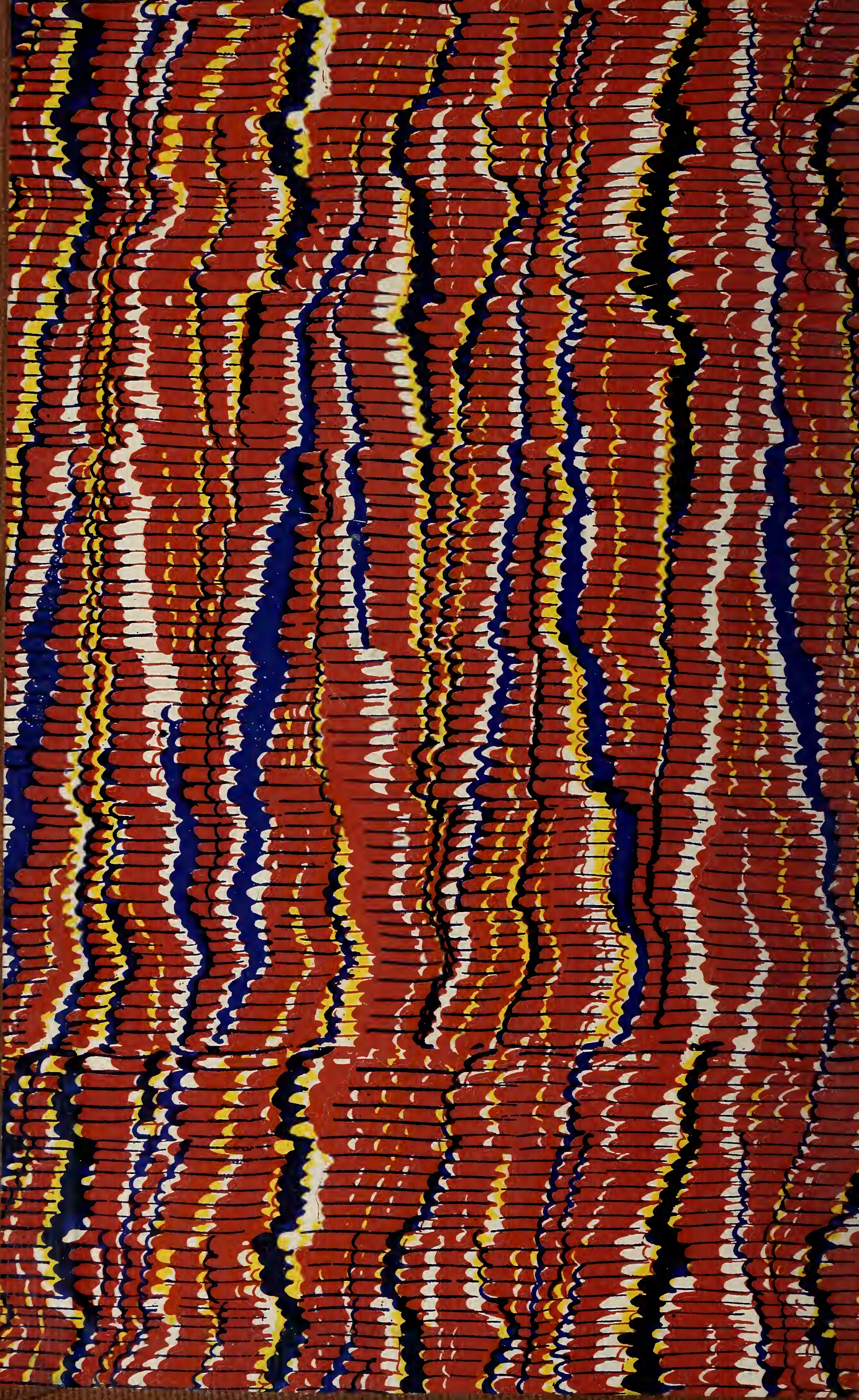

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EDITOR: EDWARD S. DANA.

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Chas. D. Walcott.

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. I.—*Late Glacial or Champlain Subsidence and Reëlevation of the St. Lawrence river basin;* by WARREN UPHAM. (With Plate I.)

THE accompanying map (Plate I) shows the maximum area covered by the ice-sheet in the St. Lawrence basin and adjoining portions of the United States and southern Canada, with approximate outlines of the glacial boundary at successive stages of its retreat. The Champlain epoch or part of the Pleistocene period including these stages of glacial recession was begun and ended, respectively, by downward and upward epeirogenic movements. It comprised the time of departure of the ice-sheet, with many small and large glacial lakes temporarily formed by its receding barrier, and with marine submergence to hundreds of feet above the present shore lines. The Late Glacial subsidence appears to have been principally completed before the retreat of the ice and deposition of the Champlain lacustrine and marine beds; but the following uplift was in progress, advancing as fast as the ice receded, from the beginning to the end of Champlain time.[*] Indeed, considerable parts of the glaciated areas of North America and Scandinavia are still undergoing small and slow oscillatory movements, not having yet, during the short Postglacial period, fully reached isostatic repose.

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[*] For a discussion of the part of this movement reëlevating the upper Mississippi region, the area of the glacial Lake Agassiz in the basin of the Red river of the North and Lake Winnipeg, and the country surrounding Hudson Bay, see the Journal of Geology, vol. ii, pp. 383–395, May–June, 1894. The dynamic causes of epeirogenic movements, and their relations to the Glacial period as the probable causes of both its beginning and end, are partly considered in that paper, but more fully in an appendix of Wright's Ice Age in North America, 1889, pp. 573–595, this Journal, III, vol. xlvi, pp. 114–121, Aug., 1893, and the Geol. Magazine, IV, vol. i, pp. 340–349, Aug., 1894.

Evidence from the Beaches of the Glacial Lakes in the St. Lawrence basin.

Well marked old channels of outflow are found extending southward, at the levels of the deserted beaches, from Lake Agassiz and from the glacial lakes which are now represented by the diminished, but still large, modern lakes Superior, Michigan, Huron, Erie, Ontario, and Champlain. The outlets prove that the great Pleistocene water bodies which occupied these basins were lakes, not gulfs or arms of the sea; and the differential uplifts of the basins, increasing toward the central part of the area of the continental ice-sheet, show that no land barriers, but the ice itself in its retreat, held in these lakes on their northward sides.

The basin of the St. Lawrence during the glacial recession held successively, and in part contemporaneously, no less than eight important glacial lakes, distinguished by their different areas, heights, and places of outlet. They are named the Western Superior and Western Erie glacial lakes; Lake Warren, the most extensive, into which the two foregoing were merged; Lake Algonquin, the successor of Lake Warren in the basins of Lakes Huron, Michigan, and Superior; Lake Lundy, the glacial representative of Lake Erie; Lake Iroquois, in the basin of Lake Ontario; Lake Hudson-Champlain; and Lake St. Lawrence, into which the two last named became merged. The glacial Lake St. Lawrence, which is the only one of the series hitherto unnamed, extended over the Ottawa, Champlain, and St. Lawrence valleys previous to the melting away of the ice barrier, remaining latest in the vicinity of Quebec, by which event the sea, at a lower level than the former lake, was admitted to these valleys.

*The Western Superior glacial lake.**—In the west part of the basin of Lake Superior the receding ice-sheet held a lake which outflowed southward through northwestern Wisconsin, across the present watershed between the Bois Brulé and St. Croix rivers. The highest shore line of this lake at Duluth is 535 feet above Lake Superior (which has a mean level 602 feet above the sea); on Mt. Josephine, about 130 miles northeast from Duluth, its height, according to leveling by Dr. A. C. Lawson,† is 607 feet; and at L'Anse and Marquette, Mich., 175 and 225 miles east of Duluth, it is found by Mr. F. B. Taylor‡ about 590 feet above the lake. The northeastward

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* Proc. A. A. A. S., vol. xxxii, for 1883, p. 230. Geol. and Nat. Hist. Survey of Minnesota, Final Report, vol. ii, 1888, p. 642; Twenty-second Ann. Rep. for 1893, pp. 54–66 (first use of this name). Bulletin Geol. Soc. Am., vol. ii, 1891, p. 258. Am. Geologist, vol. xi, p. 357, May, 1893; and vol. xiv, p. 63, July, 1894.

† Minnesota Geol. Survey, Twentieth Ann. Rep. for 1891, pp. 181–289, with map and profiles.

‡ Am. Geologist, vol. xiii, pp. 316–327 and 365–383, with maps, May and June, 1894.

uplift averages seven inches per mile; and the eastward ascent is approximately three inches per mile. The latest and lowest of the Western Superior lake beaches observed at Duluth, occupied by the "boulevard" or pleasure driveway, 475 feet above the lake, on the bluffs back of the city, appears to have an ascent of only about 35 feet in the distance to Mt. Josephine, showing that the uplift of the land was quite rapidly in progress while the ice-front still maintained the lake at the St. Croix outlet. Not long after the glacial retreat passed eastward beyond Mt. Josephine and Marquette, this lake was lowered and merged with Lake Warren across the lowlands of the northern peninsula of Michigan. The vertical interval between the final stage of the Western Superior Lake and the level of Lake Warren shown by its earliest beach at Duluth was about 60 feet. Thenceforward the outlet of Lake Warren past Chicago carried away the drainage from the glacial melting and rainfall of the Superior basin.

*The Western Erie glacial lake.**—Outflowing from the southwestern end of the Lake Erie basin by a large abandoned watercourse, which reaches from Ft. Wayne, Ind., where the St. Joseph's and St. Mary's rivers unite to form the Maumee, across the present watershed to the Wabash river, this glacial lake formed two distinct beaches, named by N. H. Winchell the Van Wert and Leipsic ridges, separated by a vertical interval of 15 to 20 or 25 feet. The upper or Van Wert beach, with its crest varying in altitude from 200 to 220 feet above Lake Erie (whose mean height is 573 feet above the sea), extends about 75 miles east to Findlay, Ohio, and nearly an equal distance northeast past Bryan, Ohio, to the vicinity of Adrian, Mich., if not farther. At Findlay the lake while forming this beach, as Winchell and Leverett have shown, was bounded on the north by the ice-sheet then forming the Blanchard moraine. The second or Leipsic beach of the Western Erie Lake, ranging in height from 190 to 210 feet, runs from Ft. Wayne eastward 175 miles to its termination, as described by Leverett, at the line of a later moraine close southwest of

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* G. K. Gilbert, this Journal, III, vol. i, pp. 339–345, with map, May, 1871; Geology of Ohio, vol. i, 1873, pp. 540–556, with two maps. N. H. Winchell, Proc. A. A. A. S., vol. xxi, for 1872, pp. 171–179; Geology of Ohio, vol. ii, 1874, pp. 56, 431–433, etc. J. S. Newberry, Geology of Ohio, vol. ii pp. 46–65, with three maps and numerous sections. E. W. Claypole, "The Lake Age in Ohio," Trans. Geol. Soc. Edinburgh, 1887, p. 42, with four maps. G. F. Wright, The Ice Age in North America, 1889, chapter xv (with reproduction of Prof. Claypole's maps, that of Lake Erie-Ontario being on p. 355). J. W. Spencer, this Journal, III, vol. xli, p. 208, with map, March, 1891; Bulletin, Geol. Soc. Am., vol. ii, 1891, pp. 465–476, with map. Frank Leverett, this Journal, III, vol. xliii, pp. 281–297, with map, April, 1892. Warren Upham, Bulletin, Geol. Soc. Am., vol. ii, p. 259; Minnesota Geol. Survey, Twenty-second Ann. Rep. for 1893, p. 62 (first use of the name *Western Erie Glacial Lake*).

Cleveland. Northeast and north from the old outlet the Leipsic beach reaches about 165 miles, past Adrian and Ypsilanti to Imlay, Mich., being nearly level to Ypsilanti, but thence in the 60 miles onward to Imlay having a rise of about 65 feet, to an altitude 849 feet above the sea. With the recession of the ice-sheet and the extension of this lake to Imlay, a lower outlet was opened over the watershed between the Shiawassee and Grand rivers in Michigan, 729 feet above the sea or 148 feet above Lakes Huron and Michigan, where the Western Erie glacial lake became confluent with Lake Warren and was thus reduced about 30 feet, falling from the Leipsic or lower Western Erie beach to the Belmore or earliest beach of Lake Warren in the Erie basin.

