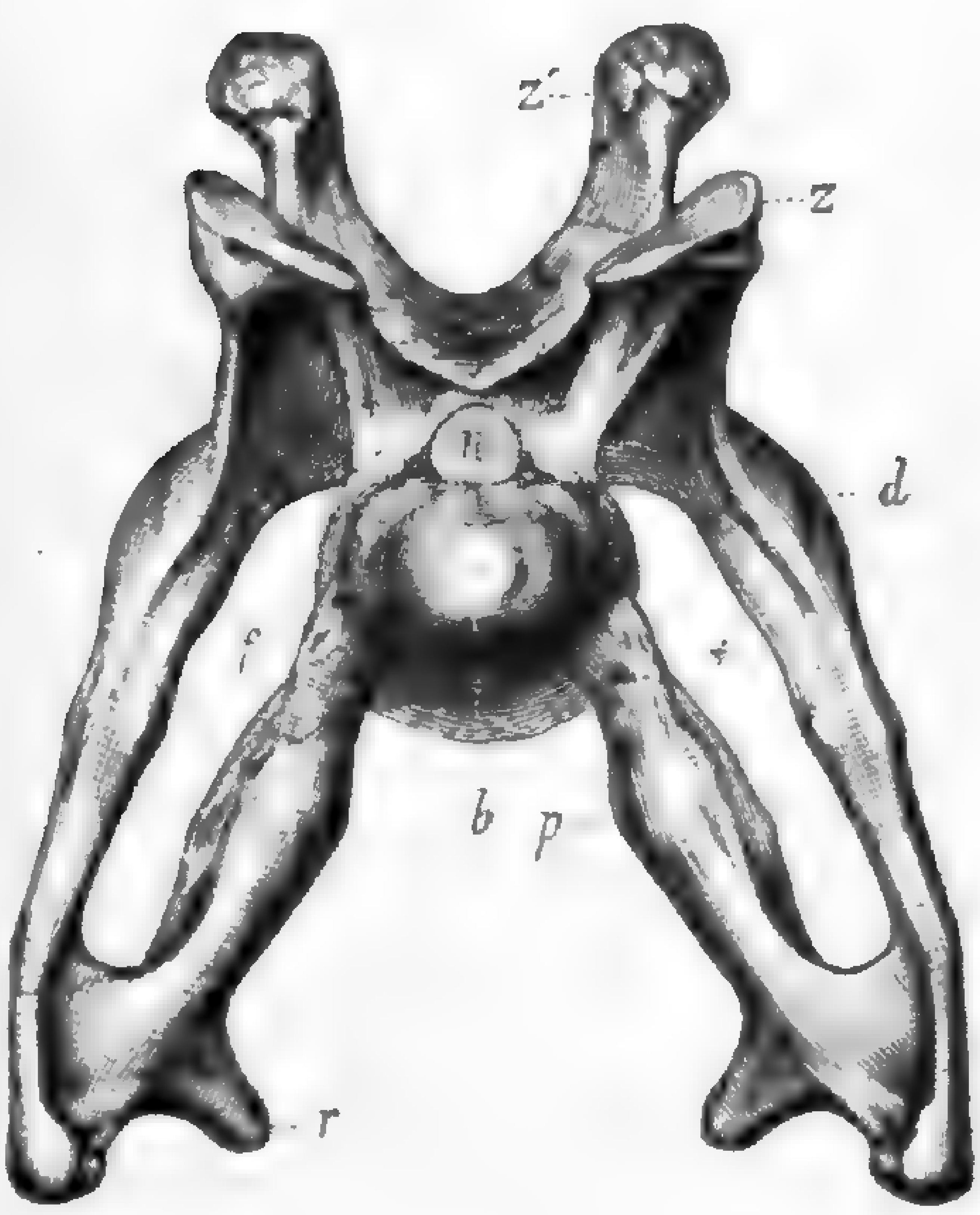


4.

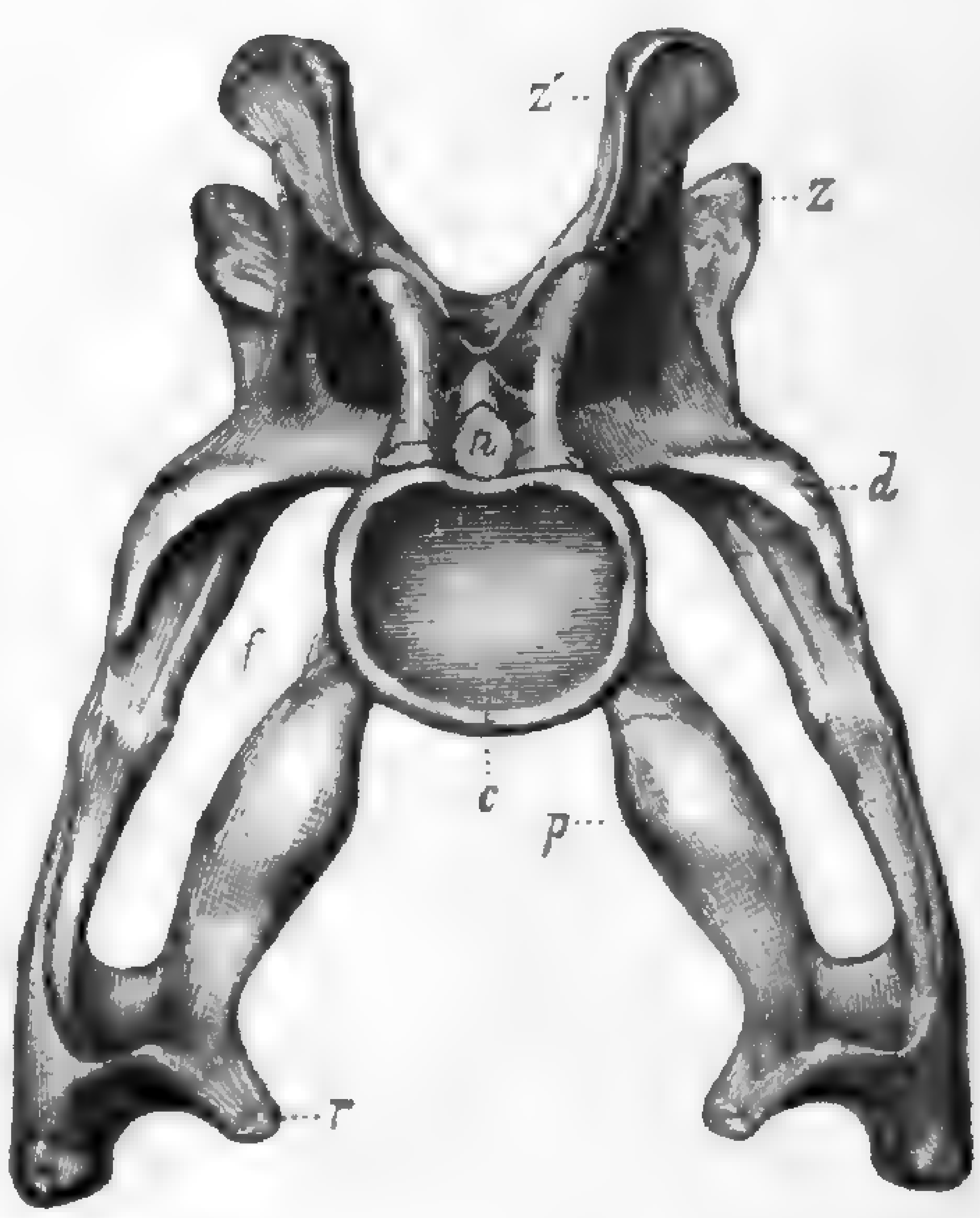
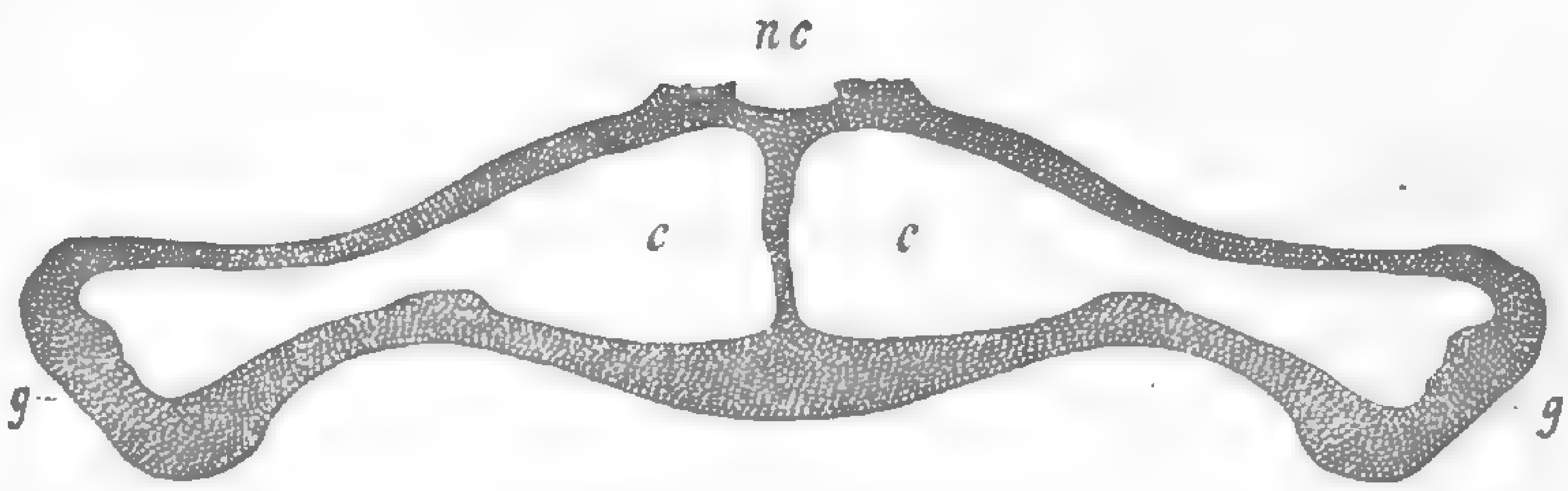


FIGURE 1.—Sixth cervical vertebra of *Brontosaurus excelsus*, Marsh, side view.
FIGURE 2.—The same vertebra, front view.
FIGURE 3.—The same, bottom view.
FIGURE 4.—The same, back view.

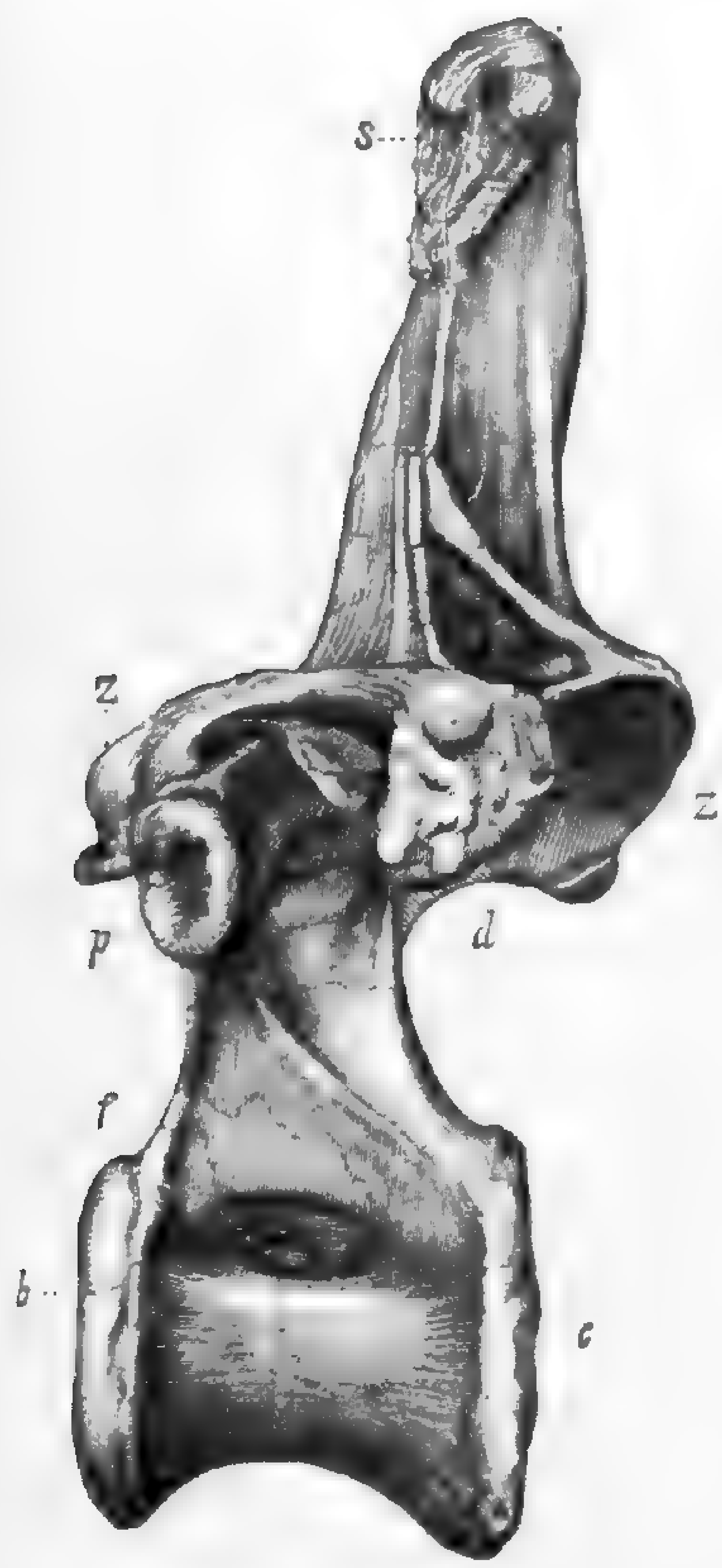
The signification of the letters is the same in all the figures, viz: *b*, ball; *c*, cup; *d*, diapophysis; *f*, lateral foramen; *n*, neural canal; *p*, parapophysis; *r*, cervical rib; *z*, anterior zygapophysis; *z′*, posterior zygapophysis.

All the figures are one-twelfth natural size.

3.



1.



2.

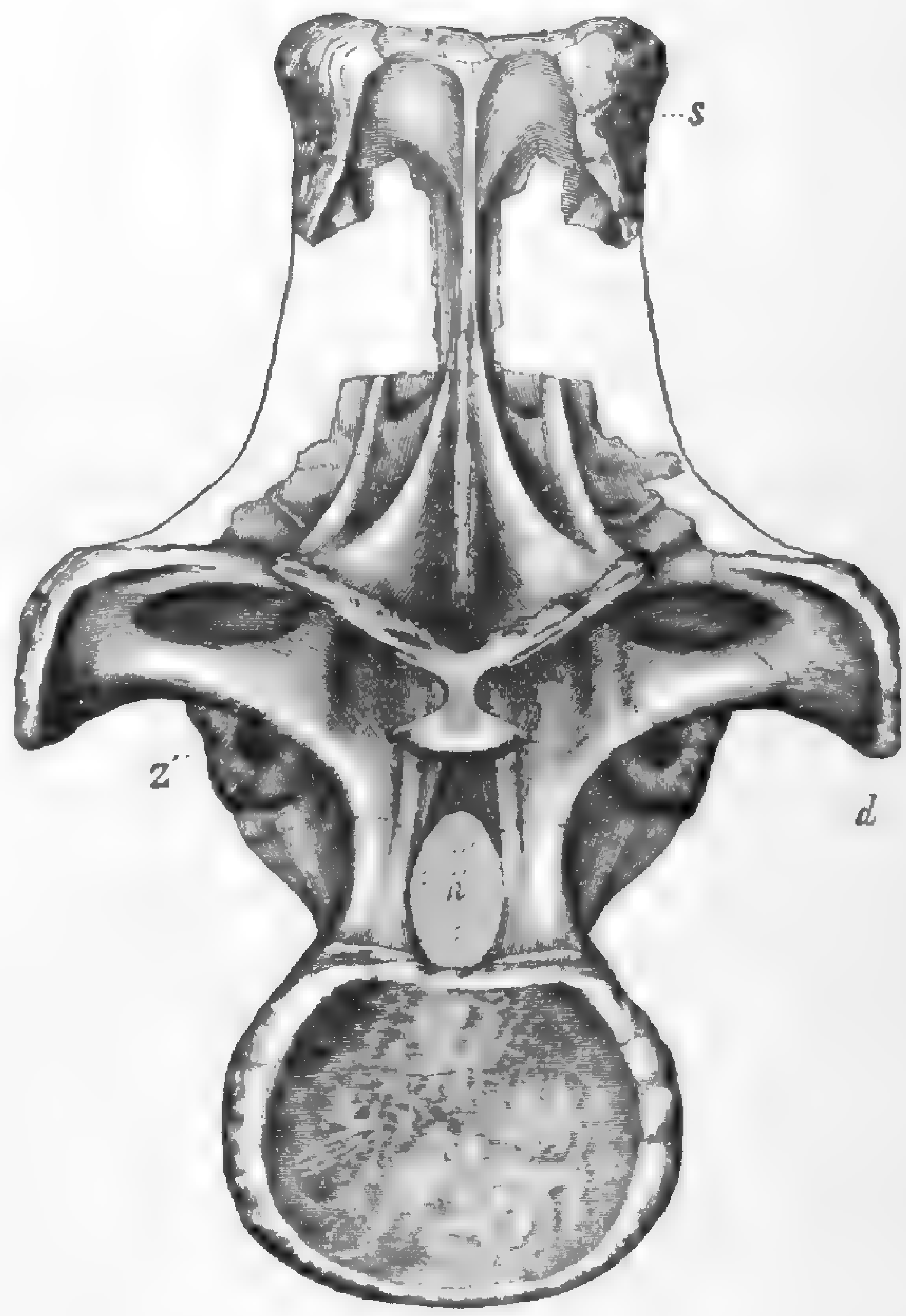
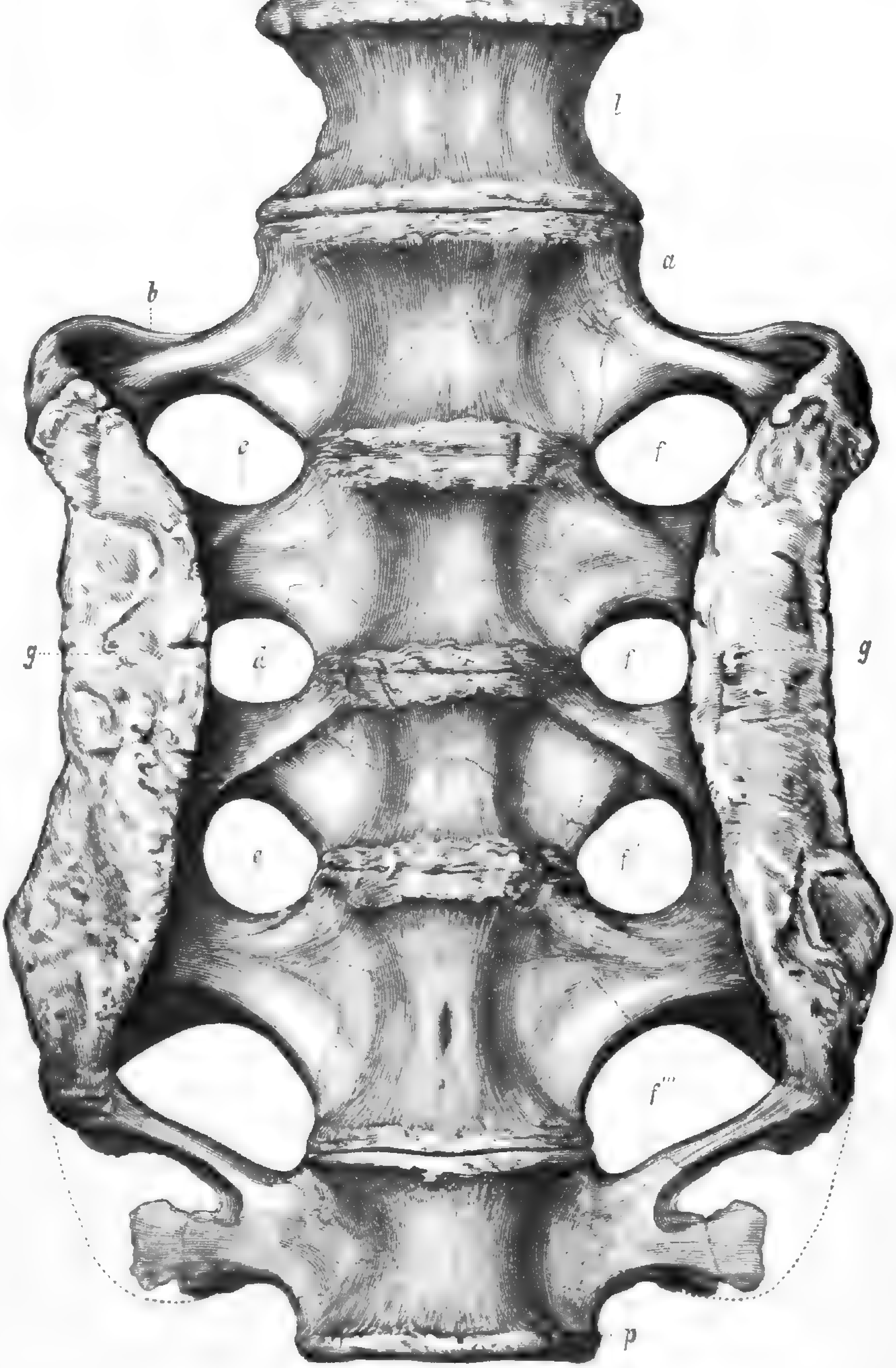


FIGURE 1.—Dorsal vertebra of *Brontosaurus excelsus*, Marsh, side view.
FIGURE 2.—The same, back view. Both one-twelfth natural size.
The signification of the letters in both figures is as follows: *b*, ball; *c*, cup; *d*, diapophysis; *f*, foramen in centrum; *n*, neural canal; *p*, parapophysis; *s*, neural spine; *z*, anterior zygapophysis; *z′*, posterior zygapophysis.
FIGURE 3.—Section through second vertebra of sacrum of *Brontosaurus excelsus*, one-tenth natural size; *c*, cavity; *g*, surface for union with ilium; *nc*, neural canal.



Sacrum of *Brontosaurus excelsus*, Marsh, seen from below; one-tenth natural size; *a*, first sacral vertebra; *b*, transverse process of first vertebra; *c*, transverse process of second vertebra; *d*, transverse process of third vertebra; *e*, transverse process of fourth vertebra; *f*, *f'*, *f''*, *f'''*, foramina between processes of sacral vertebræ; *g*, surface for union with ilium; *l*, last lumbar vertebra; *p*, last sacral vertebra.

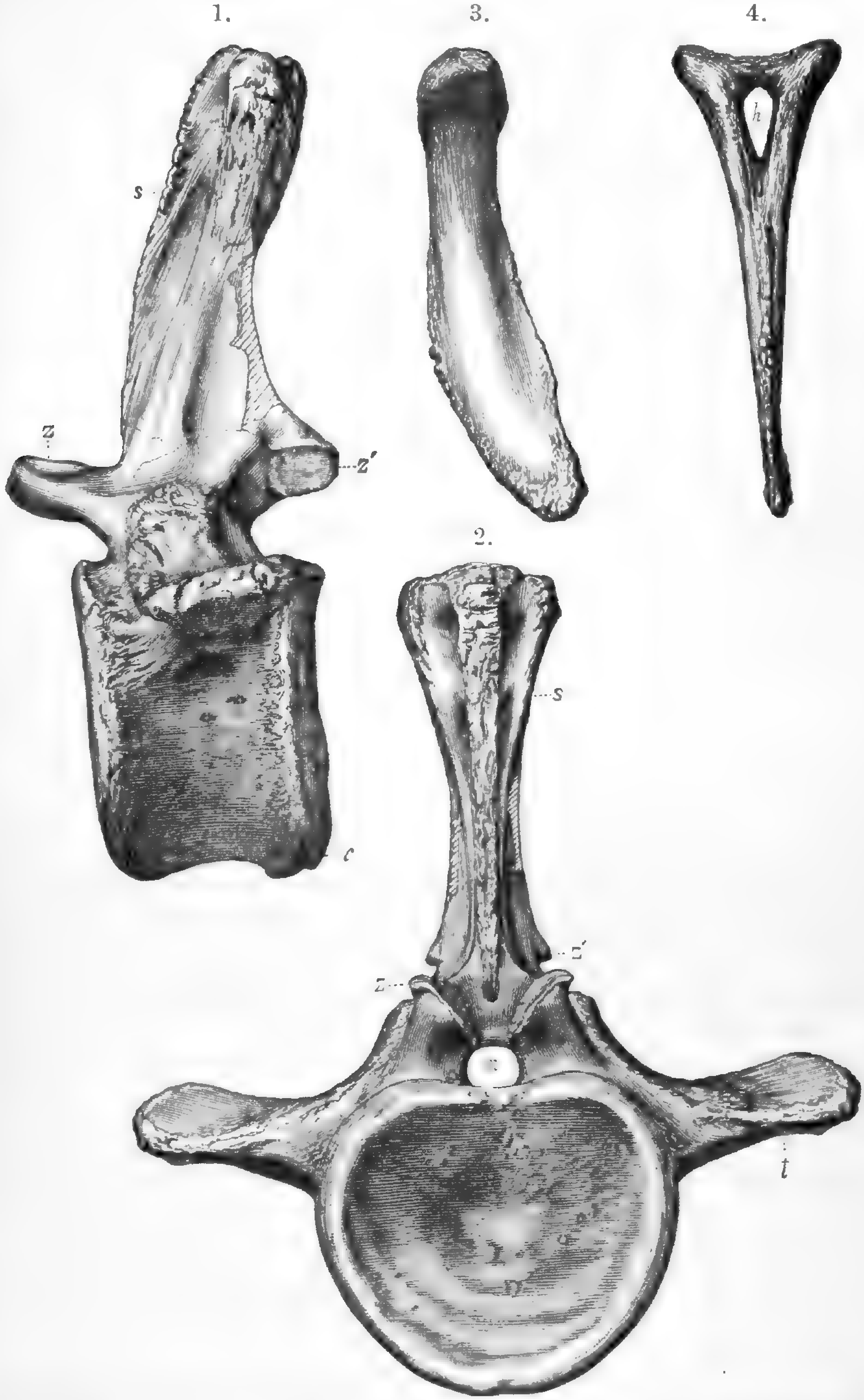


FIGURE 1.—Fourth caudal vertebra of *Brontosaurus excelsus*, Marsh, side view.

FIGURE 2.—The same, front view.

In both figures the signification of the letters is as follows: *c*, face for chevron; *n*, neural canal; *s*, neural spine; *t*, transverse process; *z*, anterior zygapophysis; *z'*, posterior zygapophysis.

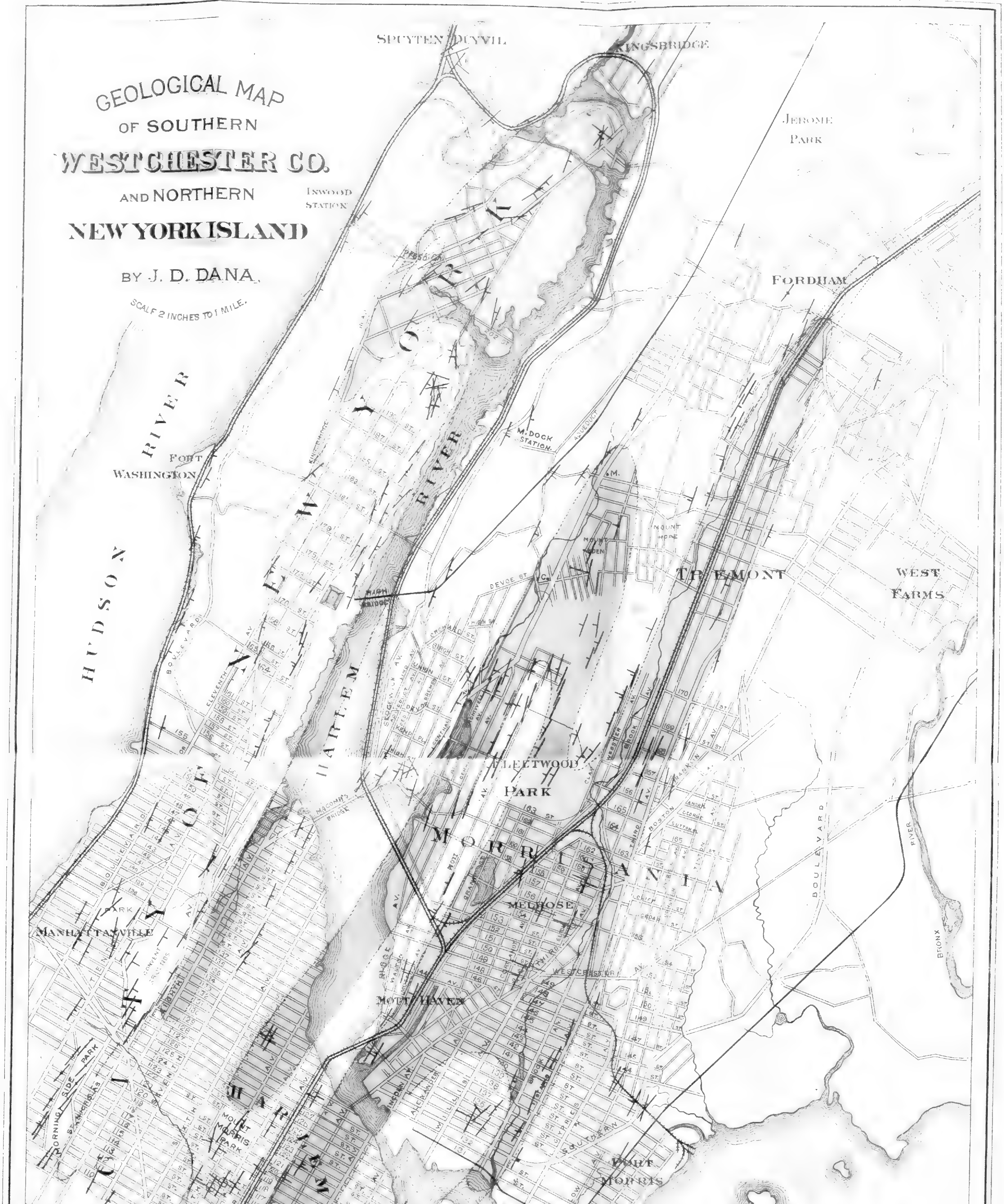
FIGURE 3.—Chevron of *Brontosaurus excelsus*, side view.

FIGURE 4.—The same, front view; *h*, hæmal canal.

All the figures are one-eighth natural size.

Pelvis of *Brontosaurus excelsus*, Marsh, seen from the left; one-sixteenth natural size; *a*, acetabulum; *f*, foramen in pubis; *il*, ilium; *is*, ischium; *p*, pubis.

In this diagram, the three pelvic bones are represented nearly in the same plane.


GEOLOGICAL MAP
OF SOUTHERN
WESTCHESTER CO.
AND NORTHERN
NEW YORK ISLAND
BY J. D. DANA.
SCALE 2 INCHES TO 1 MILE.
SPUYTEN DUYVIL
KINGSBRIDGE
JEROME PARK
INWOOD STATION
FORDHAM
HUDSON RIVER
FORT WASHINGTON
HARLEM RIVER
M. DOCK STATION
HIGH BRIDGE
TREMONT
WEST FARMS
MOUNT HOPE
FLEETWOOD PARK
MORRISANIA
MELROSE
MOTT HAVEN
NEW YORK
MANHATTANVILLE
HARLEM
MOUNT MORRIS PARK
MORNING SIDE PARK
CENTRAL PARK
RANDALL'S ISLAND
WARD'S ISLAND
PORT MORRIS
RIKERS I.
BRONX RIVER
BOULEVARD

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. LIV.—*Geological relations of the Limestone Belts of Westchester County, New York;* by JAMES D. DANA. With a map (Plate XIX).*

4. *Southern Westchester County and Northern New York Island.*

IN the account, on former pages of this memoir,† of Southern Westchester County and the adjoining part of New York or Manhattan Island, many facts of general interest were omitted. The developments which have been announced have given the region great geological importance, since they prove, on evidence both stratigraphical and paleontological, that the limestones, gneisses and mica schists are part of the long north-and-south line of the Green Mountain formations, and also part of the Lower Silurian series which spread westward over the continent.‡ I propose here to describe, more fully than has been done, the positions and relations of the limestone areas, and the flexures in these and the adjoining rocks. Toward this end

* For the earlier parts of this memoir, see pages 21, 194, 359 and 450 of the last volume.

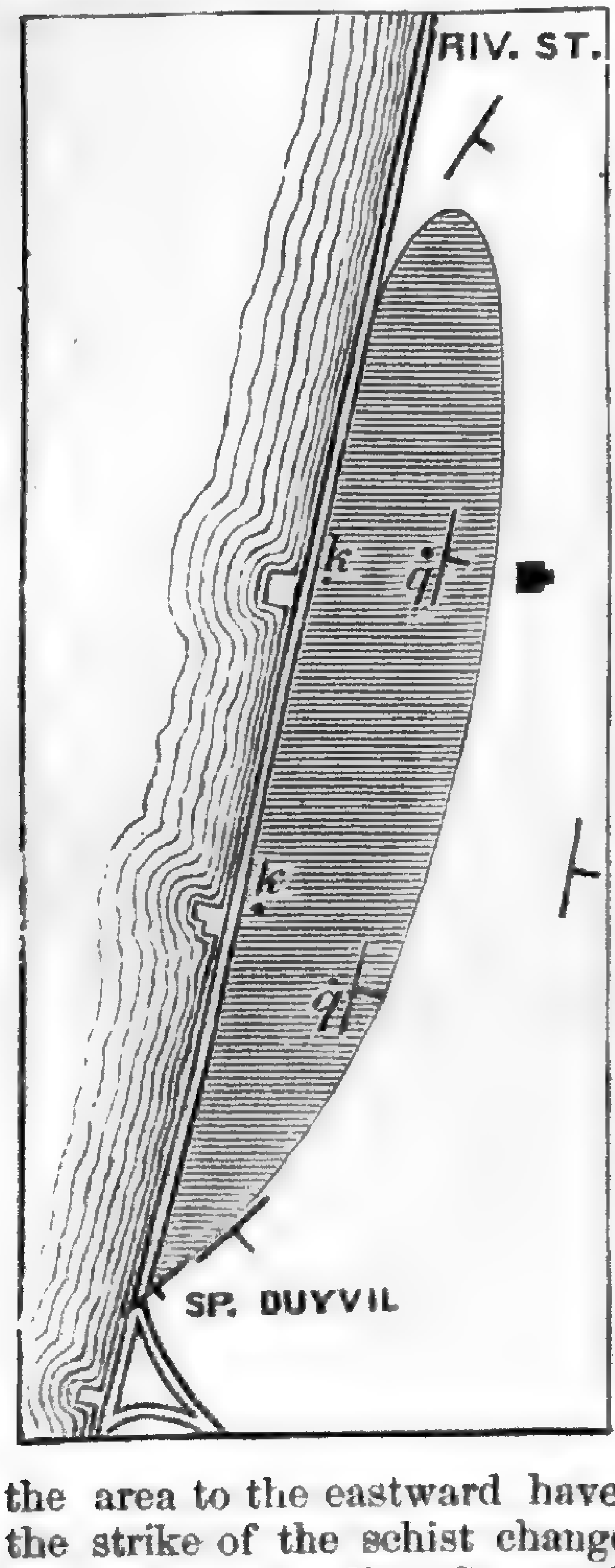
† Vol. xx. p. 360.