Upon a large area, extending from Ft. Wayne east to Cleveland and northward to Ypsilanti and Detroit, the attitude or general slopes and levels of the land have remained unchanged since the departure of the ice-sheet, for these earliest beaches and the lower beaches of Lake Warren in the same area are still nearly horizontal. The whole country there, however, has been uplifted, without tilting, about 110 feet, after the end of the separate existence of the Western Erie lake, for this is the height of the Belmore beach around the west end of Lake Erie above the highest and earliest beach of Lake Warren at Chicago. A greater and differential uplift, with rapid tilting of northward ascent, was taking place north and northeast of Detroit during the Belmore and lower stages of Lake Warren, simultaneous with the uniform elevation of the Western Erie glacial lake area. Further we learn that about half of the uplift of 110 feet for this region had occurred before the beginning of Lake Algonquin and the date of the Algonquin beach, since that beach has a height of 602 feet near the south end of Lake Huron, being 60 feet higher than the correlative sublacustrine terrace plane beneath the surface of Lake Michigan near Chicago, which marks the old Algonquin shore there.

*Lake Warren.**—Like the Western Superior and Western

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* J. W. Spencer, Science, vol. xi. p. 49, Jan. 27, 1888 (proposing this name in honor of Gen. G. K. Warren); Proc. A. A. A. S., vol. xxxvii, for 1888, pp. 197–199; Trans. Roy. Soc. of Canada, vol. vii, for 1889, sec. iv, p. 122; this Journal, III, vol. xli, pp. 201–211, with map, March, 1891; Bulletin, Geol. Soc. Am., vol. ii, pp. 465–476, with map, April, 1891; "A Review of the History of the Great Lakes," Am. Geologist, vol. xiv, pp. 289–301, Nov., 1894 (containing citations of many additional papers by Prof. Spencer and others). G. K. Gilbert, "Changes of Level of the Great Lakes," in The Forum, vol. v, pp. 417–428, June, 1888; "History of the Niagara River," in Sixth Annual Report of the Commissioners of the State Reservation at Niagara, for 1889, pp. 61–84, with eight plates (also in the Smithsonian An. Rep. for 1890, pp. 231–257); Geology of Ohio, vols. i and ii. Frank Leverett, paper before cited; "Raised Beaches of Lake Michigan," Trans. Wisconsin Academy of Sciences, Arts, and Letters, vol. vii, pp. 177–192 (read Dec. 30, 1887). A. C. Lawson, "Sketch of the Coastal Topography of the North Side of Lake Superior, with Special Reference to the

Erie glacial lakes, the far more extensive Lake Warren at the beginning of its existence occupied only the southern end of the basin of Lake Michigan. It grew northward as the ice-sheet retired, and in due time it received these two lakes to itself, expanding thus into the basins of Lakes Superior, Huron, and Erie. The maximum development of Lake Warren stretched from Thomson, Minn., above and west of Duluth, eastward to Lake Nipissing, a distance of nearly 600 miles; and from Chicago, where it outflowed to the Des Plaines, Illinois, and Mississippi rivers, it extended eastward in its highest stages across the southern peninsula of Michigan, and later by way of the strait of Mackinaw and over Lakes Huron, St. Clair, and Erie, to the west end of the Lake Ontario basin and to Crittenden in southwestern New York. This area exceeded 100,000 square miles, being nearly equal to that of the glacial Lake Agassiz. The Belmore and Nelson beaches, the two highest formed by Lake Warren in the basins of Lakes Erie, Huron, and Superior, called by Spencer the Ridgeway beach (a later name than N. H. Winchell's "Belmore ridge") in their united course about the west half of Lake Erie, show that, since the fullest expansion of this great glacial lake, the whole basin of Lake Superior and the country eastward to Lake Nipissing have been uplifted 400 to 550 or 600 feet, in comparison with Chicago and the southern part of the Lake Michigan basin, while the uplift at Cleveland has been about 115 feet, and at Crittenden, N. Y., not less than 260 feet (more probably about 300 feet).

In the vicinity of Chicago, Lake Warren formed three beaches, belonging to lake levels successively about 45 to 50 feet, 15 feet, and 30 feet above Lake Michigan. That the

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Abandoned Strands of Lake Warren," Minnesota Geol. Survey, Twentieth An. Rep. for 1891, pp. 181–289, with map, profiles, and figures from photographs. F. B. Taylor, this Journal, III, vol. xliii, pp. 210–218, March, 1892 (Mackinac island); Bulletin Geol. Soc. Am., vol. v, pp. 620–626, with maps, April, 1894 (Lake Nipissing); Am. Geologist, vol. xiii, pp. 316–327 (Green bay) and 365–383 (south coast of Lake Superior), with maps, May and June, 1894; id., vol. xiv, pp. 273–289 (east of Georgian bay), with map, Nov., 1894. The highest beach on Mackinac island, which Mr. Taylor calls the "Algonquin beach," seems to be correlative with his Nelson and higher beaches in the vicinity of Lake Nipissing, regarded in this paper as marking the early high stages of Lake Warren. C. Whittlesey, Smithsonian Contributions, vol. xv, 1864, pp. 17–22. E. Andrews, "The North American Lakes considered as Chronometers of Postglacial Time," Trans. Chicago Academy of Sciences, vol. ii. Nearly all the edition of this important paper was consumed in the Chicago fire of 1871. It is quite fully reproduced by James C. Southall, in "The Recent Origin of Man," 1875, chapter xxxiii (pp. 495–506, with sections); and in "The Epoch of the Mammoth and the Apparition of Man upon the Earth," 1878, chapter xxii (pp. 348–367, with sections). N. H. Winchell, J. S. Newberry, E. W. Claypole, and G. F. Wright, as before cited. Geol. Survey of Canada, Report of Progress to 1863, pp. 912, 913. Warren Upham, Bulletin Geol. Soc. Am., vol. ii, pp. 258–265; vol. iii, pp. 484–487. Geology of Minnesota, Twenty-second An. Rep. for 1893, as before cited. Am. Geologist, vol. xiv, pp. 62–65, July, 1894.

beach at 30 feet was formed after that at 15 feet is shown by the occurrence in some places of a peat deposit, described by Andrews and Leverett, which passes underneath the 30 feet beach and is continuous from its upper side down to the lower beach. The peat marks a land surface over which the lake rose to form the middle or third beach, after having stood at the lower or second beach for some time. Still later, however, it probably again stood at the lower level, corresponding to the present watershed in the abandoned outlet. This old channel of outflow, at its summit, as I am informed by Mr. Ossian Guthrie from the canal survey, is now 11 feet above the mean level of Lake Michigan, but the surface there is postglacial silt; at another point, where the channel bed consists of till, and at a third place where the bed is rock, its height in each case is only eight feet above the present lake, or 590 feet above the sea. The mouth of Lake Warren appears to have been at first near Lemont, on the Des Plaines river about 25 miles from the lake, where the river valley was obstructed by drift which suffered erosion, allowing the mouth of the lake to be transferred gradually upstream, at the same time being lowered, to its final position ten miles from the lake shore in Chicago. Epeirogenic movements, between the times of formation of the second and third beaches, slightly lifted the outlet and adjacent portion of the course of the Des Plaines river, as compared with the southern and southwestern part of the Lake Michigan basin, causing the old lake to extend a little farther on that side than before. Toward the north and east, however, this change was doubtless more than counteracted by the rapid differential rise of the land.

Fresh-water shells are found abundant in the 15 feet beach at Evanston and elsewhere southward through Chicago. All the species obtained, representing ten or more genera, are still living in this region. Wood of oak and cedar, and the thigh bone of a deer, have been also found in the same beach at Evanston.*

For the distance of about 185 miles from Chicago north to the south end of Green bay, the highest shore of Lake Warren appears to be now nearly level, for Mr. Taylor finds evidence of submergence only to a height of some 20 feet above that part of Green bay and the neighboring lake shore. Thence northward, however, the beach rises about 1·4 feet per mile for 110 miles to Cook's Hill, near the north end of this bay; in 60 miles from that latitude north to Houghton, it has an ascent of 260 feet, or 4⅓ feet per mile; but in about 90

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* H. M. Bannister, Geology of Illinois, vol. iii, 1868, pp. 241, 242. F. Leverett, "Raised Beaches of Lake Michigan," before cited, p. 189.

miles onward, across Lake Superior to Kaministiquia, where the shore is 455 feet above that lake, the rate of northward ascent is reduced to only a half of a foot per mile.

Along a west to east course, the Nelson beach (named by Taylor in the vicinity of North Bay, Lake Nipissing, probably not distinct from the Belmore beach in Ohio and northward to Mackinac island) is 385 feet above Lake Superior at Duluth; 410 feet at Houghton, having an eastward ascent of 25 feet in 150 miles; 414 feet at the Sault Ste. Marie, running level for 200 miles east from Houghton; and about 538 feet at the north side of Lake Nipissing, or 497 feet above that lake, and 1,140 feet above the sea. In the distance of 220 miles from Sault Ste. Marie to Lake Nipissing this beach now shows an ascent of 126 feet, or about seven inches per mile. These figures, with the preceding from Houghton to the north side of Lake Superior, justify to a remarkable degree Dr. Lawson's opinion that the ancient shore lines of Lake Warren in the Superior basin remain parallel with the water level of to-day. As compared with Chicago, the country enclosing Lake Superior has been uplifted 400 to 450 feet; and the greater part of the differential elevation, expressed by tilting, took place upon the west to east belt of the northern peninsula of Michigan.

Three beaches of Lake Warren are mapped by Spencer and named the Ridgeway, Arkona, and Forest beaches in Ohio, northwestern Michigan, and the province of Ontario north of Lake Erie. These probably represent the three noted at Chicago and about the south part of Lake Michigan. Farther north the number of distinct shore lines is much increased. In and near Duluth I find eight beaches referable to Lake Warren, the lowest being 50 feet above Lake Superior. On northern portions of the Lake Superior coast several of these seem, as shown by Lawson's observations with leveling, to be each represented by two or more shores, separated by vertical intervals of 10 feet or more. Most of the northern beaches, it should be remarked, are very feebly developed, even in the most favorable situations for their formation, and are not discernible along the far greater part of the lake borders. During all the time of differential uplifting of the Lake Warren basin and sinking of the water surface, whenever the diminishing lacustrine area was nearly unchanged for a few years or longer, the erosion and deposition effected by the great waves of storms, and the tribute of streams forming deltas, recorded these shore lines.*

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* Prof. Spencer, in his latest paper ("A Review of the History of the Great Lakes," Am. Geologist, vol. xiv, pp. 298, 301, Nov., 1894), supposes that an outflow from Lakes Superior, Huron, Michigan, and Erie, passed by the way of

*Lake Algonquin.**—When the glacial melting and retreat at length permitted an outflow from the St. Lawrence basin over a lower pass, which was through central New York to the Mohawk and Hudson, the water surface of the basins of Lakes Michigan, Huron, and Superior, fell only some 50 or 75 feet, from the latest and lowest stage of Lake Warren to its short-lived successor, Lake Algonquin. This lake appears to have been ice-dammed only at low places on its east end, as at or near the heads of the Trent and Mattawa rivers, lying respectively east of Lakes Simcoe and Nipissing, where otherwise its waters must have been somewhat further lowered to outflow by these passes. Careful study and comparison of the work of Spencer in tracing the Algonquin beach about the southern part of Lake Huron and Georgian bay, and of Taylor in exploration of his " Nipissing beach " from Duluth east along the south coast of Lake Superior and the north side of Lake Huron and Georgian bay to Lake Nipissing, convince me that these beaches were of contemporaneous formation, marking respectively the southern and northern shores of Lake Algonquin, and therefore both to be known by the name Algonquin beach of Spencer, according to the law of priority. The earliest and principal stage of Lake Algonquin is shown by these beaches to have coincided closely in area with Lakes Michigan and Superior, but to have been considerably more extensive eastward than the present Lake Huron and Georgian bay. It held a level which now by subsequent differential epeirogenic movements is left probably wholly below the level of Lake Michigan by a vertical amount ranging from almost nothing to about 40 feet. Its shores were nearly coincident with the western shore of Lake Huron, but eastward they are now elevated mostly 150 to 200 feet above that lake and Georgian bay; and in the Lake Superior basin they vary from about 50 feet above Lake Superior at its mouth, and along its northeastern and northern shores, to 25 feet at Houghton, and to a few feet or none at Duluth.

The Algonquin beach at the south end of Lake Huron coincides very closely with the land surface there and with the

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Chicago to the Des Plaines and Mississippi rivers so lately as about 1,500 years ago, when the Niagara river had cut back its gorge to the Johnson ridge, about a mile north of the present site of the falls. This would have formed a beach 10 to 15 feet above Lakes Michigan and Huron, and about 20 to 25 feet above Lake Erie, around all their shores; and the absence of such a modern and still horizontal shore line, slightly higher than the present lake levels, upon all this large area, forbids an acceptance of this hypothesis.

* J. W. Spencer, "Deformation of the Algonquin Beach, and Birth of Lake Huron," this Journal, III, vol. xli, pp. 12–21, with map, Jan., 1891; and other papers before cited. G. K. Gilbert, F. B. Taylor, and Warren Upham, as before cited for Lake Warren. G. F. Wright, Bulletin Geol. Soc. Am., vol. iv, pp. 423–5; with ensuing discussion by Dr. Robert Bell, pp. 425–7.

present St. Clair and Detroit rivers, by which the earliest outflow of the old glacial lake probably passed southward and thence ran east as a glacial River Erie, at first tributary to Lake Lundy. As soon as that very briefly existing glacial lake was drained away, the river followed the lowest part of the shallow bed of the present Lake Erie along all its extent, which then had an eastward descent of probably 200 feet, allowing no lake or only a very small one to exist in the deepest depression of the basin; and north of Buffalo it coincided with the course of the Niagara river.

Gilbert, Wright, and Spencer, have thought that for a long time the outflow of the three great lakes above Lake Erie passed by the way of Lake Nipissing to the Mattawa and Ottawa rivers. It seems to me far more probable, however, that the epeirogenic uplift of the Nipissing region, which had elevated it already about 400 feet during the existence of Lake Warren, continued so fast that both the Trent and Nipissing-Mattawa passes were raised the additional 50 feet needed to place them above the level of Lake Algonquin before the glacial retreat uncovered the country east of them so that outlets could be obtained there.

With the continuance of the uplift of the Lake Superior basin after the formation of the Algonquin beach, the mouth of Lake Superior and the Sault Ste. Marie came into existence; and this movement allowed the lake level at Duluth to fall probably 40 or 50 feet beneath the Algonquin and present shore line. Subsequent differential elevation of the eastern and northern parts of the basin, as compared with Duluth, has again brought the west end of the lake up to the Algonquin shore, but not until the St. Louis river, while the water surface stood considerably lower than now, had deeply eroded its broad channel through the very gently sloping expanse of till from Fond du Lac to the harbor of Duluth and Superior.

The differential uplift of the Algonquin beach, as compared with Chicago and the previous mouth of Lake Warren, has been about 60 feet near the mouth of Lake Huron and at Duluth; 110 feet at the mouth of Lake Superior; 200 feet at Lake Nipissing; and 240 to 290 feet at Barrie, Lorneville, and Orillia, on Lake Simcoe. A broad lobe of the waning ice sheet, terminating on the highland area between the south end of Georgian bay and the west end of Lake Ontario, appears to have delayed the elevation of that district, so that subsequent to the formation of the Algonquin beach more uplifting took place there than at the north side of Georgian bay and about Lake Nipissing. The ascent of the Algonquin beach in nearly 200 miles from the mouth of Lake Huron northeasterly to Lake Simcoe averages about a foot per mile; and thence in about 135 miles north to Lake Nipissing it descends at an average rate of about eight inches per mile.

While the eastern part of the Lake Algonquin area was being much uplifted, with the formation of other beaches below the first, probably the southern part of the Lake Michigan basin remained with a very slight change of attitude or none, having previously risen to approximately its present height, which it has since held with little or no change. But the northeastward elevation raising the country where Lake Algonquin and now Lake Huron have outflowed, gradually caused the water level at Chicago to rise some 40 feet above its old Algonquin level, which is shown by a sublacustrine terrace formed by the Algonquin wave erosion and beach accumulation.

On the Saugeen river, Ontario, and near the south end of Georgian bay, fresh-water shells are found in beds belonging to stages of Lake Algonquin respectively about 40 and 100 feet below the main and earliest Algonquin beach, or 90 and 78 feet above the present lake and bay.

*Lake Lundy.**—From the Forest beach at Crittenden, Erie county, N. Y., marking the latest level of Lake Warren, there is a descent of 125 feet between 860 and 735 feet above the sea to the earliest strand of the glacial Lake Lundy, which for a time occupied the northeastern three-fourths of the Lake Erie basin. A more conspicuous principal Lundy beach, 30 feet lower, on which is the "ridge road" named Lundy lane, near Niagara Falls, has an eastward ascent of 30 feet in about 40 miles from Font-hill, Ont., to Akron, N. Y., five miles north of Crittenden. Lake Lundy opened through a strait about 30 miles wide into the Lake Ontario basin. Its outflow passed eastward, across the country close north of the Finger lakes, to the Mohawk and Hudson valleys, still partly filled by the receding ice-sheet and permitting a series of mouths of Lake Lundy to be found at successively lower levels, until as the ice-border withdrew the water soon sank to the lowest point of the Ontario-Mohawk watershed at Rome, N. Y., where its level long remained, forming the Iroquois beach. One of the stages of the sinking Lake Lundy or incipient Lake Iroquois, probably nearly midway in altitude between the Lundy and Iroquois beaches, I find to be indicated by my studies of eskers in Rochester and Pittsford, N. Y.†

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* J. W. Spencer, "Deformation of the Lundy Beach and Birth of Lake Erie," this Journal, III, vol. xlvii, pp. 207–211, with map, March, 1894.

† Proceedings of the Rochester Academy of Science, vol. ii, pp. 196–198, Jan., 1893.

*Lake Iroquois.**—This glacial lake, outflowing at Rome to the Mohawk and Hudson, occupied less area in the west part of the Lake Ontario basin during its earliest stage than during the later and probably longer enduring lake stage by which the high Iroquois beach in that region was formed. Previous to the date of the western development of the Iroquois beach, the early water level stood at one time only a little higher than the present Lake Ontario at Toronto and Scarboro Heights, 6 to 15 miles east of Toronto, as compared with the altitude, doubtless absolutely lower than now with regard to the sea, which the land then held in that part of the lake basin. This is shown by the occurrence of fossil fresh-water mollusks of fourteen species, and wood of ash, oak, and American yew, in beds at Toronto, described by Coleman, which now are 33 to 51 feet above Lake Ontario, or 280 to 298 feet above the sea. All the mollusk species are now living; but four are restricted, so far as known, to waters tributary to the Mississippi. A boulder-bearing surface deposit above these beds proves that the front of the ice-sheet was not far distant; but the climatic conditions of that time, clearly indicated by the fauna and flora, were as mild as now. There next ensued, probably, a gradual rise of the lake, due to an uplifting of the country about its outlet at Rome, until it stood at the level of the well defined Iroquois beach, which has a height at Toronto of about 200 feet above Lake Ontario. Thick fossiliferous delta deposits had been, meanwhile, brought into the north edge of the lake at Toronto and several miles eastward along the lake-cliff section of Scarboro Heights, described by Hinde; and repeated re-advances of the ice-front, one during, and another after, the delta accumulation, formed, at the locality last noted, two deposits of till or boulder-clay.

In a limited sense the Toronto and Scarboro fossils may be called Interglacial, since they lie between deposits of glacial drift; but they seem better referred to moderate oscillations of the ice boundary than to the distinct glacial epochs which Coleman and Hinde infer from them. Both these beds and

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* J. W. Spencer, "The Deformation of the Iroquois Beach and Birth of Lake Ontario," this Journal, III, vol. xl, pp. 443–451, with map, Dec., 1890; and papers previously cited. Thomas Roy (in paper by Sir Charles Lyell), Proceedings Geol. Soc., London, vol. ii, 1837, pp. 537, 538. Sir Charles Lyell, Travels in N. A., in 1841–42, vol. ii, chapter xx. E. J. Chapman, Canadian Journal, new series, vol. vi, 1861, pp. 221–229, and 497, 498. Sandford Fleming, Can. Jour., same vol. vi, pp. 247–253. George J. Hinde, Can. Jour., vol. xv, 1877, pp. 388–413. A. P. Coleman, Am. Geologist, vol. xiii, pp. 85–95, Feb. 1894. Geol. Survey of Canada, Report of Progress to 1863, pp. 912, 913. James Hall, Geology of New York, Part iv, 1843, pp. 348–351. Baron Gerard de Geer, "On Pleistocene Changes of Level in eastern North America." Proc. Boston Soc. Nat. Hist., vol. xxv, 1892, pp. 454–477, with map; also (excepting the map) in Am. Geologist, vol. xi, pp. 22–44, Jan., 1893. G. K. Gilbert, F. B. Taylor, E. W. Claypole, G. F. Wright, and Warren Upham, as cited for Lakes Warren and Algonquin.

the richly fossiliferous Leda clays, which last overlie the latest glacial drift in the St. Lawrence, Ottawa, and Champlain valleys, may be referred to the closing stage or Champlain epoch of the Ice age; and they both testify, like the partially forest-covered Malaspina ice-sheet in Alaska, of the close sequence of a warm climate, with luxuriant plant and animal life, during and immediately after the recession of the ice-sheet. The transition from the Glacial to the Champlain climate seems readily explained by the epeirogenic depression which ended the Glacial period.*

The height of Lake Ontario is 247 feet; and that of the old Iroquois outlet crossing the water-shed at Rome is 440 feet, above the sea level. Thence the Iroquois beach in its course northward adjacent to the eastern end of Lake Ontario has a gradual ascent of about five feet per mile along a distance of 55 miles to the latitude of Watertown, where the highest beach is 730 feet above the sea, showing that a differential uplift of about 290 feet has taken place, in comparison with the Rome outlet. From Rome westward to Rochester, the beach has nearly the same height with the outlet; but farther westward it descends to 385 feet above the sea at Lewiston and 363 feet at Hamilton, at the western end of Lake Ontario. Continuing along the beach north of the lake, the same elevation as the Rome outlet is reached near Toronto, and thence east-northeastward an uplift is found, similar to that before described east of the lake, its amount near Trenton and Belleville above Rome being about 240 feet. It is to be added that northward from Rome the Iroquois beach becomes divided into a series of distinct beaches, marking stages in the northeastward rise of the land and having near Watertown a vertical range of 80 feet below the highest and oldest, which was before noted; and that westward a similar series of strand lines also lies below the highest, likewise before noted, which there, however, contrary to the order northeastward, was the newest. The highest beach near Watertown was probably contemporaneous with the fossiliferous beds of Toronto; some of the intermediate northeastern beaches corresponded to the delta deposits of Scarboro; and the lowest northeastward lake level was continuous with the highest at Toronto, Hamilton, Lewiston, and east to Rome.

Between Lakes Warren and Lundy the old water level near the west end of Lake Ontario fell 125 feet, minus some amount to be subtracted for the progressing northeastward elevation of the land. The two Lundy shores are 30 feet apart verti-

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* J. D. Dana, Trans. Conn. Acad. of Arts and Sciences, vol. ii, 1870, p. 67; this Journal, III, vol. x, pp. 168–183, Sept., 1875. Warren Upham, Glacialists' Magazine, vol. i, pp. 236–240, June, 1894.

cally. From the lower and main Lundy beach the water fell about 480 feet to the earliest stage of Lake Iroquois when the Toronto fossil shells lived in the edge of that lake, excepting that here again some undetermined amount must be subtracted to compensate the concurrent rise of the land. Adding these vertical intervals together, we have 635 feet, which probably may be reduced 100 feet, more or less, for the effects of the accompanying epeirogenic uplift. We have left some 500 or 550 feet, to be subtracted from the altitude of the old Chicago outlet of Lake Warren, believed to have been then approximately as now, 590 feet above the sea, to give the earliest altitude of the Rome outlet. It thus appears, as I concluded from a similar computation four years ago, that the Rome outlet was at first only 50 or 100 feet above the sea level.* It was gradually uplifted, participating in the differential rise of the whole Ontario basin, to about 300 feet above the sea while the outflow continued here, and to probably 350 feet or more, lacking less than 100 feet of its present height, by the time when the much farther retreat of the ice permitted the extension of the sea to Ogdensburgh and Brockville, on the St. Lawrence river near the mouth of Lake Ontario. Intermediate between Lake Iroquois and the Champlain incursion of the sea, the glacial Lake St. Lawrence, into which Lake Iroquois was merged by the retreat of the ice-sheet from the northern side of the Adirondacks, filled the Lake Ontario basin for a considerable time at levels below the Iroquois beaches.

As the area of Lake Warren was being differentially much elevated during the earlier existence of that lake, and as the area of Lake Algonquin was similarly uplifted in part or wholly contemporaneously with the Iroquois basin, so this region was being rapidly raised and tilted upward to the north and east while the lake level, held constantly without important downward cutting at the Rome outlet, inscribed many shore lines on the slowly moving land. All the movement throughout the whole region probably was upward; but the position of Rome, and its greater rise than western parts of the basin during the existence of Lake Iroquois, caused the old beaches westward to have now declining gradients.