‡ The limestone of the Green Mountain region, as has been pointed out, includes the limestones of the successive periods from the Calciferous, and probably Primordial, to the Trenton period, as proved by the occurrence of Calciferous, Quebec and Trenton fossils in the beds of the same continuous limestone formation, both to the north, in Vermont, and to the south in Dutchess County, New York. In this they resemble the Lower Silurian of much of the Mississippi basin, while in contrast with that of Central and Eastern New York. The limestones of the continental interior lie to the west of the Appalachian Mountain region, and those of the Green Mountains have their largest development in Vermont to the west of the chief line of the Green Mountains.

I have made many additional observations which are here included. The facts will be found to explain the origin of some of the features of New York Island, and indeed of New York City, while illustrating also certain general stratigraphical features of the Green Mountain system. In order that the points may be readily understood, a large geological map of the area is here added. (See Plate XIX.)

Explanations of the Map.—The accompanying map is drawn on a scale of one mile to two inches. For the sake of precision in locating observations, it has upon it the streets that have been laid out over the surface.* I have added also, from early

* This map has been copied, by permission, from one of the maps (Nos. 14, 15) of the excellent quarto Atlas of Westchester County, published by Messrs. J. B. Beers & Co., of New York. The original map of the Atlas is a third larger in scale, and gives, among its many details, the boundaries of properties, names of owners and acreage, over the less settled portion, and many other particulars of public interest. The part of New York Island north of Central Park, or of 110th Street, is about six and a quarter miles long out of the total thirteen and a half. But it contains less than one-third the whole area of the island, and but a small part of the population of the city. I here describe, by way of



Supplement to the Article in the Number for November last, a limestone area not included in the Westchester County map of that article. It extends (see the annexed figure, and, for the south extremity of the area, the northwest corner of the accompanying map, in both of which 2 inches = 1 mile) from Spuyten Duyvil, on the Hudson, nearly to the Riverdale Station (Riv. St.). The exact outline is not determinable; for there are no outcrops on the coast owing to the stratified drift; and at Spuyten Duyvil, which is made the southern extremity, the rocks at the most northern spot (abreast of the forking of the railroad and nearly on a level with the track) is micaceous gneiss containing some layers which become crumbling from weathering and apparently because filtrating waters easily remove calcium carbonate. Similar gneiss, containing thin calciferous layers, outcrops 250 yards to the northeast, and has the same strike (N. 47° E.) and dip (70°–60° E.), as if a continuation of the eastern border of the area. Farther north, there are outcrops of the limestone, and at *q*, *q*, quarries, the more northern one on the Delafield estate. At *k*, *k* are limekilns, and the masses of limestone about the more southern appear to be partly in place. To the north of the northern quarry the eastern limit probably follows the base of a high and abrupt declivity. About the northern termination of the area, outcrops of schist occur near the river south of the Riverdale Station as well as to the north and east. The limestone at and near the quarries and the schist outside of the area to the eastward have a strike of N. 10°–18° E.; but north of the area the strike of the schist changes to N. 34° E. The schist adjoining the area is largely hornblendic. Some of the beds of limestone at both quarries contain tremolite.

maps, some details as to the original topography of New York Island, which street grading has mostly or wholly obliterated, namely: the bay and stream at the north end of the Eighth Avenue Valley, whose waters flowed northward into Harlem River; and the stream of Manhattanville Valley—a remarkable depression that crosses the island, obliquely to the bedding of the rocks, from Manhattanville on the Hudson, southeast-by-east, to East River, passing over the northeast corner of Central Park, where the park has one of its ponds and a tributary brook.

The areas on the map that are colored blue are those of the limestone, the rest being occupied by schists (mica schist and gneiss); and the dotted lines which are in continuation of the belts indicate the course of the valley, along which the limestone may perhaps extend.

The T-shaped symbols, as already explained, show, by the direction of the top of the T, the direction or strike of the bedding of the limestone and schists, and by the length and direction of the stem, the amount and direction of the pitch or dip of the beds. For the convenience of the reader, I repeat the ratios *between the stem of the* T *and half its top* which are adopted to express the angles of dip.*

Dip of 80°	a ratio of 1 : 4	Dip of 35°	a ratio of 5 : 4
70°	1½ : 4	25°	6 : 4
60°	2 : 4	20°	7 : 4
50°	3 : 4	15°	8 : 4
45°	4 : 4	10°	9 : 4

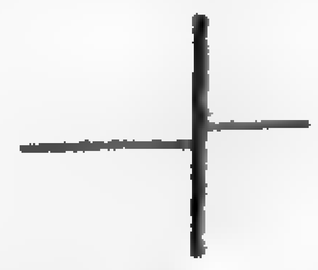
Dip of 5° a ratio of 10 : 4

A circle (fig. 21) indicates horizontality. When the dip varies greatly within very short distances, two stems are used, giving the extremes (fig. 22). If there are dips in opposite directions, stems are put on both sides of the top of the T


21.


22.


23.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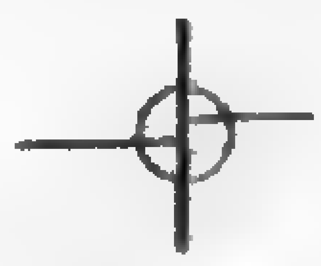

25.

(figs. 23, 24). These dips in opposite directions have two causes: *One* is a slight shifting to one side or the other of a vertical, of the axial plane of the fold; fig. 23 for example, indicates a variation from 70° W. to 80° E. The *other* is a consequence of local flexures or undulations in the stratification; as in fig. 24 (the dips indicated by which are 25° and 45°). And when such local flexures arch over, the symbol used, besides having stems in opposite directions, has a small circle at the center (the top of an arch or undulation being approximately horizontal), as in fig. 25.

* On a large manuscript map, a convenient length for the top of the T is eight millimeters; and this adopted, the above ratios are in millimeters. Or, if the top is made one-third of an inch long (about eight and one-half millimeters), the ratios are in twenty-fourths of an inch.

Additional notes on the Rocks.—The *crystalline schists* of the region, as I have stated, are mainly micaceous gneiss and coarse mica schist, the one graduating into the other; are generally garnetiferous, and in some places hornblendic, or contain hornblende schist in intercalated beds; and have been found to contain cyanite at localities between 4th and 5th Avenues and 42d and 51st Streets.* I have now to report that the schist is crowded with minute needles of fibrolite at several points between the same avenues farther to the north (north of 115th street), and also in Westchester County, north of Mott Haven, near the Mott Avenue bridge over the Hudson River railroad track: a fact which adds to the close relations between the rocks of New York and those of eastern Westchester County, at New Rochelle, and also those of the northern part of the county, south of Peekskill.†

Gneiss of the normal type—that is, containing only a moderate proportion of mica—is not common. A fine-grained, thick-bedded, light gray gneiss containing little black and white mica, makes the bluff bounding on the west the limestone area between Tremont and Morrisania, and has been quarried at several points. By microscopic examination of a thin slice, I have found it to be two-thirds granular quartz, so that it is in reality quartzytic gneiss or gneissic quartzyte. The other ingredients are orthoclase and microcline, with traces of black tourmaline. It is porous, and weathers rather deeply, and loses thus its black mica before it does its firmness. Among the thicker beds occurs an occasional thin layer of mica schist.

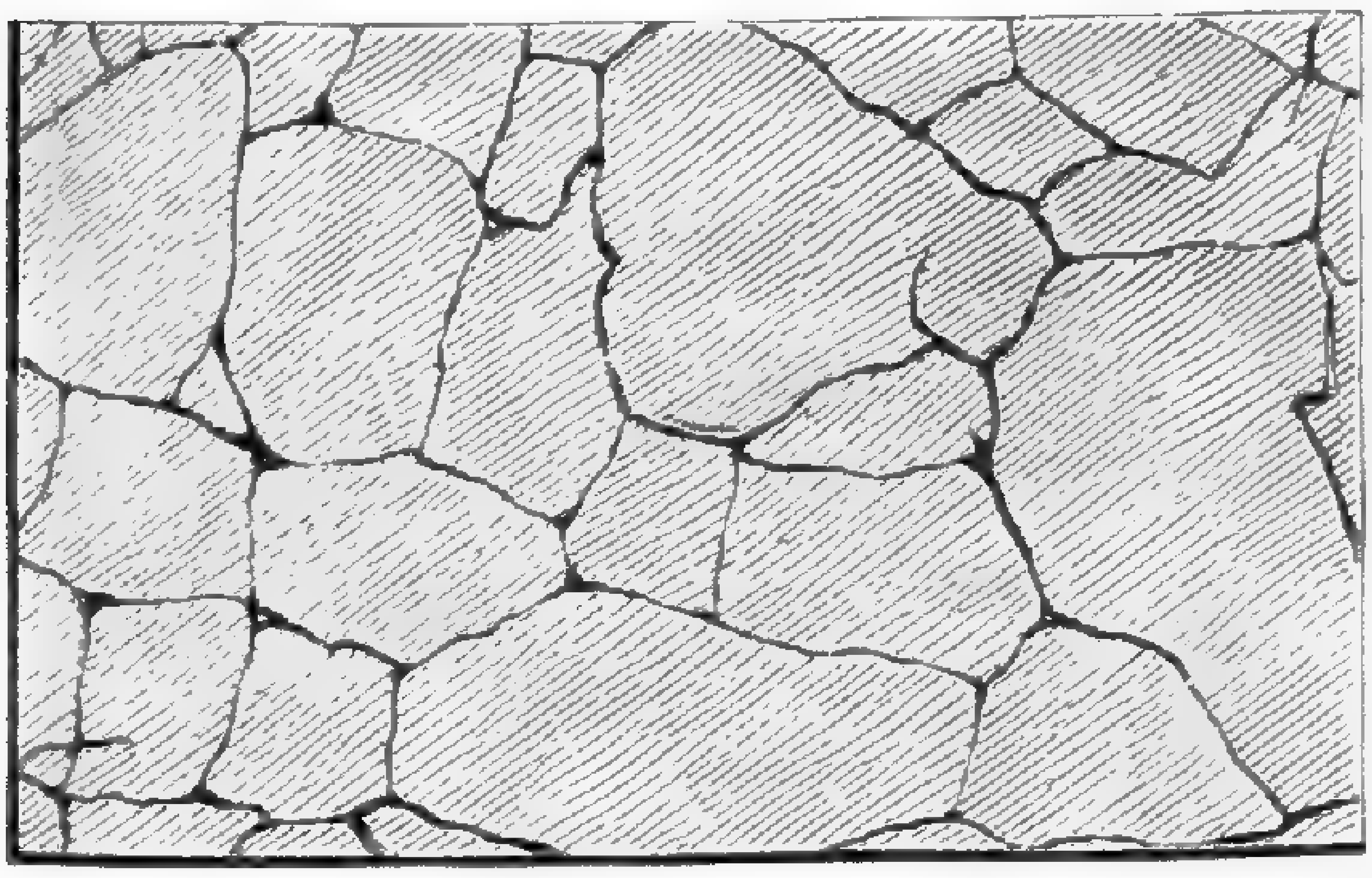
The presence of hornblende or hornblendic schist appears to have often determined a crowd of subordinate flexures and contortions in the beds, and a loss of distinctness in the minor layers. I have explained this on the ground that hornblende is relatively a fusible mineral (being of the grade 3, on von Kobell's scale of fusibility), while the feldspar (of which orthoclase is the prevailing one) and the mica (black and white) are of difficult fusibility (5 to 6, on the same scale); and, in consequence, beds that become hornblendic in the metamorphic process easily soften and bend. A good example is seen in a section on 110th Street, between 9th and 10th Avenues, where the micaceous gneiss has high dip (mostly 80° to 90°, but varying locally) and in some parts contains much hornblende. This street (the 110th) here cuts through the schist transversely to its bedding, and has on the north side a vertical face of an

* Cyanite was first found on New York Island by Mr. Issachar Cozzens, as reported by Dr. Torrey in this Journal, vi, 364 (1823); and Mr. Cozzens, in his "Geological History of Manhattan or New York Island" (1843), mentions the neighborhood of the Deaf and Dumb Asylum (which was then situated between 49th and 50th Streets and 4th and 5th Avenues) as the locality.

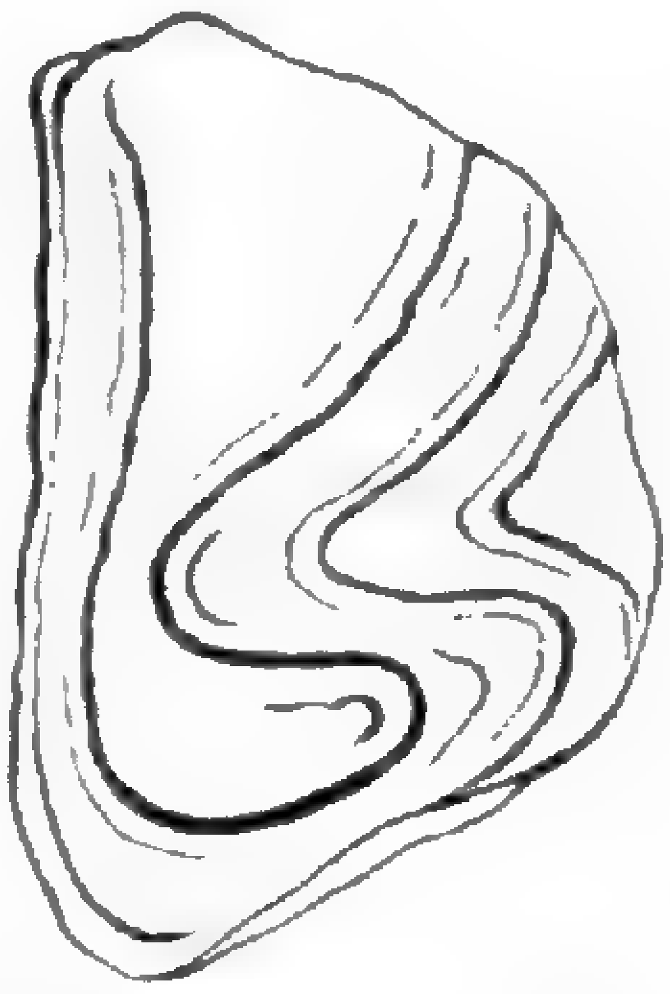
† This Journal, xx, 24, 200, 206.

extensive joint or fracture. The surface over a large area looks as if made up of the flat ends of great and nearly horizontal columns (fig. 26). The rock is here largely hornblendic,

26.



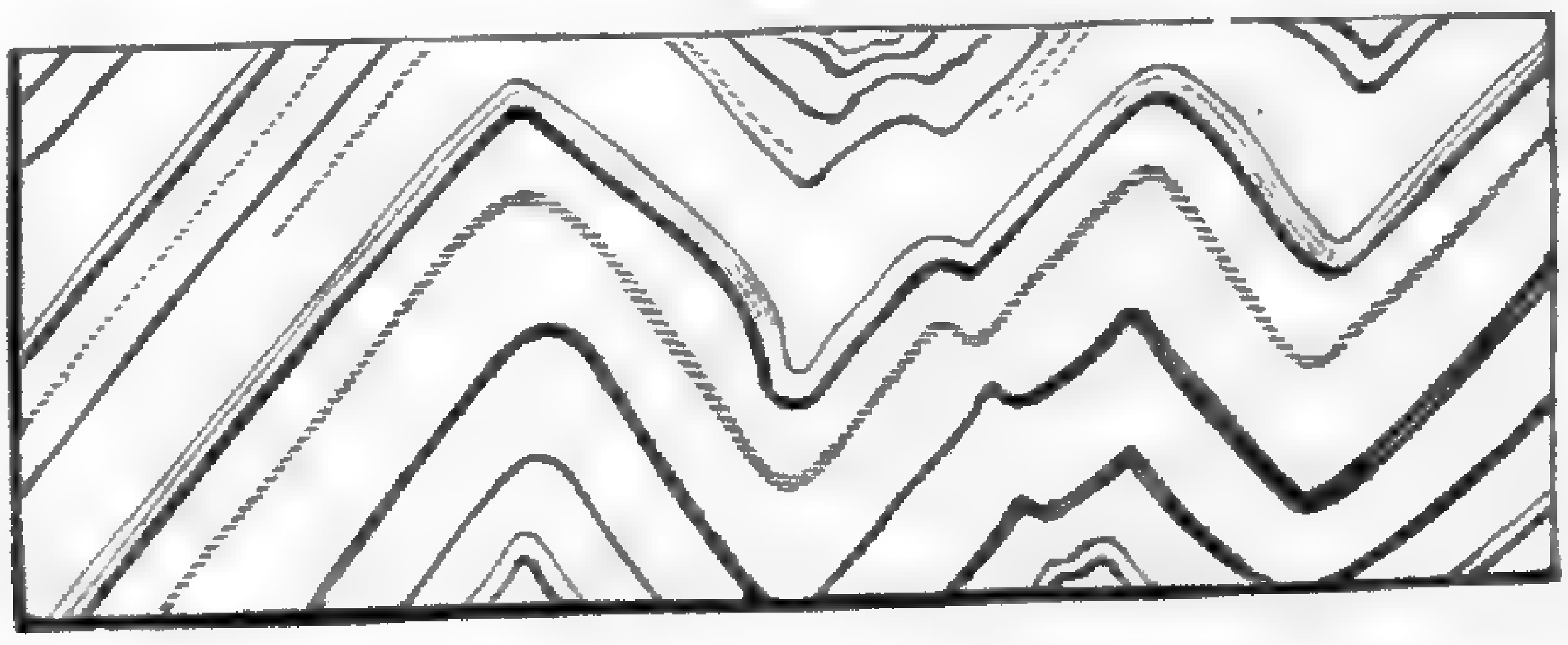
27.



and the columns are obscure in their interior bedding; but through the weathering or rusting of the flat end, the fact is at times revealed that they are a compacted roll or zigzag of layers, as in the annexed cut (fig. 27), representing one of them twenty inches in breadth.* Such observations show why hornblendic metamorphic rocks, when containing little or no quartz, often fail of bedding, and look enough like igneous rocks to be frequently referred, without a question, to that class.

I have observed other examples on New York Island, and one of the most remarkable of them in the 11th Avenue Park, between 133d and 138th streets. The rock over the higher rocky portion of the Park, north of the center (as long known) is largely hornblende schist, in many parts epidotic. The beds are bent in zigzags, and sometimes vary 90° in strike in a few

28.



yards, owing to the small variously inclined flexures. Fig. 28 represents a portion of one of the zigzag surfaces, only twelve feet broad, north of the summit arbor. The mica schist and micaceous gneiss outcropping on 10th and 11th Avenues vary little in strike or dip. Such zigzags, however, although common in the hornblendic beds, are not confined to them.

* Such facts explain the statement of Dr. L. D. Gale respecting hornblende beds in the gneiss of 7th Avenue, south of McComb's Bridge (cited in Mather's N. Y. Report, p. 599): "in places hornblende so predominates as to cause the rock to assume a columnar structure."

The *crystalline limestone*—strictly dolomite—often contains so much dark brown or black mica in scales as to look like a thick-bedded gneiss; yet it betrays its true nature, here as usually elsewhere, by the occurrence of some crumbling surfaces. Besides tremolite, chlorite, with a little graphite and brown or black sphene, as before reported, the limestone contains white pyroxene in crystals, and green pyroxene in coccolite-like grains. The white crystals accompany tremolite in northern New York, near the King's Bridge Road,* and the coccolite variety characterizes part of the limestone of the "Mount Eden" region, north of Fleetwood Park. Orthoclase in cleavable pieces also is sometimes an impurity of the limestone; and pyrite is a common source of disintegration and iron-rust stains.

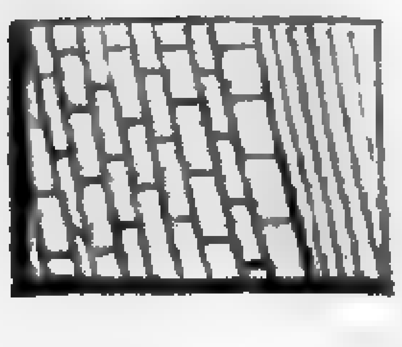
The limestone areas are in part low and marshy, owing to the easy destruction of the rock. But in some parts of the region there are long, broad ridges, a hundred feet or so in height. One of these ridges extends from Morrisania to Fordham, and many quarries have been opened in it. Another of them, equally prominent but of the less pure, gneiss-like limestone, passes through "Mount Eden," and has given occasion to the extravagant expression *Mount* in the name of this locality of prospective streets and houses.

After these general remarks, I proceed to the special facts connected with the limestone areas and the associated schists.

1. Limestone Area, No. 1.

A. *The portions of the Area in Westchester County.*—The general fact has been stated that, in this easternmost of the belts, the beds on the *eastern* side have a high *eastward* dip (figure 29), and on the *western* usually a high *westward* dip, corresponding with the idea that the beds make an anticlinal flexure. This steep dip continues on the eastern portion quite to the Harlem; but on the western, it varies in its northern part to 70° E., and south of Tremont station from 80° W. to 60° W., becoming 50° W. and less in local folds.

29.



The center of the belt from Fordham to Morrisania, where it commences to widen, has equally high dip; but south of this

* The crystals occur over the surface of the ground or rock where the limestone has crumbled from weathering. They are found in such places more easily than in the solid rock in which the accompanying crystals of tremolite tend to conceal or disguise them. They may be found half a mile south of King's Bridge, west of the King's Bridge Road.

The specimens from this locality were first recognized as pyroxene by the Abbé Haüy, after an examination of crystals sent him by Dr. Archibald Bruce, the editor of Bruce's Mineralogical Journal. The fact is reported in the last number of that Journal, published in 1814, on page 266.

there are undulations in the beds with dips of 45° to 30° and less, both eastward and westward, corresponding with a widening out of the anticlinal. These undulations (of which there are successions across the region) are well shown in Melrose, on Elton Avenue, above 159th Street (see map), and also near

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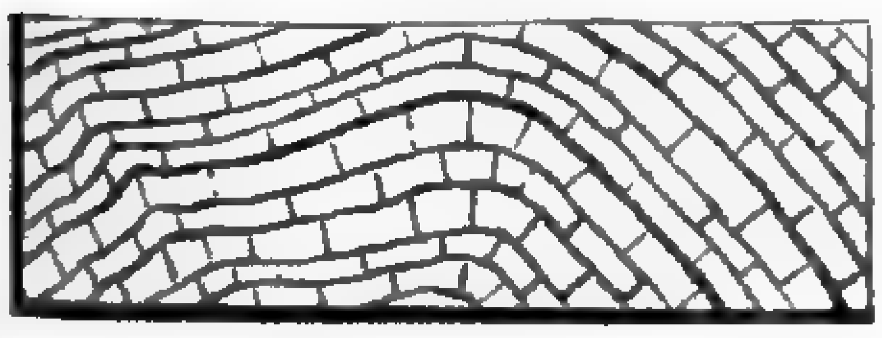
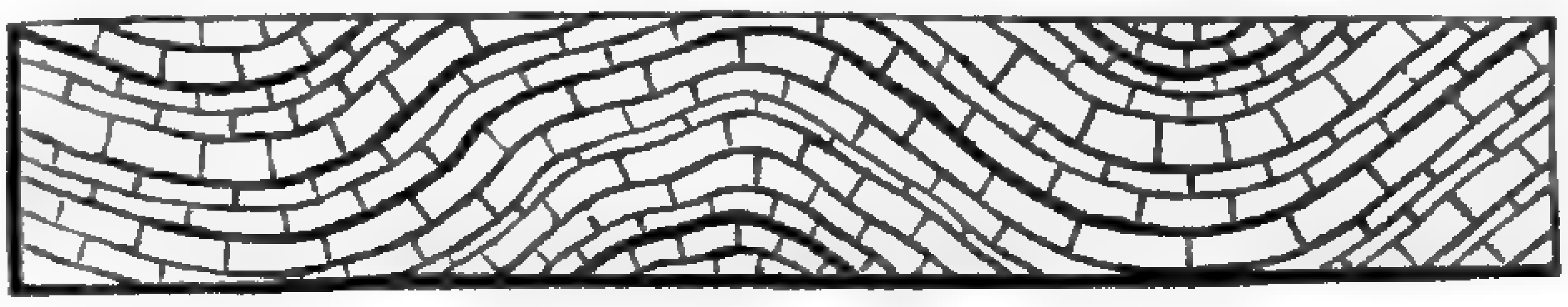


31.



156th and 155th Streets, (fig. 30, representing a length of thirty-five yards) and on 150th Street, east of Cortlandt Avenue (fig. 31, representing a length of one hundred yards). There are outcrops also on 149th Street.

Farther south, about 140th Street, or below this, the limestone area is divided into two bands, an eastern and western, separated by schist—whether *underlying* or *overlying* schist, is considered beyond.

The outcrops of schist which prove this occur to the south, between 133d and 136th Streets, east of Willis Avenue (a spot marked by T-symbols on the map). The micaceous beds are undulating, with the dip in part small and varying from east to west, thus conforming in character to the limestone in the broad part of the anticlinal from 150th to 159th Streets. But on its eastern side near the limestone, that is, toward the east side of the anticlinal, the dip becomes high (70°–90° E.), conforming to that of the limestone.

The general facts respecting the Mott Haven band of limestone have been stated on page 360 of the last volume of this Journal.

The schist making the bluff or steep border along most of the west side of this limestone belt between Fordham and Morrisania is in general the quartzytic gneiss mentioned on page 428, though in some portions micaceous gneiss or hornblende schist.

B. *The limestone area in New York Island.*—The *eastern* of the two *limestone bands* does not come out to view south of Harlem River. It probably extends on beneath the low, now grass-covered, grounds of the west side of Randall Island, the once marshy coast opposite, and the channel of East River.

The *schist between the eastern and western bands* is exposed, north of 94th Street, at present, so far as I have found, only at a point on its eastern margin—the whole area, like that corresponding to it immediately north of Harlem River, having been low when civilization took possession. The one outcrop referred to occurs on East River, fifty feet north of 123d Street, and is exposed only at low tide. The micaceous gneiss is thin schistose, and the beds have a strike of N. 26° E., with the dip 60° W. But farther south in the same line, that is, east of 3d Avenue, there are large outcrops of micaceous gneiss between 89th and 70th Streets, having the strike of the bedding N. 30° E. The beds are undulating, pitching at small angles both eastward and westward, except east of Avenue A toward

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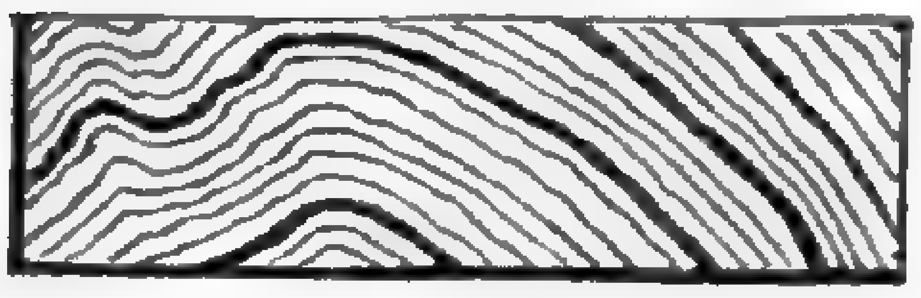

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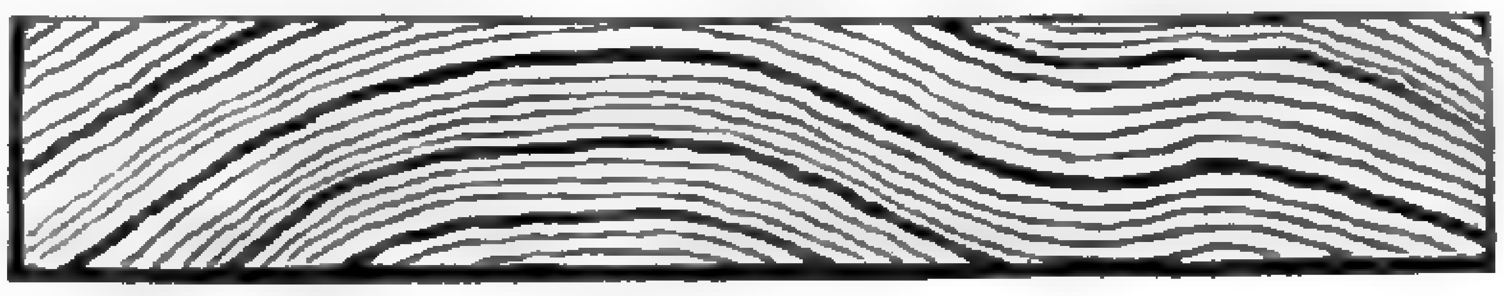
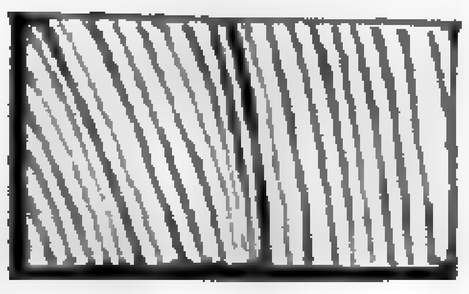


or near East River, where the dips become high—90° to 70° E. Fig. 32 represents a section on 75th Street, east of Avenue A; fig. 33, another on 77th Street, east of the same avenue; fig. 34, a portion of a section near East River.

34.



They thus accord in position with the similarly situated beds north of the Harlem, and would seem to indicate that the anticlinal is distinguishable at least to this distance, although it is hardly probable that the limestone continues so far down the river.

The *western* or *Mott Haven Limestone band* outcrops on the island between 118th and 124th Streets. The ledge of limestone with intercalated gneiss, north of 122d Street and east of and adjoining Lexington Avenue, first described by Mr. R. P. Stevens,* is the principal locality remaining. It is about 125 feet in breadth. His section of the limestone and schist contains an anticlinal flexure (now hardly distinct); but the mass exposed is certainly but a small part of the whole limestone band, and the flexure is evidently one of the local flexures so common in the stratification of that vicinity. The easternmost of the beds on 122d Street—which is about 35 feet wide and the purest—bends from N. 28° E. (the normal strike) to N. 54° E., and disappears beneath the adjoining yard and house; and probably the chief part of the limestone band is situated farther to the east along 3d Avenue. There are also three layers of limestone in the schist south of 122d Street. Besides these outcrops, there is much calcareous material in portions of the gneiss east of 4th Avenue between 118th and 120th Streets, as reported by Dr. Gale, and also on 124th Street, which localities lie to the west of the general range of the band.

As to the southern limit of the band there is no positive evidence. In view of the range of low land directly south along and east of 3d Avenue, and the outcrops of schist on the western side, it probably goes at least as far as 103d Street. Mr. R. P. Stevens, in the paper already referred to, states that limestone was found 18 feet below the surface, in 50th Street, between 3d and 4th Avenues, in excavating for a culvert; and this must belong to the same band, although the limestone is

* Annals of Lyc. Nat. Hist. of N. York, viii, 116, 1865.

interrupted over more or less of the interval between, by the gneiss.

The *schists west of this line of limestone* show themselves prominently on New York Island east of 4th Avenue between 129th and 130th Streets, and also both west and east farther south between 125th and 114th Streets. The beds have, in general, a dip of 60° to 50°. But there are broad and narrow undulations, with eastward and westward dips, as represented on the map, and illustrated as to general character in figs. 32, 33. Some portions are *fibrolitic*, as stated above; and this fact, taken in connection with the existence of the related cyanitic schist in the same line of bedding or strike near 42d and 45th Streets, is much in favor of the conclusion that this western overlying stratum of schist continues southward at least to 42d Street, or the vicinity of the Grand Central Station; and the fact that limestone exists in the same line of strike in 50th Street sustains this conclusion.

2. Limestone Area, No. 2.

A. *In Westchester County.*—The limestone area No. 2, or that of the valley of Cromwell's Creek (called also the Clove) joins that already described through the region of Fleetwood Park, as shown on the map. The northern limit of the belt is about two miles north of McComb's (or Central) Bridge. At this north extremity (in the region of the Manhattan House, M.) two valleys come up from the south and meet—the one just mentioned or "the Clove," and a more eastern, which passes into Fleetwood Park. The limestone of Morrisania extends westward over three-fourths of Fleetwood Park, and then northward (as the map shows) to join the limestone of the Cromwell Creek Valley. The high land between the two valleys forming the western side of Fleetwood Park consists mainly of schist. But farther north the schist makes only its western portion for 600 yards, and then narrows out leaving limestone alone, excepting an occasional intercalation of gneiss; and it is the kind of limestone already spoken of as firm and gneiss-like in aspect, and as containing much mica and in places green coccolite. From the ridge, the limestone extends across Cromwell Creek Valley; but it is here much less firm, and has in general small and varying dip. The beds are well displayed just east of Central Avenue a mile north of McComb's bridge (near Judge Smith's House) where the layers dip eastward from 30° to 70° and some are remarkably chloritic; and also less satisfactorily, half a mile farther north (opposite Sibbern's Club House, C.). Limestone of the firm thick-bedded kind is exposed to view also on the rising land east of the lower part of Cromwell's Creek and, at one place, in sight from the east end of the 161st Street bridge (the first north of McComb's), it has been quarried.

The *schist* east of the limestone along the west side of Fleetwood Park is nearly vertical in its bedding. That on the west side has, north of 167th Street, a high dip to the eastward, like the prevailing dip of the limestone; but south of this it becomes nearly vertical, and then westerly, and, within a fourth of a mile of McComb's bridge, the beds have widely varying dip with large contortions in the bedding, though westerly dips prevail; yet on the Harlem River side, the beds have greater regularity and stand nearly vertical. As shown below, they here face the Harlem River band of limestone.

B. *On New York Island.*—In New York, the limestone band of Cromwell Creek Valley is in sight only, as has been mentioned, between 131st and 133d Streets, about one hundred and forty yards east of 6th Avenue.* The width of the open lot north of 132d Street covered by the outcropping limestone is about fifty yards. Excepting a layer of schist six or seven feet thick the rock is all a coarsely crystalline limestone. Its average strike is N. 28° E., and the dip is mostly to the eastward 60°, but varying to 40° and less. There are also westward dips and, near the middle of the area, small local flexures.

To the south of 132d Street, where also there is an open lot, but narrower, the limestone shows itself at some places over the surface of the lot, and then disappears as it passes under a fence located half way to 131st Street; farther south it is covered by yards and buildings and other "city improvements." At the outcrops in this lot the beds are nearly vertical and have the direction N. 24°–28° E. Just east, a rocky ledge stands facing 132d Street, which, for seventy feet, fronts the open lot north of the street and is chiefly of limestone; the remaining thirty feet are of mica schist with a layer of limestone near its middle. The beds of the western part of the ledge are vertical, but those to the eastward are variously flexed. There is nothing at the locality to authorize a positive conclusion as to whether the body of the limestone band lies to the east or west of this locality.