Lake Hudson-Champlain.†—The absence of marine fossils

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* Bulletin Geol. Soc. Am., vol, ii, pp. 260-262.

† Warren Upham. Bulletin Geol. Soc. Am., vol. i. p. 566; vol. ii, p. 265; vol. iii, pp. 484–487 (first using this name). C. H. Hitchcock, Geology of Vermont, 1861, vol. i, pp. 93–167, with map. J. S. Newberry, Pop. Sci. Monthly, vol. xiii, 1879, pp. 641–660. F. J. H. Merrill, this Journal, III, vol. xli, pp. 460–466, June, 1891. W. M. Davis, Proc. Boston Soc. Nat. Hist., vol. xxv, 1891, pp. 318–334. S. Prentiss Baldwin, "Pleistocene History of the Champlain Valley," Am. Geologist, vol. xiii, pp. 170–184, with map, March, 1894. Baron de Geer, as cited for Lake Iroquois.

in beds overlying the glacial drift on the shores of southern New England, Long Island, and New Jersey, and the water-courses which extend from the terminal moraine on Long Island southward across the adjacent modified drift plain and continue beneath the sea level of the Great South bay and other bays between the shore and its bordering long beaches, prove that this coast stood higher than now when the ice-sheet extended to its farthest limit. A measure of this elevation of the seaboard in the vicinity of New York during the Champlain epoch is supplied, as I believe, by the shallow submarine channel of the Hudson, which has been traced by the soundings of the U. S. Coast Survey from about 12 miles off Sandy Hook to a distance of about 90 miles southeastward. This submerged channel, lying between the present mouth of the Hudson and the very deep submarine fjord of this river, ranges from 10 to 15 fathoms in depth, with an average width of 1¼ miles, along its extent of 80 miles, the depth being measured from the top of its banks, which, with the adjacent sea-bed, are covered by 15 to 40 fathoms of water, increasing southeastward with the slope of this margin of the continental plateau. During the whole or a considerable part of the time of the glacial Lake Iroquois, this area stretching 100 miles southeastward from New York was probably a land surface, across which the Hudson flowed with a slight descent to the sea. But northward from the present mouth of the Hudson the land at that time stood lower than now; and the amount of its depression, beginning near the city of New York and increasing from south to north, as shown by terraces and deltas of the glacial Lake Hudson-Champlain, which were formed before this long and narrow lake became merged in the glacial Lake St. Lawrence, was nearly 180 feet at West Point, 275 feet at Catskill, and 340 feet at Albany and Schenectady. From these figures, however, we must subtract the amount of descent of the Hudson river, which in its channel outside the present harbor of New York may probably have been once 50 or 60 feet in its length of about 100 miles.

Before the time of disappearance of the ice-barrier from the St. Lawrence valley at Quebec, the descent of the Hudson river beyond New York city may have diminished, or the seaboard at New York may have sunk so as to bring the shore line nearly to its present position; but the Hudson valley meanwhile had been uplifted, so that the outflow from the Lake St. Lawrence crossed the low divide, now about 150 feet above the sea, between Lake Champlain and the Hudson. This is known by the extension of fossiliferous marine deposits along the Lake Champlain basin nearly to its southern end, while they are wholly wanting along all the Hudson valley.

Indeed, the outflowing river from Lakes Iroquois, Hudson-Champlain, and St. Lawrence, or the Hudson during the Post-glacial period, channeled the lower part of this valley to a depth of about 100 feet below the present sea level, proving that the land there, as Merrill points out, stood so much higher than now at some time after the ice retreated.

According to the observations of Davis, Baldwin, and Baron de Geer, the highest shore line of the Lake Hudson-Champlain is now elevated to about 275 feet above the sea at Catskill, N. Y.; 550 feet in Chesterfield, N. Y., on the west side of Lake Champlain opposite to Burlington; and 658 feet at St. Albans, Vt. Assuming that the mouth of the lake, near New York city, was 50 feet above the sea, the differential northward uplift of the originally level shore has been at the rate of about two feet per mile for the 100 miles from the present mouth of the Hudson to Catskill; 1·7 feet per mile for the next 160 miles north to Chesterfield; and about three and a half feet per mile in the next 30 miles north-northeastward to St. Albans. Perhaps a higher beach may exist in Chesterfield, which would bring these gradients nearer to uniformity. The series noted there by Baldwin comprises eight beaches referable to the successive water levels of Lake Hudson-Champlain, Lake St. Lawrence, and the sea in the Champlain basin, their heights above the sea level of to-day being 550 feet, 530, 470, 423, 386, 365, 335, and 290 feet. The mean level of Lake Champlain is 97 feet above the sea, and its maximum depth 402 feet. The lower four of these beaches belonged to the Champlain arm of the enlarged Gulf of St. Lawrence, as shown by the height of its sand deltas and associated fossiliferous clays; but the higher four represent stages of the Lakes Hudson-Champlain and St. Lawrence. These shore lines, like those of the glacial lakes farther west to Lake Agassiz, were probably formed during times of rest or slackening in the somewhat intermittent epeirogenic elevation of the land.

*Lake St. Lawrence.**—The records of the Glacial and Champlain epochs in the St. Lawrence valley have been most fully studied during many years by Sir William Dawson, to whose work chiefly we are indebted for detailed descriptions of the evidences of the marine submergence of that region to a maxi-

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* Sir J. William Dawson, The Canadian Ice Age (Montreal, 1893), p. 301, with maps and sections, views of scenery, and nine plates of Pleistocene fossils. This volume sums up the author's work since 1855 on the glacial drift and associated lacustrine and Champlain marine formations of the St. Lawrence valley, embodying the studies which had been published in many papers in the "Canadian Naturalist and Geologist" and elsewhere. He had given a similar summary in a pamphlet of 112 pages, "Notes on the Post-pliocene of Canada." in 1872. J. W. Spencer, G. K. Gilbert, Baron de Geer, S. Prentiss Baldwin, and Warren Upham, as before cited for Lakes Warren, Algonquin, Iroquois, and Hudson-Champlain.

mum height at Montreal somewhat exceeding 500 feet above the present sea level. Earlier than that time of occupation of the depressed broad valley by the sea, it was filled from Lake Ontario to near Quebec, by a great glacial lake, held on its northeast side by the receding continental ice-sheet. The directions of the glacial striæ and transportation of the drift in the St. Lawrence valley, running southwestward at Montreal and onward to the great lakes, but eastward from Quebec down the shores of the Gulf of St. Lawrence, and southeast across Nova Scotia and New Brunswick, show that the latest remnant of the ice barrier blockading this valley was melted away in the neighborhood of Quebec, then admitting the sea to a large, low region westward. Until this barrier was removed, a glacial lake, which here for convenience of description and citation is designated as the Lake St. Lawrence, dating from the confluence of Lakes Iroquois and Hudson-Champlain and growing northward and eastward, spread over the Ottawa valley probably to the mouth of the Mattawa, and down the St. Lawrence, as fast as the ice-front was melted back.

When Lake Iroquois ceased to outflow at Rome and, after intervening stages of outlets existing for a short time at successively lower levels north of the Adirondacks, began to occupy the Champlain basin and the St. Lawrence valley northward, changing thus to the Lake St. Lawrence, its surface fell by these stages about 250 feet to the glacial Lake Hudson-Champlain, which had doubtless reached northward nearly to the St. Lawrence. After this reduction of the water body in the Ontario basin, it still had a depth of about 150 feet over the present mouth of Lake Ontario, as shown by a beach traced by Gilbert, which thence rises northeastward but declines toward the south and southwest. Its plane, which is nearly parallel with the higher Iroquois beaches, sinks to the present lake level near Oswego, N. Y. Farther southwestward the shore of the glacial lake at this lower stage has been since submerged by Lake Ontario. The Niagara river was then longer than now, and the lower part of its extent has become covered by the present lake. From the time of the union of Lakes Iroquois and Hudson-Champlain, a strait, at first about 150 feet deep, but later probably diminished on account of the rise of the land to a depth of about 50 feet, joined the broad expanse of water in the Ontario basin with the larger expanse in the St. Lawrence and Ottawa valleys and the basin of Lake Champlain. At the subsequent time of ingress of the sea past Quebec the level of Lake St. Lawrence fell probably 50 feet or less to the ocean level. The place of the glacial lake so far westward as the Thousand Islands was then taken by the sea, with the marine fauna which is preserved in the Leda clays and Saxicava sands.

The Champlain Marine Submergence.

That the land northward from Boston was lower than now while the ice-sheet was being melted away, is proved by the occurrence of fossil mollusks of far northern range, including *Leda arctica* Gray, which is now found living only in the Arctic seas, preferring localities which receive muddy streams from existing glaciers and from the Greenland ice-sheet. This species is plentiful in the stratified clays resting on the till in the St. Lawrence valley and in New Brunswick and Maine, extending southward to Portsmouth, N. H. But it is known that the land was elevated from this depression to about its present height before the sea here became warm and the southern mollusks, which exist as colonies in the Gulf of St. Lawrence, migrated thither, for these southern species are not included in the extensive lists of the fossil fauna found in the beds overlying the till.

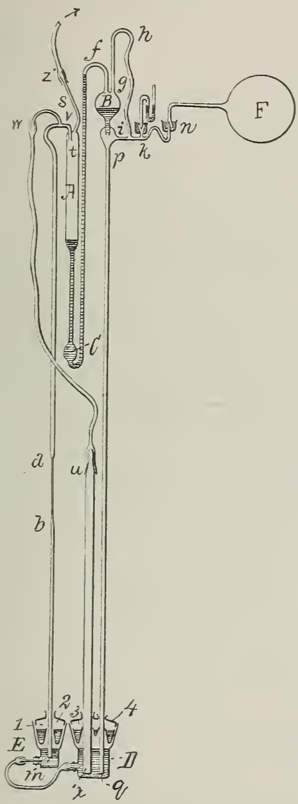
In the St. Lawrence basin these marine deposits reach to the southern end of Lake Champlain, to Ogdensburgh and Brockville, and at least to Pembroke and Allumette island, in the Ottawa river, about 75 miles above the city of Ottawa. The isthmus of Chiegnecto, connecting Nova Scotia with New Brunswick, was submerged, and the sea extended 50 to 100 miles up the valleys of the chief rivers of Maine and New Brunswick. The uplift of this region from the Champlain sea level was 10 to 25 feet in the vicinity of Boston and northeastward to Cape Ann; about 150 feet near Portsmouth, N. H.; from 150 to about 300 feet along the coast of Maine and southern New Brunswick; about 40 feet on the northwestern shore of Nova Scotia; thence increasing westward to 200 feet in the Bay of Chaleurs, 375 feet in the St. Lawrence valley opposite the Saguenay, and about 560 feet at Montreal; 150 to 400 or 500 feet, increasing from south to north, along the basin of Lake Champlain; about 275 feet at Ogdensburgh, and 450 feet near the city of Ottawa. The differential elevation was practically completed, as we have seen from the boreal character of the Champlain marine molluscan fauna, shortly after the departure of the ice-sheet. With the areas of the glacial Lakes Agassiz, Warren, and Iroquois, in the interior of the continent, this coastal region gives testimony of a wave-like epeirogenic elevation of the formerly ice-laden portion of the earth's crust, proportionate with the glacial melting and closely following the retreat of the ice from its boundaries of greatest extent inward to the areas on which its waning remnants lingered the latest.

On the Green Mountains of Vermont, the White Mountains region, and indeed probably over a large part of New England, a tract of the departing ice-sheet remained after the access of the sea to the St. Lawrence basin left the New England ice as an isolated mass. This is known by the large tribute of stratified drift quickly brought by streams from the melting ice of the Green Mountains area and deposited as gravel and sand deltas and offshore clays of the Winooski, LaMoille, and Missisquoi rivers, described by Hitchcock and Baldwin, in the east border of the Champlain arm of the sea. On the west, too, a considerable remnant of the ice-sheet seems to have remained unmelted until this time on the Adirondacks, and to have likewise supplied the deltas and marine clays of the Au Sable, Saranac, and Chazy rivers in New York. Deflections of glacial striation down the valleys, with corresponding drift transportation and formation of local moraines across some of the mountain valleys, have been recorded by Hitchcock, Stone, and others, in Vermont and New Hampshire; but the time allowed for such glacial action, under the warm Champlain climate, was very short. The earlier melting of the ice along the St. Lawrence valley than on these mountain tracts was due on one side to the laving action of the waves of Lakes Iroquois and St. Lawrence, and on the other side to the washing of the ice-cliffs by the fast encroaching sea in the Gulf of St. Lawrence, until at last near Quebec the barrier was severed.