How far this Cromwell Valley belt extends south of 131st Street is uncertain. The surface continues low to 124th Street, where rise the rocky ledges of Mt. Morris Park, and this may well be its southern limit. It is a question, however, whether it does not narrow and pass by the west side of the park, and, continuing southward, enter the low northeast corner of Central Park; in which case 103d Street would be its farthest possible limit since on 102d the schists of Central Park spread eastward across 5th Avenue, and so bring to an end the low valley-like area.

* This Journal, xx, 362 (Nov., 1880), where I cite a remark respecting it from R. P. Stevens in Ann. Lyc. Nat. Hist., N. Y., viii, 116.

3. Limestone Area, No. 3.

A. *The Limestone.*—The main facts respecting this area have already been given, and I have little to add except the evidence with reference to its extension down Harlem River. The map shows its position south of King's Bridge—its spreading over the Inwood Parade grounds,* the site selected for the proposed exposition of 1883—and its dividing into a *western* band which extends southward along the valley occupied by the King's Bridge Road, the chief highway of Northern New York, and an *eastern*, of greater length.

The western band I have not traced by outcrops beyond 194th Street; but the valley is so well defined by its western wall of schist and its flat bottom that there is little doubt as to the continuation of the limestone to 187th Street, and it may not end short of 183d Street, where the valley fades out.† The most southern locality of limestone mentioned by Dr. Gale and Professor Mather is just north of the Inwood Presbyterian Church, to the north of which all the old quarries of the region are situated.

Dr. Gale states, as quoted on page 519 of Mather's N. Y. Report, that "at 157th Street, about 100 feet west of 10th Avenue, the rock is entirely changed both in composition and structure; in composition it is a mixture of limestone and serpentine." I have not succeeded in finding this outcrop, probably because of changes since made in the surface by grading. The locality is nearly in the line that the western band would follow.

The existence of an eastern limestone band down Harlem River is placed beyond question by the fact—made known to me by Mr. Benjamin S. Church, Resident Engineer in charge of the Croton Water Works—that part of the piers of the Croton Aqueduct bridge, called High Bridge, rest on limestone. The map gives the position of the bridge. The following figure represents a sectional view of the structure reduced from a tracing obtained for me by Mr. Church at the Engineer's office in New York.‡

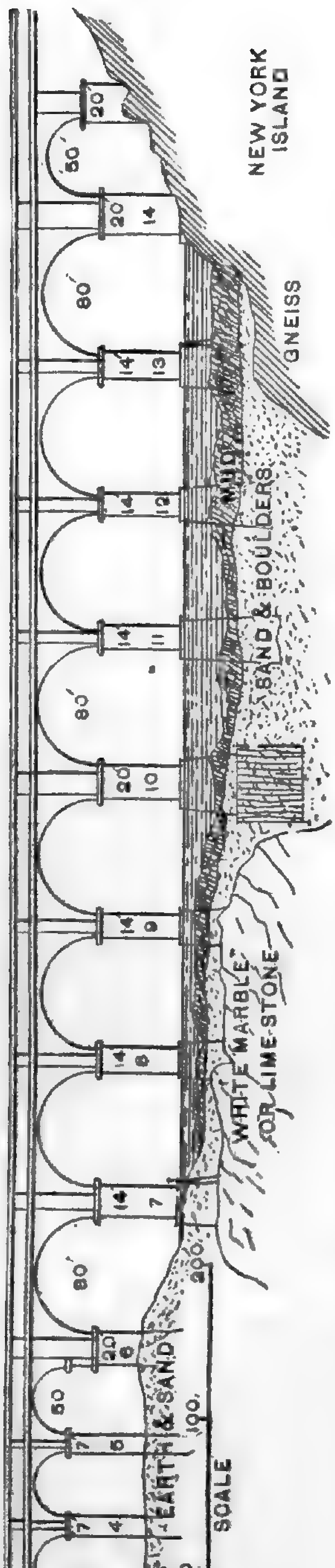
Of the piers, numbers 7, 8, 9 have the foundations planted on

* These grounds lie directly north of Sherman's Creek, east of the King's Bridge Road.

† Within this limestone area, east of the Inwood "Presbyterian Church," there is a small isolated area of micaceous gneiss, having a nearly northeast strike. It crosses the King's Bridge Road northeast of the church, and is about 225 yards long and 75 wide.

The magnesian character of this King's Bridge limestone was first determined by Mr. I. Cozzens, who states in his "Geological History of Manhattan Island." that it afforded him 28 per cent of carbonate of magnesia, and adds that he made epsom salts of it.

‡ The extremities of the bridge are left off in the copy here presented to reduce it to the length of the page, they being unessential to the illustration of the geological facts.



Sectional view of the Croton Aqueduct (or High) Bridge crossing the Harlem River between Westchester County and New York Island.

limestone, while numbers 3, 4, 5, 6, 10, 11, 12 are built on piles *which do not reach to rock.* In the case of piers 10, 11, 12, the stone foundations, as I have learned from the same authority, go down thirty feet below high water, and the piles fifty feet farther. The lower ends of these piles are consequently *eighty feet below high water level* and yet do not reach the bottom of the river channel. The depth of the excavation, which is thus proved to exist there, makes it extremely probable that the material excavated to such a depth was limestone and, therefore, that this rock extends eastward nearly to pier 13. In the case of pier No. 9, the limestone was reached at a depth of twenty-six feet at the southeast corner of the foundation and thirty-four feet at the northeast corner.

On such evidence, it is certain that the limestone passes the bridge, and exceedingly probable that it extends to the bend at 155th Street; and, since *the valley continues southward* in the same line along the old cove and streamlet shown on the map at the head of 8th Avenue, and, beyond this, along a range of what once were alluvial flats, but are now kitchen-garden plots, either side of the avenue, it is very probable that the limestone also continues.* These low lands or flats extend quite to Central Park, or 110th Street, and terminate in the depression adjoining its west corner, at 106th Street; whether the limestone also extends to the Park is among the doubtful points which only boring or excavation can now settle.

B. *Schist east of this Eastern (or Harlem River) limestone band.*—South of Mc Comb's Bridge, along 7th Avenue, there are ledges of micaceous gneiss which are continued to 135th Street; the beds are nearly vertical, the dip being 70° to 80° to the eastward to 90°, and the strike varies little from N. 28° E. The beds directly north of McComb's Bridge are

* Respecting this upper part of 8th Avenue, Dr. Gale says: "The valley through which 8th Avenue passes is throughout its course a perfect level and but a few feet above the level of Harlem River."

described above. On Harlem River about a mile north of this bridge (or 1½ mile south of King's Bridge), at Morris Dock Station, a light gray, fine-grained gneiss outcrops, which effervesces on the application of acid on account of the presence of calcareous or dolomitic material. This characteristic appears to show that it lies near the eastern border of the Harlem River limestone. North of this, to King's Bridge, there are no other outcrops.

C. *Schist west of the Harlem River or Eastern limestone band.*—At the north end of 10th avenue, south of Sherman's Creek, where grading has exposed a section of the high prominence once surmounted by "Fort George," the micaceous gneiss varies greatly in position, owing to irregular flexures, its dips changing from horizontal to vertical, and the direction from N.E. to N.W. But to the south along the avenue and between it and the river, down to 155th Street, the beds are quite uniform in position, being nearly vertical, 70° E. to 70° W., with the westing most prevalent, and the average strike N. 28° E. Farther south, the same steep or nearly vertical bedding continues to Central Park, the dip being generally 85° E. to 70° E., and the strike averaging N. 29° E.

4. Stratigraphical relations of the Limestone and Schist of the different Areas.

Mutual relations of the limestones.—From the statement of facts which has been made and the exhibition of them on the map, it is evident that the limestone of area No. 1 and that of No. 2 are one and the same mass or formation.

As to the identity with these of the limestone of the western area, No. 3, the proof is less positive, since No. 2 is nowhere visibly continuous with it, as it is with No. 1. I have suspected that there might be a connection in the bed of Harlem River at McComb's bridge, because of the varying flexures and low dips in the stratification just north of it (much like those of the schist south of Sherman's Creek, as shown on the map) and the contrast in this respect with the beds just south of the bridge. But after a careful study of the beds of both places, I think it improbable. Farther south, over the large area between 135th Street and 110th Street (or Central Park), the land is low, from a line east of 6th Avenue to one west of the 8th, so low that grading for streets has been carried on by filling, not by excavation, and no rocks in place have been encountered. Such features are of the kind natural to a limestone area, and suggest that a union of the limestone bands of the 8th and 6th avenues may take place somewhere between 135th and 120th Streets.

South of this flat country there is a sudden transition to gneissic hills—those of the Park; the limestone is absent. Nothing is seen of the 8th Avenue belt, or of that east of 6th Avenue. Whether the formation continues southward underneath the schist or not is a problem for further investigation. Some facts that may have a bearing on this point are mentioned on page 363 of the last volume of this Journal.

Thickness of the limestone.—The thickness of the limestone formation may be best derived from the northern part of Area No. 1, in Tremont. Since the beds stand nearly vertical, the thickness is about half the width, and therefore not far from 750 feet. From the section at High Bridge over the Harlem, the thickness there may be 700 feet, but probably is not over 600.

Flexures of the limestone and schists.—The fact that in Area No. 1, in Westchester County, the dips are westward on the western side (with exceptions to the north) and eastward, on the eastern, is sustained by my later as well as earlier observations, and seems to support the conclusion that the limestone makes an anticlinal or upward flexure. If this inference is correct, then the schist adjoining the limestone on its west side lies in a synclinal fold; and the broad part of the Cromwell Creek limestone band, in the vicinity of Mount Eden, and for the half mile south, is in an anticlinal: a single anticlinal only, although so wide; for the limestone in its western half is in low undulations where exposed farther south, and in its eastern generally dips 50° to 60°, and even less on Mount Eden. The limestone band along the Harlem includes but one thickness of the formation and may be the eastern band of either a very broad synclinal or anticlinal; probably the former, since westerly dips prevail on the Harlem River or eastern side of the schist and easterly on that of the Hudson.

But, on the other hand, the schists north of Tremont next west of limestone area No. 1, so generally dip *eastward* that it is a fair question whether the limestone of area No. 1 is not in a synclinal instead of an anticlinal. Again, at the extremity of this ridge of schist on the north side of Fleetwood Park (see map) the dip is westward on the west, and eastward on the east, as if the schist of this belt was in an anticlinal instead of synclinal.

35.

(Fig. 35 represents a portion of the eastern end of this section.) Further, the Mt. Eden limestone dips to the *westward* while the schists to the west of it, on the west side of Cromwell Creek, dip eastward; and this favors the idea of a synclinal for this limestone instead of an anticlinal.

These statements make it manifest that the question as to the actual character of the flexures is not easily cleared of the doubts that arise from local displacements and from varying positions of the axial plane of the flexures. Uncertainties exist also because of the covering of soil or drift over a large part of the region.

Although the plotting of sections from the obtainable facts (exhibited on the map) is consequently unsatisfactory work, I present the following sections (see page 441) as probably, in a general way, correct. The four sections cross the region from west (the left) to east: No. 1, through Tremont; 2, through Morrisania, along 168th Street, just north of Fleetwood Park; 3, through Melrose, along 159th Street; 4, through Mott Haven, along 138th Street. A section through Harlem would differ little from the last.

The sections speak for themselves, and to one who will examine them and the map together, and carefully compare each with the others, little explanation need be given. The limestone stratum is the blocked portion; that of the underlying schist is closely lined; that of the overlying schist more openly lined, with alternate broken lines.*

It is seen that, on this view of the flexures, the ridge of schist west of the limestone of Fordham and Tremont is part of an *underlying* stratum; and it is interesting to observe that the rock is to a large extent *quartzytic* gneiss, which suggests that it may correspond to the Potsdam sandstone and the schist associated with it in some regions (as near Peekskill and Tompkins' Cove). Its veins are mostly of quartz. The synclinal of the Cromwell's Creek limestone, shown in section 1, becomes covered with schist—*overlying* schist—south of Mt. Eden, as appears in section 2, and this ridge extends south to Mott Haven, appearing in sections 3 and 4, and beyond. It is in places fibrolitic to the north of Mott Haven, as well as to the south.

Whether the schist between Cromwell's Creek and the Harlem River limestone is in one, two, or more folds is uncertain; if in only one, the actual thickness of this underlying stratum of schist is large, and only a small lower portion of it is contained in the belt of schist west of Tremont.

The two westernmost bands of limestone in section 1 are those of Area No. 3,—the eastern or Harlem River band, and the western or King's Bridge Road band. They are represented as the opposite sides of a synclinal with *overlying* schist between. In the other sections only the eastern of the two occurs. This schist is mostly micaceous gneiss and mica schist, all the way to 110th Street, but contains in some parts hornblende schist.

* The local flexures in the beds are intended to show only that there are local flexures, not to represent special flexures.

5. Origin of various Topographical Features of New York Island.

Valleys and Low Areas.—From the distribution of the limestone, as exhibited on the map, and the fact of its easy wear or erosion, we derive explanations of several topographical features of New York Island and the adjoining region. For example we learn—

Why Harlem river has its present position and depth, and its north and south course; Why there is an "Eighth Avenue valley;" Why the "Inwood parade grounds" are a broad rolling region from the Harlem to the King's Bridge Road; Why, south of the Inwood Presbyterian Church, there was a King's Bridge Road valley, to fix the position of that old highway; Why Sherman's Creek bends around the Fort George heights; Why Cromwell's Creek exists and the valley or "Clove" to the north; Why Fleetwood Park is low and nearly flat, except its western side; Why Third Avenue in Harlem and the region east of it is low; Why wide flats (with small exceptions), extend from East River more than two-thirds of the way across the island, just north of Central Park; and, perhaps, why there is an East River channel.

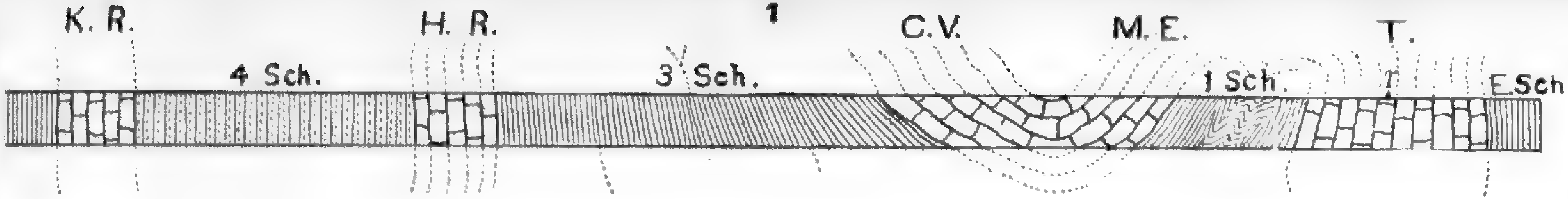
The limestone lands that are not low may owe their height to the fact that erosion follows water courses; but, besides, the rock when in nearly vertical beds—usually the fact in such places—is generally of a firmer kind, because the pressure which gave the beds this position, served to compact the rock and so favored closer and better consolidation.

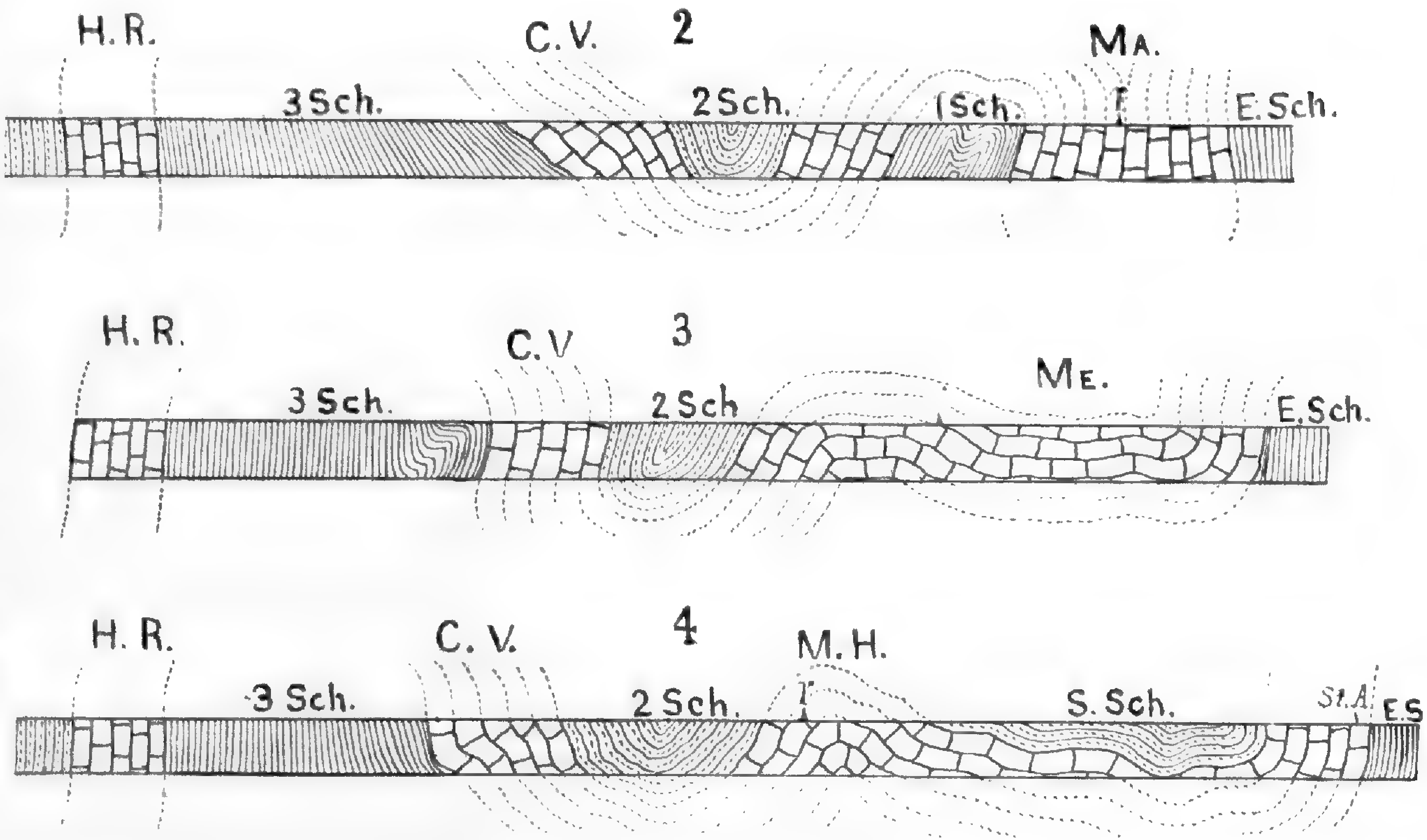
Trends of Ledges and City Avenues.—We also find a good reason for the precise direction given by the city surveyors to the New York avenues—it being the mean direction of the strike or direction of the bedding in the gneiss, and thence of the rocky ledges of the island. Many parts of the avenues in the northern half of the island have now a low even wall on one side or the other, made by a flat and nearly vertical cleavage-surface of the schist.*

The Manhattanville Valley.—The Manhattanville Valley (or Manhattanville and Harlem, as called by Dr. Gale), which cuts across the island obliquely from Manhattanville on the Hudson in a nearly southeastward direction, is one of its most extraordinary geological and topographical features, as mentioned on page 427. It reached East River, in a broad creek and marsh south of 108th Street; and so low lay the surface along it from one side of the island to the other, that in 1826 a canal was projected that should here connect Harlem River with the Hudson; and the canal was so far constructed that a celebration took place of the completion of the first lock.

* The avenues of New York run N. 28° 50¼′ E. This parallelism between the strike of the beds and the avenues is referred to by Dr. Gale.

36.





EXPLANATIONS:—*r*, track of N. Y. & H. R. R.; M. E., Mount Eden limestone; C. V., limestone of Cromwell's Creek valley; H. R., Harlem River limestone; K. R., King's Bridge Road limestone, making with H. R. a synclinal.—E. Sch., schist east of limestone Area No. 1; 1 Sch., first belt of schist west of eastern limestone, being that of Mount Hope in section 1 (not in sections 3 and 4); 2 Sch., belt of schist along Mott Av. (not in section 1, but over limestone in sections 2, 3 and 4); 3 Sch., 3d belt of schist; 4 Sch., 4th belt of schist, overlying limestone in the western synclinal; S. Sch., schist overlying limestone of eastern area here in a broad synclinal; *St. A.*, St. Ann's Avenue.

The valley is supposed by Dr. Gale to have had a glacial origin, since it follows quite closely the course of the glacial grooves over the island. But the rocks point to its earlier existence and a profounder cause.

The general direction or strike of the beds of schist on the west side of 8th Avenue is about N. 29° E.—the dip being nearly vertical. But near this Manhattanville Valley, the strike, while normal to the north of it, to the south diverges from this, and in a way to show that *the valley probably had its initiation in an oblique wrenching and faulting of the rocks.* The map gives the facts, by means of the T symbols, better than can be done by words, representing along the high rocky land of Morning Side Park, an increase of easting to the northward up to the valley; and then, north of it, along St. Nicholas avenue, on the eastern side of the Convent Grounds, the usual or normal strikes. Besides this fact, derived from the strike of the rocks, there is another of apparent importance in the position of the rocky bluffs; for they are 100 yards farther west just south of the valley than they are north of it; in other words the alluvial flats—now garden plots—at the base of these bluffs extend 100 yards farther west along by the north part of the Morning Side Park than by the Convent Grounds.

There is still a third fact bearing on this question of a wrenching. Along the southwest part of the Convent Grounds, the beds of schist have an eastward pitch or dip of 50° to 60°, while 80° to 90° on the east side and to the north. The variation in the pitch of the beds might have resulted from a local anticlinal; but it is probably due to simply an irregular bending of the schist; for, on 10th Avenue, just northwest, the beds of schist become again nearly vertical, and quite so in the eastern part of the Park and north of it. Whatever be true as to the nature of the flexure, the facts support the idea of a wrenching in the schists of the vicinity; for these variations in pitch are not found south of the Manhattanville Valley.*

Finally, we may conclude that the pre-determinations of the fundamental features of New York Island date back to the era of the Lower Silurian, and to the epoch of mountain-making at its close. No other rocks that now remain have been added by subsequent geological operations excepting the loose or

* If the occurrence of limestone and serpentine on 157th Street near 10th Avenue, mentioned by Dr. Gale (see page 423) should be verified, it would give some support to the view that the western band of limestone of Area No. 3 is continued at intervals south of 183d Street; and in that case it is possible, though hardly probable, that it determined the course of the valley which passes southward through the "Park" between nearly vertically bedded schist, and thence along the west side of the Convent Grounds to Manhattanville Valley at 9th Avenue. Were such the fact, the western band of limestone, or its place in the synclinal, would there join the eastern band.

unconsolidated material of the surface. Fissures and faults may have occurred through subterranean movements; but the work of shaping its ledges has gone forward chiefly by the action of the sun, atmosphere, ocean, rivers, and ice; and the present condition, barring human encroachments, is the final result. Man's encroachments have dried up the Manhattanville stream and its marshes, excepting the small part that has been left as a pond in the northeast corner of Central Park, with its tributary rivulet; and the old alluvial flats that remain will soon grow houses in place of garden vegetables. In these and other ways the opportunity for the geological study of the island is rapidly passing. Whoever cares to see the disappearing limestone outcrops in Harlem, between 3d and 4th and 5th and 6th Avenues, must make his excursion soon.

[To be continued.]

ART. LV.—*Papers on Thermometry from the Winchester Observatory of Yale College;* by LEONARD WALDO.

[Continued from page 226.]

FOR the comparison of standard thermometers the observatory has had constructed by J. and H. J. Green, of New York, a water comparator which consists essentially of an outer and inner vessel with an intermediate space of $1{\cdot}5^{cm}$ filled with lamp-black. The outside cylinder is of copper and is 21^{cm} in diameter and 72^{cm} high. The inner cylinder is of brass. Two stop-cocks, one at the top and another at the bottom of the double cylinder, allow of the easy addition to or the lessening of, the water within. The agitation of the water is accomplished by a brass ring plunger $19{\cdot}2^{cm}$ in diameter and having a circular aperture of 7^{cm} to allow of the placing in position of the thermometer stand within. The thermometers are completely submerged, and after agitation the plunger is brought to rest at such a height that its disc forms with a perforated disc fixed to the thermometer stand, a metal diaphragm which prevents the circulation of the water during the reading of the thermometers.

The temperature being brought to the requisite height by a Bunsen burner beneath the comparator, the burner is withdrawn, the water is thoroughly agitated by the plunger, which is brought to rest finally with its disc in the same place as the stationary disc of the thermometer stand (through which the thermometers pass) and after a few moments the thermometers are read in the usual manner through a thick glass window in front. For high or low temperatures it is convenient to prevent radiation from or to the base of the cylinders by a mat which can be brought close against the base when the Bunsen burner is removed.* With this apparatus, and with the assistance of Mr. O. T. Sherman, a comparison between the German standards "Fuess 89" and "Fuess 50," the French standards "Tonnelot 2584" and "Tonnelot 2585,"†

* The general principle is that of Pierre. Vid. Recherches sur la Thermometrie et sur la dilatation des Liquides, par J. I. Pierre. Caen, 1878, p. 57.

† Of the various methods proposed for the determination of the calibration errors of thermometers, those of Newmann and Bessel leave little to be desired for elegance or rigor of treatment. As a matter of practice, however, especially where many thermometers are to be furnished with calibration corrections, these methods require too much time except for the most refined work. The following method will give the calibration corrections at nine points (inclusive of the terminal points) equi-distant with three columns of mercury, or at seventeen points with four columns. The columns need be only approximately of the lengths of $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, etc., of the length to be calibrated respectively, and the principle of subdivision is employed rather than the super-addition of short calibrating columns. The objection to the method is that no weight is given to the summation of short mercury columns in determining the calibration corrections at long intervals. The increase of accuracy by the introduction of the short columns for multiples of their own length is doubtful, however, when the number of additional readings is considered.

Let l = the length of a column of mercury occupying the half of the distance between the freezing and boiling points in a thermometer nearest the freezing point.

l_1 = the length of a column of mercury occupying the half of the distance between the freezing and boiling points in a thermometer nearest the boiling point.

$\frac{1}{2}(l_1 - l) = \Delta_{\frac{8}{16}} = +a =$ the calibration correction for the point midway between the freezing and boiling point.

$\ldots \Delta_{\frac{2}{16}} \ldots \Delta_{\frac{4}{16}} \ldots \Delta_{\frac{1}{n}} =$ these corrections for points situated $\ldots \frac{2}{16} \ldots \frac{4}{16} \ldots \frac{1}{n}$th of the distance between the freezing and boiling point, assuming that the errors of calibration at the freezing and boiling points are zero.

$b, b',$ = the calibration correction at the points corresponding to $\Delta_{\frac{4}{16}}$ and $\Delta_{\frac{12}{16}}$ on the assumption that the correction at the point $\Delta_{\frac{8}{16}}$ is zero.

c, c', c'', c''' = the calibration correction at the points corresponding to $\Delta_{\frac{2}{16}}$, $\Delta_{\frac{6}{16}}$, $\Delta_{\frac{10}{16}}$, $\Delta_{\frac{14}{16}}$ on the assumption that the corrections at the points $\Delta_{\frac{4}{16}}$ and $\Delta_{\frac{12}{16}}$ are each equal to zero.

$d, d', d'' \ldots d^{vii}$ = the calibration correction at the points corresponding to $\Delta_{\frac{1}{16}}$, $\Delta_{\frac{3}{16}}$, $\Delta_{\frac{5}{16}}$, ... $\Delta_{\frac{15}{16}}$ on the assumption that the corrections at the points $\Delta_{\frac{2}{16}}$, $\Delta_{\frac{6}{16}}$, $\Delta_{\frac{10}{16}}$, $\Delta_{\frac{14}{16}}$ are each equal to zero.

And we may write, for a calibration determination at fifteen intermediate points, the following equations which admit of rapid and simple computation:

$$
\begin{array}{ll|ll}
\Delta_0 & = 0 & \Delta_{\frac{8}{16}} & = a \\
\Delta_{\frac{1}{16}} & = \frac{1}{8}a + \frac{1}{4}b + \frac{1}{2}c + d & \Delta_{\frac{9}{16}} & = \frac{7}{8}a + \frac{1}{4}b' + \frac{1}{2}c'' + d^{iv} \\
\Delta_{\frac{2}{16}} & = \frac{2}{8}a + \frac{2}{4}b + c & & \ldots\ldots\ldots \\
\Delta_{\frac{3}{16}} & = \frac{3}{8}a + \frac{3}{4}b + \frac{1}{2}c + d' & \Delta_{\frac{12}{16}} & = \frac{4}{8}a + b' \\
\Delta_{\frac{4}{16}} & = \frac{4}{8}a + b & & \ldots\ldots\ldots \\
\Delta_{\frac{5}{16}} & = \frac{5}{8}a + \frac{3}{4}b + \frac{1}{2}c' + d'' & \Delta_{\frac{15}{16}} & = \frac{1}{8}a + \frac{1}{4}b' + \frac{1}{2}c''' + d^{vii} \\
\Delta_{\frac{6}{16}} & = \frac{6}{8}a + \frac{2}{4}b \quad c' & \Delta_1 & = 0 \\
\Delta_{\frac{7}{16}} & = \frac{7}{8}a + \frac{1}{4}b + \frac{1}{2}c' + d''' & &
\end{array}
$$

For a calibration computation for seven intermediate points, instead of fifteen, we simply omit the formulæ containing d, d', etc., and conversely the computation and the Kew standards "Kew 578" and "Kew 584" was made. The usual precautions were taken to arrange the thermometer readings so as to free them from the effects of comparator radiation, and after correcting the observations for their known errors of calibration and zero points, the Fuess and Tonnelot readings were subtracted from the Kew readings and from the residuals thus obtained a curve was drawn from which the following corrections were obtained, expressed in Centigrade degrees.

Corrections (depending on the glass and the thermometer construction) necessary to reduce the Fuess and Tonnelot standards to the Kew standards.

Reading.	Δ Fuess 89 and Fuess 50.	Δ Tonnelot 2584 and Tonnelot 2585.	Reading.	Δ Fuess 89 and Fuess 50.	Δ Tonnelot 2584 and Tonnelot 2585.
0°	0°·00	0°·00	55°	−0°·20	−0°·24
5	−0·02	0·00	60	−0·19	−0·28
10	−0·03	0·00	65	−0·17	−0·28
15	−0·05	−0·02	70	−0·15	−0·27
20	−0·07	−0·05	75	−0·14	−0·26
25	−0·09	−0·09	80	−0·12	−0·25
30	−0·11	−0·11	85	−0·10	−0·22
35	−0·13	−0·14	90	−0·07	−0·19
40	−0·15	−0·17	95	−0·05	−0·09
45	−0·17	−0·20	100	0·00	0·00
50	−0·19	−0·22			

I have also received, through the courtesy of Professor Rowland, of the Johns Hopkins University, the notes of comparison made between Kew 584, Fuess 50, Tonnelot 2585 and the standards of his laboratory, Baudin 6163, Baudin 6165, Baudin

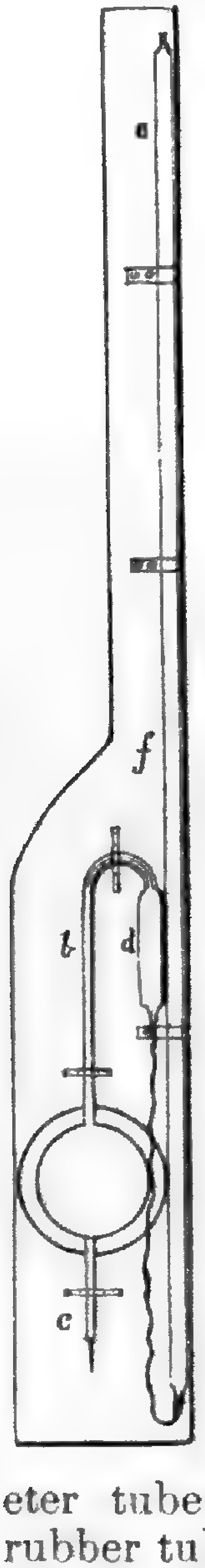
may be made to include thirty-one intermediate points by the insertion of another term, e, e', etc.

As an illustration, take the following example of the calibration of the thermometer "Tonnelot 2585," which is graduated in Fahrenheit's scale from the freezing to the boiling points and has $1° = 1{\cdot}8^{mm}$. The columns marked l_1 and l contain the lengths of the three columns of mercury at the respective places in the thermometer tube indicated by a, b, b', and c, c', c'', c''': of course l_1 merely indicates that it is the upper column and has a value of about 89°, 43° and 24° successively.

	l_1	l			
				$\Delta_0 = {\cdot}000$	$= 0°{\cdot}000$ at $32°{\cdot}0$F.
$2a$	$= 89°{\cdot}190 -$	$89°{\cdot}220$	$\therefore a = -0°{\cdot}015$ and	$\Delta_{\frac{2}{16}} = -{\cdot}004 - {\cdot}002 + {\cdot}018$	$= +{\cdot}012$ at $54{\cdot}5$F.
$2b$	$= 42{\cdot}743 -$	$42{\cdot}752$	$b = -\ 0{\cdot}005$ and	$\Delta_{\frac{4}{16}} = -{\cdot}008 - {\cdot}005$	$= -{\cdot}013$ at $77{\cdot}0$F.
$2b'$	$= 42{\cdot}700 -$	42.720	$b' = -\ 0{\cdot}010$ and	$\Delta_{\frac{6}{16}} = -{\cdot}012 - {\cdot}002 - {\cdot}006$	$= -{\cdot}020$ at $99{\cdot}5$F.
$2c$	$= 23{\cdot}630 -$	$23{\cdot}593$	$c = +\ 0{\cdot}018$ and	$\Delta_{\frac{8}{16}} = -{\cdot}015$	$= -{\cdot}015$ at $122{\cdot}0$F.
$2c'$	$= 23{\cdot}600 -$	$23{\cdot}613$	$c' = -\ 0{\cdot}006$ and	$\Delta_{\frac{10}{16}} = -{\cdot}012 - {\cdot}005 + {\cdot}002$	$= -{\cdot}009$ at $144{\cdot}5$F.
$2c''$	$= 23{\cdot}620 -$	$23{\cdot}617$	$c'' = +\ 0{\cdot}002$ and	$\Delta_{\frac{12}{16}} = -{\cdot}008 - {\cdot}010$	$= -{\cdot}018$ at $167{\cdot}0$F.
$2c'''$	$= 23{\cdot}600 -$	$23{\cdot}612$	$c''' = -\ 0{\cdot}006$ and	$\Delta_{\frac{14}{16}} = -{\cdot}004 - {\cdot}005 - {\cdot}006$	$= -{\cdot}015$ at $189{\cdot}5$F.
				$\Delta_1 = 0{\cdot}000$	$= 0{\cdot}000$ at $212{\cdot}0$F.

The Tonnelot thermometers referred to were made in April, 1879, and have a graduation extending from + 5° to + 230° F. with about $1{\cdot}8^{mm}$ to 1°. They are divided to 0°·5 F., having a total length of about 455^{mm} with cylindrical bulbs about 40^{mm} long. They are beautifully calibrated and are otherwise highly creditable to their maker, Tonnelot, of Paris.