From the Champlain submergence our Atlantic coast was raised somewhat higher than now; and its latest movement from New Jersey to southern Greenland has been a moderate depression. The vertical amount of this postglacial elevation above the present height, and of the recent subsidence, on all the coast of New Jersey, New England, and the eastern provinces of Canada, is known to have ranged from 10 feet to a maximum of at least 80 feet at the head of the Bay of Fundy, as is attested in many places by stumps of forests, rooted where they grew, and by peat beds now submerged by the sea. As in Scandinavia, the restoration of isostatic equilibrium is attended by minor oscillations, the conditions requisite for repose having been overpassed by the early reëlevation of outer portions of each of these great glaciated areas. The close of the Ice age was not long ago, geologically speaking, for equilibrium of the disturbed areas has not yet been restored.

Art. II.—*An Automatic Mercury Vacuum Pump;* by M. I. Pupin, Ph.D., Columbia College.

The pump which forms the subject of the following description is a combination of two distinct forms of apparatus. First, a *suction-pump* capable of raising mercury to practically any height and secondly, an *ordinary Sprengel pump.* The part connecting the two is a syphon barometer, properly disposed with respect to the two parts which it connects.



Referring now to the diagram I shall describe each part separately and shall then explain the modus operandi of the combination.

1. *The Suction Pump.*

It consists of the reservoir A to which are joined the short tube *n* and the tube *t v m* which I shall call *the suction tube.* A short branch tube *v w* is connected by a rubber tube *w u* to the wide tube *u x.* This wide tube I shall call the *valve tube.* The suction tube and the valve tube dip in two separate mercury vessels E and D which are provided with specially constructed glass dishes 1, 2, 3, 4 containing concentrated sulphuric acid for drying purposes. The two vessels are connected to each other by means of a rubber tube. A part of the suction tube *a b* about 20^{cm} long has a cross-section one-half as large as that of the rest of the tube.

2. *The Sprengel Pump.*

It is of the ordinary type and consists of the reservoir B from which the mercury drops into a long tube *p q*, *the tube of descent.* This tube may be given any convenient length; 160^{cm} will be found sufficient for rapid working. The tube of descent carries a lateral extension which is connected to the reservoir B by means of the tube *g h i.* The object of this connection is to keep the gas pressure above and below the mercury in the reservoir the same. Two ground joints *k* and *n* are made air-tight by the mercury which fills the surrounding hoods. These joints connect this extension to a manometer and the vessel F which is to be exhausted.

3. *The Syphon barometer connection.*

This is the part consisting of the bulb *c* and the tube *c f*. The length of this tube is about 80^{cm}.

All the parts are made of glass.

The modus operandi.

First a little mercury is poured through *z s* into A until the reservoir *c* is about half full, which is considerably more than sufficient to fill the tube *c f*. By means of a rubber tube, *z s* is connected then to a water-pump or any other suction pump that may be available. Suppose that this auxiliary suction pump is capable of reducing the pressure in A to say 40^{mm} and suppose also that the barometric pressure is 760^{mm}. Owing to the action of the auxiliary suction pump the gas pressure in A is continually reduced and therefore also in F and in all other parts connected with A. Mercury rises in the valve and suction tubes and also in the tube of descent. The extremity *m* of the suction tube is placed at such a distance below the initial level of the mercury in E and D that when the mercury column in the suction tube is about 60^{cm} long the mercury level in E (which sinks rapidly on account of the rising of the mercury into the valve tube) has just reached *m*. From that moment on no more mercury gets into the suction tube. But owing to the action of the auxiliary pump the pressure in A is being still reduced, hence the column in the valve tube rises still higher and the level in E sinks still lower. In the mean time the column in the suction tube rises bodily owing to the external air pressure until it reaches the narrow part *a b* when it begins to lengthen out, and since *a b* is 20^{cm} long and the initial length of the mercury column is 60^{cm} it follows that this column will be lengthened out to 70^{cm} and no more. Hence as soon as the pressure in A has been reduced by 70^{cm} this column will rise with accelerated velocity until it is injected by the external air pressure into the reservoir A. The external air rushes then into A and through *t v w* into the valve tube. The valve tube column sinks and the level in E rises. But it will rise more rapidly in D than in E owing to the friction of the narrow rubber tube connecting the two vessels E and D. Hence it will continue to rise for a short time even after it has reached *m* and by closing the suction tube started again the action of the auxiliary suction pump.

This retardation of the level in E is of considerable importance, for if the suction tube had no contraction *a b* and if the two levels in E and D were continually of the same height then the mercury would be sucked up through the suction tube not in form of solid columns but in form of numerous drops separated from each other by air bubbles. This would render the rapidity of action less satisfactory; besides, it would also cause a rapid oxidation of the mercury.

As soon as the quantity of mercury injected into A brings the distance between the level in A and the point *f* into the vicinity of the barometric height then the mercury begins to overflow from the syphon tube into the reservoir B and the exhausting of F begins. By squeezing the tube connecting E and D the rapidity of supply to B is varied, hence the quantity of mercury in B can thus very easily be kept within certain desirable limits.

The simplicity and the convenience of the apparatus need n. comment. Suffice it to observe that it has no stopcocks and that it can operate with a much smaller quantity of mercury than required by ordinary mercury pumps.

My experiments with vacuum tube discharges suggested long ago to my mind a pump of this type; but want of time and of a glass blower at a convenient distance prevented me from giving my ideas on this matter a practical test, until last summer.* I intend to publish soon numerical data concerning the rapidity of working of the various forms of pumps of this type. The vacua obtainable by it are, of course, the same as those obtainable by the ordinary form of the Sprengel pump.

Electrical Laboratory, Dec. 17th, 1894. Columbia College, New York.

Art. III.—*On Graphical Thermodynamics;* by René de Saussure.

Translated by the author from vol. xxxi of the *Archives des Sciences physiques et naturelles*, May, 1894.

1. Heat is usually regarded as a periodical motion of the particles constituting the material bodies; if this be true, the variations in the physical state of a substance are due to the variations of the state of this periodical motion; in other words, the physical state of the substance is a function of the state of the periodical motion. Since the periodical motion of the particles can be defined by its kinetic energy and by the

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* [More particular details of construction will be given to Messrs. Eimer & Amend, 18th Street and 3d Ave., New York, and to Herr Kramer, Glasbläser, Fridrich Str., Freiburg, Baden]

duration of its period, the physical state of the substance can be completely defined by means of these two data, provided that the weight of the substance remains the same.

It is by so defining the state of a body, that Clausius succeeded in demonstrating the fundamental theorems of thermodynamics, with the help only of the laws of mechanics, without making any hypothesis as to the form of the trajectories described by the particles of the body.

But if it is desired to establish the theory of the transformations which take place in a substance under the influence of heat, it is necessary to define the nature of the periodical motions, as well as in the theory of light. We can assume for instance, that this motion is a straight vibratory motion on either side of a fixed center.

By this hypothesis, we still need two data to define completely the motion of the particles, i. e., the amplitude a and the duration i of one period of the vibratory motion. And since the state of the substance (whose mass is taken as the unit) is a result of the state of motion of the particles, the state of said substance can be considered as a function of the two variables a and i.

2. On the other hand, to define the physical state of a substance by means of experimental data, the variables used are: the volume V, the absolute temperature T and the outside pressure P (the mass being still taken as the unit).*

Hence, the state of a body can also be regarded as a function of the three variables: P, V and T. But these variables are not independent, that is to say: the same weight of the same body cannot occupy the same volume at the same pressure and at different temperatures, since two variables are sufficient to define the state of the substance. For each body, there is a relation $F(P, V, T) = 0$ known as the *equation* of said body, so that the value of either of the three variables P, V or T is a direct result of the values attributed to the two others.

Considering P, V and T as three coördinates, the equation $F(P, V, T) = 0$ represents a surface, any point of which corresponds to a certain state of the body. This surface is therefore a "representative locus" of the different states under which the body can exist, and is known as the "*thermodynamic surface.*"

3. When the physical state of a substance is defined by the first method, i. e., by means of the amplitude a and of the period i of the vibratory motion which constitutes the heat, the variables a and i can also be treated as two coördinates,

---

* In the following study, we assume that all the particles of the body are at the same temperature, i. e., that they all have an identical vibratory motion.

and the physical state can be represented on a piece of paper by the point corresponding to these coördinates. In this case, the piece of paper itself or a part of it, is the representative locus of the different states under which the substance can exist.

It follows that each point of the thermodynamic surface $F(P, V, T) = 0$ corresponds to a point on the sheet of paper, and conversely. If the variables P, V and T vary continuously, the variables a and i shall also vary continuously, since the variation of the state of the body is itself continuous; so that the coördinates P, V, T are continuous functions of the coördinates a and i.

$$\left\{\begin{array}{l} P = \lambda(a, i) \\ V = \mu(a, i) \\ T = \upsilon(a, i) \end{array}\right. \qquad (1)$$

These three equations can be regarded as the general equation to the thermodynamic surface in terms of two auxiliary variables a and i; hence, by eliminating a and i between them, the result must be: $F(P, V, T) = 0$.

The variables a and i can be considered as the coördinates of any point on the thermodynamic surface. Any relation between a and i represents a curve traced on this surface, i. e., a cycle of transformations undergone by the substance. We have just seen that the functions λ, μ, υ must be such as to lead to the relation $F(P, V, T) = 0$ by eliminating a and i between equations (1); but as long as these functions are submitted only to this condition, the variables a and i are still arbitrary variables and do not necessarily denote the amplitude and the period of the vibratory motion, since there are an infinite number of ways of representing the same surface by means of two auxiliary variables. For instance, the equation of the body: $T = f(P, V)$ can be put under the form:

$$\left\{\begin{array}{l} P = u \\ V = v \\ T = f(u, v) \end{array}\right.$$

u and v being the two auxiliary coördinates chosen to represent graphically the cycles of transformations.

These coördinates u and v being equal to P and V respectively, the graphical representation thus obtained would be the same as the one first introduced in thermodynamics by Clapeyron, and would have the same property, i. e., the area lying between the axis of V, two ordinates and the path described by the body would be equal to the external work.

If other coördinates are chosen, the properties of the graphical representation will change, for it is evident that these properties depend essentially upon the choice of the two auxiliary variables a and i; therefore, they ought to be chosen in such a way as to give the best possible graphical representation of the cycles of transformation, i. e., in such a way as to enable us to determine graphically the greatest possible number of the physical elements depending upon the transformation, by means of geometrical magnitudes depending only upon the form and position of the path described by the body in the adopted system of coördinates. Before defining this system, let us examine what conditions must be fulfilled by the functions λ, μ, υ, in order that the auxiliary variables a and i be respectively the amplitude and the period of the vibratory motion.

4. Denoting by m the mass of one of the particles composing the substance and by u the mean velocity of the vibratory motion, the expression $\frac{1}{2}\Sigma mu^2$ is the actual kinetic energy of the heat (the sum Σ being extended to all the particles). Dividing this sum by the mechanical equivalent of heat E, the result is equal to the amount of heat actually contained in the body.

This amount of heat is proportional to the absolute temperature, hence:

$$\tfrac{1}{2}\Sigma mu^2 = \mathrm{KTE} \tag{2}$$

K being a constant.

Denoting by f the mean value of the force producing the vibratory motion, the formulæ:

$$fa = mu^2$$

$$f = 2\pi^2 m \frac{a}{i^2} \tag{3}$$

can be established without difficulty, since in all vibratory motions of small amplitude, the force producing the vibration is proportional to the displacement of the particles.

Combining equations (2) and (3) and noticing that $\Sigma m = 1$ and that the mean velocity u is the same for all the particles of the substance, we shall obtain:

$$\mathrm{T} = \frac{\pi^2}{\mathrm{KE}} \frac{a^2}{i^2} \tag{4}$$

which is the expression of T in terms of a and i, and is therefore identical to the third of equations (1); in other words, when the two auxiliary variables a and i denote the amplitude and the period of the vibratory motion, the function v is no longer arbitrary, and the equation to the thermodynamic surface is:

$$\begin{cases} \mathrm{P} = \lambda(a, i) \\ \mathrm{V} = \mu(a, i) \\ \mathrm{T} = \dfrac{\pi^2}{\mathrm{KE}} \dfrac{a^2}{i^2} \end{cases} \tag{5}$$

the functions λ and μ being still submitted to the condition that the result of eliminating a and i between equations (5) be: $F(P, V, T) = 0$.

When the functions λ and μ have been determined for a particular substance, equations (5) do not only represent the thermodynamic surface, but also the value of the two elements (a and i) of the vibratory motion, corresponding to any state of the substance defined by experimental data (P, V, T).