7316, and Kew 104, which afford the means of expressing the three first named thermometers in terms of the air thermometer used by Professor Rowland. After tabulating the corrected observations and referring each thermometer to Rowland's absolute scale* a combination of the Yale and Johns Hopkins comparisons gives as a probable value of the relation between these standards and the air thermometer, the following system of corrections to be applied to the Kew, Fuess and Tonnelot standards respectively.



Reading.	Tonnelot 2585.	Fuess 50.
0°	0°·00	0°·00
5	−0·02	−0·03
10	−0·03	−0·05
15	−0·05	−0·08
20	−0·07	−0·10
25	−0·09	−0·13
30	−0·11	−0·15
35	−0·13	−0·17
40	−0·15	−0·18
45	−0·17	−0·19
50	−0·19	−0·21
55	−0·20	−0·21
60	−0·21	−0·20
65	−0·20	−0·20
70	−0·20	−0·19
75	−0·18	−0·17
80	−0·17	−0·14
85	−0·14	−0·12
90	−0·11	−0·09
95	−0·05	−0·05
100	0·00	0·00

Kew 584.

The curve for this thermometer shows slight irregularities on both sides of the absolute scale, in no case giving a correction exceeding − 0°·04 C., and generally within −0°·02 C. of it. Since to adopt these corrections would imply that Jolly's air thermometer gives correct indications to 0·1^{mm}, I consider the comparison as uncertain, and assume that Kew 584 has a small, undetermined negative correction to reduce its readings to the absolute scale between +25° and +75° C.

In order to examine into a small systematic difference which exists between the comparisons made by Professor Rowland and ourselves, an air thermometer, of the form shown in the cut, was placed in the comparator with the standards above described. This modified form of Jolly's thermometer consists of a large spherical bulb (about 5^{cm} in diameter) with a capillary tube at *c* which serves a purpose in attaching the bulb to the brass plate *c f e* and is used as an entrance tube for dry air in filling. When filled the tube *c* is sealed in the blow-pipe flame. The capillary *b* ends in a barometer tube *d*, 5^{cm} in length, at the lower end of which a rubber tube forms the connection with a long barometer tube, *f e*, of the same glass as *d*. Tube *f e* projects through an aperture in the top of the comparator and has a smooth vertical motion in a V-shaped trough in which it is held by springs. Its vertical motion is communicated by the hand of an assistant.

* Vid. On the Mechanical Equivalent of Heat. Proc. Am. Acad., Bost., 1880, p. 113.

The advantage of this form of air thermometer is that the whole of the apparatus is at the temperature of the comparator, and is placed in a medium which will give us with great precision the temperature of the mercury in the air thermometer tubes. The corrections for the air contained in the capillary tube and above the mercury in the small chamber become zero. There is also no necessity for the long capillary tubes and fragile joints which occur when the Jolly's air thermometer has its mercury columns outside of the comparator.

The disadvantage of this form is that above 40° C. the correction for the tension of mercury vapor in the columns is difficult to determine. I had hoped to give our own comparison with this air thermometer in this paper, but I have only had time to satisfy myself that we reach very nearly the same results as Professor Rowland has done before us. In a subsequent paper I hope to discuss this part of the question.

It will have been observed that the three forms of thermometers chosen are typical and represent the forms now in use by scientific men.

The general characteristics of the above classes of thermometers may be described as follows:

Designation.	Characteristics.
1. Kew standards.	Thick stems, medium sized cylindrical bulbs blown from a separate piece of glass and joined to the thermometer stem. This glass, however, is supposed to be from the same pot as the glass of which the stem is composed. Flint glass known as "Powell's best flint."
2. Fuess standards.	Thin stem, small cylindrical bulbs blown from the same glass. Detached porcelain scale. Glass unknown.
3. Tonnelot standards.	Medium stem, long cylindrical bulbs blown from the same glass. The comparison with the Johns Hopkins Baudin thermometers shows the glass to be practically the same in both.

From a consideration of the above comparisons we reach the following conclusions:

1. The Kew standards made from the glass known as "Powell's* best flint," and of the chemical and physical constitution of the Kew standards 578 and 584 are very nearly coincident with the air thermometer between the freezing and boiling points of water; the maximum correction not exceeding $-0°{\cdot}05$ C. and reaching its maximum probably in the vicinity of 60° C.

2. The Fuess standards have a maximum correction of about $-0°{\cdot}20$ C., which occurs at a point beyond the 50° point.

* Jas. Powell & Sons, Whitefriars Glass Works. Temple street, E. C., London. I have written to these gentlemen for the chemical constitution of this glass, but they are unwilling, presumably from business reasons, to state the proportions used in its manufacture.

3. The Tonnelot standards have a maximum correction of about $-0°·25$ C., which occurs at some point beyond 50°.

There has not yet been proposed a thermometer which can be used to supplant the mercurial. A slight experience with the air or non-mercurial liquid thermometers will satisfy the observer that they are too difficult to use for ordinary scientific work outside of researches in thermometry. The non-mercurial liquid thermometer wets the glass and absorbs air to such an extent as to always make it unreliable, though the peculiar errors depending on the glass itself are reduced to an exceedingly small amount owing to the large linear expansion of any liquid used for a thermometric substance as compared with mercury.

It becomes therefore of importance that we should have a glass of known constitution and methods of manufacture, for mercurial standards. It is not sufficient that we should know only the commercial name of the glass, because this seldom gives any good idea of its constitution. Presumably the chemical constitution of the glass is of more importance than its manipulation in manufacture, and it hardly seems just to science for the glass makers to decline to furnish such data regarding thermometer tubing as will best enable students to investigate the peculiarities of particular standards. The manufacturers could hardly suffer financially from such a revelation, since the manufacture of thermometer tubing is so largely a question of individual skill in drawing the tubing from the mass.

Out of a very large number from many makers which we have examined in this connection, it may be safely said that the glass used in the Kew thermometers (and in general in the best modern English thermometers) most nearly gives a mercurial standard agreeing with the air thermometer. The French and German glass differ in general ¼° C. from this standard at 50° C., and the best American glass now used in thermometers about the same amount.

For our own convenience in the preparation of standards we desire to pursue our inquiries far enough to determine if possible in how far the behavior of glass as a thermometric substance is affected by its constitution and its methods of manufacture. The present state of the matter leads to a confusion in the making and examination of standards which is perplexing alike to the maker and the student of science who has not the refined appliances necessary to refer every thermometer to the air standard.

After publishing the description of the Fuess standards at p. 227, I received a note from Dr. Fœrster asking me to give publicity to the following letter from Dr. Thiesen in reply to

Professor Rowland's views regarding the Geissler thermometers, expressed in his memoir referred to. I append to the letter a further defence by Professor Rowland of his views.

A letter from M. Thiesen replying to Rowland's criticism of the Geissler thermometers.

Herr Professor Rowland hat sich an mehreren Stellen seiner Abhandlung "*On the Mechanical Equivalent of Heat,*" (Proc. Am. Ac. Arts and Sciences, Vol. XV.), in sehr starken Worten verurtheilend über die Geissler'schen Thermometer ausgesprochen. Es wird keiner eingehenden Vergleichung der Vorzüge und Nachtheile der von den verschiedenen Verfertigern herrührenden und in den einzelnen Ländern bevorzugten Formen des Quecksilberthermometers bedürfen, um nachzuweisen, dass das von Herrn Rowland gefällte Urtheil zu weit geht, da die beiden von Herrn Rowland gerügten Fehler der Geissler'schen Instrumente nicht derartige sind, dass sie zu ernsten Bedenken gegen den wissenschaftlichen Gebrauch dieser Instrumente Veranlassung geben.

Zunächst verwirft Herr Rowland das Geissler'sche Thermometer, weil dasselbe am Ende der Kapillarröhre kein Reservoir trägt.* Der Nutzen eines derartigen Reservoirs ist aus den von Herrn Rowland (Seite 79) angeführten Gründen anzuerkennen. Es erleichtert die Kalibrirung des Thermometers, es erlaubt, nach Walferdin's Vorgang das Instrument auch bei höhern Temperaturen zu gebrauchen, und es vermindert die Schädlichkeit der im Quecksilber zurückgebliebenen Spuren von Luft. Aus diesen Gründen sind auch bereits vor dem Erscheinen der Abhandlung des Herrn Rowland deutsche Fabrikanten auf den Nutzen dieses Reservoirs hingewiesen worden. Allein deshalb darf der Mangel eines Reservoirs nicht zur Verwerfung des Instrumentes führen. Auch beim Mangel eines Reservoirs gelingt die Kalibrirung eines Thermometers leicht und sicher. Herrn Professor W. Foerster zu Berlin sind zahlreiche, meist von Beamten der Kaiserlichen Normal-Aichungs-Kommission ausgeführte Kalibrirungen von Thermometern mittelst einer Anzahl (öfters über 20) abgetrennter Quecksilberfäden von genau bestimmter Länge, aber kein Fall bekannt, in welchem die Abtrennung eines Fadens nicht gelungen wäre. Der Gebrauch eines Thermometers bei höhern Temperaturen, als sie abgelesen werden können, wenn alles Quecksilber eine zusammenhängende Masse bildet, dürfte keinem wirklichen Bedürfnisse entsprechen und kann nicht zu genauen Resultaten führen, sobald der Eispunkt des Thermometers in seinem neuen Zustande nach Abtrennung einer Quantität des Quecksilbers nicht abgelesen werden kann. Die in den Geissler'schen Thermometern

* Seite 79: Geissler and Casella omit it (the reservoir), which should condemn their thermometers. Seite 117: The Geissler also had none, but I succeeded in separating a column. The absence of a reservoir at the top should immediately condemn a standard, for there is no certainty in the work done with it.

noch vorhandenen Spuren von Luft endlich können nur bei sehr engen Röhren Störungen verursachen.

Der zweite Fehler, welchen Herr Rowland dem Geissler'schen Thermometer vorwirft, ist seine von Rowland gefundene grosse Abweichung vom Luftthermometer.* Eine solche Abweichung wird nur dann schädlich wirken können, wenn sie übersehen wird; bestimmt man, wie Herr Rowland es that, die Abweichung vom Luftthermometer experimentell, so wird es wenig ausmachen, ob die an den Thermometerablesungen anzubringende Korrektion gross oder klein ist. Ausserdem aber ist, es muss ausgesprochen werden, die von Herrn Rowland gefundene Abweichung der einzelnen Thermometer von Luftthermometer ohne dauernde Bedeutung. Das — der leider auch in Deutschland bisher meist üblichen Rechnungsweise entsprechende — Verfahren Rowland's, die Ablesungen der Thermometer bei den verschiedenen Temperaturen mit einander zu verbinden, ohne der gleichzeitigen Aenderung des Eispunktes der Thermometer Rechnung zu tragen, führt zu Resultaten, welche vom Alter des Thermometers, von seiner Behandlung vor und dem *modus procedendi* während der Vergleichungen abhängen.† Resultate, welche wesentlich nur von der Natur des Thermometers abhängen, ergeben sich dagegen, wenn unmittelbar nach der Vergleichung bei den einzelnen Temperaturen der Eispunkt des Thermometers bestimmt und in Rechnung gezogen wird.‡ Wenn Herr Rowland sich die Mühe geben wollte, neuerdings das Geissler'sche Thermometer oder auch Baudin 6167, welches eine dem Geissler'schen ähnliche Korrektion ergab, auf 100° C. zu erwärmen und etwa mit einem der andern inzwischen mehrere Monate unberührten Baudin'schen Thermometer bei 0°, 50° und 100° C°. zu vergleichen, so dürfte er bei 50° eine wesentlich kleinere Differenz zwischen diesen Thermometern, vielleicht sogar eine von entgegengesetztem Zeichen als 1878 finden.

Zum Schlusse mag noch erwähnt werden, dass von Beobachtern, welche sich eingehender mit dem Quecksilberthermometer beschäftigt haben, auch andere Fehler der Geissler'schen Thermometer aufgefunden sind, welche mehr mit der Eigenart dieser Thermometer verknüpft sind, als die von Rowland gerügten Mängel. Diese Uebelstände sind zum Theil durch wesentliche Neuerungen, welche in der Fabrikation der deutschen Thermometer in den letzten Jahren gemacht wurden, beseitigt worden.§

Berlin, den 11. März 1881. Dr. M. THIESEN.

* Seite 76: which is the worst in this respect. Seite 118: The Geissler still seems to retain its preëminence as having the greatest error of the lot.

† Siehe die Aenderung des 0°–100° Intervalls des Kew standard. Seite 97.

‡ Vergl. Pernet "Beiträge zur Thermometrie in Carl's Repertorium für Experimentalphysik, Bd. XI, S. 257, München 1875," und namentlich die im Druck befindlichen "Metronomischen Beiträge No. 3, herausg. von W. Foerster, Berlin 1881," und eine ebenfalls im Druck befindliche Publikation des Bureau International des Poids et Mesures zu Sèvres.

§ Siehe Loewenherz "Bericht über die Wissenschaftlichen Instrumente auf der Berliner Gewerbeausstellung im Jahre 1879, Berlin 1880, Seite 213, 214."

Remarks by Professor Rowland on the preceding letter, in a communication dated Johns Hopkins University, April 29, 1881.

Through the kindness of Dr. Waldo, I have been allowed to see the above and would like to give a few words of explanation.

In reading what I had to say with respect to the Geissler thermometer, the reader should remember that I was not writing on general thermometry, but only on that part which should be useful to me in measuring *differences of temperature within the limits of* 0 *and* 45° C. And so I merely made a study of thermometers, their change of zero and other points, as it affected the problem which I had before me. I am well aware that there are formulæ for giving the changed readings of thermometers due to previous heating, but, according to well known principles in such cases, I prefered to eliminate such error by the proper use of the thermometer rather than trust to an uncertain theory.

In the course of my investigation I discovered the fact that the Geissler thermometers, especially the one I then used, departed more from the air thermometer than any other. Now the Geissler thermometer has been used for many years by physicists, principally German, *without* any reduction to the air thermometer. And this correction was so great, amounting to over 0°·3 C., for the specimen I used, at the 45° point, that I thought it right to call attention to the point. And I acknowledge that the picture was present in my mind of a physicist reading a thermometer from a distance by a telescope to avoid the heat of the body and parallax, and recording his results to thousandth of a degree, and all this on a thermometer having an error of 0°·3.C.! As Dr. Thiesen remarks: If one is to compare his thermometer with the air thermometer, the amount of correction is of little importance: but departure from the air thermometer is certainly not a recommendation and, indeed, must introduce slight errors. The most accurate readings which one can make on an air thermometer will vary several hundredths of a degree.

Hence we can never use with accuracy the direct comparison with the air thermometer but must express the difference of the two instruments by some formula of the form

$$\Delta = a + bt + ct^2 + \&c.$$

Should we take an infinite number of terms this formula would express all the irregularities of our observations. But by limiting the number of terms the curve of differences becomes smoother and smoother and the formula expresses less and less the irregularities of the experiment. The number of terms to be used is a matter of judgment, and this point I sought to determine by the use of the observations of Regnault and others. The rejection of the higher powers of t is more or less of an assumption founded on the fact that we are reasonably certain that the curve of differences between the mercurial and the air thermometer is a smooth curve. It is evident that the less the correction to be introduced the less the rejection of the higher powers of t will affect our results.

We now come to my criticism of the Geissler thermometer for not having a reservoir at the top. Dr. Thiesen has in some way misunderstood my principal reason for its presence. My reason was not that "es vermindert die Schädlichkeit der im Quecksilber zurückgebliebenen Spuren von Luft" but that only by its use can the mercury in the bulb be entirely free from air. Take a thermometer and turn it with the bulb on top. If the thermometer is large, in nine cases out of ten the mercury will separate and fall down: allow it to remain and observe the bubble-like vacuum in the bulb. Turn the bulb in various directions so as to, as it were, wash the whole interior of the bulb, and then bring the thermometer into a vertical position, keeping the bubble in sight. As the mercury flows back, the bubble diminishes and finally, in a good thermometer, almost disappears: but in most thermometers a good sized bubble of air, in some cases as large as the wire of a pin, remains. It is the most important function of a reservoir at the top to permit such manipulations as to drive all such air into the top reservoir and to make the mercury and the glass assume such perfect contact that the bulb can be turned uppermost without the mercury separating, even in thermometers of large size and with good generous bulbs. In many Geissler thermometers such a test might succeed, not on account of the freedom from air, but because the capillary tube and bulb are so small and the column so short that the capillary action is sufficient to prevent the fall. Now I think that a thermometer in which there is this layer of air around the mercury in the bulb must be uncertain in its action; hence my opinion is unaltered that all thermometers in which we cannot remove this layer or at least make certain of its absence should be rejected.

Furthermore, with respect to calibration, the reservoir is not essential to the calibration of thermometers whose range is 0 and 100° C. But my remarks apply better to those whose range is between 0 and 30° C. or 40° C. Here calibration is impossible with a short column at ordinary temperatures unless some of the mercury can be stored up in the reservoir so as to allow the column to move over the whole scale. And it is within this limit that thermometers are of the greatest value in the physical laboratory.

The other defects of the Geissler thermometer, the scale which was always coming loose, the metal cap which was never tight and always allowed water to enter, the small capillary tube which wandered with perfect irregularity from side to side over the scale, all these were so obvious that I confined my remarks to the more obscure errors.

Furthermore, I believe there is some error in most Geissler thermometers from the small size of the bulb and the capillary tube, and this I have mentioned on p. 124 of the paper referred to. Pfaundler and Platter, in a paper on the specific heat of water, in Poggendorff's Annalen for 1870, found an immense variation within small limits. In a subsequent paper* the authors

* Poggendorff's Annalen, cxli, p. 537.

traced this error to the lagging of the thermometer behind its true reading.

The authors used Geissler thermometers *graduated* to $\frac{1}{50}°$ C.! In a series of experiments made by plunging the thermometer into water after slightly heating or cooling the thermometer so that in one case the mercury fell and the other rose to the the required point. When the thermometer fell about 6° or 8° C. it lagged behind 0°·0654 and when it rose 3° or 4° it lagged 0°·022, making a difference of 0°·087 C.! Now my thermometers made by Baudin show no effect of this kind. They indicate accurately the temperature whether they rise or fall to the given point, provided the interval is not too great. The fact then remains that a Geissler thermometer *graduated* to $\frac{1}{50}°$ C. may be *uncertain* to 0°·087 C., while a Baudin graduated to mm., one mm. being from $\frac{1}{10}°$ to $\frac{1}{14}°$ C. is not uncertain to 0°·01 or 0°·02 C. May not the cause be found in the layer of air around the mercury of the bulb which cannot be removed without a reservoir at the top? Or may we not also look for such an effect from the minute size of the bore of the capillary tube which creates a different pressure in the bulb from a rising or falling meniscus? Possibly the two may be combined.

ART. LVI.—*On the Reduction of Air-pressure to Sea-level, and the Determination of Elevations by the Barometer*; by H. A. HAZEN, A.M.

IT is apparent that the two divisions of this subject are so intimately connected that the formula which may be determined for the one will apply to the other.

In the last number of this Journal, page 365, it has been shown that the barometric formula of Laplace does not prove satisfactory in making reductions of individual observations to sea-level, if the elevation of the station equals 6,000′. In continuing the discussion the effects of humidity and latitude are for the present omitted; neither can affect the results aimed at, for the reason that the corrections due to them, when applied, can only affect the final result by a small, nearly constant quantity.

We will determine first the exact variations, at some elevation, of the hights computed from Laplace, at different pressures and temperatures. The method proposed on page 364, which I have already quoted, has been adopted in constructing Table I. Valdobbia and Alessandria, inland stations of Italy, have been chosen, as mean daily observations for $8\frac{1}{2}$ years at these stations have been published side by side in the Moncalieri Meteorological Bulletin. Valdobbia is about 8,200′

high, situated in latitude 46° north, and seventy miles from Alessandria, in 45° north latitude and 318′ high.

TABLE I.—(In millimeters).

	−6° C.	−3°.	0°.	3°.	6°.	9°.	12°.	15°.	18°.	21°.
550	744·0	743·9	741·1	739·8	----	----	----	----	----	----
555	752·0	749·5	746·6	745·2	744·1	742·5	----	----	----	----
560	757·1	755·6	753·9	752·1	750·0	748·2	746·2	744·7	743·0	----
565	762·5	761·0	759·6	758·1	755·3	754·4	752·3	750·3	744·5	----
570	769·0	763·0	764·8	763·0	761·5	759·0	758·1	756·1	754·6	753·1

In this table the first horizontal row of figures represents the mean temperature between the two stations, each vertical column contains a mean of all the pressures observed at the lower station for $3\frac{1}{2}$ years at the time of the mean temperature at the head of the column, hence the column headed 0° contains a mean of all the pressures at Alessandria between the mean temperatures of −1·5° C. and +1·5° C., distributed along the column according to the pressure at Valdobbia, as indicated on the left, the original table runs to single millimeters. It will now be seen that we have the mean temperature between the two stations and the mean pressure at the upper and lower stations for a range of 27° C. of temperature and 20mm. of pressure, from which we may compute, by Laplace, the difference of elevation of the two stations, as in Table II.

TABLE II.—(In meters).
Elevation of Valdobbia above Alessandria.

	−6° C.	−3°.	0°.	3°.	6°.	9°.	12°.	15°.	18°.	21°.
551	2380	2374	2396	2386	----	----	----	----	----	----
552	2376	2376	2376	2390	2396	----	----	----	----	----
553	2371	2376	2390	2387	2411	----	----	----	----	----
554	2379	2374	2381	2388	2391	----	----	----	----	----
555	2385	2378	2370	2382	2397	2405	----	----	----	----
556	2402	2375	2378	2381	2388	2407	----	----	----	----
557	2368	2375	2374	2396	2399	2411	2392	----	----	----
558	2362	2379	2383	2379	2396	2396	----	----	----	----
559	2360	2366	2373	2379	2379	2386	2395	2395	----	----
560	2356	2369	2377	2383	2388	2395	2399	2411	2419	----
561	2351	2364	2373	2377	2386	2395	2397	2407	2437	----
562	2342	2370	2376	2376	2382	2398	2393	2406	----	----
563	2351	2355	2374	2374	2387	2393	2400	2403	2419	----
564	2347	2359	2368	2365	2386	2388	2396	2409	2414	----
565	2343	2355	2374	2376	2373	2390	2393	2399	2417	----
566	2340	2345	2359	2369	2369	2384	2394	2397	2409	----
567	2340	2353	2357	2370	2378	2383	2388	2402	2408	2421
568	2331	2352	2357	2371	2367	2383	2389	2397	2407	2416
569	2320	2342	2354	2366	2356	2375	2389	2393	2402	2414
570	2331	2316	2351	2358	2369	2368	2385	2391	2399	2412

From this table it is evident that there is a great uniformity in the variation of the elevation as computed from Laplace.

The computed result is the smallest for a low temperature and high pressure, and largest for a high temperature and low pressure. Can these variations be accounted for?

All who have discussed this subject are agreed that some modification of the formula is necessary. R. S. Williamson has written a treatise upon this matter in which he explains certain changes which he has made in the temperature and pressure terms of the formula, but these did not give satisfactory results, and he concludes that owing to variations of climate at different places, no general formula can be obtained for all cases.

The latest researches on this subject in the United States, so far as known, have been made by Professor J. D. Whitney, of Harvard College, who published a very important addition to barometric hypsometry in 1874. Prof. Whitney confines his researches to the region lying west of the Rocky Mountains. On page 9 of his "Barometric Hypsometry" we find, "From the observed hights of the columns of mercury in two barometers at different altitudes, but not separated by any great distance horizontally, we have at once the weights of a column of air reaching from the lower instrument to the outer limit of the atmosphere and of that portion of the air-column which rises above the upper instrument. The weight of the column of air between the two instruments is therefore known, and it would seem at first sight as if trustworthy results, or, at least, a very close approximation to the truth might be obtained. Laplace was the first to propose a complete formula." On page 13 we find, "Laplace's original formula comprised four terms, which may be designated as the *pressure* term, including, as is usual, the principal numerical coëfficient; the *temperature* term; the correction for *latitude;* and the correction for the change in the hight of the mercury column in the barometer, caused by the *variation in the intensity of gravity* with increase of altitude." After an extended discussion entirely upon a theoretical basis, Prof. Whitney concludes, "The pressure term, at least, is to be considered essentially unalterable." He considers that all the variations may be due to the temperature term, and has prepared a set of tables for correcting altitudes, in the western portion of the United States, as computed from Laplace.

Let us examine these points: if the only motions of the atmosphere were in a vertical direction and due essentially to the temperature, the solution of the problem would appear not difficult.

At first sight it seems as though the *temperature* term would be the easiest determined and the one least liable to change, for the reason that the temperature is almost entirely affected by only one great invariable cause. Thus we find the same mean temperature in April and October of each year, the lowest in

January and the highest in July. If the temperature term only were at fault, we should expect to find a regularity in the variation of the difference of elevation as computed from the mean of each of the months, also the *same variation at all places;* that is, if we should find the highest result in July and the lowest in January in any one place, any theory which could be applied to the variation of the temperature at different altitudes must necessarily give in general the same results at all isolated peaks throughout the world; but neither of these suppositions is according to fact, as has been shown in the May number, page 363, where we see that the *highest* value of the elevation of Mt. Washington, above Portland, as computed from Laplace, was in March, and the *lowest* in August, whereas in the elevation of Pike's Peak above Dodge City, the *highest* value was in July and the *lowest* in December.

We may then consider that the temperature term will remain nearly constant so far as it is affected by the heat of the sun; this hypothesis will be strongly supported by a practical demonstration in the course of this discussion.

On the other hand, the pressure term is affected by a great variety of causes. In summer there is an upward motion of the atmosphere, the ocean relatively to the land is cool and the air moves toward the region that is coolest, while in winter exactly the reverse takes place. This may explain the facts just mentioned. Mt. Washington, near the coast, is very little affected by this motion, and the results differ but little in January and July.

There seems to be, also, a constant motion of the atmosphere toward the east, slower in summer than in winter. It has also been found in a large number of cases that the difference of elevation as computed from the mean of the March and April observations, is frequently greater than that from other months. This may be due to a general diminution of the pressure at the lower station, which does not seem to extend to an elevation of 6,000′; such a diminution has been found at over 500 stations in the middle latitudes, but only at the lower stations. It would certainly seem, then, that the pressure term is more liable to change than the temperature term.

In order to separate the various elements which enter into the formula of Laplace, the following method is proposed: If tables be constructed from Laplace according to the plan of the table on page 370, this Journal, last number, for each thousand feet of elevation, it will be possible to obtain the laws of variation of the reductions to sea-level and represent them by a formula which shall dispense with logarithms and separate the various terms.

The following formulæ are founded on such a plan:

$$\text{For } 1000' : \mathrm{C} = 1''\cdot1675 - 0''.0389\,(30'' - p) - 0''\cdot00245\,(t - 32^\circ) + 0''\cdot0000065\,(t - 32^\circ)\,(t - 52^\circ)$$

$$\text{For } 2000' : \mathrm{C} = 2''\cdot3803 - 0''\cdot0794\,(30'' - p) - 0''\cdot00490\,(t - 32^\circ) + 0''\cdot0000130\,(t - 32^\circ)\,(t - 52^\circ)$$

$$\text{For } 3000' : \mathrm{C} = 3''\cdot6401 - 0''\cdot1214\,(30'' - p) - 0''\cdot00735\,(t - 32^\circ) + 0''\cdot0000195\,(t - 32^\circ)\,(t - 52^\circ)$$

The temperature term might have been much simplified, but this harmonizes best with later work. These formulæ were constructed up to an elevation of 8,000′, and from a combination of the eight the following general formula was obtained:

$$\begin{aligned} \mathrm{C} = {} & \cdot0000000000003h^3 \\ & + [''\cdot000000021702 - 0''\cdot0000000008(30'' - p)]h^2 \\ & + [0''\cdot001145482 - 0''\cdot0000381\,(30'' - p) \\ & - 0''\cdot00000245(t - 32^\circ) + 0''\cdot0000000065\,(t - 32^\circ)\,(t - 52^\circ)]h \end{aligned}$$

in which C = reduction to sea, h is hight of station in feet, p is pressure at station, and t the mean temperature at the time of observation, between station and sea.

If, now, we assume a pressure of 30″ and consider the total hight above such a pressure, as proposed by Prof. Angot, of Paris, we may put $30'' - p$ for C in the above formula, and solving for h obtain the following expression, which is general for any altitude:

$$h = \frac{\sqrt{4b \times (30'' - p) + a^2} - a}{2b} - 0''\cdot0000000003h^3 \qquad (1).$$

in which $a = 0''\cdot001145482 - 0''\cdot00000245\,(t - 32^\circ) + 0''\cdot0000000065\,(t - 32^\circ)\,(t - 52^\circ) - 0''\cdot0000381\,(30'' - p)$

and $b = 0''\cdot000000021702 - 0''\cdot0000000008\,(30'' - p)$.

In constructing the formula a slight change from a rigid value of Laplace has been made for a known variation at Mt. Washington. In applying the formula an approximate elevation is computed from the first term and a correction applied to this from the second term. Tables have been constructed for elevations from −200′ to 9,000′ by means of this formula.

The hight of Mt. Washington above Portland by various formulæ is given in Table III.

The results in column 4 vary the most, and show, as has already been suggested, that no general formula can be determined for all stations. The results in column 6 show the ease with which the original formula of Laplace may be modified for different places, also the accuracy of this general method of procedure. May it not be possible to determine a general formula from the actual observations in different places, which shall require but a slight and readily-determined change to make it applicable to any locality?

TABLE III.—Mt. Washington above Portland, true difference 6240′.

	Laplace.	Difference from mean.	Angot.	Difference from mean.	Hazen (1).	Difference from mean.
January	6264′	+16′	6329′	+80′	6245′	+ 2′
February	6268	+20	6299	+50	6242	− 1
March	6284	+36	6306	+57	6265	+22
April	6242	− 6	6244	− 5	6244	+ 1
May	6232	−16	6201	−48	6234	− 9
June	6233	−15	6201	−48	6236	− 7
July	6225	−23	6158	−91	6233	−10
August	6215	−33	6198	−51	6225	−18
September	6236	−12	6217	−32	6230	−13
October	6249	+ 1	6253	+ 4	6246	+ 3
November	6275	+27	6286	+37	6271	+28
December	6259	+11	6296	+47	6246	+ 3
Year	6256		6267		6241	
Mean 12 mo's	6248		6249		6243	

The following suggestion is made in the absence of any other: Let all the observations for a series of years, at an elevated and at a lower neighboring station, be grouped as has already been proposed, then determine a formula which shall best represent all the observations, or, in other words, the laws

TABLE IV.

Law of variation of the temperature term at different pressures, and of the pressure term at different temperatures, at Valdobbia and Great Saint Bernard.

Pressure.	Temperature term variation for each degree Centigrade.		Temperat'e.	Pressure term variation for each millimeter.	
	Val. and Al.	Ber. and Al.		Val. and Al.	Ber. and Al.
551mm	0·733mm	----	− 6°mm	0·18mm	·31mm
552	·610	----	− 3	·15	·13
553	·500	----	0	·20	·22
554	·633	----	3	·23	·24
555	·467	0·55mm	6	·23	·17
556	·767	·63	9	·25	·30
557	·547	·48	12	·22	·26
558	·613	·62	15	·10	·16
559	·640	·58	18	·12	·17
560	·590	·76	21	·00	·00
561	·570	·65			
562	·640	·58			
563	·650	·57			
564	·570	·58			
565	·543	·66			
566	·603	·55			
567	·547	·58			
568	·580	·54			
569	·503	·60			
570	·560	·65			
571	·590	·59			
572	·610	----			
573	·567	----			
Mean	·593	·598			

of variation, at any station, of pressures and temperatures at different temperatures and pressures.

It would seem that if there be taken a sufficient number of stations, near enough together, at different elevations, the above result might be attained.

There are very great difficulties in obtaining satisfactory results at present, owing to the great distance between stations and the lack of reliable elevations. In Table IV we find, in the case of reduction from a higher to a lower station, the law of the variation of the temperature term at different pressures and the law of the pressure term at different temperatures, as determined from a comparison of all the mean daily observations at Valdobbia and Alessandria during 3½ years; comparisons are also given for the same time between Great St. Bernard and Alessandria.

There is a remarkable uniformity in the temperature term variation at all pressures at both stations, but the pressure term variation is subject to breaks and rather regularly diminishes as the temperature increases.

The following formulæ have been constructed from the actual observations at several elevations in Italy and Switzerland:

Great Saint Bernard and Geneva: $C = 9''\cdot68 - 0''\cdot22\,(30'' - p)$
$- 0''\cdot014\,(t - 32°)$

Monte Cavo and Rome: $C = 3''\cdot66 - 0''\cdot10(30'' - p)$
$- 0''\cdot0052(t - 32°)$

Mondovi and Alessandria: $C = 2''\cdot10 - 0''\cdot06(30'' - p)$
$- 0''\cdot0027\,(t - 32°)$

and from these the general formula,

$$C = 0''\cdot0000000117h^2 + 0''\cdot0011068h - 0''\cdot000029(30'' - p)h$$
$$- 0''\cdot0000016\,(t - 32°)h + 0''\cdot0214$$

$$h\text{, in feet,} = \frac{\sqrt{4b(30'' - p - 0''\cdot0214) + a^2} - a}{2b} \qquad (2)$$

in this $a = 0''\cdot0011068 - 0''\cdot000029\,(30'' - p) - 0''\cdot0000016\,(t - 32°)$
and $b = 0''\cdot0000000117.$

Table V gives difference of elevation by various formulæ.

The results by Angot are better than by Laplace. It will be noticed that the sixth column has been computed from a formula into which the original observations at Valdobbia have not entered and in so far goes to show the reliability of this method. The formula applies best to elevations of about 8000′.

TABLE V.—Valdobbia above Alessandria.

Month.	Laplace.	Difference from mean.	Angot.	Difference from mean.	Hazen (2).	Difference from mean.
January	7699′	−98′	7904′	+51′	7863′	− 6′
February	7796	− 1	7904	+51	7916	+47
March	7823	+26	7904	+51	7911	+42
April	7811	+14	7835	−18	7887	+18
May	7848	+51	7851	−2	7887	+18
June	7823	+26	7792	−61	7844	−25
July	7842	+45	7818	−35	7854	−15
August	7848	+51	7822	−31	7860	− 9
September	7827	+30	7861	+ 8	7860	− 9
October	7801	+ 4	7854	+ 1	7847	−22
November	7735	−62	7828	−25	7830	−39
December	7709	−88	7858	+ 5	7862	− 7
Year	7808		7851		7862	
Mean of months	7797		7853		7869	

The following formulæ are added:

Mount Washington and Portland $C = 6''\cdot82 - 0''\cdot12\ (30'' - p)$
$- 0''\cdot012\ (t - 32°)$

Professor Whitney has made nearly three years' observations at Sacramento and Summit, California, stations 77 miles apart with a difference of altitude of 6989′. The formula at these stations is $C = 5''\cdot24 + 0''\cdot25\,(30'' - p) - 0''\cdot010\,(t - 32°)$, the reversal of the sign in the pressure term from minus to plus has been already noticed in the May number, page 366.

It has been shown, then,

1st. The formula of Laplace gives too small results at high pressures and low temperatures and too great at low pressures and high temperatures.

2d. The pressure term is more liable to variation than the temperature term.

3d. It is possible to so arrange the formula of Laplace as to separate the terms, and dispense with the use of logarithms.