The last of equations (5) is the same for all substances, except that the value of the constant K changes from one substance to another. The determination of the functions λ and μ will be investigated after we shall have studied the properties of the graphical representation, which properties can be found by assuming that these functions are known.

5. When a substance undergoes an elementary and reversible transformation,* the amount of heat dH, absorbed by the unit of mass, is composed of two parts: the variation of the actual energy of the heat contained in the substance, and the amount of heat absorbed by the total work (external and internal).

The first part is the elementary variation of the expression $\frac{1}{E}\Sigma\frac{1}{2}mu^2$, as found above; the second is the heat absorbed by the work done by the force f for a variation da of the amplitude. Hence:

$$EdH = d\Sigma\tfrac{1}{2}mu^2 + \Sigma f da$$

But, by differentiating equation (2):

$$d\Sigma\tfrac{1}{2}mu^2 = KEdT$$

This relation shows that the constant K is the quotient of the variation of the actual amount of heat contained in the substance, by the corresponding variation of temperature, so that K is by definition the *absolute specific heat* of the substance.

We have also, from preceding formulæ:

$$\Sigma f da = \Sigma mu^2 \frac{da}{a} = 2KTE\frac{da}{a}$$

Whence finally

$$dH = KdT + 2KT\frac{da}{a}$$

Such is the expression of dH in terms of T and a; equation (4) gives by differentiation:

$$\frac{da}{a} = \frac{di}{i} + \frac{1}{2}\frac{dT}{T}$$

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* The formulæ contained in this paragraph have been already established in "La Thermodynamique et ses principales applications," by J. Moutier, Paris, 1885; we recall them here, as we will have to use them in some of the demonstrations.

By the aid of this equation and of the preceding one, the value of dH can also be obtained in terms of T and i or of a and i:

$$\left\{\begin{aligned} \frac{dH}{T} &= K\left(\frac{dT}{T}+2\frac{da}{a}\right) \\ \frac{dH}{T} &= 2K\left(\frac{dT}{T}+\frac{di}{i}\right) \\ \frac{dH}{T} &= 2K\left(2\frac{da}{a}-\frac{di}{i}\right) \end{aligned}\right. \qquad (6)$$

6. The two variables, which we intend to take as coördinates in this graphical study, depend directly upon the amplitude a and the period i of the vibratory motion of heat; denoting these variables by φ and s, we shall define them by the equations:

$$\left\{\begin{aligned} \varphi &= \frac{\pi}{i^2} \\ S &= \pi a^2 \end{aligned}\right. \qquad (7)$$

By the aid of equation (7), any of the formulæ given above and involving a and i, can be transformed into corresponding formulæ involving φ and s.

For instance, by solving equations (7) with respect to a and i, and substituting the result in equations (5), we shall obtain the equation to the thermodynamic surface in terms of φ and s, as follows:

$$\left\{\begin{aligned} P &= f(\varphi, s) \\ V &= g(\varphi, s) \\ T &= \frac{1}{KE}\varphi s \end{aligned}\right. \qquad (8)$$

All the other equations can be transformed in the same manner, so that it is understood that the two independent variables are now φ and s, and that these two quantities shall be taken as the coördinates of the point representing the physical state of the substance.

As these variables have been defined in an arbitrary manner, let us first investigate their physical nature. To reach this end, we must consider the vibratory motion of the particles as the projection of a uniform circular motion on one of its diameters; the radius of the circle is then equal to the amplitude of the vibration, and the velocity of the uniform motion is equal to the maximum velocity of the vibratory motion. It can readily be seen, that the centripetal force of the circular motion is equal to the mean value f of the force supposed to produce the vibratory motion.

The total work (external and internal) absorbed by the substance during an elementary transformation is $\Sigma f da$ as seen above. We can write identically:

$$fda = \left(\frac{f}{2\pi a}\right)(2\pi ada)$$

Let $\frac{f}{2\pi a} = \varphi_m$. Since $2\pi a$ is equal to the length of the circumference, φ_m represents geometrically the value of the centripetal force referred to the unit of length, i. e., a pressure, of so many pounds per foot, supposed to be acting on the circumference of the circle.

Let $2\pi ada = ds$ or $\pi a^2 = s$. Then s is the area of the circle.

According to these definitions:

$$\Sigma fda = \Sigma \varphi_m ds$$

If now in the equation $\varphi_m = \frac{f}{2\pi a}$ f be replaced by its value as given in equation (3), the result is:

$$\varphi_m = \frac{\pi m}{i^2}$$

and since $\Sigma m = 1$:

$$\Sigma \varphi_m = \frac{\pi}{i^2} = \varphi$$

Whence:

$$\Sigma fda = \Sigma(\varphi_m ds) = (\Sigma \varphi_m) ds = \varphi ds$$

With:

$$\varphi = \frac{\pi}{i^2} \text{ and } s = \pi a^2$$

The last two equations are precisely the ones by which φ and s have been first defined.

Since $\varphi = \varphi_m$ when $m = 1$, and since φ_m is the pressure supposed to be acting on the circumference of the circle corresponding to the particle of mass m, we can define the physical nature of φ and s as follows: If the unit of mass of a substance be represented geometrically or symbolically by a circle, the physical state of said substance can be completely defined by the area s of the circle and by a pressure φ, supposed to be acting on the circumference of the circle. The two data, thus defining the state of the substance, are precisely the coördinates φ and s, which determine the position of the point representing this state. For this reason, the abscissa s shall be called the "*symbolical volume*" and the ordinate φ the "*symbolical pressure*" of the substance.

As the considerations developed in this paragraph are somewhat abstract, it must not be forgotten that the graphical method, which is the object of this study is quite independent of these theoretical considerations, since the two variables φ

and s can always be regarded as two variables defined by the equations: $\varphi = \frac{\pi}{i^2}$ and $s = \pi a^2$, whatever be their physical nature; moreover, we shall find other reasons for regarding φ as a pressure and s as a volume.

Properties of the graphical method.

7. Let M be the point representing any physical state of a substance, and φ and s its coördinates, then according to the previous definitions:

$$a = \sqrt{\frac{s}{\pi}} \text{ and } i = \sqrt{\frac{\pi}{\varphi}}$$

So that a and i, hence the state of the vibratory motion, are readily obtained from the actual value of the coördinates of point M.

Denoting by R the total work absorbed during a transformation, we have found that:

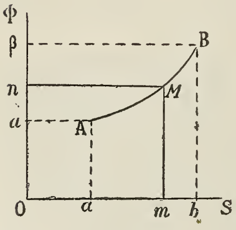
$$d\mathrm{R} = \Sigma f da = \varphi ds$$

Whence by integration:

$$\mathrm{R} = \int_a^b \varphi ds$$

i. e., if AB be the curve (fig. 1) representing the path of the substance referred to the coördinates φ and s, the total work (external and internal) absorbed during the transformation is equal to the area $AabB$ limited by the path, the axis of s and the two extreme ordinates.

1.



Comparing this result with the property of Clapeyron's graphical method, we see that the symbolical pressure and the symbolical volume are in the same relation with the total work, as the ordinary pressure and volume are with the external work.

8. The last of equations (8):

$$\varphi s = \mathrm{KTE}$$

holding true for all substances, shows that the area of the rectangle $MmOn$ formed by the coördinates φ and s, is equal to the actual amount of energy contained in the substance at the physical state M. Thus, if AB represents the path of the substance the area of the rectangles $AaO\alpha$ and $BbO\beta$ is equal to the energy of the heat contained in the substance at its initial and final states.

Since the energy of the heat : KTE is proportional to the temperature T, we can also say that the area of the rectangle MO is proportional to the temperature of the substance at the state M.

When a substance undergoes a transformation, its temperature being maintained constant, the second member of the equation $\varphi s = \mathrm{KTE}$ remains constant. Hence, the general equation of the isothermal lines is :

$$\varphi = \text{constant}$$

which is the equation of equilateral hyperbolas, whose asymptotes coincide with the axes of coördinates. The isothermal lines are the same for all substances, since the equation : $\varphi s = \mathrm{KTE}$ applies to any substance.

Remark : As $\varphi s = \pi^2 \frac{a^2}{i^2} = \mathrm{KTE}$, we see that the ratio of the square of the amplitude to the square of the period of the vibratory motion of the heat, is proportional to the temperature ; so that this ratio remains constant as long as the temperature of the body is maintained constant.

9. The amount of heat, dH, absorbed during an elementary transformation, is composed of two parts : 1st, the variation of the actual amount of heat contained in the substance, which amount equals $\frac{1}{\mathrm{E}} \varphi s$; 2d, the heat absorbed by the total work done during the elementary transformation, which is $d\mathrm{R} = \varphi ds$.

Hence : $$\mathrm{E}d\mathrm{H} = d(\varphi s) + \varphi ds$$

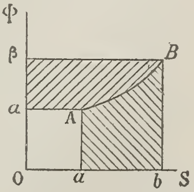
Or : $$\mathrm{E}d\mathrm{H} = sd\varphi + 2\varphi ds \qquad (9)$$

Whence, for a finite transformation :

$$\mathrm{EH} = \int_a^\beta sd\varphi + 2\int_a^b \varphi ds$$

We see from this equation, that the amount of heat necessary to let the substance describe a certain path AB (fig. 2) is proportional to the area $A\alpha\beta B$ plus twice the area $AabB$ (both of these areas being determined by the path AB).

2.



When a substance undergoes a transformation without transmission of heat, the path described is called an "*adiabatic*" or "*isentropic line.*" This path is determined by the condition :

$$d\mathrm{H} = 0$$

Or $$sd\varphi + 2\varphi ds = 0$$

Whence by integration :

$$\varphi s^2 = \text{constant}$$

Such is the general equation to the adiabatic lines for any substance. These lines are of the third degree and belong to the hyperbolic species.

10. *Clausius' Theorem.*—Equation (9) can be written :

$$\mathrm{E}d\mathrm{H} = \varphi s\left(\frac{d\varphi}{\varphi} + 2\frac{ds}{s}\right)$$

Or again, by the aid of the relation: $\varphi s = \mathrm{KTE}$:

$$\frac{dH}{\mathrm{T}} = \mathrm{K}\left(\frac{d\varphi}{\varphi} + 2\frac{ds}{s}\right)$$

Whence, for a finite transformation :

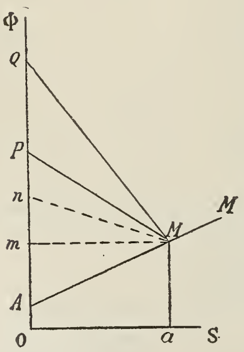
$$\int_{\mathrm{A}}^{\mathrm{B}} \frac{d\mathrm{H}}{\mathrm{T}} = \mathrm{K}(\log \varphi_{\mathrm{B}} s_{\mathrm{B}}^2 - \log \varphi_{\mathrm{A}} s_{\mathrm{A}}^2)$$

When the path is a closed cycle, A = B ; in this case :

$$\int \frac{d\mathrm{H}}{\mathrm{T}} = 0$$

Graphical representation of the Specific Heat.

3.



11. Let M be the initial state of the substance (fig. 3) ; and suppose an elementary path MM' to be described in a certain direction. Amongst the infinite number of directions around M, some are of special interest :

1st. The direction of the isothermal, whose equation is : $\varphi s = \varphi_0 s_0$; φ_0 and s_0 denoting the coördinates of point M. This equation has been derived from the condition : $\mathrm{T} = \text{constant}$ or $d\mathrm{T} = 0$.

2d. The direction of the adiabatic, whose equation is: $\varphi s^2 = \varphi_0 s^2_0$, derived from the condition : $d\mathrm{H} = 0$.

All the other directions of special interest are found in the same way by equating to zero one of the differential quantities entering the equations. Thus, we shall obtain :

3d. The direction and equation of the path described by the substance when its volume is maintained constant, by putting $d\mathrm{V} = 0$ or $\mathrm{V} = \text{constant}$; substituting to V its value in terms of φ and s as given in equations (8), gives for the equation to the curve of constant volume passing through M :

$$g(\varphi, s) = g(\varphi_0, s_0)$$

4th. The equation of the path described when the pressure is maintained constant, by putting $dP = 0$ or $P =$ constant, or again by the same substitution :

$$f(\varphi, s) = f(\varphi_0, s_0)$$

5th. The equation to the curve of constant symbolical volume; since $s = \pi a^2$, the amplitude a is constant when s is constant, hence this curve can be defined as the path described by the substance when the amplitude of the vibratory motion is maintained constant and its equation is found by putting $ds = 0$, whence :

$$s = s_0$$

which is the equation to a straight line parallel to the axis of φ.