4th. It is possible to construct a formula from the actual observations which shall give satisfactory results.

The following paragraphs have been taken from an article in "Nature" for April 14th, 1881 (just received), on *Periodic Oscillations of Barometric Pressure*, by J. ALLAN BROUN, F.R.S., (now deceased). They are of interest as confirming some of the views advanced in the above paper.

Sedgwick has said: ["To explain difficulties in these questions" (relating to pressure and temperature) "the atmospheric strata have been shuffled in accordance with laboratory experiments."]

"If we suppose that the attraction of gravity is not the only attraction which affects the pressure of the atmosphere, but that this pressure varies through some other attracting force such as an electric attraction of the sun depending upon the varying humidity of the air and this again depending on its temperature; we should find another method of relating the two variations which does not exist if gravitation alone is employed. It is quite certain that many physicists will not admit the idea of an electric attraction on our atmosphere in the present state of our knowledge, hence the efforts to make expansion, and a shuffling of the atmospheric strata suffice. We must not, however, in our ignorance, attempt to force conclusions in opposition to facts, and if these can be satisfied more easily and with greater probabilites in its favor by the aid of the hypothesis of an electric attraction of the sun, that hypothesis will have a better claim to acceptation than the other. I shall here note a few facts which cannot be explained by thermic actions.

1. I have shown that on the average of many years' observation in our latitudes the mean pressure diminishes at the rate of 0″·038 of mercury for every one hundred miles we proceed toward the north. This has been called a gradient from the similar term used in railway slopes: but it is no slope, it is a level of a surface of equilibrium like that of the sea. It is the mean hights of the barometer at the sea-level which indicate the form, if we may so say, of the equilibrating atmosphere.

2. In India we have seen that the atmospheric pressure oscillates at each station even when these are quite near to each other, independently of the known laws of equilibrium of gases. When we turn to the semi-diurnal oscillation of the barometer we are only amused at the attempts made to explain it by shuffling the atmospheric strata. Nothing can be more certain than that the theories of expansion, or resistance to expansion and overflow, are the vain efforts to make the laws of nature agree with a theory. Over the great ocean within the tropics, where the diurnal variations of temperature are small and the air is absolutely without perceptible currents for days together, the barometer rises and falls a tenth of an inch twice in twenty-four hours with the regularity of the solar clock. The action of the sun on the whole atmosphere which produces this movement varies chiefly during the day hours at inland stations with the temperature oscillation, so that, as in the case of the annual variation, the fall of the barometer at 4 P.M. is greater in the same latitude as the temperature is higher. This variation occurs during the most complete calms; the smoke rises vertically from the plains of Tinnevelly; no current is visible in the motion of the clouds; yet the barometer falls at four in the morning as it did at four in the afternoon, only it falls less."

ART. LVII.—*Occurrence of a nodule of Chromite in the interior of compact Meteoric Iron from Cohahuila;* by J. LAWRENCE SMITH, Louisville, Ky.

THE masses of iron from Cohahuila that I have designated the Butcher Meteorites,* to distinguish them from other meteorites of the same locality, have already afforded me several most interesting and novel results; among them, concretions of aragonite on the exterior (doubtless formed after their fall from surrounding conditions), and, more particularly, the new and interesting mineral, daubréelite,† concreted in the interior of the troilite nodules that exist in this iron. A great number of sections have been cut and daubréelite is always found with its well defined characteristics.

Recently I have had made two additional large sections. They have furnished, however, but few nodules. One of these was a well-defined, symmetrically oval nodule, 17 mm. by 12 mm., its diameters situated 6 centimeters from the exterior surface, compact solid iron intervening between the surface and the nodule.

* This Journal, ii, Nov., 1871. † Ib., xvi, Oct., 1875.

I was at once struck with its being different from any nodule I had yet observed in meteoric iron. There was no troilite in it; and although black it was not graphite; so that I supposed it might consist entirely of daubréelite. But its luster was more vitreous than in this last mineral. On examining carefully with a lens, I found in the black material a few particles of a translucent mineral, some particles of which were almost colorless, and one or two of a greenish hue (doubtless magnesian silicate); and, besides, there were a few specks of iron only traceable by the magnet.

The nodule was virtually a black granular mass. As stated, it was first taken for daubréelite. The smallest particle rubbed fine and fused with borax gave the intense green of chrome; but, to my surprise, when the powder was heated in nitric acid over a water bath, not the slightest impression was made upon it, showing that it was not daubréelite, which is soluble in nitric acid leaving a dark green residue. Heating it in fused carbonate of soda in no way changed its insolubility in acids. These reactions convinced me that I had *chromite;* and on fusing 150 milligrams of the finely pulverized mineral with ten times its weight of bisulphate of soda, it was thoroughly attacked but not dissolved. On treating with water, and fusing the residue with carbonate of soda and niter, and proceeding with the analysis as is usual in the case of chromite, there was obtained,

Chromic oxide	62·71—$\overline{\dddot{\mathrm{Cr}}}$
Ferrous oxide	33·83—$\dot{\mathrm{Fe}}$

the iron oxide being in the solution from the fused mass, after treatment with bisulphate of soda. The composition thus found is that of chromite. Traces of magnesia, cobalt and silica were detected; the magnesia and silica doubtless came from the siliceous mineral already referred to, which is either enstatite or olivine.

The result of these observations, then, is to establish the existence of a new mineral concretion in the interior of meteoric iron; for while chromite has been known to be associated with meteorites, this is the first instance of its having been found embedded in this manner in the interior of meteoric iron. The fact thus increases the interest of the Butcher meteorites, which have furnished such beautiful and distinguishing concretions of two chrome minerals.

I should state that some of the particles of chromite, under the microscope and with very intense light, are feebly translucent and have a dark reddish purple color. This translucency of chromite has been observed by the assistant of the Professor of Geology in the College of France. The name of this assistant I do not now recollect and I cannot now place my hands on the results of his researches in this direction.

Art. LVIII.—*Upon the Production of Sound by Radiant Energy*; by Alexander Graham Bell.

[Read before the National Academy of Sciences, April 21, 1881.]

In a paper read before the American Association for the Advancement of Science, last August, I described certain experiments made by Mr. Sumner Tainter and myself which had resulted in the construction of a "*Photophone*," or apparatus for the production of sound by light;* and it will be my object to-day to describe the progress we have made in the investigation of photophonic phenomena since the date of this communication.

In my Boston paper the discovery was announced that thin disks of very many different substances *emitted sounds* when exposed to the action of a rapidly-interrupted beam of sunlight. The great variety of material used in these experiments led me to believe that sonorousness under such circumstances would be found to be a general property of all matter.

At that time we had failed to obtain audible effects from masses of the various substances which became sonorous in the condition of thin diaphragms, but this failure was explained upon the supposition that the molecular disturbance produced by the light was chiefly a surface action, and that under the circumstances of the experiments the vibration had to be transmitted through the mass of the substance in order to affect the ear. It was therefore supposed that, if we could lead to the ear air that was directly in contact with the illuminated surface, louder sounds might be obtained, and solid masses be found to be as sonorous as thin diaphragms. The first experiments made to verify this hypothesis pointed towards success. A beam of sunlight was focussed into one end of an open tube, the ear being placed at the other end. Upon interrupting the beam, a clear, musical tone was heard, the pitch of which depended upon the frequency of the interruption of the light and the loudness upon the material composing the tube.

At this stage our experiments were interrupted, as circumstances called me to Europe.

While in Paris a new form of the experiment occurred to my mind, which would not only enable us to investigate the sounds produced by masses, but would also permit us to test the more general proposition that *sonorousness, under the influence of intermittent light, is a property common to all matter.*

* Proceedings of American Association for the Advancement of Science, Aug. 27th, 1880; see, also, this Journal, vol. xx. p. 305; Journal of the American Electrical Society, vol. iii, p. 3; Journal of the Society of Telegraph Engineers and Electricians, vol. ix, p. 404; Annales de Chimie et de Physique, vol. xxi.

The substance to be tested was to be placed in the interior of a transparent vessel, made of some material which (like glass) is transparent to light, but practically opaque to sound.

Under such circumstances the light could get in, but the sound produced by the vibration of the substance could not get out. The audible effects could be studied by placing the ear in communication with the interior of the vessel by means of a hearing tube.

Some preliminary experiments were made in Paris to test this idea, and the results were so promising that they were communicated to the French Academy on the 11th of October, 1880, in a note read for me by M. Antoine Breguet.* Shortly afterwards I wrote to Mr. Tainter, suggesting that he should carry on the investigation in America, as circumstances prevented me from doing so myself in Europe. As these experiments seem to have formed the common starting point for a series of independent researches of the most important character, carried on simultaneously, in America by Mr. Tainter, and in Europe by M. Mercadier,† Prof. Tyndall,‡ W. E. Röntgen,§ and W. H. Preece,‖ I may be permitted to quote from my letter to Mr. Tainter the passage describing the experiments referred to:

"Metropolitan Hotel, Rue Cambon, Paris,
November 2, 1880.

"Dear Mr. Tainter:

* * * "I have devised a method of producing sounds by the action of an intermittent beam of light from substances that cannot be obtained in the shape of thin diaphragms or in the tubular form; indeed, the method is specially adapted to testing the generality of the phenomenon we have discovered, as it can be adapted to solids, liquids, and gases.

"Place the substance to be experimented with in a glass test-tube, connect a rubber tube with the mouth of the test-tube, placing the other end of the pipe to the ear. Then focus the intermittent beam upon the substance in the tube. I have tried a large number of substances in this way with great success, although it is extremely difficult to get a glimpse of the sun here, and when it does shine the intensity of the light is not to be compared with that to be obtained in Washington. I got splendid effects from crystals of bichromate of potash, crystals of sulphate

* Comptes Rendus, vol. xci, p. 595.

† "Notes on Radiophony," Comptes Rendus, Dec. 6 and 13, 1880; Feb. 21 and 28, 1881. See, also, Journal de Physique, vol. x, p. 53.

‡ "Action of an Intermittent Beam of Radiant Heat upon Gaseous Matter." Proc. Royal Society, Jan. 13, 1881, vol. xxxi, p. 307.

§ "On the tones which arise from the intermittent illumination of a gas." See Annalen der Phys. und Chemie, Jan., 1881, no. 1, p. 155.

‖ "On the Conversion of Radiant Energy into Sonorous Vibrations." Proc. Royal Society, March 10, 1881, vol. xxxi, p. 506.

of copper, and from tobacco smoke, A whole cigar placed in the test-tube produced a very loud sound. I could not hear anything from plain water, but when the water was discolored with ink a feeble sound was heard. I would suggest that you might repeat these experiments and extend the results," &c., &c.

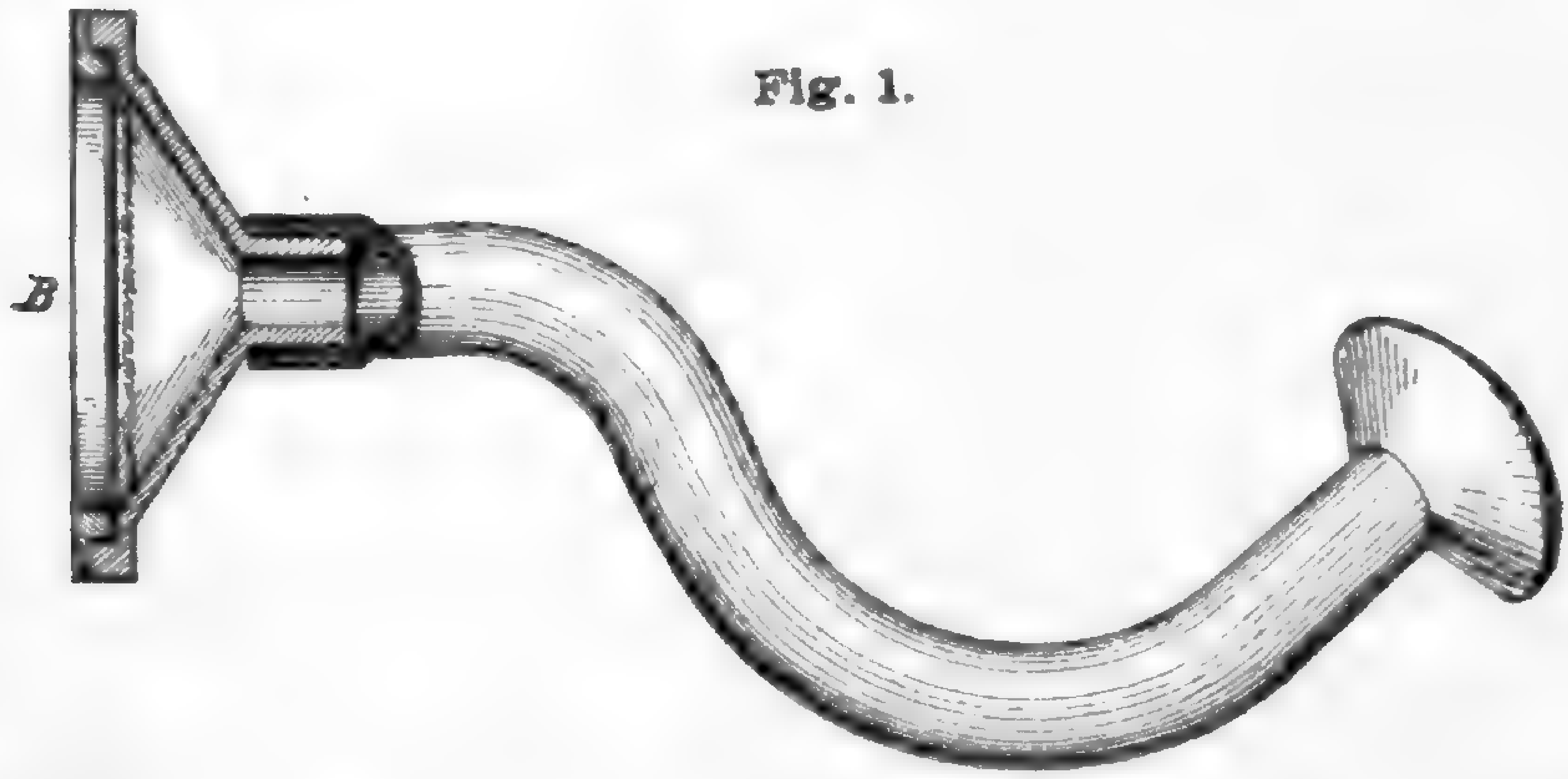
Experiments with Solids.

Upon my return to Washington in the early part of January,* Mr. Tainter communicated to me the results of the experiments he had made in my laboratory during my absence in Europe.

He had commenced by examining the sonorous properties of a vast number of substances enclosed in test-tubes in a simple empirical search for loud effects. He was thus led gradually to the discovery that cotton-wool, worsted, silk, and fibrous materials generally, produced much louder sounds than hard rigid bodies like crystals, or diaphragms such as we had hitherto used.

In order to study the effects under better circumstances he enclosed his materials in a conical cavity in a piece of brass closed by a flat plate of glass. A brass tube leading into the cavity served for connection with the hearing-tube. When this conical cavity was stuffed with worsted or other fibrous materials the sounds produced were much louder than when a test-tube was employed. This form of receiver is shown in figure 1.

Fig. 1.



Mr. Tainter next collected silks and worsteds of different colors, and speedily found that the darkest shades produced the best effects. Black worsted especially gave an extremely loud sound.

As white cotton-wool had proved itself equal, if not superior, to any other white fibrous material before tried, he was anxious to obtain colored specimens for comparison. Not having any at hand, however, he tried the effect of darkening some cotton-wool with lamp-black. Such a marked reinforcement of the sound resulted that he was induced to try lamp-black alone.

* On the 7th of January.

About a teaspoonful of lamp-black was placed in a test-tube and exposed to an intermittent beam of sunlight. The sound produced was much louder than any heard before.

Upon smoking a piece of plate-glass, and holding it in the intermittent beam with the lamp-black surface towards the sun, the sound produced was loud enough to be heard, with attention, in any part of the room. With the lamp-black surface turned from the sun the sound was much feebler.

Mr. Tainter repeated these experiments for me immediately upon my return to Washington, so that I might verify his results.

Upon smoking the interior of the conical cavity shown in figure 1, and then exposing it to the intermittent beam, with the glass lid in position as shown, the effect was perfectly startling. The sound was so loud as to be actually painful to an ear placed closely against the end of the hearing-tube. The sounds, however, were sensibly louder when we placed some smoked wire gauze in the receiver, as illustrated in the drawing, figure 1.

When the beam was thrown into a resonator, the interior of which had been smoked over a lamp, most curious alternations of sound and silence were observed. The interrupting disk was set rotating at a high rate of speed, and was then allowed to come gradually to rest. An extremely feeble musical tone was at first heard, which fell in pitch as the rate of interruption grew less. The loudness of the sound produced varied in the most interesting manner. Minor reinforcements were constantly occurring, which became more and more marked as the true pitch of the resonator was neared. When at last the frequency of interruption corresponded to the frequency of the fundamental of the resonator, the sound was so loud that it might have been heard by an audience of hundreds of people.

The effects produced by lamp-black seemed to me to be very extraordinary, especially as I had a distinct recollection of experiments made in the summer of 1880 with smoked diaphragms, in which no such reinforcement was noticed.

Upon examining the records of our past photophonic experiments we found in vol. vii, p. 57, the following note:

"Experiment V.—Mica diaphragm covered with lamp-black on side exposed to light.

"Result: distinct sound about same as without lamp-black.—*A. G. B., July 18th*, 1880.

"Verified the above, but think it somewhat louder than when used without lamp-black."—*S. T., July 18th*, 1880.

Upon repeating this old experiment we arrived at the same result as that noted. Little if any augmentation of sound resulted from smoking the mica. In this experiment the effect was observed by placing the mica diaphragm against the ear and also by listening through a hearing-tube, one end of which was closed by the diaphragm. The sound was found to be more audible through the free air when the ear was placed as near to the lamp-black surface as it could be brought without shading it. Thus the vibrations produced in lamp-black under the above circumstances do not appear to be communicated to any very appreciable extent to the diaphragm on which the lamp-black is deposited.

At the time of my communication to the American Association I had been unable to satisfy myself that the substances which had become sonorous under the direct influence of intermittent sunlight were capable of reproducing the sounds of articulate speech under the action of an undulatory beam from our photophonic transmitter. The difficulty in ascertaining this will be understood by considering that the sounds emitted by thin diaphragms and tubes were so feeble that it was impracticable to produce audible effects from substances in these conditions at any considerable distance from the transmitter; but it was equally impossible to judge of the effects produced by our articulate transmitter at a short distance away because the speaker's voice was directly audible through the air. The extremely loud sounds produced from lamp-black have enabled us to demonstrate the feasibility of using this substance in an articulating photophone in place of the electrical receiver formerly employed.

The drawing (fig. 2) illustrates the mode in which the experiment was conducted. The diaphragm of the transmitter (A) was only five centimeters in diameter, the diameter of the receiver (B) was also five centimeters, and the distance between the two was 40 meters, or 800 times the diameter of the transmitting diaphragm. We were unable to experiment at greater distances without a heliostat on account of the difficulty of keeping the light steadily directed on the receiver. Words and sentences spoken into the transmitter in a low tone of voice were audibly reproduced by the lamp-black receiver.

In fig. 3 is shown a mode of interrupting a beam of sunlight for producing distant effects without the use of lenses. Two similarly perforated disks are employed, one of which is set in rapid rotation, while the other remains stationary. This form of interrupter is also admirably adapted for work with artificial light. The receiver illustrated in the drawing consists of a parabolic reflector, in the focus of which is placed a glass vessel (A) containing lamp-black or other sensitive substance, and connected with a hearing-tube. The beam of light is interrupted by its passage through the two slotted disks shown at B,

Fig. 2.

Fig. 3.

and in operating the instrument musical signals like the dots and dashes of the Morse alphabet are produced from the sensitive receiver (A) by slight motions of the mirror (C) about its axis (D).

In place of the parabolic reflector shown in the figure a conical reflector like that recommended by Professor Sylvanus Thompson * can be used, in which case a cylindrical glass vessel would be preferable to the flask (A) shown in the figure.

In regard to the sensitive materials that can be employed, our experiments indicate that in the case of solids the physical condition and the color markedly influence the intensity of the sonorous effects. *The loudest sounds are produced from substances in a loose, porous, spongy condition, and from those that have the darkest or most absorbent colors.*

The materials from which the best effects have been obtained are cotton-wool, worsted, fibrous materials generally, cork, sponge, platinum and other metals in a spongy condition, and lamp-black.

The loud sounds produced from such substances may perhaps be explained in the following manner: Let us consider, for example, the case of lamp-black—a substance which becomes heated by exposure to rays of all refrangibility. I look upon a mass of this substance as a sort of sponge, with its pores filled with air instead of water. When a beam of sunlight falls upon this mass, the particles of lamp-black are heated, and consequently expand, causing a contraction of the air-spaces or pores among them.

Under these circumstances a pulse of air should be expelled, just as we would squeeze out water from a sponge.

The force with which the air is expelled must be greatly increased by the expansion of the air itself, due to contact with the heated particles of lamp-black. When the light is cut off the converse process takes place. The lamp-black particles cool and contract, thus enlarging the air spaces among them, and the enclosed air also becomes cool. Under these circumstances a partial vacuum should be formed among the particles, and the outside air would then be absorbed, as water is by a sponge when the pressure of the hand is removed.

I imagine that in some such manner as this a wave of condensation is started in the atmosphere each time a beam of sunlight falls upon lamp-black, and a wave of rarefaction is originated when the light is cut off. *We can thus understand how it is that a substance like lamp-black produces intense sonorous vibrations in the surrounding air, while at the same time it communicates a very feeble vibration to the diaphragm or solid bed upon which it rests.*

* Phil. Mag., April, 1881, vol. xi, p. 286.

This curious fact was independently observed in England by Mr. Preece, and it led him to question whether, in our experiments with thin diaphragms, the sound heard was due to the vibration of the disk or (as Professor Hughes had suggested) to the expansion and contraction of the air in contact with the disk confined in the cavity behind the diaphragm. In his paper read before the Royal Society on the 10th of March, Mr. Preece describes experiments from which he claims to have proved that the effects are wholly due to the vibrations of the confined air, and that the *disks do not vibrate at all.*

I shall briefly state my reasons for disagreeing with him in this conclusion:

1. When an intermittent beam of sunlight is focussed upon a sheet of hard rubber or other material, a musical tone can be heard, not only by placing the ear immediately behind the part receiving the beam, but by placing it against any portion of the sheet, even though this may be a foot or more from the place acted upon by the light.

2. When the beam is thrown upon the diaphragm of a "Blake Transmitter," a loud musical tone is produced by a telephone connected in the same galvanic circuit with the carbon button (A,) fig. 4. Good effects are also produced when the carbon button (A) forms, with the battery (B,) a portion of the primary circuit of an induction coil, the telephone (C) being placed in the secondary circuit. In these cases the wooden box and mouth-piece of the transmitter should be removed, so that no air-cavities may be left on either side of the diaphragm.

It is evident, therefore, that in the case of thin disks a real vibration of the diaphragm is caused by the action of the intermittent beam, independently of any expansion and contraction of the air confined in the cavity behind the diaphragm.

Lord Rayleigh has shown mathematically that a to-and-fro vibration, of sufficient amplitude to produce an audible sound, would result from a periodical communication and abstraction of heat, and he says: "We may conclude, I think, that there is at present no reason for discarding the obvious explanation that the sounds in question are due to the bending of the plates under unequal heating." (Nature, xxiii, p. 274.)

Mr. Preece, however, seeks to prove that the sonorous effects cannot be explained upon this supposition; but his experimental data are not sufficient to support his conclusion. Mr. Preece expected that if Lord Rayleigh's explanation was correct, the expansion and contraction of a thin strip under the influence of an intermittent beam could be caused to open and close a galvanic circuit so as to produce a musical tone from a telephone in the circuit. But this was an inadequate way to

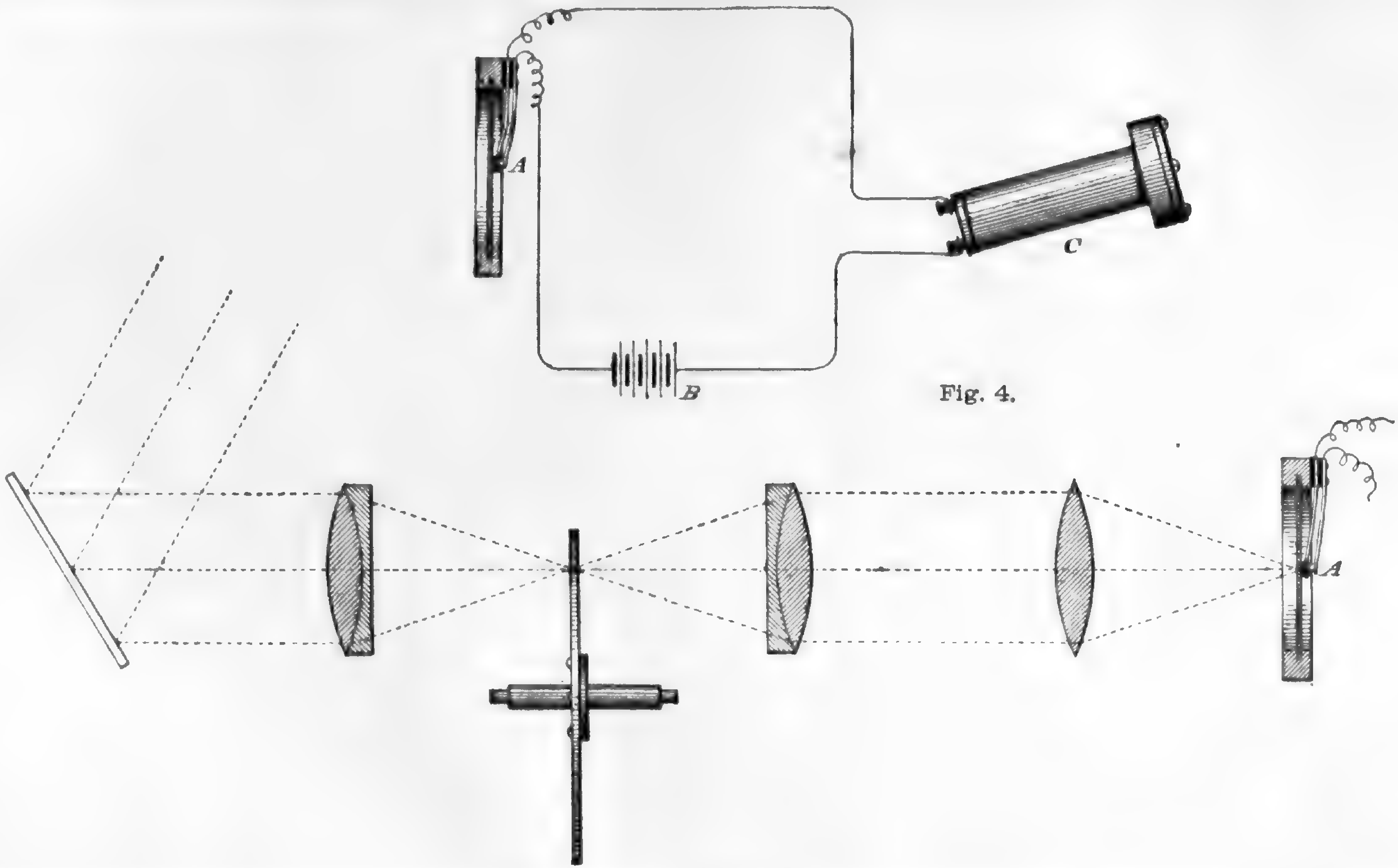


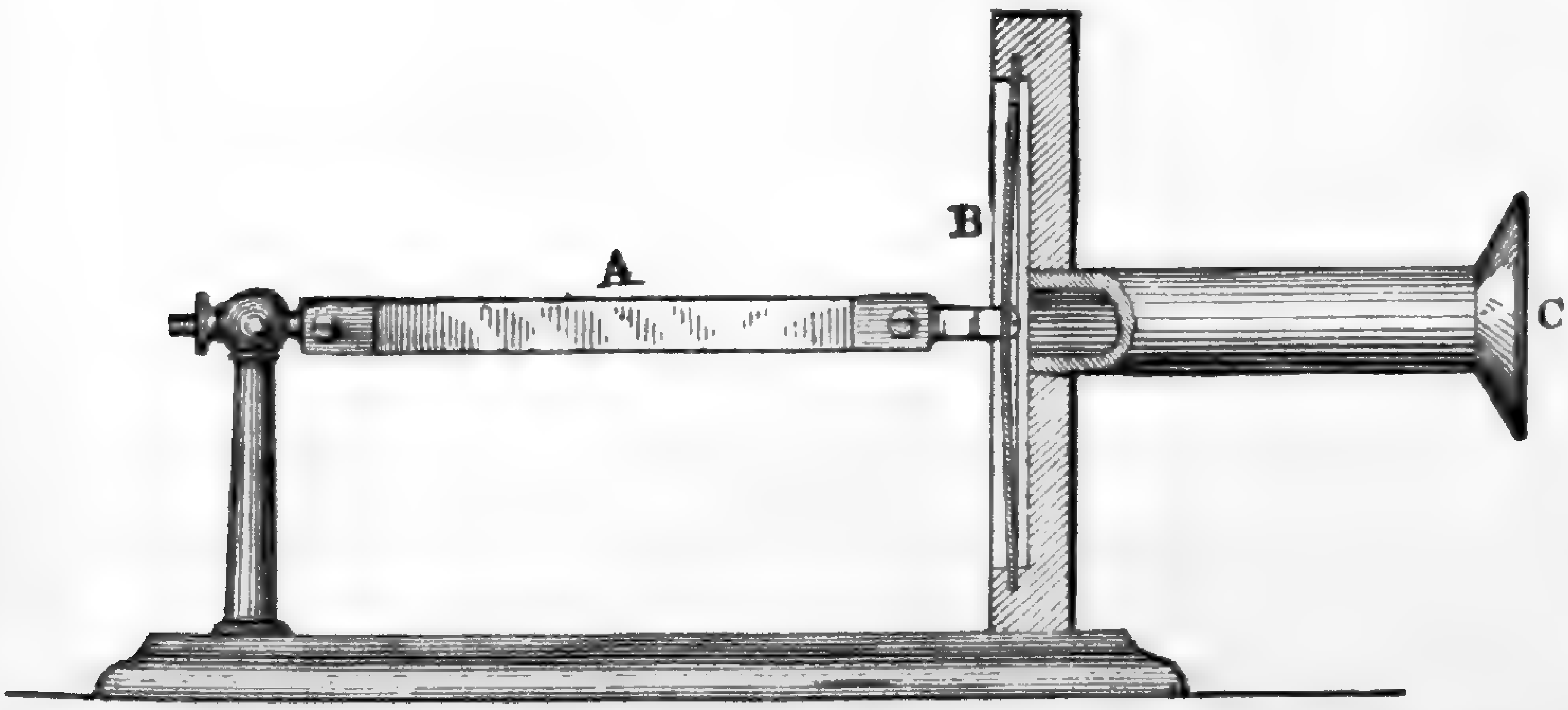
Fig. 4.

test the point at issue, for Lord Rayleigh has shown (Proc. of Roy. Soc., 1877) that an audible sound can be produced by a vibration whose amplitude is *less than a ten millionth of a centimeter*, and certainly such a vibration as that would not have sufficed to operate a "make-and-break contact" like that used by Mr. Preece. The negative results obtained by him cannot, therefore, be considered conclusive.

The following experiments (devised by Mr. Tainter) have given results decidedly more favorable to the theory of Lord Rayleigh than to that of Mr. Preece:

1. A strip (A) similar to that used in Mr. Preece's experiment was attached firmly to the center of an iron diaphragm (B,) as shown in figure 5, and was then pulled taut at right angles

Fig. 5.



to the plane of the diaphragm. When the intermittent beam was focussed upon the strip (A) a clear musical tone could be heard by applying the ear to the hearing-tube (C).

This seemed to indicate a rapid expansion and contraction of the substance under trial.

But a vibration of the diaphragm (B) would also have resulted if the thin strip (A) had acquired a to-and-fro motion, due either to the direct impact of the beam or to the sudden expansion of the air in contact with the strip.

2. To test whether this had been the case an additional strip (D) was attached by its central point only to the strip under trial, and was then submitted to the action of the beam, as shown in fig. 6.

It was presumed that if the vibration of the diaphragm (B) had been due to a *pushing force* acting on the strip (A), that the addition of the strip (D) would not interfere with the effect. But if, on the other hand, it had been due to the longitudinal expansion and contraction of the strip (A), the sound would cease, or at least be reduced. The beam of light falling upon strip (D) was now interrupted as before by the rapid rotation of a perforated disk, which was allowed to come gradually to rest.

No sound was heard excepting at a certain speed of rotation, when a feeble musical tone became audible.

This result is confirmatory of the first.

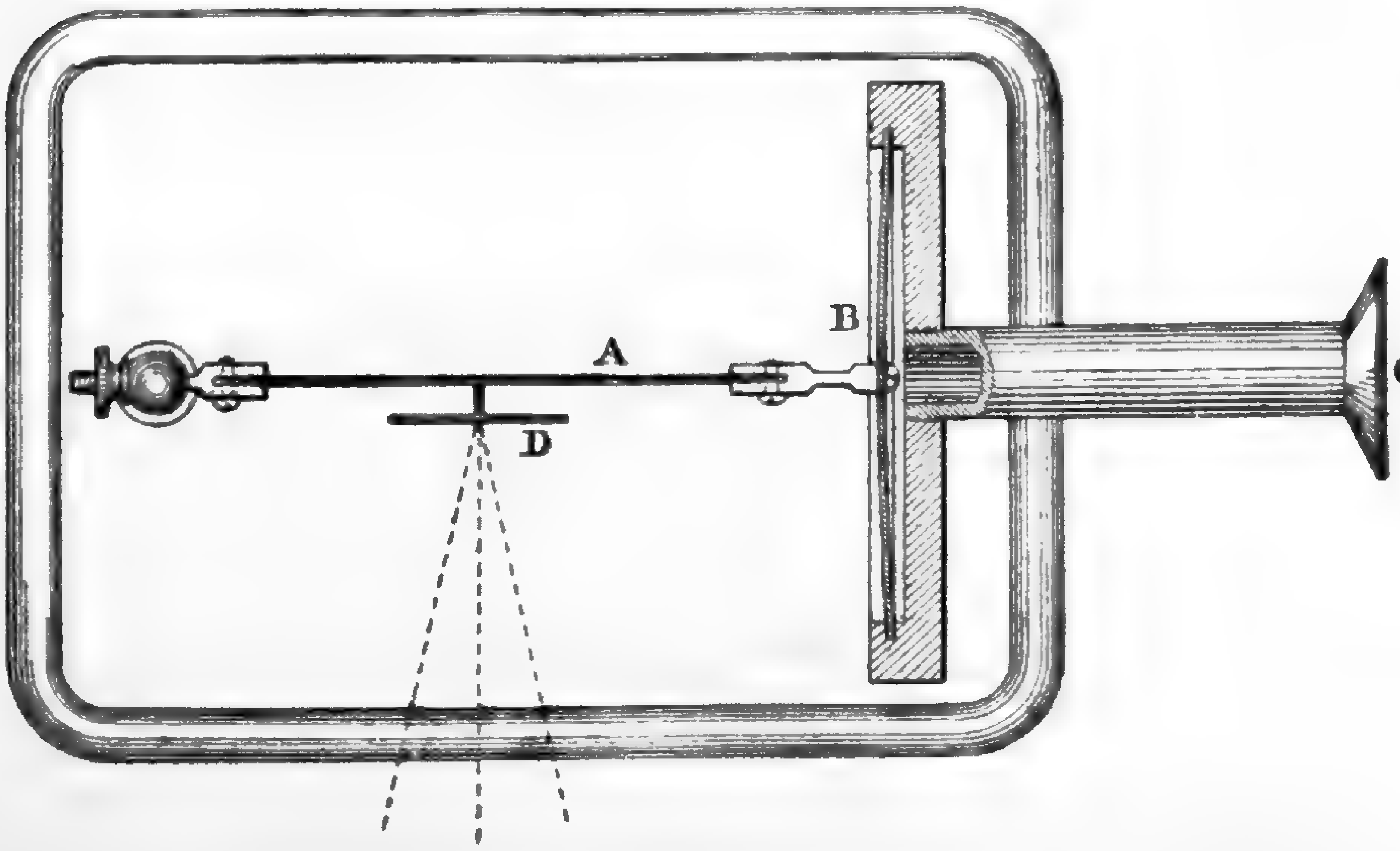


Fig. 6.