6th. The curve of constant symbolical pressure, which, since $\varphi = \frac{\pi}{i^2}$, can be defined as the path described when the period of the vibratory motion of the heat is maintained constant. The equation of this curve is derived from the condition : $d\varphi = 0$, whence:

$$\varphi = \varphi_0$$

which represents a straight line parallel to the axis of s.

7th. The path along which the total work $dR = 0$, or $\varphi ds = 0$, or :

$$s = s_0$$

which is the same as the equation to the curve of constant symbolical volume.

8th. The path along which the external work $d\tau = 0$ or $PdV = 0$ or:

$$V = \text{constant}$$

We see here again that the symbolical volume is in the same relation with the total work as is the ordinary volume with the external work.

We might also remark that since $dR = 0$ along the curve of constant symbolical volume, this curve may be defined as representing a transformation in which all the heat furnished is used in raising the temperature of the substance (or increasing its heat-energy), no part of it being transformed into work.

9th. The path along which the internal work, $dI = 0$ or: $dR - dT = 0$ or again : $\varphi ds - PdV = 0$. Expressing P and V in terms of φ and s, with the aid of equations (8) :

$$\varphi ds - f(\varphi, s) d[g(\varphi, s)] = 0$$

which will furnish by integration the equation of the required curve.

Such are the principal curves passing through any point M. When M describes an elementary path MM', the direction of

MM' determines the value of the quotient $\frac{d\varphi}{ds}$. The heat absorbed in this elementary transformation is given by:

$$\mathrm{E}d\mathrm{H} = sd\varphi + 2\varphi ds$$

and the corresponding variation of temperature, by :

$$\mathrm{KE}d\mathrm{T} = sd\varphi + \varphi ds$$

Dividing member to member, and putting $\frac{d\mathrm{H}}{d\mathrm{T}} = \gamma$ for abreviation, we have :

$$\frac{\gamma}{\mathrm{K}} = \frac{sd\varphi + 2\varphi ds}{sd\varphi + \varphi ds} \qquad (10)$$

The quotient $\gamma = \frac{d\mathrm{H}}{d\mathrm{T}}$ may be called the specific heat of the substance at the state *M* and for the direction *MM'* (since γ varies with the value of $\frac{d\varphi}{ds}$, i. e., the direction of *MM'*).

When $\frac{d\varphi}{ds}$ has such a value that the direction *MM'* coincides with that of the tangent to the curve of constant volume, the corresponding value of γ is evidently the "*specific heat at constant volume*" at the state *M*, which specific heat we shall denote by the letter c.

In the same way, when $\frac{d\varphi}{ds}$ has such a value that *MM'* coincides with the tangent to the curve of constant pressure, the corresponding value of γ is by definition the "*specific heat at constant pressure*" of the substance at the state *M*; this specific heat will be denoted by the letter *C*.

The value of γ corresponding to a direction parallel to the axis of φ may be called for the same reason: the "*specific heat at constant symbolical volume*;" and that corresponding to a direction parallel to the axis of s: the "*specific heat at constant symbolical pressure*."

Now, equation (10) can be written :

$$\frac{\gamma}{\mathrm{K}} = \frac{s\frac{d\varphi}{ds} + 2\varphi}{s\frac{d\varphi}{ds} + \varphi}$$

Let us produce *MM'* until it intersects the axis of φ at point *A*, and measure on this axis three equal lengths : *om*, *mP* and *PQ*, each one of them equal to the ordinate φ of point *M*; then, we shall have:

$$\overline{m\mathrm{A}} = s\frac{d\varphi}{ds} \quad \overline{m\mathrm{Q}} = 2\varphi \text{ and } \overline{m\mathrm{P}} = \varphi$$

Whence, by substitution:

$$\frac{\gamma}{K}=\frac{\overline{mA}+\overline{mQ}}{\overline{mA}+\overline{mP}}=\frac{\overline{AQ}}{\overline{AP}}$$

Thus we see that the specific heat corresponding to any direction $\overline{MA}$ is to the absolute specific heat of the substance as the distances from point *A* (determined by the direction $\overline{MA}$ itself) to the stationary points *P* and *Q*.

The specific heats *c* and *C* can then be easily obtained graphically by tracing the tangents at point *M* to the curve of constant volume and to the curve of constant pressure; or, if desired, we can also make use of the specific heats to find these tangents. Let us study now the variation of the specific heat γ, when the direction of the element *MM′* changes, by revolving around point *M*.

1st. Suppose that *MM′* or *MA* be at first parallel to the axis of φ; point *A* is then removed to an infinite distance in the negative direction of the axis of φ and we have: $\frac{\gamma}{K}=\frac{\overline{AQ}}{\overline{AP}}=1$ or $\gamma=K$. In other words, the specific heat at constant symbolical volume is equal to the absolute specific heat of the substance, and therefore does not depend on its physical state.

2d. When $\overline{MA}$, by revolving ninety degrees around M, coincides with $\overline{Mm}$ we have: $\frac{\gamma}{K}=\frac{\overline{AQ}}{\overline{AP}}=\frac{\overline{mQ}}{\overline{mP}}=2$, or $\gamma=2K$, i. e.: the specific heat at constant symbolical pressure is equal to twice the absolute specific heat of the substance and remains therefore also constant, when the state of the substance changes.

3d. When $\overline{MA}$ has reached the position $\overline{Mn}$ (*n* being the center of $\overline{mP}$), $\frac{\gamma}{K}=\frac{\overline{AQ}}{\overline{AP}}=\frac{\overline{nQ}}{\overline{nP}}=3$, or $\gamma=3K$.

This value is of some interest, since the specific heat at constant volume of certain solid substances has been found to be equal to three times their absolute specific heat; hence, for those substances, $\overline{Mn}$ is the tangent at *M* to the curve of constant volume.

4th. When $\overline{MA}$ coincides with $\overline{MP}$:

$$\frac{\gamma}{K}=\frac{\overline{AQ}}{\overline{AP}}=\frac{\overline{PQ}}{0}=\infty$$

Whence: $\gamma=\frac{dH}{dT}=\infty$ or $dT=0$ or again $T=$ constant. This shows that $\overline{\mathrm{MP}}$ is the tangent to the isothermal passing through M.

5th. From P to Q, the quotient $\frac{\overline{\mathrm{AQ}}}{\overline{\mathrm{AP}}}$ becomes negative and is decreasing, i. e., dH and dT have opposite signs.

6th. When $\overline{\mathrm{MA}}$ coincides with $\overline{\mathrm{MQ}}$:

$$\frac{\gamma}{\mathrm{K}} = \frac{\overline{\mathrm{AQ}}}{\overline{\mathrm{AP}}} = \frac{0}{\overline{\mathrm{PQ}}} = 0$$

whence: $\gamma = \frac{d\mathrm{H}}{d\mathrm{T}} = 0$ or $d\mathrm{H} = 0$. Hence $\overline{\mathrm{MQ}}$ is the tangent to the adiabatic passing through M.

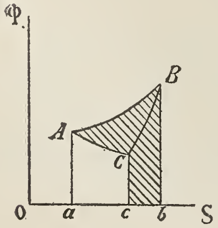
7th. Above point Q, $\frac{\overline{\mathrm{AQ}}}{\overline{\mathrm{AP}}}$ is again positive and increases from zero (at Q) to one (at infinity).

Thus the tangents $\overline{\mathrm{MP}}$ and $\overline{\mathrm{MQ}}$ to the isothermal and to the adiabatic, divide the space around point M into four regions. When the path described by the substance passes from one of these regions into another, a change of sign occurs either in dH or in dT; this change taking place for dH on the adiabatic, and for dT on the isothermal.

The points P and Q remain stationary, not only when $\overline{MA}$ revolves around point M but also when point M itself moves on a parallel to the axis of s (since the position of P and Q depends only on the ordinate φ of point M). Hence if we trace the tangents to the isothermal and to the adiabatic at each point of this parallel, these tangents will form two pencils converging respectively at P and at Q. For the same reason, if we draw the tangents to the curve of constant pressure or of constant volume, at two different points on this parallel, these two tangents shall intersect each other on the axis of φ (provided however that the two points be sufficiently near each other so that the specific heats can be regarded as having practically the same value for both points).

12. We have seen that the area $AabB$ (fig. 4) is equal to the total work, R, absorbed during the transformation AB. In order to determine graphically the value of the external work T and that of the internal work I, trace the curve of constant volume AC and also the curve BC along which the internal work $d\mathrm{I} = 0$. These curves intersect at C and the area $AabB$ is now divided into two parts: the hatched part $ACcbB$ being equal to the external work T, while the remaining part $AacC$ is equal to the internal work, absorbed by the substance when describing the path AB.

4.



The demonstration is based upon the fact that the internal work depends only upon the initial and final states of the body and not upon the path described, so that the internal work along *AB* is equal to the internal work along *ACB*; but, by hypothesis, the internal work along *CB* equals zero; hence, the internal work from *A* to *B* is equal to the internal work from *A* to *C*. On the other hand, the total work from *A* to *C* is given by the area *AacC*; but the external work from *A* to *C* is equal to zero, since the volume remains constant along the path *AC*; hence the area *AacC* is also equal to the internal work from *A* to *C*, which is the same as the internal work from *A* to *B*, as just seen.

The area *AacC* giving the internal work *I* along the path *AB*, the remaining area *ACcbB* must be equal to the external work *T* along the same path. Since the external work can be easily computed in most cases, this demonstration gives us also a graphical method for tracing, through any point *B*, the curve defined by the condition $d\mathrm{I}=0$: trace any path *BA* through *B*, compute the external work from *B* to *A* and subtract it from area *AabB*; the result is the internal work from *B* to *A*; trace through *A* the curve of constant volume *AC* and an ordinate *cC* cutting off an area *AacC* equal to the internal work previously computed. The point *C* thus obtained is a point of the required curve. Other points can be found in the same way, by moving point *A* on the curve *BA*. Since the path *BA* is arbitrary, it must be chosen so that the external work can be easily computed; for instance, if *BA* be the curve of constant pressure passing through *B*, then the external work:

$$\int_{\mathrm{B}}^{\mathrm{A}} \mathrm{P}d\mathrm{V} = \mathrm{P}\int_{\mathrm{B}}^{\mathrm{A}} d\mathrm{V} = \mathrm{P}(\mathrm{V}_{\mathrm{A}} - \mathrm{V}_{\mathrm{B}})$$

Remark: When the path described by point *M* is a closed cycle, the area enclosed by it is equal to the total work absorbed by the substance; but, since the final state is the same as the initial state, the internal work is equal to zero; hence said area is also equal to the *external* work done by the substance, as this is the case in Clapeyron's graphical representation where *P* and *V* are taken as coördinates; this result can be expressed by the equation:

$$\int \varphi ds = \int \mathrm{P}d\mathrm{V}$$

which applies only to a closed cycle. We shall soon express the same equation under a different form.

Graphical representation of the various physical coefficients.

13. When a surface is defined by three equations giving the value of the coördinates P, V, T of any one of its points, in terms of two auxiliary variables φ and s, it can be divided into an infinite number of infinitely small parallelograms by two systems of curves, obtained respectively by putting $\varphi =$ constant and $s =$ constant in the three equations to the surface. The area $d\omega$ of any one of these elementary parallelograms is given by the formula:

$$d\omega = (A^2 + B^2 + C^2)^{\frac{1}{2}} d\varphi ds$$

in which A, B, C have the following values:

$$\begin{cases} \pm A = \frac{dV}{d\varphi}\frac{dT}{ds} - \frac{dT}{d\varphi}\frac{dV}{ds} \\ \pm B = \frac{dT}{d\varphi}\frac{dP}{ds} - \frac{dP}{d\varphi}\frac{dT}{ds} \\ \pm C = \frac{dP}{d\varphi}\frac{dV}{ds} - \frac{dV}{d\varphi}\frac{dP}{ds} \end{cases}$$

The projection of the element $d\omega$ on the plane POV is equal to: $\pm C d\varphi ds$; and the area of this projection is equal, according to the fundamental property of Clapeyron's graphical representation, to the external work done by the substance when describing a path corresponding to the outline of the parallelogram $d\omega$. On the other hand, when φ and s are taken as coördinates, the element $d\omega$ is represented by a small rectangle, whose sides are respectively $d\varphi$ and ds, since this element is cut off by the curves: $\varphi =$ constant and $s =$ constant; the area of this rectangle is: $d\varphi \,.\, ds$ and is equal, according to the last remark (§ 12), to the external work done by the substance when describing the outline of the same element $d\omega$, hence:

$$\pm C d\varphi ds = d\varphi ds$$

Or:

$$C = \pm 1$$

Replacing C by its value, we find a new condition to which the functions f and g (equations 8) are submitted, i. e.:

$$\frac{df}{d\varphi}\frac{dg}{ds} - \frac{dg}{d\varphi}\frac{df}{ds} = \pm 1$$

This condition will be utilized in the determination of the functions f and g, as it is a more convenient form of the condition found above: $\int \varphi ds = \int P dv$, for any closed cycle.