The audibility of the effect at a particular rate of interruption suggests the explanation that the strip D had a normal rate of vibration of its own.

When the frequency of the interruption of the light corresponded to this, the strip was probably thrown into vibration after the manner of a tuning-fork, in which case a to-and fro vibration would be propagated down its stem or central support to the strip (A).

This indirectly proves the value of the experiment.

The list of solid substances that have been submitted to experiment in my laboratory is too long to be quoted here, and I shall merely say that we have not yet found one solid body that has failed to become sonorous under proper conditions of experiment.*

Experiments with Liquids.

The sounds produced by liquids are much more difficult to observe than those produced by solids. The high absorptive power possessed by most liquids would lead one to expect intense vibrations from the action of intermittent light, but the

* Carbon and thin microscope glass are mentioned in my Boston paper as non-responsive, and powdered chlorate of potash in the communication to the French Academy, (Comptes Rendus, vol. xcl, p. 595.) All these substances have since yielded sounds under more careful conditions of experiment.

number of sonorous liquids that have so far been found is extremely limited, and the sounds produced are so feeble as to be heard only by the greatest attention and under the best circumstances of experiment. In the experiments made in my laboratory a very long test-tube was filled with the liquid under examination, and a flexible rubber tube was slipped over the mouth far enough down to prevent the possibility of any light reaching the vapor above the surface. Precautions were also taken to prevent reflection from the bottom of the test-tube. An intermittent beam of sunlight was then focussed upon the liquid in the middle portion of the test-tube by means of a lens of large diameter.

Results.

Clear water	No sound audible.
Water discolored by ink	Feeble sound.
Mercury	No sound heard.
Sulphuric ether*	Feeble, but distinct sound.
Ammonia	" " " "
Ammonio-sulphate of copper	" " " "
Writing ink	" " " "
Indigo in sulphuric acid	" " " "
Chloride of copper*	" " " "

The liquids distinguished by an asterisk gave the best sounds.

Acoustic vibrations are always much enfeebled in passing from liquids to gases, and it is probable that a form of experiment may be devised which will yield better results by communicating the vibrations of the liquid to the ear through the medium of a solid rod.

Experiments with Gaseous Matter.

On the 29th of November, 1880, I had the pleasure of showing to Professor Tyndall in the laboratory of the Royal Institution the experiments described in the letter to Mr. Tainter, from which I have quoted above, and Professor Tyndall at once expressed the opinion that the sounds were due to rapid changes of temperature in the body submitted to the action of the beam. Finding that no experiments had been made at that time to test the sonorous properties of different gases, he suggested filling one test-tube with the vapor of sulphuric ether (a good absorbent of heat), and another with the vapor of bisulphide of carbon (a poor absorbent), and he predicted that if any sound was heard it would be louder in the former case than in the latter.

The experiment was immediately made, and the result verified the prediction.

Since the publication of the memoirs of Röntgen* and Tyndall† we have repeated these experiments, and have extended the inquiry to a number of other gaseous bodies, obtaining in every case similar results to those noted in the memoirs referred to.

The vapors of the following substances were found to be highly sonorous in the intermittent beam: water vapor, coal gas, sulphuric ether, alcohol, ammonia, amylene, ethyl bromide, diethylamene, mercury, iodine, and peroxide of nitrogen. The loudest sounds were obtained from iodine and peroxide of nitrogen.

I have now shown that sounds are produced by the direct action of intermittent sunlight from substances in every physical condition (solid, liquid, and gaseous), and the probability is therefore very greatly increased that sonorousness under such circumstances will be found to be a universal property of matter.

Upon Substitutes for Selenium in Electrical Receivers.

At the time of my communication to the American Association the loudest effects obtained were produced by the use of selenium, arranged in a cell of suitable construction, and placed in a galvanic circuit with a telephone. Upon allowing an intermittent beam of sunlight to fall upon the selenium a musical tone of great intensity was produced from the telephone connected with it.

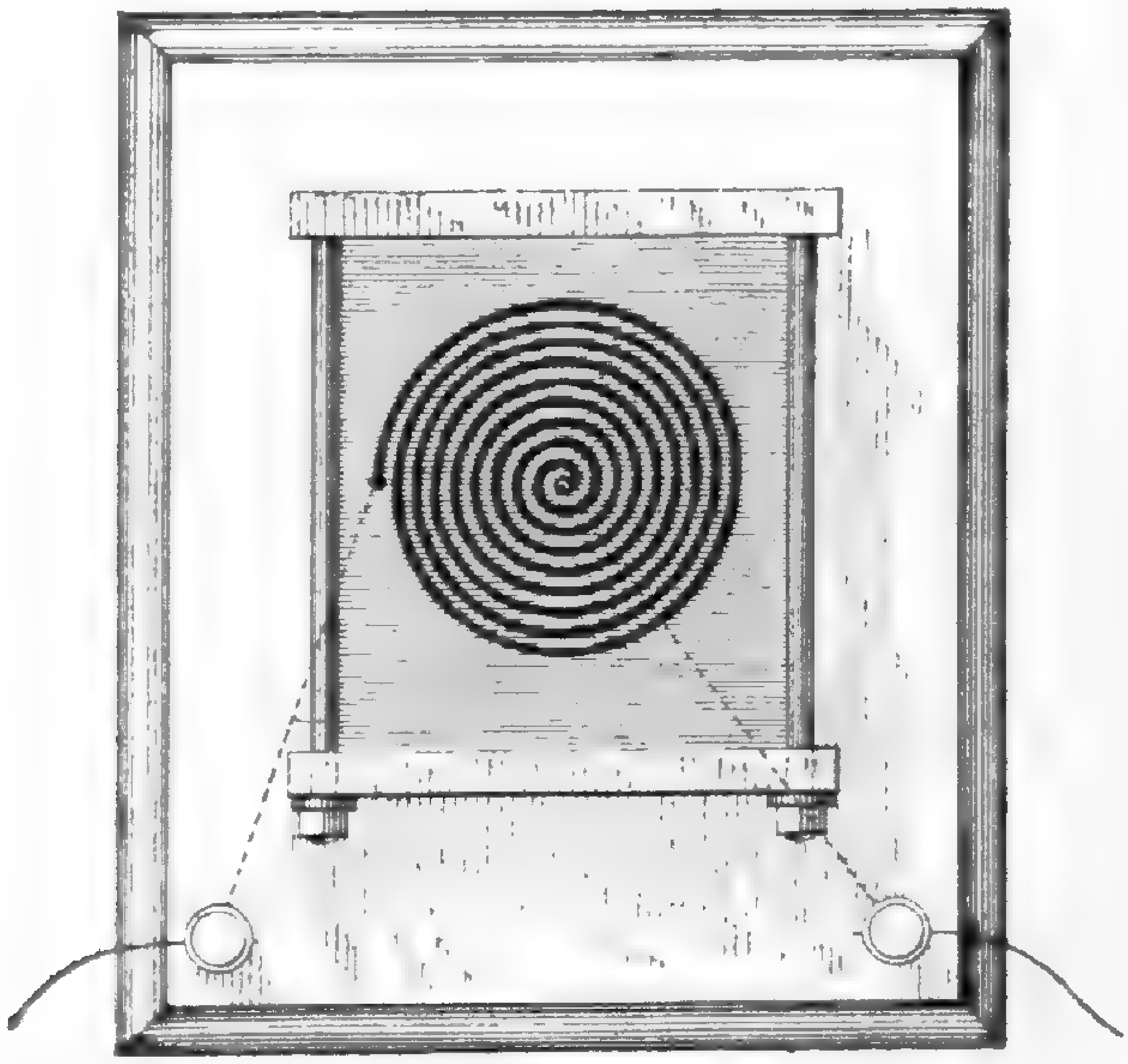
But the selenium was very inconstant in its action. Two pieces of selenium (even of the same stick) seldom yielded the same results under identical circumstances of annealing, etc. While in Europe last autumn, Dr. Chichester Bell, of University College, London, suggested to me that this inconstancy of result might be due to chemical impurities in the selenium used. Dr. Bell has since visited my laboratory in Washington, and has made a chemical examination of the various samples of selenium I had collected from different parts of the world. As I understand it to be his intention to publish the results of this analysis very soon, I shall make no further mention of his investigation than to state that he has found sulphur, iron, lead, and arsenic in the so-called "selenium," with traces of organic matter; that a quantitative examination has revealed the fact that sulphur constitutes nearly one per cent of the whole mass; and that when these impurities are eliminated the selenium appears to be more constant in its action and more sensitive to light.

Professor W. G. Adams‡ has shown that tellurium, like

* Ann. der Phys. und Chem., 1881, No. 1, p. 155.
† Proc. Roy. Soc., vol. xxxi, p. 307.
‡ Proc. Roy. Soc., vol. xxiv, p. 163.

selenium, has its electrical resistance affected by light, and we have attempted to utilize this substance in place of selenium. The arrangement of cell (shown in fig. 7) was constructed for this purpose in the early part of 1880; but we failed at that

Fig. 7.



time to obtain any indications of sensitiveness with a reflecting galvanometer. We have since found, however, that when this tellurium spiral is connected in circuit with a galvanic battery and telephone, and exposed to the action of an intermittent beam of sunlight, a distinct musical tone is produced by the telephone. The audible effect is much increased by placing the tellurium cell with the battery in the primary circuit of an induction coil, and placing the telephone in the secondary circuit.

The enormously high resistance of selenium and the extremely low resistance of tellurium suggested the thought that an alloy of these two substances might possess intermediate electrical properties. We have accordingly mixed together selenium and tellurium in different proportions, and while we do not feel warranted at the present time in making definite statements concerning the results, I may say that such alloys have proved to be sensitive to the action of light.

It occurred to Mr. Tainter before my return to Washington last January that the very great molecular disturbance produced in lamp-black by the action of intermittent sunlight should produce a corresponding disturbance in an electrical current passed through it, in which case lamp-black could be employed in place of selenium in an electrical receiver. This has turned out to be the case, and the importance of the discovery is very great, especially when we consider the expense of such rare substances as selenium and tellurium.

The form of lamp-black cell we have found most effective is shown in fig. 8. Silver is deposited upon a plate of glass, and a zigzag line is then scratched through the film, as shown,

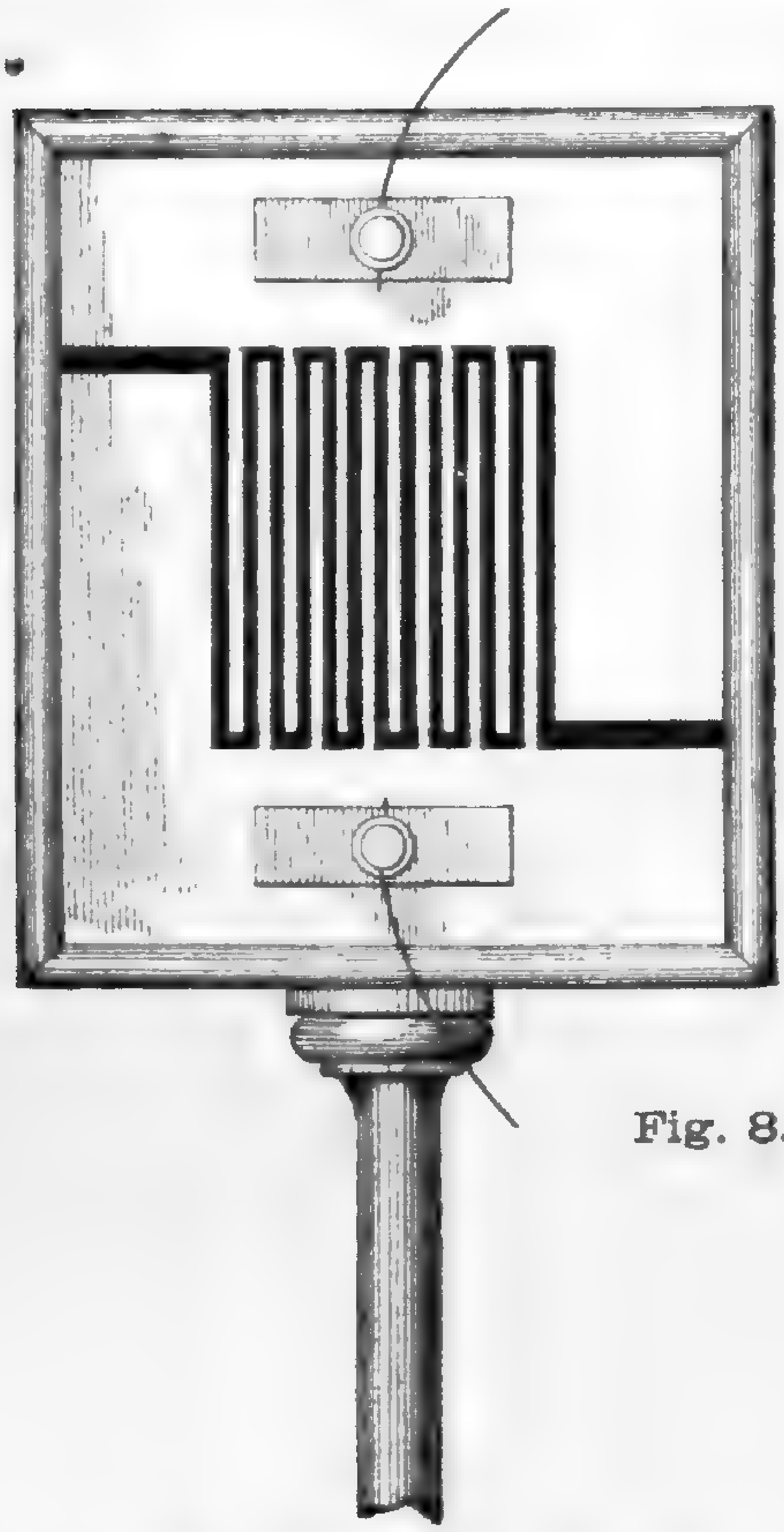


Fig. 8.

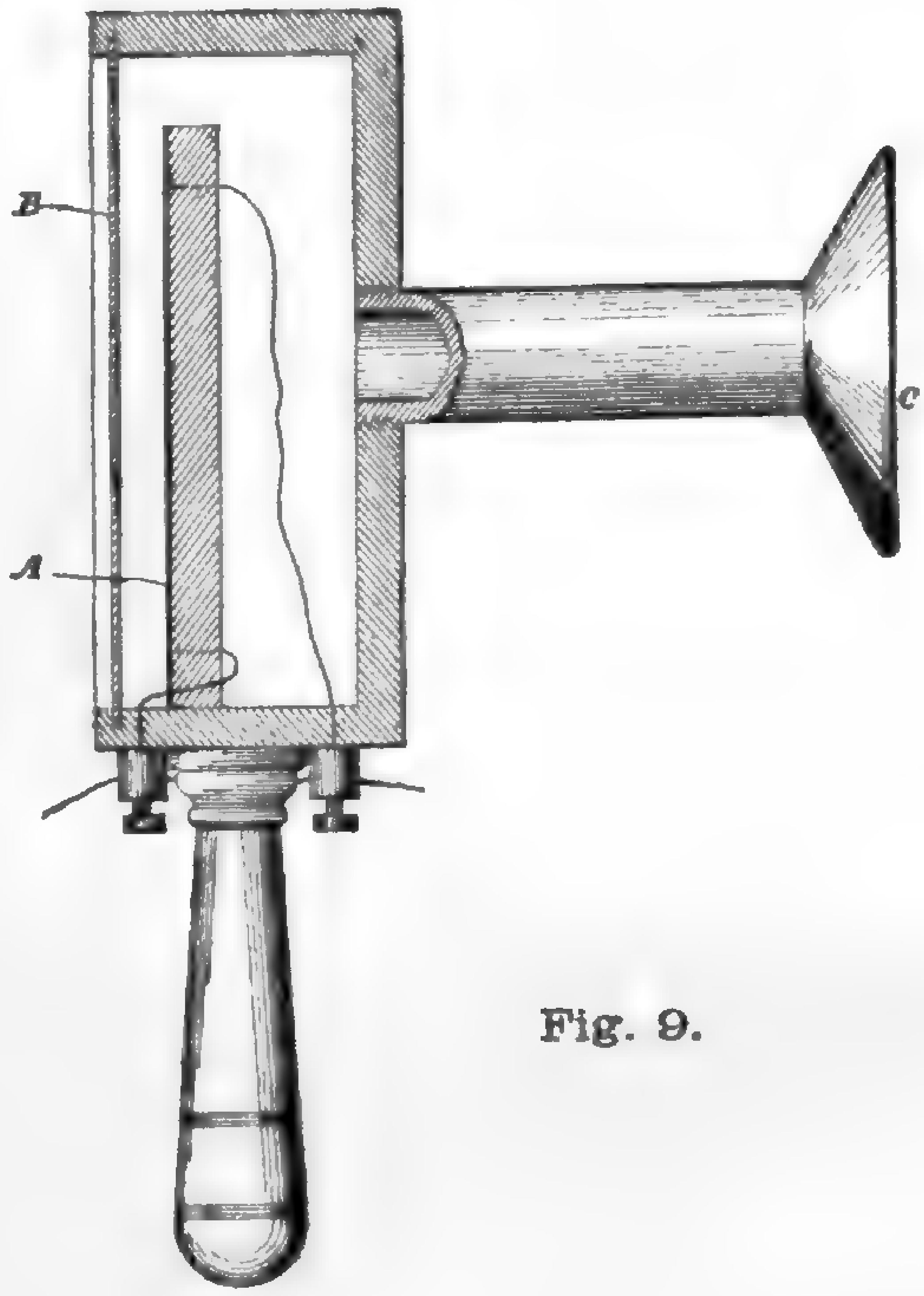


Fig. 9.

dividing the silver surface into two portions insulated from one another, having the form of two combs with interlocking teeth.

Each comb is attached to a screw-cup, so that the cell can be placed in an electrical circuit when required. The surface is then smoked until a good film of lamp-black is obtained, filling the interstices between the teeth of the silver combs. When the lamp-black cell is connected with a telephone and galvanic battery, and exposed to the influence of an intermittent beam of sunlight, a loud musical tone is produced by the telephone. This result seems to be due rather to the physical condition than to the nature of the conducting material employed, as metals in a spongy condition produce similar effects. For instance, when an electrical current is passed through spongy platinum while it is exposed to intermittent sunlight, a distinct musical tone is produced by a telephone in the same circuit. In all such cases the effect is increased by the use of an induction coil; and the sensitive cells can be employed for the reproduction of articulate speech as well as for the production of musical sounds.

We have also found that loud sounds are produced from lamp-black by passing through it an intermittent electrical current; and that it can be used as a telephonic receiver for the reproduction of articulate speech by electrical means.

A convenient mode of arranging a lamp-black cell for experimental purposes is shown in fig. 9. When an intermittent current is passed through the lamp-black (A,) or when an intermittent beam of sunlight falls upon it through the glass plate B, a loud musical tone can be heard by applying the ear to the hearing-tube C. When the light and the electrical current act simultaneously, two musical tones are perceived, which produce beats when nearly of the same pitch. By proper arrangements a complete interference of sound can undoubtedly be produced.

Upon the measurement of the Sonorous Effects produced by different substances.

We have observed that different substances produce sounds of very different intensities under similar circumstances of experiment, and it has appeared to us that very valuable information might be obtained if we could measure the audible effects produced. For this purpose we have constructed several different forms of apparatus for studying the effects, but as our researches are not yet complete, I shall confine myself to a simple description of some of the forms of apparatus we have devised.

When a beam of light is brought to a focus by means of a lens, the beam diverging from the focal point becomes weaker as the distance increases in a calculable degree. Hence, if we can determine the distances from the focal point at which two different substances emit sounds of equal intensity, we can calculate their relative sonorous powers.

Preliminary experiments were made by Mr. Tainter during my absence in Europe to ascertain the distance from the focal point of a lens at which the sound produced by a substance became inaudible. A few of the results obtained will show the enormous differences existing between different substances in this respect.

Mr. Tainter was convinced from these experiments that this field of research promised valuable results, and he at once devised an apparatus for studying the effects, which he described to me upon my return from Europe. The apparatus has since been constructed and I take great pleasure in showing it to you to-day.

Distance from Focal Point of Lens at which Sounds became Inaudible with different substances.

Zinc diaphragm, (polished)		1·51m
Hard rubber diaphragm		1·90
Tin-foil "		2·00
Telephone "	(Japanned iron)	2·15
Zinc "	(unpolished)	2·15
White silk,	(In receiver shown in fig. 1)	3·10
White worsted,	" " " "	4·01
Yellow worsted,	" " " "	4·06
Yellow silk,	" " " "	4·13
White cotton-wool,	" " " "	4·38
Green silk,	" " " "	4·52
Blue worsted,	" " " "	4·69
Purple silk,	" " " "	4·82
Brown silk,	" " " "	5·02
Black silk,	" " " "	5·21
Red silk,	" " " "	5·24
Black worsted,	" " " "	6·50
Lamp-black. In this case the limit of audibility could not be determined on account of want of space. Sound perfectly audible at a distance of		10·00

(1.) A beam of light is received by two similar lenses (A B, fig. 10.) which bring the light to a focus on either side of the interrupting disk (C). The two substances, whose sonorous powers are to be compared, are placed in the receiving vessels (D E) (so arranged as to expose equal surfaces to the action of the beam) which communicate by flexible tubes (F G) of equal length, with the common hearing-tube (H). The receivers (D E) are placed upon slides, which can be moved along the graduated supports (I K). The beams of light passing through the interrupting disk (C) are alternately cut off by the swinging of a pendulum (L). Thus a musical tone is produced alternately from the substance in D and from that in E. One of the receivers is kept at a constant point upon its scale, and the other receiver is moved toward or from the focus of its beam until the ear decides that the sounds produced from D and E are of equal intensity. The relative positions of the receivers are then noted.

(2.) Another method of investigation is based upon the production of an interference of sound, and the apparatus employed is shown in fig. 11. The interrupter consists of a tuning-fork (A), which is kept in continuous vibration by means of an electro-magnet (B).

A powerful beam of light is brought to a focus between the prongs of the tuning-fork (A), and the passage of the beam is more or less obstructed by the vibration of the opaque screens (C D) carried by the prongs of the fork.

Fig. 10.

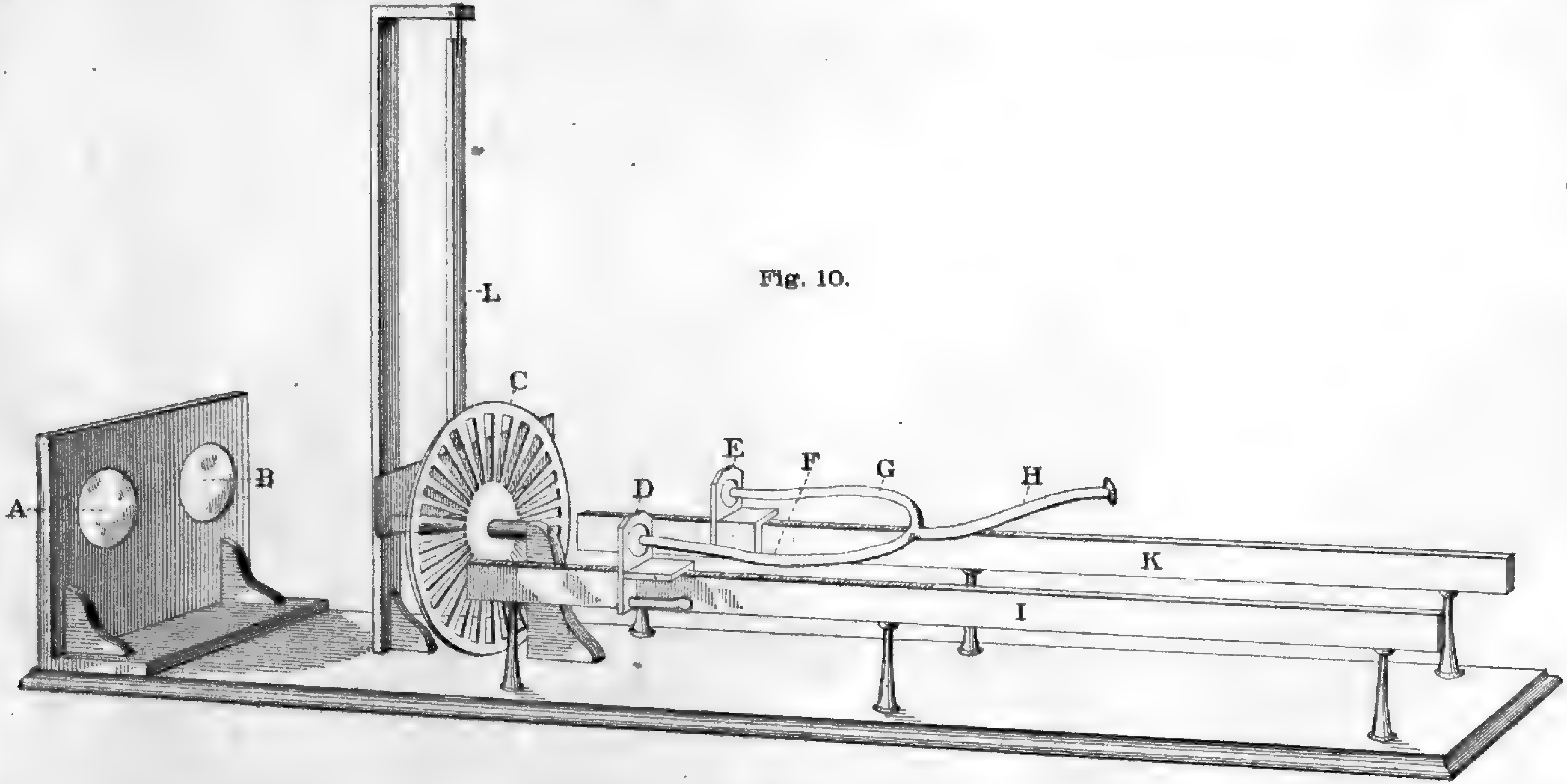


Fig. 11.

As the tuning-fork (A) produces a sound by its own vibration, it is placed at a sufficient distance away to be inaudible through the air, and a system of lenses is employed for the purpose of bringing the undulating beam of light to the receiving lens (E) with as little loss as possible. The two receivers (F G) are attached to slides which move upon the graduated supports (H I) on opposite sides of the axis of the beam, and the receivers are connected by flexible tubes of unequal length (K L) communicating with the common hearing-tube (M).

The length of the tube (K) is such that the sonorous vibrations from the receivers (F G) reach the common hearing-tube (M) in opposite phases. Under these circumstances silence is produced when the vibrations in the receiver (F G) are of equal intensity. When the intensities are unequal, a residual effect is perceived. In operating the instrument the position of the receiver (G) remains constant, and the receiver (F) is moved to or from the focus of the beam until complete silence is produced. The relative positions of the two receivers are then noted.

(3.) Another mode is as follows: The loudness of a musical tone produced by the action of light is compared with the loudness of a tone of similar pitch produced by electrical means. A rheostat introduced into the circuit enables us to measure the amount of resistance required to render the electrical sound equal in intensity to the other.

(4.) If the tuning-fork (A) in fig. 11 is thrown into vibration by an undulatory instead of an intermittent current passed through the electro-magnet, (B,) it is probable that a musical tone, electrically produced in the receiver (F) by the action of the same current, would be found capable of extinguishing the effect produced in the receiver (G) by the action of the undulatory beam of light, in which case it should be possible to establish an acoustic balance between the effects produced by light and electricity by introducing sufficient resistance into the electric circuit.

Upon the nature of the rays that produce Sonorous effects in different substances.

In my paper read before the American Association last August and in the present paper I have used the word "light" in its usual rather than its scientific sense, and I have not hitherto attempted to discriminate the effects produced by the different constituents of ordinary light, the thermal, luminous, and actinic rays. I find, however, that the adoption of the word "photophone" by Mr. Tainter and myself has led to the assumption that we believed the audible effects discovered by us to be due entirely to the action of luminous rays. The meaning we have uniformly attached to the words "photophone" and "light" will be obvious from the following passage, quoted from my Boston paper:

"Although effects are produced as above shown by forms of radiant energy, which are invisible, we have named the apparatus for the production and reproduction of sound in this way the 'photophone' *because an ordinary beam of light contains the rays which are operative.*"

To avoid in future any misunderstandings upon this point we have decided to adopt the term "*radiophone*," proposed by M. Mercadier, as a general term signifying an apparatus for the production of sound by any form of radiant energy, limiting the words *thermophone*, *photophone*, and *actinophone* to apparatus for the production of sound by thermal, luminous or actinic rays respectively.

M. Mercadier, in the course of his researches in radiophony, passed an intermittent beam from an electric lamp through a prism, and then examined the audible effects produced in different parts of the spectrum. (*Comptes Rendus*, Dec. 6th, 1880.)

We have repeated this experiment, using the sun as our source of radiation, and have obtained results somewhat different from those noted by M. Mercadier.

(1.) A beam of sunlight was reflected from a heliostat (A, fig. 12) through an achromatic lens (B), so as to form an image of the sun upon the slit (C).

The beam then passed through another achromatic lens (D) and through a bisulphide of carbon prism (E), forming a spectrum of great intensity, which, when focussed upon a screen, was found to be sufficiently pure to show the principal absorption lines of the solar spectrum.

The disk-interrupter (F) was then turned with sufficient rapidity to produce from five to six hundred interruptions of the light per second, and the spectrum was explored with the receiver (G), which was so arranged that the lamp-black surface exposed was limited by a slit, as shown.

Under these circumstances sounds were obtained in every part of the visible spectrum (excepting the extreme half of the violet), as well as in the ultra-red. A continuous increase in the loudness of the sound was observed upon moving the receiver (G) gradually from the violet into the ultra-red. The point of maximum sound lay very far out in the ultra-red. Beyond this point the sound began to decrease, and then stopped so suddenly that a very slight motion of the receiver (G) made all the difference between almost maximum sound and complete silence.*

* The results obtained in this and subsequent experiments are shown in a tabulated form in fig. 14.

Fig. 12.

(2.) The lamp-blacked wire gauze was then removed and the interior of the receiver (G) was filled with red worsted. Upon exploring the spectrum as before, entirely different results were obtained. The maximum effect was produced in the green at that part where the red worsted appeared to be black. On either side of this point the sound gradually died away, becoming inaudible on the one side in the middle of the indigo, and on the other at a short distance outside the edge of the red.

(3.) Upon substituting green silk for red worsted the limits of audition appeared to be the middle of the blue and a point a short distance out in the ultra-red. Maximum in the red.

(4.) Some hard rubber shavings were now placed in the receiver (G). The limits of inaudibility appeared to be on the one hand the junction of the green and blue, and on the other the outside edge of the red. Maximum in the yellow. Mr. Tainter thought he could hear a little way into the ultra-red, and to his ear the maximum was about the junction of the red and orange.*

(5.) A test-tube containing the vapor of sulphuric ether was then substituted for the receiver (G). Commencing at the violet end, the test-tube was gradually moved down the spectrum and out into the ultra-red without audible effect, but when a certain point far out in the ultra-red was reached a distinct musical tone suddenly made its appearance, which disappeared as suddenly on moving the test-tube a very little further on.

(6.) Upon exploring the spectrum with a test-tube containing the vapor of iodine the limits of audibility appeared to be the middle of the red and the junction of the blue and indigo. Maximum in the green.

(7.) A test-tube containing peroxide of nitrogen was substituted for that containing iodine. Distinct sounds were obtained in all parts of the visible spectrum, but no sounds were observed in the ultra-red. The sounds were well marked in all parts of the violet, and I even fancied that the audible effect extended a little way into the ultra-violet, but of this I cannot be certain. Upon examining the absorption spectrum of peroxide of nitrogen it was at once observed that the maximum sound was produced in that part of the spectrum where the greatest number of absorption lines made their appearance.

(8.) The spectrum was now explored by a selenium cell, and the audible effects were observed by means of a telephone in the same galvanic circuit with the cell. The maximum effect was produced in the red about its junction with the orange. The audible effect extended a little way into the ultra-red on

* In the diagram fig. 14 a mean of these readings is shown.

the one hand and up as high as the middle of the violet on the other.

Although the experiments so far made can only be considered as preliminary to others of a more refined nature, I think we are warranted in concluding that *the nature of the rays that produce sonorous effects in different substances depends upon the nature of the substances that are exposed to the beam, and that the sounds are in every case due to those rays of the spectrum that are absorbed by the body.*

The Spectrophone.

Our experiments upon the range of audibility of different substances in the spectrum have led us to the construction of a new instrument for use in spectrum analysis, which was described and exhibited to the Philosophical Society of Washington last Saturday.* The eye-piece of a spectroscope is removed, and sensitive substances are placed in the focal point of the instrument behind an opaque diaphragm containing a slit. These substances are put in communication with the ear by means of a hearing-tube, and thus the instrument is converted into a veritable "spectrophone," like that shown in fig. 13.

Suppose we smoke the interior of our spectrophonic receiver, and fill the cavity with peroxide of nitrogen gas. We have then a combination that gives us good sounds in all parts of the spectrum (visible and invisible), except the ultra-violet. Now, pass a rapidly-interrupted beam of light through some substance whose absorption spectrum is to be investigated, and bands of sound and silence are observed upon exploring the spectrum, the silent positions corresponding to the absorption bands. Of course, the ear cannot for one moment compete with the eye in the examination of the visible part of the spectrum; but in the invisible part beyond the red, where the eye is useless, the ear is invaluable. In working in this region of the spectrum, lamp-black alone may be used in the spectrophonic receiver. Indeed, the sounds produced by this substance in the ultra-red are so well marked as to constitute our instrument a most reliable and convenient substitute for the thermo-pile. A few experiments that have been made may be interesting.

(1.) The interrupted beam was filtered through a saturated solution of alum.

Result: The range of audibility in the ultra-red was slightly reduced by the absorption of a narrow band of the rays of lowest refrangibility. The sounds in the visible part of the spectrum seemed to be unaffected.

* Proc. of Phil. Soc. of Washington, April 16, 1881.

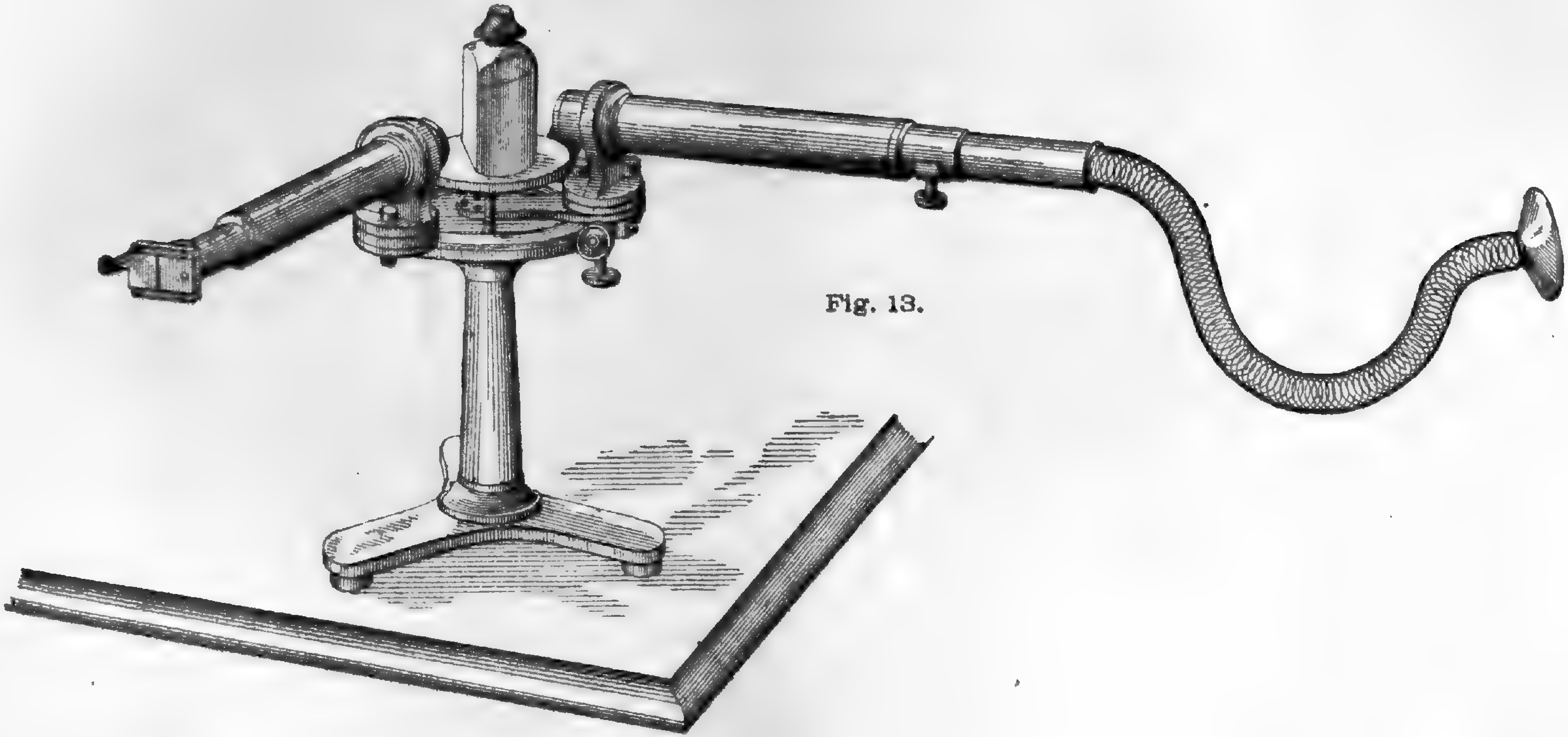
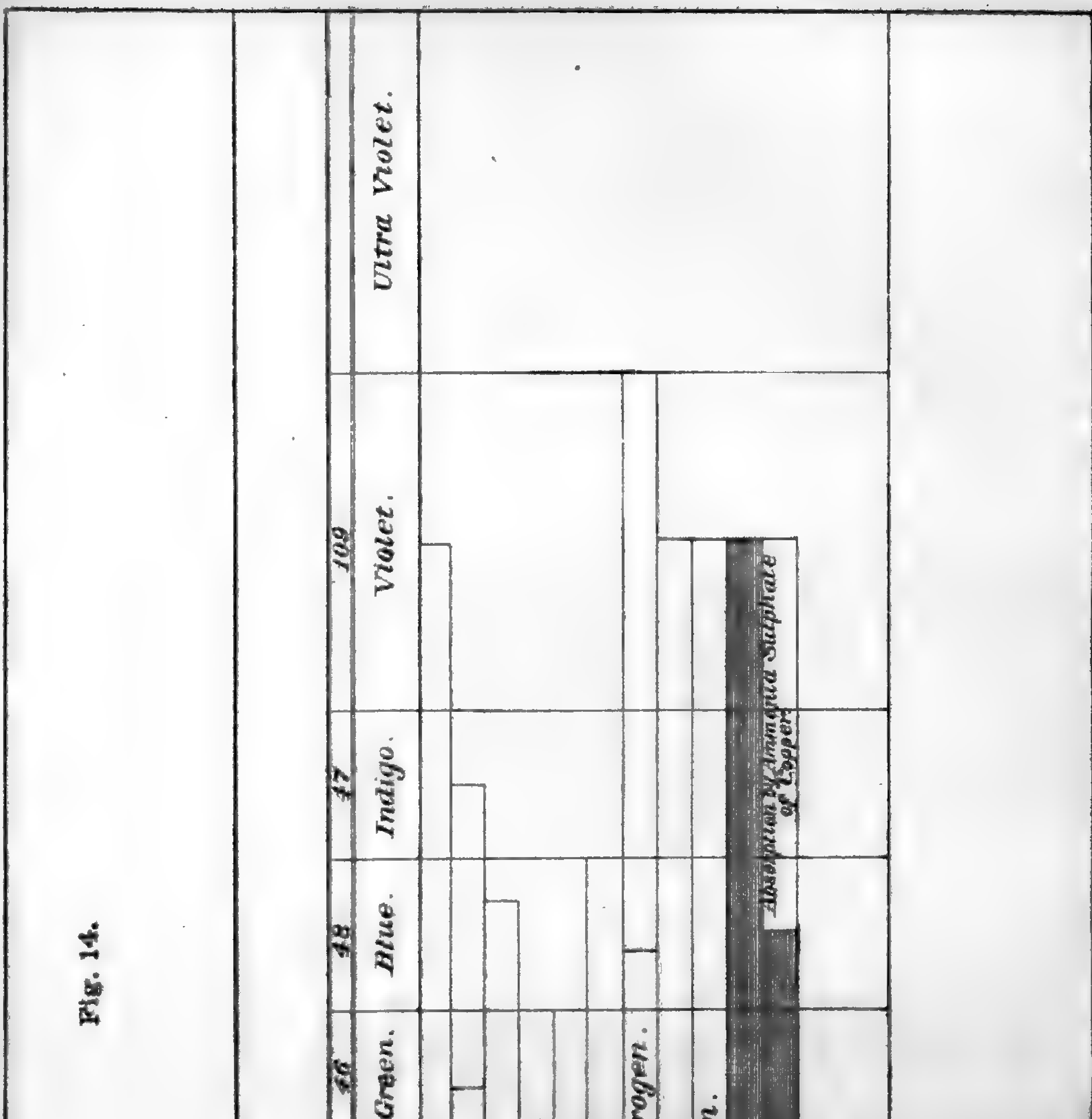


Fig. 13.

Fig. 14.


Ultra Red.
Red.
Orange
Yellow
Green.
Blue.
Indigo.
Violet.
Ultra Violet.
56
27
27
46
48
47
109
Lamp Black
Red Worsted.
Green Silk.
Hard Rubber shavings.
Vapor of Sulphuric Ether.
Iodine vapor.
Peroxide of Nitrogen.
Selenium.
Absorption by Alum.
Absorption by Hard Rubber.

(2.) A thin sheet of hard rubber was interposed in the path of the beam.

Result: Well-marked sounds in every part of the ultra-red. No sounds in the visible part of the spectrum, excepting the extreme half of the red.

These experiments reveal the cause of the curious fact alluded to in my paper read before the American Association last August—that sounds were heard from selenium when the beam was filtered through both hard rubber and alum at the same time. (See table of results in fig. 14).

(3.) A solution of ammonia-sulphate of copper was tried.

Result: When placed in the path of the beam the spectrum disappeared, with the exception of the blue and violet end. To the eye the spectrum was thus reduced to a single broad band of blue-violet light. To the ear, however, the spectrum revealed itself as two bands of sound with a broad space of silence between. The invisible rays transmitted constituted a narrow band just outside the red.

I think I have said enough to convince you of the value of this new method of examination, but I do not wish you to understand that we look upon our results as by any means complete. It is often more interesting to observe the first totterings of a child than to watch the firm tread of a full-grown man, and I feel that *our* first footsteps in this new field of science may have more of interest to you than the fuller results of mature research. This must be my excuse for having dwelt so long upon the details of incomplete experiments.

I recognize the fact that the spectrophone must ever remain a mere adjunct to the spectroscope, but I anticipate that it has a wide and independent field of usefulness in the investigation of absorption spectra in the ultra-red.

ART. LIX.—*The Solar Parallax as derived from the American Photographs of the Transit of Venus*, 1874, *December* 8–9; by D. P. TODD, M.A., Assistant in the Office of the American Ephemeris and Nautical Almanac.

HITHERTO no value of the solar parallax has been derived from the observations of the transit of Venus made at the American stations in 1874.

In the volume of observations recently issued, Part the First, *General Discussion of Results*, are given most of the data which are necessary for the derivation of the solar parallax from (1) the photographs of the transit, (2) the optic observations of the transit. We shall concern ourselves only with the photographic results: these are presented in pages 104–117, in very nearly the form of equations of condition involving the correction of the difference of right ascension of the sun and Venus, the correction of the difference of declination of the sun and Venus, and the correction of the assumed value of the solar parallax. The residual differences, (O.—C.), being given in distance, *s*, and in position-angle, *p*, every photograph furnishes two distinct equations of condition. The total number of photographs is two hundred and thirteen, distributed among the several stations as follows:—

THE NORTHERN STATIONS.	
Wladiwostok	13
Nagasaki	45
Peking	26

THE SOUTHERN STATIONS.	
Kerguelen	8
Hobart Town	37
Campbelltown	32
Queenstown	45
Chatham Island	7

These equations cannot be regarded as definitive: in addition to the corrections for longitude of the stations (provisional values having been adopted in several cases), three small corrections arising from the absorption of the solar and the terrestrial atmospheres have still to be applied, whose general effect on the solar parallax has been considered immediately preceding the equations of condition themselves, pages 102–103. The first and the second effects being supposably small and acting contrariwise on the solar parallax, we may, without very great uncertainty, disregard their combined action. The third correction should be investigated independently from the equations of condition themselves; and this again cannot advantageously be done until the definitive longitudes have been obtained: all the effects of absorption of the solar and the terrestrial atmospheres may then be most opportunely considered.

The Equations of Condition in s.

Putting, then, $\delta\lambda_1$, $\delta\lambda_2$ . . . $\delta\lambda_8$ equal to zero, every photograph gives one equation of condition in s of the form

$$0 = a\,\delta A + b\,\delta D + c\,\delta\varpi - (O.-C.)$$

The normal equations in s are as follow :—

$$\begin{aligned} &+ 23{\cdot}99\,\delta A + 24{\cdot}71\,\delta D - 28{\cdot}72\,\delta\varpi - 82{\cdot}17 = 0\\ &+ 24{\cdot}71\,\delta A + 184{\cdot}46\,\delta D - 3{\cdot}16\,\delta\varpi - 439{\cdot}51 = 0\\ &- 28{\cdot}72\,\delta A - 3{\cdot}16\,\delta D + 484{\cdot}51\,\delta\varpi + 21{\cdot}72 = 0\end{aligned}$$

whose solution gives—

$$\begin{aligned}\delta A &= +\,1''{\cdot}181 \pm 0''{\cdot}202\\ \delta D &= +\,2''{\cdot}225 \pm 0''{\cdot}070\\ \delta\varpi &= +\,0''{\cdot}0397 \pm 0''{\cdot}0418\end{aligned}$$

The probable error of a single photograph is $0''{\cdot}88$.

The sums of the squares of the absolute terms in the equations of condition are as follow :—

$$\begin{aligned}[nn]_W &= 52''{\cdot}48\\ [nn]_N &= 318{\cdot}25\\ [nn]_P &= 130{\cdot}18\end{aligned} \qquad \begin{aligned}[nn]_K &= 37''{\cdot}02\\ [nn]_H &= 115{\cdot}65\\ [nn]_C &= 414{\cdot}46\\ [nn]_Q &= 337{\cdot}63\\ [nn]_{Ch} &= 27{\cdot}83\\ \hline [nn] &= 1433{\cdot}50\end{aligned}$$

The sums of the squares of the outstanding residuals are as follow :—

$$\begin{aligned}[vv]_W &= 7''{\cdot}14\\ [vv]_N &= 52{\cdot}47\\ [vv]_P &= 29{\cdot}28\end{aligned} \qquad \begin{aligned}[vv]_K &= 20''{\cdot}44\\ [vv]_H &= 59{\cdot}74\\ [vv]_C &= 95{\cdot}16\\ [vv]_Q &= 85{\cdot}67\\ [vv]_{Ch} &= 8{\cdot}91\\ \hline [vv] &= 358{\cdot}81\end{aligned}$$

The Equations of Condition in p.

Putting, as before, $\delta\lambda_1$, $\delta\lambda_2$ . . . $\delta\lambda_8$ equal to zero, every photograph gives one equation of condition in p of the form

$$0 = a'\,\delta A + b'\,\delta D + c'\,\delta\varpi - (O.'-C.')$$

The normal equations in p are as follow :—

$$\begin{aligned} &+ 8682117\,\delta A - 1404261\,\delta D - 138999{\cdot}20\,\delta\varpi - 142109{\cdot}4 = 0\\ &- 1404261\,\delta A + 1521370\,\delta D - 25093{\cdot}11\,\delta\varpi + 10442{\cdot}1 = 0\\ &- 138999{\cdot}20\,\delta A - 25093{\cdot}11\,\delta D + 7326{\cdot}76\,\delta\varpi + 2651{\cdot}6 = 0\end{aligned}$$

whose solution gives—

$$\begin{aligned}\delta A &= +\,1''{\cdot}109 \pm 0''{\cdot}109\\ \delta D &= +\,0''{\cdot}637 \pm 0''{\cdot}224\\ \delta\varpi &= +\,0''{\cdot}0252 \pm 0''{\cdot}0595\end{aligned}$$

The probable error of a single photograph is $3'{\cdot}447$.

The sums of the squares of the absolute terms in the equations of condition are as follow:—

$$[nn]_W = 358'\cdot65 \qquad [nn]_K = 381'\cdot20$$
$$[nn]_N = 1271\cdot49 \qquad [nn]_H = 1924\cdot85$$
$$[nn]_P = 269\cdot08 \qquad [nn]_C = 2044\cdot68$$
$$[nn]_Q = 1462\cdot97$$
$$[nn]_{Ch} = 220\cdot70$$
$$[nn] = 7933\cdot62$$

The sums of the squares of the outstanding residuals are as follow:—

$$[vv]_W = 323'\cdot65 \qquad [vv]_K = 174'\cdot34$$
$$[vv]_N = 972\cdot02 \qquad [vv]_H = 840\cdot69$$
$$[vv]_P = 519\cdot77 \qquad [vv]_C = 1236\cdot90$$
$$[vv]_Q = 1232\cdot09$$
$$[vv]_{Ch} = 176\cdot04$$
$$[vv] = 5475\cdot50$$

Final Values of δA, δD, $\delta\varpi$.

It seems likely that some of the probable errors of these quantities which have been derived are illusory. The best course, however, which we can now pursue will be to combine the values of δA, δD, and $\delta\varpi$ obtained from the two solutions in accordance with the weights depending upon these probable errors.

We thus have, for δA,

From solution in s, $\delta A = +\ 1''\cdot181 \pm 0''\cdot202$
From solution in p, $\delta A = +\ 1''\cdot109 \pm 0''\cdot109$
Final value, $\delta A = +\ 0^s\cdot075 \pm 0^s\cdot006$

And for δD,

From solution in s. $\delta D = +\ 2''\cdot225 \pm 0''\cdot070$
From solution in p, $\delta D = +\ 0''\cdot637 \pm 0''\cdot224$
Final value, $\delta D = +\ 2''\cdot083 \pm 0''\cdot067$

And for $\delta\varpi$,

From solution in s, $\delta\varpi = +\ 0''\cdot0397 \pm 0''\cdot0418$
From solution in p, $\delta\varpi = +\ 0''\cdot0252 \pm 0''\cdot0595$
Final value, $\delta\varpi = +\ 0''\cdot035 \pm 0''\cdot034$

The assumed value of ϖ being $8''\cdot848$, we have, finally, for the mean equatorial horizontal parallax of the sun,

$$8''\cdot883 \pm 0''\cdot034$$

corresponding (if we adopt the dimensions of the earth given by Colonel A. R. Clarke*) to a distance between the centres of the sun and earth equal to

148,103,000 kilometers = 92,028,000 miles.

Washington, April 27, 1881.

* Geodesy . . . Oxford, Clarendon Press, 1880, page 319.

Art. LX.—*On some remarkable Fossil Fishes from the Devonian Rocks of Scaumenac Bay, in the Province of Quebec;* by J. F. Whiteaves.

Immediately after my paper on the Canadian *Pterichthys** was written, Mr. A. H. Foord, of the Geological Survey of Canada, went down to the Baie des Chaleurs and spent two months and a half of the summer of 1880 in a careful and systematic examination of the fish-bearing beds of the Devonian rocks of the north bank of the mouth of the Restigouche River. The exact locality at which the *Pterichthys Canadensis* was found is not the Baie des Chaleurs proper but Scaumenac (sometimes written Escuminac) Bay, Restigouche Harbor, in the County of Bonaventure. On the shores of this bay a series of shales, sandstones and conglomerates, now known to be of Devonian age, are overlaid, apparently unconformably, by the red sandstones and conglomerates of the "Bonaventure Formation."

From these Devonian rocks Mr. Foord succeeded in obtaining a large and interesting collection of fossil fishes. Fully four-fifths of the entire number of specimens in this collection are referable to the genus *Pterichthys*, which, at this locality, seems to be represented by only one species, the *P. Canadensis*. Some of these are nearly perfect and want only the fins proper and the tail, while others are mere isolated plates or detached portions of the pectoral spines. One of the specimens shows that the Canadian *Pterichthys* had two labial appendages or barbels attached to the front margin of the head. These barbels are almost exactly similar in shape to those indicated by dotted lines in the ideal representation of the genus *Pterichthys* on Plate VI of the "Monographie des Poissons Fossiles du Vieux Grès Rouge," which Agassiz claims to have seen in his *P. latus*, but in *P. Canadensis* the barbels are very close together at their bases. In two other specimens of a *Pterichthys* collected by Mr. Foord, two remarkable, flattened conical, dermal processes are plainly visible on the helmet, one on each side of the orbital cavity. Posteriorly each process appears to fit into the angle formed by the junction of the prelateral with the nuchal and post-lateral plates, while anteriorly they are each directed obliquely outward and forward across the prelaterals, which they partly cover. In one of the specimens the dermal processes, which are ornamented with a sculpture precisely similar to that of all the other plates, are half an inch long and two lines and a half broad near their base. They taper gradually from their base to an obtuse point and are pressed close to the surface of the helmet.

In addition to these remains of *Pterichthys*, there are examples of eight or nine species of fossil fishes in Mr. Foord's collection, which belong to at least seven genera. The following is a brief description of the most striking characters of six of these species,

* On a new species of *Pterichthys*, allied to *Bothriolepis ornata* Eichwald, etc., this Journal, xx, 132, August, 1880.

the affinities of the remainder not having yet been satisfactorily ascertained :

Diplacanthus.

Two specimens, one showing scales and longitudinally grooved fin spines and the other a large portion of the body, of a small, smooth-scaled *Diplacanthus*, very like the *D. striatus* of Agassiz and possibly identical with that species.

Phaneropleuron curtum, sp. nov.

Four crushed and distorted but nearly perfect examples and several fragments of a new species of *Phaneropleuron*, which differs from the *P. Andersoni* of Huxley, from the Old Red Sandstone of Dura Den, in its smaller size and in its much greater height or depth as compared with its length. *P. Andersoni* is represented as being about five and a half times as long as high, whereas in the largest specimen of *P. curtum* yet collected, which is six inches long, the length is not much more than twice the height.

Eusthenopteron Foordi, nov. gen. et sp.

The name *Eusthenopteron** is proposed for a supposed new genus which resembles the *Tristichopterus* of Sir Philip Egerton in the shape and ornamentation of its scales and cranial plates, in the circumstance that the fin rays of its anal and second dorsal fins are both supported by three osselets articulated to a broad interspinous apophysis, and in some other important particulars. But the vertebral centers of *Tristichopterus* are said to be ossified, and the osselets which support the rays of the lower lobe of the tail are described as "springing from eight or nine interspinous bones," whereas in *Eusthenopteron* the vertebral centers are not ossified and the caudal osselets are articulated to the modified hœmal spines. In *Eusthenoptheron*, too, the osselets and interspinous bones of the anal and second dorsal are larger than those of *Tristichopterus*, and different also in their shape and relative proportions.

The species, which is named after its discoverer, Mr. A. H. Foord, may be recognized by its large size (it appears to have attained to a length of two feet or more) and by its narrowly elongated and acutely pointed first dorsal fin.

Glyptolepis microlepidotus Agassiz.

A single, nearly perfect specimen of a small-scaled *Glyptolepis* which cannot at present be distinguished from the above named European species.

Glyptolepis ——.

A second species of *Glyptolepis*, apparently allied to the *G. leptopterus* of Agassiz, is indicated by a number of large detached scales, nearly an inch in diameter, which are associated with slender rib-bones, an operculum and a fragment of a jaw with teeth, on the same small slabs of shale.

* From εὐ-σθενης, stout, and πτερον, a fin.

Cheirolepis Canadensis, nov. sp.

Four exquisitely preserved specimens, two of which are nearly perfect, of a large *Cheirolepis* which resembles the *C. macrocephalus* of McCoy and the *C. Cumingiæ* of Agassiz in the size, contour and sculpture of the scales of the body and fins, but which seems to differ from both in the relative position of its fins. In *C. Canadensis* the ventrals are separated from the pectorals by a short interval and from the anal by a much longer one. In *C. macrocephalus*, on the other hand, the ventrals are represented by McCoy as being nearer to the anal than they are to the pectorals, while in *C. Cumingiæ*, according to Hugh Miller, "the large pectorals almost encroach on the ventrals and the ventrals on the anal fin."

A more detailed description of these species will be found in the current number of the "Canadian Naturalist."*

The existence of fossil plants as well as of fish remains in the Devonian shales and sandstones of Scaumenac Bay was noticed by Dr. Abraham Gesner in 1842, and from these rocks Mr. Foord also obtained four species of ferns, which have recently been reported on by Principal Dawson.

The analogies between the fossil fauna of the fish-bearing beds of Scaumenac Bay and that of the Old Red Sandstone of Scotland and Russia are very striking. The *Pterichthys Canadensis* is still doubtfully distinct from the *Bothriolepis ornata* of Europe; the fragments of a *Diplacanthus* obtained by Mr. Foord have apparently much the same characters as the *D. striatus* of Agassiz, and the genus *Phaneropleuron* can now be shown to occur in the Devonian rocks of Canada as well as in those of Scotland. *Eusthenopteron* has many features in common with *Tristichopterus*; one species of *Glyptolepis* from Scaumenac Bay seems to be identical with the *G. microlepidotus* of Agassiz, from Lethen Bar, while the other bears a general resemblance to the *G. leptopterus* of the same author; and lastly, *Cheirolepis Canadensis* is certainly very closely allied to two Scotch species.

These Devonian rocks at Scaumenac may have been of freshwater or estuarine origin, for no traces of any marine invertebrata have yet been detected in any of them and the fossil fishes which they contain are invariably found associated with land plants.

Montreal, April 7th, 1881.

Art. LXI.—*On the Rain-Fall in Wallingford, Connecticut, between* 1856 *and* 1881; Record kept by B. F. Harrison.

The following table gives the amount in inches of rain and melted snow for each month of each year. The depth of snow in the winter months is also given. The record extends from April, 1856 to December, 1880, inclusive, with, however, the exception

* Vol. x, new series.

of the five closing months of 1862, and the years 1863, 1864. At the close the means for each month are given, and also the final average for the whole period over which the observations extend.

	1856.		1857.		1858.		1859.		1860.		1861.	
	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.
January	----	----	4·39	27·70	3·13	4·00	6·94	31·00	2·38	11·60	4·07	20·00
Febru'y	----	----	2·08	2·75	1·92	5·00	4·24	13·00	3·13	17·50	2·90	----
March	----	----	2·47	10·00	1·57	13·50	8·45	6·00	2·62	·50	5·02	27·00
April	4·10	----	7·11	----	3·87	----	3·76	----	2·11	·50	5·83	9·00
May	6·85	----	7·76	----	2·62	----	4·73	----	4·04	----	5·67	----
June	3·07	----	3·23	----	5·08	----	6·25	----	1·90	----	3·68	----
July	2·93	----	8·29	----	3·26	----	2·58	----	2·72	----	2·85	----
August	11·68	----	5·62	----	4·02	----	6·12	----	5·53	----	5·66	----
Septem.	3·22	----	3·17	----	5·18	----	5·63	----	3·38	----	4·61	----
October	1·98	----	5·88	----	3·29	----	1·91	----	3·10	----	2·40	----
Novem.	2·67	2·50	2·06	----	3·23	13·00	2·49	----	6·37	----	4·47	4·00
Decem'r	6·61	12·50	5·79	5·90	4·47	3·00	4·01	5·50	4·97	10·50	1·77	----
Total	43·11	15·00	57·85	46·35	41·64	38·50	57.11	55·50	42·25	40·60	48·93	60·00

	1862.		1865.		1866.		1867.		1868.		1869.	
January	5·71	16·00	4·92	11·50	1·71	14·50	2·42	26·00	4·55	27·00	3·05	5·00
Febru'y	3·01	19·00	4·60	2·00	6·48	5·00	2·64	20·00	1·69	12·00	5·22	13·00
March	4·30	4·00	6·31	----	3·41	3·00	4·08	16·00	2·66	15·00	7·02	13·00
April	1·93	----	3·26	----	2·89	----	2·76	----	5·58	15·00	2·16	----
May	2·93	----	7·26	----	5·80	----	6·31	----	7·79	----	6·36	----
June	7·60	----	4·89	----	4·31	----	5·40	----	3·67	----	3·23	----
July	5·28	----	6·84	----	3·28	----	2·45	----	2·44	----	2·98	----
August	----	----	1·57	----	4·21	----	10·53	----	7·27	----	1·95	----
Septem.	----	----	1·38	----	6·17	----	2·59	----	8·40	----	3·27	----
October	----	----	4·33	----	3·35	----	5·91	----	·93	----	13·29	----
Novem.	----	----	3·15	----	4·96	----	3·50	6·00	4·31	----	3·58	2·00
Decem'r	----	----	4·01	10·00	4·38	10·50	2·70	13·00	2·47	12·00	6·35	15·00
Total	30·76	39·00	52·52	23·50	50·95	33·00	51·29	81·00	51·76	81·00	58·46	48·00

	1870.		1871.		1872.		1873.		1874.		1875.	
January	6·38	6·00	3·88	24·00	1·47	2·00	6·71	17·00	6·51	17·00	2·90	11·00
Febru'y	5·19	16·00	3·99	22·00	2·99	12·50	3·52	13·00	3·88	26·00	5·18	8·50
March	5·60	19·00	6·54	---	4·16	7·00	2·50	2·00	1·53	6·00	5·48	29·50
April	6·21	----	3·84	4·00	1·72	1·00	3·28	1,00	7·88	7·00	3·74	18·50
May	1·39	----	4·37	----	3·60	----	5·42	----	3·78	----	2·12	----
June	3·12	----	6·27	----	4·23	----	·38	----	1·93	----	3·37	----
July	2·96	----	2·03	----	5·02	----	2·17	----	4·54	----	3·21	----
August	2·11	----	7·04	----	6·96	----	9·93	----	7·13	----	4·88	----
Septem.	1·40	----	2·02	----	4·31	----	2·16	----	3·29	----	2·10	----
October	5·37	----	5·55	----	2·70	----	5·03	----	1·20	----	3·32	----
Novem.	3·43	----	4·62	·50	5·38	10·50	4·36	4·00	3·12	·50	5·72	----
Decem'r	2·19	7·00	3·23	13·50	3·66	33·50	4·84	20·00	2·32	10·00	1·37	3·50
Total	45·35	48·00	53·38	64·00	46·20	66·50	50·30	57·00	47·11	66·50	43·39	71·00

	1876.		1877.		1878.		1879.		1880.	
January	1·36	3·00	3·47	18·00	5·83	5·50	2·64	20·50	4·02	5·00
Febru'y	5·26	13·00	1·50	2·50	5.71	9·00	3·88	11·50	3·79	8·50
March	10·90	5·00	8·30	5·00	2·95	----	4·93	10·50	3·63	10·00
April	4·98	----	2·35	----	4·73	----	5·80	----	4·59	----
May	3·61	----	1·07	----	3·44	----	2·32	----	1·16	----
June	1·40	----	6·59	----	3·97	----	3·90	----	2·04	----
July	10·01	----	2·35	----	3·40	----	8·99	----	5·38	----
August	1·69	----	4·63	----	3·96	----	8·04	----	4·62	----
Septem.	5·00	----	·65	----	4·87	----	1·80	----	3·86	----
October	1·43	1·00	8·34	----	2·73	----	1·30	----	3·89	----
Novem.	4·37	1·50	6·81	----	5·87	·50	2·00	1·50	2·87	1·00
Decem'r	4·19	24·50	1·76	----	7·06	7·00	4·19	7·50	3·00	16·50
Total	54·20	48·00	47·82	25·50	54·52	22·00	49·79	51·50	42·85	41·00

Final Averages.

	Total rain-fall for each month.	Monthly Average.	Total fall of snow for each month.	Monthly Average.
January	88·44	4·020	307·30	14·66
February	82·40	3.745	232·75	11·08
March	95·03	4·318	134·50	6·41
April	94·46	4·107	56·00	2·66
May	100·40	4·365	----	----
June	92·51	4·020	----	----
July	85·96	3·739	----	----
August	126·15	5·734	----	----
September	78·46	3·566	----	----
October	87·22	3·963	1·00	·05
November	89·44	4·065	34·50	·16
December	85·34	3·880	228·40	10·87

Total rain-fall for 22 years and 4 months	1,105·81 inches.
Average annual rain-fall (including melted snow)	49·52
Total fall of snow	994·45
Average annual fall of snow	45·89

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Direct Synthesis of Ammonia.*—While passing nitrogen gas over freshly hydrogenized copper at a red heat, Johnson observed the formation of traces of ammonia. He therefore repeated his experiments and passed a mixture of pure nitrogen—evolved from ammonium nitrite—and hydrogen over spongy platinum at a low red heat. The hydrogen was produced first and then passed through silver nitrate and oil of vitriol, over pumice moistened with sulphuric acid, through Nessler's reagent and then over the spongy platinum. After the platinum had been heated to redness in the hydrogen and the absence of ammonia proved, the nitrogen was evolved and passed through the purify-

ing and drying apparatus with the hydrogen. When the mixture reached the hot platinum, ammonia was produced, the Nessler test became brown, the well known odor was perceived, red litmus was turned blue and white fumes were produced with hydrochloric acid. Quantitative experiments showed the production of 5·9 mgrms. NH_3 per hour in this apparatus. This result having been objected to on the ground that the vapor of some salt of ammonia might be carried by the rapid stream of gas through the solutions and be dissociated in the hot platinum, the author has made further experiments on the question. Hydrogen was passed through the apparatus till free from ammonia, and after the platinum was cold, nitrogen was passed through for the purpose of displacing the hydrogen; so that on subsequent heating in pure nitrogen the ammonia salt if present might be dissociated and yield its ammonia. But on admitting the nitrogen to the cold platinum, ammonia was produced, 24 mgrms. in an hour. The experiment was then repeated with nitrogen obtained by passing air over heated copper; but no ammonia appeared. Nor was any produced when the nitrogen prepared from the nitrite was previously passed over heated copper. Two hypotheses suggested themselves: either the heat rendered the nitrogen inactive, or some nitrogen oxide, which was present and yielded the ammonia, was removed by the hot copper. On examination it appeared that the nitrogen prepared from ammonium nitrite always contains some nitric oxide. To remove this, the nitrogen was passed through ferrous sulphate; and to test its purity it was then passed through a tared tube containing freshly-reduced copper heated to redness, the tube being weighed every hour. When the gas passed over a sufficient length of the ferrous sulphate solution, no increase in weight was observed in the copper tube. The nitrogen being now free from oxides, was used with hydrogen as before; and with cold spongy platinum, 3 mgrms. of ammonia was produced in an hour. But when the mixture of gases was passed over heated asbestus before reaching the platinum, though traces of ammonia were produced in the asbestus, none whatever appeared in the platinum until the asbestus tube had so far cooled as to be handled. Hence, it appears that the formation of ammonia is arrested by passing the nitrogen through a red-hot tube; and the author thinks this evidence strong that nitrogen, like phosphorus, exists in an active and an inactive state, the latter produced by heat.—*J. Chem. Soc.*, xxxix, 128, 130, March, 1881. G. F. B.

2. *On Blood-crystals and their Coloring Matter.*—STRUVE has observed that freshly prepared blood-crystals, after being rendered insoluble by the action of alcohol, their form remaining unchanged, may be completely decolorized by treatment with alcoholic ammonia. Glacial acetic acid causes them to swell, and extracts the color. When it evaporates they shrink, becoming irregular in form, but reassume their original size and shape on adding more acid. Concentrated sulphuric acid acts similarly on

the crystals but decomposes the coloring matter, removing the iron, and producing hematoporphyrin having a distinct absorption spectrum. The author therefore concludes that the blood crystals are really crystals of globulin mechanically mixed with the coloring matter, a view originally held by Reichert in 1847.—*Ber. Berl. Chem. Ges.*, xiv, 930, Apr., 1881. G. F. B.

3. *On the Absorption Spectra of Colorless Liquids.*—RUSSELL and LAPRAIK have repeated and extended their observations of last summer on the absorption bands in the spectra of liquids ordinarily considered colorless. The spectra were in all cases observed with the eye, the spectroscope used being made by Desaga and having a single prism of heavy glass. The sources of light were a large Argand gas burner and the lime cylinder. Before reaching the slit, the light traversed a column of the liquid from 2 to 8 feet long. A plate is given showing the bands in the spectra of thirty-four liquids. Water, in a tube 6 feet in length gives a distinct absorption band between the 600 and 610 divisions of the scale, these divisions corresponding to millionths of a millimeter. It is darker on the more refrangible side and ends sharply, fading off gradually on the other side. The general absorption extends to about 665 in the red, and there appears to be a second band at 705–723. These bands are unaffected by temperature and also by salts in solution. Ordinary alcohol (in which absorption bands were first recognized) gives a band at 630. Methyl, propyl and amyl alcohols also give bands, the band being nearer the red the higher the alcohol in the series. The saline ethers show a band slightly nearer the blue end. Ethyl iodide gives a second band from 716 to 724. Amyl nitrate, acetate and iodide give bands like that of amyl alcohol, but a trifle nearer the blue. Amylene gives a band coincident with that of the saline ethers. The existence of the same band in all these amyl compounds shows its independence of the acid radical. Chloroform shows a faint band from 607 to 616, and a dark and sharp one from 711 to 717. Ethyl oxide gives the characteristic ethyl bands. Aldehyde and acetic acid show a large absorption at the red and a faint band, that of the latter body being the more refrangible. Benzene, in an 8-feet column, shows two bands, one from 606 to 616 and the other from 703 to 714, both remarkably sharp and dark. Methyl-benzene (toluene) shows the same bands but the former has become fainter while the latter is as dark as before. Xylene shows the same process continued farther. Mono- and di-chlorbenzene, the latter dissolved in ether, give the same bands, but the 606 band is fainter than in benzene. Napthalene fused gave three bands, two agreeing exactly with the benzene bands and the third with the general absorption of this body. Two feet of naphthalene produced as much absorption as six or eight times as much benzene; and benzene in its turn is more powerful as an absorber than either toluene or xylene. Phenol gives two bands, one agreeing nearly with the water band, the other from 679 to 710. Ammonia in aqueous solution shows five bands; the darkest is from 649 to 654;

two others coincide nearly, the one with the water, the other with the alcohol band; another narrow and sharp from 566 to 570; and a fifth from 698 to 708, clouded by the general absorption. In alcohol and ether changes were visible due probably to the less solubility of ammonia in these menstrua. Methylamine shows a fading out of the more refrangible bands and a strengthening of the 649 band. Ethylamine, di-ethylamine and triethylamine showed the effect of progressively replacing hydrogen by the alcohol radical. Aniline, toluidine and dimethylaniline, and also turpentine were examined. The only liquids which did not show bands were carbon disulphide and tetrachloride.—*J. Chem. Soc.*, xxxix, 168, April, 1881. G. F. B.

4. *On the supposed "Polarization of Sound."*—Professor S. W. Robinson has recently described a series of experiments intended to show the effect upon a sound wave of repeated reflections from a membranous medium placed at a given angle to the line of propagation. An L-shaped tube, one inch in diameter and three inches in length, was constructed of tin, the two branches meeting at an obtuse angle. The convex portion of the joint was replaced by a membrane gummed to the tube. This membrane was so placed that the normal to it made with the axes of the inclined branches of the tube angles each equal to the polarizing angle of incidence; this angle was so taken, after the methods of optics, that its tangent was equal to the ratio of velocities of propagation for the gas within (coal gas, $v=1420$), and that without (air, $v=1125$). A series of these L-tubes were connected together, and so arranged that the membranes were either all parallel, or, by a turn of half the system in a central joint, the two parts ("analyzer" and "polarizer") could be made perpendicular to each other. The openings at the two extremities were closed by membranes at right angles to the tubes. It was now expected that the sound impulse received at one extremity would be propagated through the tube, and at each of the joints covered with membranes there would be both reflection onward and refraction into the outside medium, and this would be shown by the effect at the other end. In the experiments the tube was filled by coal gas coming in near one end and having an exit, by a jet, at the other, where it was ignited; this was adopted to insure a constant pressure. No clear effect was observed when a simple sound was made before the first membrane, and hence an impulse, analogous to a simple sound wave, was obtained by the blow of a small ivory ball on the first membrane. This was suspended by a thread in front of the membrane, and was so arranged that it could be dropped through a given height against it; a second ball of glass, similarly suspended, rested lightly against the other terminal membrane, and the distance to which it was thrown by the impulse propagated through the tube was noted by a scale. The first ball was dropped several times at intervals of ten seconds, and each corresponding deflection of the other ball noted; then one half of the system was turned 90° in the central joint, as

above described, and the effect again noted; then a further turn of 90° was made, and so on. Several series of experiments were carried on: in one series of eighty trials the mean deflection when the membranes of the two halves of the tube were parallel was 6·47, and when perpendicular to each other 5·43, a diminution of intensity corresponding to 16·1 per cent; in another series the results were 1·68 and 1·04, corresponding to a diminution of 38·1 per cent. When the tubes were filled with air no deflection was observed.

The author concludes that by the repeated reflections from the surfaces of the membranes separating the coal gas and air a diminution in intensity is produced according to the relative positions of the membranes, analogous to the effects produced in the case of light by repeated reflections from a series of glass plates. From this he concludes that sound vibrations undergo true polarization also. In regard to this it may be said that while the method of experiment is ingenious and the results possess considerable interest, the subject seems to demand further experiment before conclusions can be safely drawn. The individual trials, while not agreeing very closely, certainly point to a marked difference between the parallel and perpendicular positions of the two sets of reflecting surfaces, but it seems probable that this may be explained by some peculiarity in the mechanical construction of the apparatus.

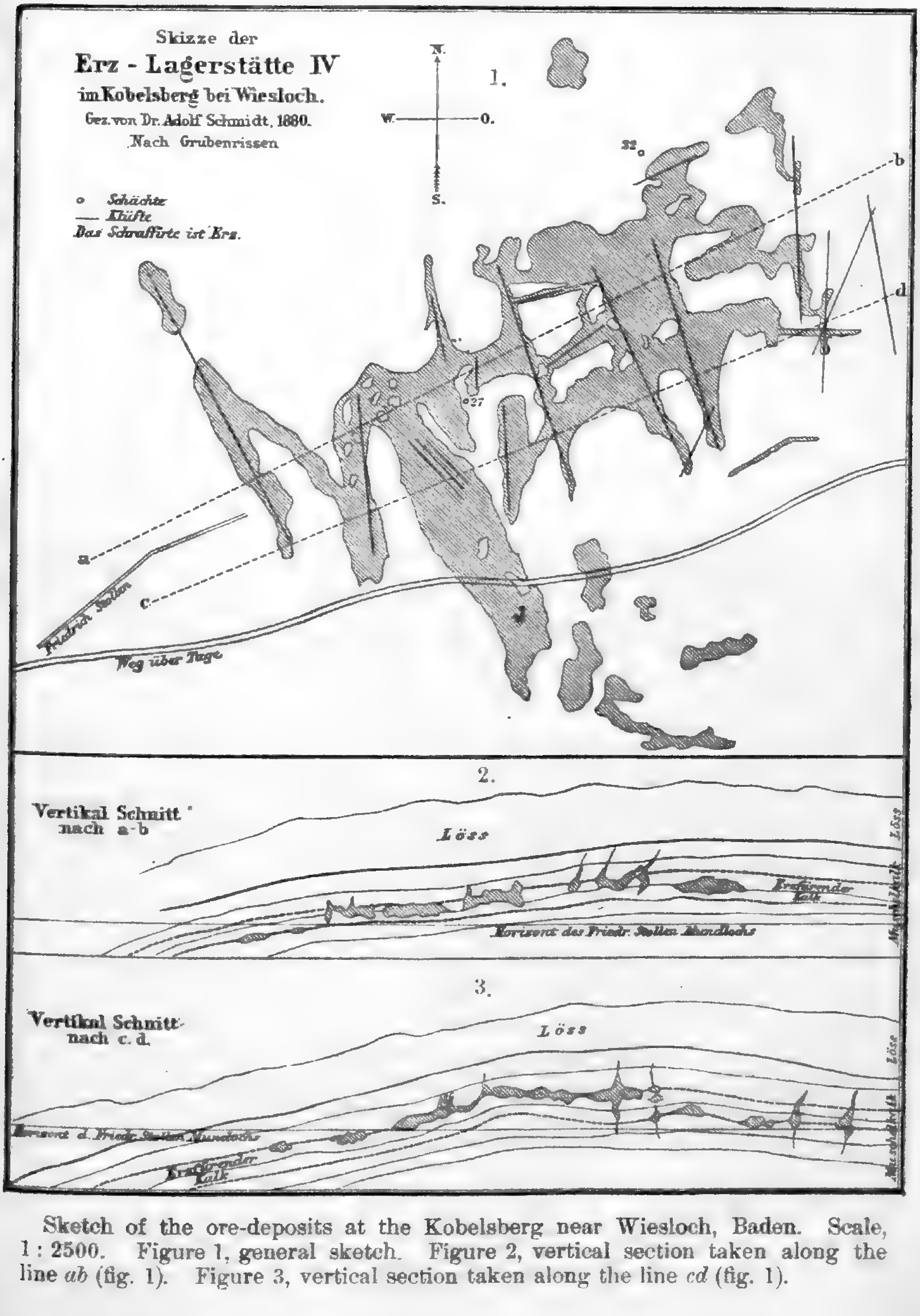
Assuming the polarization of the longitudinal vibrations of sound to have been absolutely demonstrated, the author goes further and draws conclusions, which are far too sweeping considering the nature of the premises—namely: that all vibrations in extended media, as light, are only longitudinal, and that when polarization takes place the vibrations become transversal.—*Journ. Frank. Institute*, 1881.

II. Geology and Natural History.

1. *The Zinc-ore Deposits of Wiesloch in Baden*; by Dr. Adolf Schmidt.* 122 pp. 8vo, with 3 plates. Heidelberg, 1881. (Carl Winter).—The deposits of zinc-ore, described by Dr. Schmidt, are situated near the village of Wiesloch, Baden, about 7½ miles south of Heidelberg. The "Buntsandstein" which has a considerable development at Heidelberg, dips gently to the south, and near Nussloch it disappears from the surface and the overlying "Muschelkalk" takes its place; this forms the rock in which the zinc deposits occur. The zinc is found as the sulphide, sphalerite or zinc blende, the carbonate, smithsonite, with hydrozincite in limited quantities. The sphalerite, which is mined only over a limited area, is regarded as the oldest deposit; it is, much of it, in the form of shell blende ("Schalenblende,") consisting of thin wavy layers of cryptocrystalline blende of different colors, and often alternating with galenite or marcasite; much of it is

* Die Zinkerz-lagerstätten von Wiesloch, Baden, von Dr. A. Schmidt.

stalactitic in form. Ordinary sphalerite with distinctly crystalline structure also occurs. The zinc carbonate, which forms the mass of the ore, occurs sometimes distinctly crystallized; also in the vitreous form called "zinkglas," the granular massive form, and finally in pseudomorphous deposits after other minerals and after various fossil shells. Of these the granular mineral, "Galmei," has the greatest economic importance.



Sketch of the ore-deposits at the Kobelsberg near Wiesloch, Baden. Scale, 1 : 2500. Figure 1, general sketch. Figure 2, vertical section taken along the line *ab* (fig. 1). Figure 3, vertical section taken along the line *cd* (fig. 1).

Five independent deposits of ore have been worked in this region. These are irregular masses of ore, some five to seven meters in thickness, but with a considerable horizontal extent and with the greatest development in a north and south direction. The smallest deposit is about 140 meters long and 70 broad; and the dimensions of the largest are 600 and 300 meters. When examined more closely, each of these deposits is found to consist not of an uninterrupted and solid body of ore, but rather of a large number of small bodies, more or less continuous, enclosing masses of limestone. Figure 1 gives a ground sketch of one of the five ore deposits mentioned, and shows the peculiar lenticular forms of the ore masses (here the carbonate.) In general they extend in a northwesterly and southeasterly direction, and are joined together in an irregular way, as exhibited in the plate. Figures 2 and 3 represent two cross-sections, the first taken along the line *ab*, in figure 1, and the second along *cd*; these show still more clearly the form and distribution of the zinc ore in the enclosing limestone. The single masses have a maximum thickness of five meters, a varying breadth from 1 to 12 meters, and length from 10 to 100 meters. The ore masses are mostly confined to the layer of limestone called the ore-bearing bed ("Erzführender Kalk"), and follows generally its upper border passing only to a limited extent into the rock above; in some cases they pass suddenly from this upper line to the lower and extend along this—(figure 3). In all cases the ore takes the place of the limestone, showing that the ore deposit was preceded by the removal of the limestone.

These separate lenticular masses consist of the carbonate with more or less red clay, intermixed in some cases, the latter being in excess. The firmest and richest ore is found at the bottom, and consists of thin, wavy layers which can often be separated from one another, although, as a whole, it is massive and nearly pure. Above this nearly solid ore comes a middle portion made up of interlacing lines or threads of the pure ore with the space between, in part or wholly filled by masses of clay or loam. Finally the upper portion consists almost exclusively of clay with very thin and irregular threads of ore, and with numerous concretionary masses from the size of a hazelnut to the finest of particles, intimately intermingled with the clay. In most cases the ore is easily separated from the sides of the enclosing rock, though not infrequently the carbonate is firmly bound to the limestone and passes gradually into it; in such cases it is common to find the fossil shells changed into the zinc carbonate, and here, evidently, the mineral has arisen not by direct deposit but by a process of alteration of the limestone.

In regard to the origin of these deposits of zinc ore the conclusion is reached that they have been made in most cases by the direct filling of previously made cavities and cracks in the limestone, although in some cases the deposit of the zinc and the removal of the limestone must have gone on together. The forming of the larger of the cavities is to be referred to the horizontal movement which resulted in the elevation of the Odenwald, and took place in connection with the formation of the Rhine valley. The original ores were the sulphides (sphalerite, marcasite and galenite), deposited from aqueous solutions infiltrating from above, as is proved by the existence of stalactites. The zinc carbonate which, as stated, forms the greater part of the ore taken out, must have been formed mostly from the oxidation of the zinc sulphide. This process of alteration was probably due originally to the action of the decomposition products of the marcasite which was deposited with the sphalerite, leading first to the formation of the zinc sulphate; and then from this there followed, with the calcium carbonate, the formation of the zinc carbonate and gypsum. This change of zinc carbonate is a process which can be successfully imitated in the laboratory. In addition to the carbonate which has been thus formed from the alteration of the zinc sulphide there is also to be recognized that which has resulted from the alteration of limestone, and by direct deposit from solution.

Dr. Schmidt's memoir, from which the above facts and accompanying plate have been taken, is of great interest both to the theoretical and mining geologist. It is in some respects a continuation of the valuable work by the same author on the lead mines of Missouri, published in 1874 in connection with the Report on the Geological Survey of Missouri, and noticed in vol. x, 1875, of this Journal.

2. *Geological Map of the United States*, compiled by C. H. Hitchcock; issued both in sheets and on rollers. New York, 1881. With an explanatory pamphlet in large 8vo of 30 pages. (Published by J. Bien). — This colored geological map of the United States has a breadth of thirteen feet and a length of eight. "It is made for a wall map," and apparently chiefly to serve the purpose of the lecturer, the details being few and the style of work coarse compared with what we find on foreign geological maps of like size. The formations distinguished embrace three divisions under the Tertiary; the Laramie, Cretaceous and Jura-Trias under the Mesozoic; three under the Carboniferous; one for the Devonian; three for the Silurian, the lower being the Cambrian or Primordial; and *four* for the Metamorphic rocks, namely, the Huronian, the gneiss of the Atlantic slope "including the Montalban and metamorphic Paleozoic," the Labrador or Norian, and the Laurentian. The compiler has sought assistance from all available sources, and has endeavored to give the latest and best results. Great difficulties have come as regards the western portion from the incompleteness of the geological surveys of the regions, and some parts might well have been left uncolored.

Professor Hitchcock has naturally introduced his own views of New England geology, on part of which the writer has found occasion, through his extended surveys, to differ from him. The sentence, "if orography is determined by stratigraphy, then the gneisses of New England are mainly of pre-Silurian age," would, according to the writer's observations, be more nearly correct if a *not* were introduced before the word *mainly.* It appears to the writer, further, that if all the pre-Cambrian (=pre-Primordial =Archæan) areas had received one color, and, at the same time, such metamorphic rocks as are not known by stratigraphical evidence to belong to this division, or to any of those higher in the series, had been left without color, the map would have been more satisfactory. The Huronian cannot be told by lithological tests, and the Huronian areas, so made, that have any other basis than a lithological are very limited, and would have been sufficiently distinguished by lining.

But the metamorphic areas are only a very small part of the formations represented. The chart also gives the outlines, more or less well ascertained, of the areas of eruptive rocks in the west; the southern limit of Glacier phenomena east of the Rocky Mountains, from Newberry, and the courses of what have been called *terminal* moraines—which, for the most part, are far from corresponding with the most southern Glacier limit, and therefore are as far from the southern line along which *true terminal* moraines might be looked for.

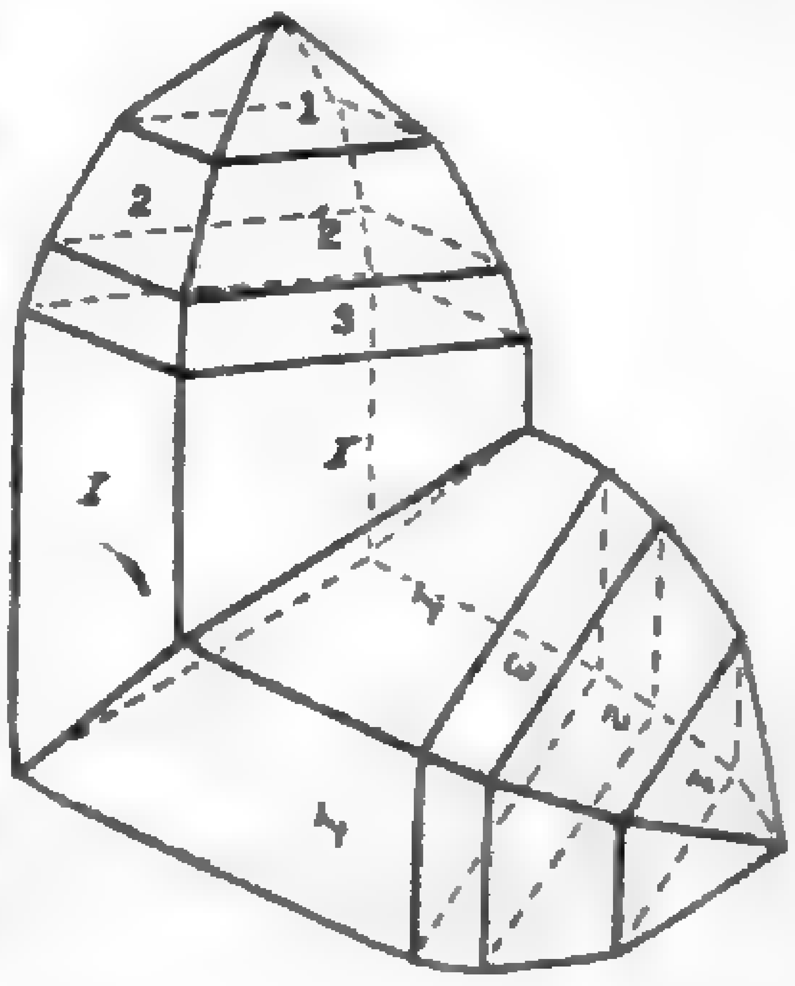
As to artistic merit, the chart has little—greatly disappointing expectation. The colors have been selected and grouped without system or judgment, and are put on not by the chromo-lithographic process, but coarsely by hand, and the effect is both unpleasing and confusing. Where the sheets (of which the chart is made up) join, an area on one is sometimes cut short off instead of having a continuation of the color on the other. Still the chart will be of much service to geologists and in the geological lecture room.

3. *Report on the Geology of Southern New Brunswick*, 1878–1879; by Professors L. W. BAILEY, G. I. MATTHEW and R. W. ELLS. Geological Survey of Canada. 26 pp. 8vo. Montreal, 1880. (Dawson Brothers).—This report contains the results of geological observations in the counties Charlotte, Sunbury, Queens, Kings, St. John and Albert. It is accompanied by a geological map of Southern New Brunswick in three parts which out of the four are issued. The map is printed handsomely and effectively in colors, and shows excellent progress by the geologists of the State in their work. There is also a large sheet of geological sections, but with too many doubtful points among them to be in all cases easily understood or satisfactorily interpreted. Careful observations of the strike and dip at each and every outcrop of the rocks, crystalline and uncrystalline, over the whole region, are needed for conclusions as to the stratigraphy.

4. *Text Book of Systematic Mineralogy;* by HENRY BAUERMANN, F.G.S. 367 pp. 12mo. London, 1881, (Longmans, Green and Co.)—This text-book is devoted to a discussion of the general principles of crystallography, and physical and chemical mineralogy; the descriptive mineralogy is to follow in a compan-

ion volume. In the crystallography the author wisely chooses the system of Miller for full development, while the notations of Weiss, Naumann and Lévy are also explained. The statements which precede on the general relations of the systems as to symmetry, and also the descriptions of the various forms under each system, are given with admirable fullness and clearness, and the figures are also numerous and excellent. The author states that he intentionally omits the subject of practical calculation, but had it been possible to abridge a little at other points so as to have made room for a few pages on this part of the subject the usefulness of the book would have been much increased. The difficult subject of optical mineralogy is presented with unusual success, and this also is true of the other topics under physical as also under chemical mineralogy. This volume cannot fail to be widely useful to mineralogical students.

5. *Geniculated Zircons, from Renfrew, Canada;* by W. E. HIDDEN (communicated, March 18).—Undoubted twins of Zircon have lately been observed by the writer from the new locality of apatite and sphene at Renfrew, Canada. The twinning plane (see figure) is 1-i, the same as in cassiterite and rutile. The twin, from which the accompanying figure was drawn, weighed over 35 grams, was remarkably perfect and had well polished planes. The color was deep brown-lake and it was transparent in spots. The twins of zircon heretofore described* have been microscopic, and at best questionable.



6. *Rabenhorst's Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz;* vol. I, parts 1 and 2; by Dr. G. WINTER.—Although the present work is ostensibly a second edition of Rabenhorst's Kryptogamen-Flora, which first appeared in 1844, it has been enlarged and re-arranged to such an extent that it bears little resemblance to the first edition. The new edition is prepared by Grunow, Hauck, Limpricht, Richter, Winter and others, and from this list of names it will be seen that the scope of the work is considerably greater than that of the first edition, which was written by Rabenhorst alone. The marine algæ, for instance, which were before omitted, are to be described by Hauck, whose residence at Triest has given him an opportunity to explore the interesting coast of the northern Adriatic. The two parts already published include the *Schizomycetes, Saccharomycetes, Entomophthoreæ* and *Ustilagineæ* by Winter. The whole account, including about 150 pages, begins with an introduction on the morphology and physiology of Fungi, with rather minute directions about collecting and mounting specimens. As in Rabenhorst's "Flora Europæa Algarum Aquæ Dulcis," the description of the species of the different orders is preceded by wood

* See Meyer, ZS. G., Ges., xxx, 11,352; Stapff, l. c., xxx, 133, xxxi, 405; Hussak, Min. Petr. Mitth., i, 277, 1878.

cuts illustrating the genera. Under the *Schizomycetes* the cuts are taken principally from Cohn, Koch and Warming, and they are very well executed. The descriptions given by Winter are also excellent, neither uncomfortably condensed nor too diffuse. From the nature of the subject the descriptions of the species should necessarily be followed by notes on the development and variations, and the editor has given much desirable information on the *Schizomycetes*, principally from the works of Cohn and Warming, and in the *Ustilagineæ* the notes are enriched by numerous original observations. W. G. F.

7. *Notes Algologiques, deuxième fascicule;* by Ed. Bornet and G. Thuret.—The second part of the "Notes Algologiques," including 25 quarto lithographic plates and the index to parts one and two, is quite equal to the portion already issued in the clearness of the text and beauty of the plates, which are only surpassed by those of the "Etudes Phycologiques" of the same authors. The second fasciculus differs from the first in that comparatively more attention is paid to the systematic study of the species described, whereas the first fasciculus was devoted mainly to the development of the species. The bulk of the present volume is devoted to the species of *Phycochromaceæ*, especially to the genera *Nostoc* and *Scytonema*, which are given with great minuteness. The portion on *Nostoc* is really a monograph of that genus. Twenty-nine species are recognized and a very large number of synonyms are included under them. To illustrate, *N. commune* Vaucher, as it is commonly called, is referred to the older *N. cinoflonum* Tournefort, and under that name Bornet and Thuret include no less than 32 synonyms. Under *Scytonema* 21 species are recognized, and *S. Ravenelii* Wood has included under it as synonyms *Symphyosiphon Wollei* Bornet, published by Wolle in the Torrey Bulletin, 1877. The American reader will be interested in the account of the species of *Calothrix* and *Isactis*, most of the species figured being common on the American coast. Under *Hormactis Balani*, reference is made to the only species found in the United States, which was at first supposed to be new and was provisionally named *H. Farlowii*. It was afterwards recognized by Dr. Bornet as identical with *Nostoc Quoyi* Ag., of the Marianne Islands, which according to Bornet, is a true *Hormactis*. *H. Quoyi* is known only from the locality named in the Pacific and from the coast of New England, an unusual range for one of the *Phycochromaceæ*. W. G. F.

8. *On the Zoological affinities of Halysites;* by A. E. Verrill.—Of the so-called "tabulate corals" many genera have already had their zoological positions determined. Thus, Agassiz, in 1847, ascertained the hydroid nature of Millepora, and his observations have been fully confirmed by Mosely and others. That Pocillipora and its allies, living and extinct, are true madreporarian corals was shown by me in 1867. That Favosites and the related extinct genera are closely allied to the modern Alveopora and Porites was also demonstrated by me in 1872.*

* This Journal, iii, 187–194.

Mosely, while on the Challenger Expedition, was fortunate in examining the animal of Heliopora. He proved that it belongs to the Alcyonaria, and referred to the same group various fossil genera, in some cases apparently without sufficient reason.

The affinities of the genus *Halysites*, the common "chain coral" of the Silurian, have hitherto been very doubtful. Within a few days Mr. H. T. Woodman has shown me a very remarkable specimen of this genus, in which the internal structure is beautifully preserved. In this example, which is a fragment several inches across, the large tubes contain twelve well-developed and regular septa extending to the center. Their edges are slightly serrulate, and do not rise above the tubes. In other words, the structure is that of a true madreporarian coral.

Mr. Woodman informs me that this specimen is a fragment from a large mass eight to ten feet across, and that "the larger part of the mass was like the common specimens, showing no rays; but here and there, in spots, all over the face of the mass, the septa were as well preserved as in the fragment shown to you."

III. Miscellaneous Scientific Intelligence.

1. *Elements of Comet* (α), 1881, *Swift.*—The elements and the ephemeris for May of comet (α), 1881, Swift, have been calculated by Mr. S. C. Chandler, Jr., at Boston, and by Dr. R. Copeland and Mr. J. G. Lohse at the Dun Echt Observatory in Scotland. These results have been exchanged across the ocean by cable, according to a code adopted by the Boston Scientific Society; they are published in Special Circulars No. 11 and No. 12 of the Science Observer. Mr. Chandler remarked that the comet was (May 7th) a faint round disc less than 1′ in diameter, with some central condensation and ill-defined edges. The orbit does not resemble that of any known comet. The elements are as follows: 1 those of Chandler, 2 those of Copeland and Lohse.

1.

Per. Passage, 1881, May 20·164 Washington Mean Time.

Long. Perihelion,	289°	21′·5	Eq. 1881·0
Long. Node,	108	44·1	
Inclination,	85	29·0	

Log. q, 9·74330
Motion direct.

2.

Per. Passage, 1881, May 20·67, Greenwich Mean Time.

Long. Perihelion,	300°	2′	Eq. 1881·0.
Long. Node,	124	54	
$\omega = \pi - \Omega$,	175	8	
Inclination,	78	48	

Log. $q = 9·7674$ $q = 5854$.
Motion direct.

2. *National Academy of Sciences.*—The following is a list of the papers read at the session of the National Academy of Sciences at Washington, in April:

A. GRAHAM BELL: Upon the production of sound by radiant energy.

S. P. LANGLEY: The solar constant; The color of the sun; On mountain observations.

C. S. PEIRCE: On the progress of pendulum work.

GEO. F. BARKER: On electric light photometry; On incandescent lights; On the condenser method of measuring high tension currents; On the carbon lamp fiber in the thermo balance.

EDW. S. MORSE: On the utilization of the sun's rays in heating and ventilating.

J. W. MALLET: Results just obtained with regard to the molecular weight of hydro-fluoric acid.

C. H. F. PETERS: A method for finding the proximities of the orbits of minor planets.

ELIAS LOOMIS: Reduction to sea-level of barometric observations made at elevated stations.

W. H. DALL: Recent researches in the vicinity of Behring's Strait, comprising: I. An account of the land-ice of Kotzebue Sound and the Arctic Coast. II. Additions to our knowledge of the currents and temperature of the ocean in the vicinity of Behring's Strait.

E. W. HILGARD: On the later Tertiary of the Gulf of Mexico.

T. STERRY HUNT: On the auriferous gravels of California; On the domain of physiology.

B. ALVORD: The compass plant of the Western prairie.

E. D. COPE: On the relation between strains and impacts and the structures of the feet of mammalia.

R. PUMPELLY: On the relation of soils to health.

J. P. LESLEY: Biographical memoir of S. S. Haldeman.

3. *Popular Lectures on Scientific Subjects;* by H. HELMHOLTZ, translated by E. Atkinson. Second series. 265 pp. 8vo. New York (D. Appleton and Co.).—The subjects of these lectures, for the general interest of which the author's previous publications are a sufficient guarantee, are: 1, Gustav Magnus; 2, Origin and significance of geometrical atoms; 3, Relation of optics to painting; 4, Origin of the planetary system; 5, Thought in medicine; 6, Academic freedom in German universities.

4. *The Constants of Nature, Part IV; Atomic weight determinations; a digest of the investigations published since* 1814; by GEORGE F. BECKER. 149 pp. 8vo. Washington, 1880, (Smithsonian Miscellaneous Collections).—Mr. Becker has brought together in small compass a large amount of material, which cannot fail to be of much practical value to the working chemist. The abstracts are necessarily very brief, but when more is needed reference can be readily made to the original papers, the abstract being at least sufficient to show what may be expected in them.

Observations of the Transit of Venus, Dec. 8–9, 1874, made and reduced under the direction of the Commission created by Congress. Edited by Simon Newcomb, U. S. Navy, Secretary of the Commission. 157 pp., 4to, with two plates. Washington, 1881.

The Total Solar Eclipse of July 29, 1878. Observations at Pike's Peak, Colorado. Report by Professor S. P. Langley. pp. 203–217, with a plate.

Observations on Jupiter, by L. Trouvelot; pp. 299–321, from the Proceedings of the American Academy of Arts and Sciences, vol. xvi.

Mittheilungen aus der Zoologischen Station zu Neapel, zugleich ein Repertorium für Mittelmeerkunde, vol. ii, II, III, pp. 123–413.

Working Drawings: How to make and use them; by L. M. Haupt. 55 pp. 12mo, with 30 figures. Philadelphia, 1881. (J. M. Stoddart & Co.)

APPENDIX.

Art. LXII.—*Notice of new Jurassic Mammals*; by Professor O. C. Marsh.

Among the fossils from the Atlantosaurus beds of the Rocky Mountains recently received at the Yale College Museum, are the remains of several mammals distinct from those hitherto described by the writer.* These include two new genera, and four species, which are described below. This material throws much light on the specimens previously discovered, and also shows some peculiar characters not before seen in mammals.

Allodon laticeps, gen. et sp. nov.

The type specimen of the present species is a left upper jaw, with molar and premolar teeth in good preservation. This specimen indicates that the skull was a short and broad one. The anterior half of the zygoma is in place, and shows that the arch was strong, and widely expanded. There are five premolars, and two molars in position, and in front of this series is a single alveolus which was occupied by a small premolar, or perhaps by a weak canine. The premolars have each two fangs, and tuberculated crowns, which are nearly flat on the inner side, and rounded externally. The two true molars strongly resemble those of *Microlestes*, and hence are similar in form to the lower molars of *Plagiaulax* and *Ctenacodon*. The crowns are very low, and are divided into an outer and an inner half by a deep worn groove. The last molar has its longitudinal groove in a line with the inner margin of the other teeth. The principal measurements of this specimen are as follows:

Space occupied by seven posterior teeth	8·mm
Extent of two true molars	2·5
Distance from orbit to margin of upper jaw	2·
Extent of maxillary above second premolar	2·

* This Journal, vol. xv, p. 459, vol. xviii, pp. 60, 215 and 396, and vol. xx, p. 235.

The affinities of this peculiar species are not easy to determine, but it should probably be placed in the *Plagiaulacidæ*. The number of premolars shows that it is distinct from the known genera of this group.

The only specimen known indicates an animal about as large as a weasel. It was found in the Upper Jurassic deposits of Wyoming.

Ctenacodon nanus, sp. nov.

A second and smaller species of this genus is indicated by two lower jaws, found separately. One of these, the type specimen, has the four premolars and two molars in place, and well preserved. The former teeth all have two fangs, and smooth, sharp compressed crowns. The last premolar only has its summit marked by faint notches. The molars have one cone with a broad base on the outer side, and three low inner cones of nearly equal size. Between these is a deep worn longitudinal valley, as in the molars of *Allodon*, above described. There is no cingulum, and the two molars are of the same size. The coronoid process rises immediately behind the last molar. The ridge starting at the base of the coronoid and extending forward on the outer side is much sharper than in the larger species (*Ctenacodon serratus*).

The following measurements will indicate the size of this specimen:

Extent of premolar and molar series	6·mm
Extent of premolar series	4·
Antero-posterior diameter of last premolar	1·5
Height of crown	1·25
Height of condyle	2·5
Width of condyle	1·5

The specimens representing the present species are from the Atlantosaurus beds of Wyoming.

Docodon striatus, gen. et sp. nov.

The present genus is most nearly allied to *Diplocynodon*, but may be distinguished from it by having, in the lower jaw behind the canine, eleven teeth instead of twelve. The canine has two fangs, as in that genus, and the molar teeth also correspond closely in form. In the present species, the lower jaws are long and comparatively slender. The symphysis is very long, and the mylohyoid groove extends forward to its upper border. The inner side of the lower jaw is distinctly striate. The condyle is wider than in *Diplocynodon victor*.

Some of the dimensions of the type specimen are as follows:

Distance from apex of canine to end of condyle	31·mm
Extent of premolar and molar series	17·
Depth of lower jaw below last molar	4·
Depth of lower jaw below canine	3·
Height of crown of canine	2·5

The only known remains of the present species are from the Upper Jurassic deposits in Wyoming.

Dryolestes gracilis, sp. nov.

The present species, which is the smallest of the genus, is represented by several lower jaws, which are unusually long and slender, and nearly straight. In the type specimen, there were eleven teeth behind the canine, which was of moderate size. The fangs of the molar teeth are not placed one in front of the other, but opposite, with one large fang on the outside, and a small inner one beside it. This peculiar feature appears in all the species of *Dryolestes*, but has not been observed in any other mammals, recent or extinct. The mylohyoid groove in this specimen is deep, and extends forward, nearly parallel with the lower border, to the symphysis. The following measurements show the size of the best preserved lower jaw referred to the present species:

Extent of eleven posterior teeth	11·mm
Extent of last five teeth	6·
Depth of jaw below canine	1·
Depth of jaw below last molar	2·

All the known specimens of this species are from the Upper Jurassic deposits of Wyoming Territory.

Yale College, New Haven, May 24th, 1881.

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* The Index contains the general heads BOTANY, GEOLOGY, MINERALOGY, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

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