By the aid of equation $T = \frac{\varphi s}{KE}$, we have:

$$\frac{dT}{d\varphi}=\frac{s}{KE} \text{ and } \frac{dT}{ds}=\frac{\varphi}{KE}$$

Hence:

$$\begin{cases} A=\pm\dfrac{1}{KE}\left(\varphi\dfrac{dV}{d\varphi}-s\dfrac{dV}{ds}\right) \\ B=\pm\dfrac{1}{KE}\left(s\dfrac{dP}{ds}-\varphi\dfrac{dP}{d\varphi}\right) \\ C=\pm 1 \end{cases} \tag{11}$$

These formulæ give the value of *A*, *B*, *C* corresponding to any physical state of the substance defined by the coördinates φ and s.

If we now express each one of the physical coefficients in terms of *A*, *B*, *C* we shall be able to compute the value of these coefficients for any state of the substance, by means of equations (8), since *A*, *B*, *C* are depending upon equations (8) by means of equations (11).

When the thermodynamic surface is given under the ordinary form $T=f(P,V)$, it is always possible to introduce two auxiliary variables, by putting:

$$\begin{cases} P=u \\ V=v \\ T=f(u,v) \end{cases}$$

whence:

Under this form, the area $d\varepsilon$ of the elementary parallelograms cut off by the curves u = constant and v = constant, is:

$$d\varepsilon=(A_1^2+B_1^2+C_1^2)^{\frac{1}{2}}dudv$$

in which:

$$A_1=\pm\frac{dT}{dP} \quad B_1=\pm\frac{dT}{dV} \quad C_1=\pm 1$$

The element $d\varepsilon$ is not the same as the element $d\omega$, but it has the same tangent plane. If we measure off on the normal to the surface a length:

$$N=(A^2+B^2+C^2)^{\frac{1}{2}}$$

the components of *N* parallel to the axes of coördinates shall be respectively: *A*, *B* and *C*. Now, since the normal and the axes of coördinates are the same for both elements and since the components *C* and C_1 are equal ($C=\pm 1=C_1$), the other two components must be equal to each other, thus:

$$A=A_1=\pm\frac{dT}{dP}$$

$$B=B_1=\pm\frac{dT}{dV}$$

In other words:

$$\frac{dP}{dT} = \pm \frac{1}{A}, \ V \text{ being constant}$$

$$\frac{dV}{dT} = \pm \frac{1}{B}, \ P \text{ being constant.}$$

The various physical coefficients can now be expressed in terms of *A* and *B:*

1st. *Coefficient of dilatation at constant pressure* (α).—We have by definition:

$$\alpha = \frac{1}{V}\frac{dV}{dT}, \ P \text{ being constant}$$

Hence: $$\alpha = \pm \frac{1}{VB}$$

2d. *Coefficient of dilatation at constant volume* (β).—Again, by definition:

$$\beta = \frac{1}{P}\frac{dP}{dT}, \ V \text{ being constant.}$$

Whence: $$\beta = \pm \frac{1}{PA}$$

3d. *Coefficient of compressibility at constant temperature* (μ).—By definition:

$$\mu = -\frac{1}{V}\frac{dV}{dP}, \ T \text{ being constant.}$$

Whence: $$\mu = \mp \frac{1}{V}\frac{A}{B}$$

4th. *Specific heat at constant pressure* (*C*).—We have found: $\frac{C}{K} = \frac{sd\varphi + 2\varphi ds}{sd\varphi + \varphi ds}$, the quotient $\frac{d\varphi}{ds}$ being here defined by the condition: P = constant, or:

$$dP = \frac{dP}{d\varphi}d\varphi + \frac{dP}{ds}ds = 0$$

By combining these two equations, we shall obtain:

$$C - K = \pm \frac{\varphi}{EB}\frac{dP}{d\varphi}$$

5th. *Specific heat at constant volume* (c).—Similar equations lead to the similar result:

$$c - K = \pm \frac{\varphi}{EA}\frac{dV}{d\varphi}$$

Remark: Subtracting this equation from the preceding one, it gives:

$$C - c = \pm \frac{T}{E}\frac{1}{AB}$$

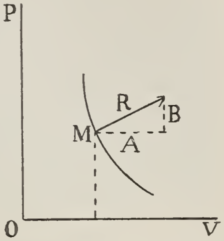
6th. *Latent heat of dilatation* (l)*:*

$$l = \frac{T}{E}\frac{dP}{dT} = \pm \frac{T}{EA}$$

In short, all the different physical coefficients can be expressed very simply in terms of A and B, so that if the value of A and B can be obtained by a graphical method, these coefficients may also be regarded as known graphically.

A and B are the components of N parallel to the axes OV and OP, i. e.: parallel to the axes of coördinates used in Clapeyron's graphical method. Hence if M represents the state of the substance (fig. 5), defined by its volume and its pressure, the component A will be parallel to OV, while B will be parallel to OP and the resultant R will be the projection of N on the plane POV.

5.



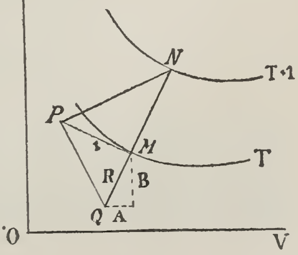
Now, if R be known both in length and direction, the components A and B (and therefore all the physical coefficients) can be obtained graphically, so that it will not be necessary to compute A and B from the equations to the thermodynamic surface. The projecting plane of N is perpendicular to the contour lines of the thermodynamic surface (i. e., supposing that the plane POV is horizontal). These contour lines are precisely the isothermal curves, hence the direction of R can be obtained graphically by the condition that it be perpendicular to the isothermal MT passing through M.

On the other hand, the length of R is determined by the fact that the vertical component C is equal to the unit.

The altitude of point M in space is equal to the temperature T; hence, since $C = 1$, the altitude of the other extremity of N is equal to $T+1$; in other words, this extremity is the point where the normal to the thermodynamic surface intersects the horizontal plane of the isothermal $T+1$, so that it can be obtained graphically by a simple construction of descriptive geometry, as follows:

Draw through M the normal to the isothermal MT (fig. 6) and let N denote the point where this normal intersects the isothermal $T+1$; draw MP tangent to the isothermal and measure off $MP=1$; join N to P; draw at P a perpendicular to NP and let Q denote the point where it intersects the normal MN produced; then MQ will be equal to R both in length and direction.

6.



The isothermal $T+1$ can be replaced by the isothermal $T+n$, provided that the result be divided by n, and also that the portion MN of the normal be short enough to be practically straight, notwithstanding the curvature of the surface. R being obtained graphically, the components A and B are readily obtained by drawing parallels to the axes of coördinates through the points M and Q.

This graphical determination of R, does not apply when φ and s are chosen as coördinates: in this case A and B have to be computed by the aid of equations (11); but, when this has been done, A and B can still be considered as two magnitudes parallel to the axes $o\varphi$ and os and they can be combined into a single one R having a definite direction, so that in any case, all the physical coefficients referring to a particular state of the substance can be represented graphically by a single magnitude of a certain length, drawn in a proper direction.

Research of the thermodynamic function.

14. The thermodynamic function of a given substance may be known under the usual form: $F(P, V, T) = 0$, or it may not be known at all, as is the case for most substances.

In the first case, the thermodynamic function can be expressed in terms of φ and s by the aid of the equations:

$$\left\{\begin{aligned} dH &= cdT + ldV \\ dH &= CdT + hdP \\ \frac{dH}{T} &= K\left(\frac{d\varphi}{\varphi} + 2\frac{ds}{s}\right) \\ \frac{dT}{T} &= \frac{d\varphi}{\varphi} + \frac{ds}{s} \end{aligned}\right.$$

By combining these equations, they can be written:

$$\left\{\begin{aligned} \frac{l}{T}dV + (c-K)\frac{dT}{T} &= K\frac{ds}{s} \\ \frac{l}{T}dV + (c-2K)\frac{dT}{T} &= -K\frac{d\varphi}{\varphi} \end{aligned}\right. \qquad (12)$$

$$\left\{\begin{aligned} \frac{h}{T}dP + (C-K)\frac{dT}{T} &= K\frac{ds}{s} \\ \frac{h}{T}dP + (C-2K)\frac{dT}{T} &= -K\frac{d\varphi}{\varphi} \end{aligned}\right.$$

Let us take for instance the case of the perfect gases, whose thermodynamic function is $PV = RT$, R being a constant.

If in the third of the equations to the thermodynamic surface, which is $\varphi s = KTE$ for any substance, φ and s be replaced by their value in terms of P and V, obtained from the first two equations, the result will be the thermodynamic function under the usual form: so that we might say that the thermodynamic function of any substance expresses the fact that the product of the symbolical pressure by the symbolical volume is proportional to the absolute temperature.

But the thermodynamic function of perfect gases expresses also that the product of the pressure by the volume is proportional to the absolute temperature. Hence, for perfect gases, the symbolical pressures and volumes can be respectively replaced by the ordinary pressures and volumes; and since there is the same relation between the total work and the symbolical pressure and volume, as there is between the external work and the ordinary pressure and volume, it follows that for perfect gases the total work is equivalent to the external work, in other words there is no internal work in perfect gases. So that, for these gases:

$$\int \varphi ds = \int \mathrm{P} d\mathrm{V}$$

even when the cycle is not closed.

For the same reason, the curves of constant volume must be the same as the curves of constant symbolical volume, i. e., they must be straight lines parallel to the axis of φ, for if s be constant, $ds = 0$ or: $\varphi ds = \mathrm{P}d\mathrm{V} = 0$, hence $d\mathrm{V} = 0$ or $\mathrm{V} =$ constant. And according to what has been said in the graphical determination of specific heats, it follows also that the specific heat at constant volume of a perfect gas is equal to its absolute specific heat: $c = K$. All these results are well known, but as they have been established only by experiment, we have tried to show how they are direct consequences of the laws of thermodynamics.

Now that $c = K$ for perfect gases, equation (12) reduces to:

$$\frac{l}{\mathrm{T}} d\mathrm{V} = \mathrm{K}\frac{ds}{s}$$

On the other hand:

$$\frac{l}{\mathrm{T}} = \frac{1}{\mathrm{E}}\frac{d\mathrm{P}}{d\mathrm{T}} = \frac{\mathrm{R}}{\mathrm{EV}}$$

Hence, by substitution:

$$\frac{\mathrm{R}}{\mathrm{E}}\frac{d\mathrm{V}}{\mathrm{V}} = \mathrm{K}\frac{ds}{s}$$

and by integration:

$$\mathrm{V} = \mathrm{M}s^{\frac{\mathrm{KE}}{\mathrm{R}}}$$

M being an arbitrary constant. We have also, for any substance:

$$T = \frac{\varphi s}{KE}$$

Substituting these values of *V* and *T* in the thermodynamic function: PV = RT, it gives:

$$P = \frac{R}{MKE} \varphi s^{1-\frac{KE}{R}}$$

Finally, if we put $\frac{KE}{R} = a$ for abreviation, the thermodynamic function of perfect gases, expressed in terms of φ and s, is:

$$\begin{cases} P = \dfrac{\varphi s^{1-a}}{aM} \\ V = Ms^{a} \\ T = \dfrac{\varphi s}{aR} \end{cases}$$

Remarks: By differentiating the second of these equations and multiplying the result by the first one, we see that $PdV = \varphi ds$ as stated above. The equation $V = Ms^a$ shows that the volume of a perfect gas happens to be independent of φ, i. e., of the period of the vibratory motion. In other words, the amplitude a keeps the same value as long as the volume remains the same (*V* being constant when s or a is constant). This is not true of other substances, as in the general case, the expression of *V* involves φ as well as $s(V = g(\varphi, s))$. This example shows how the thermodynamic function can be expressed in terms of φ and s, when it is already known under the usual form: $F(P, V, T) = 0$. In general, this problem consists in transforming the given equation $F(P, V, T) = 0$ into three others giving the value of *P*, *V* and *T* in terms of two auxiliary variables φ and s, which must satisfy the conditions found above:

$$\varphi s = KTE$$

$$\frac{dP}{d\varphi}\frac{dV}{ds} - \frac{dV}{d\varphi}\frac{dP}{ds} = \pm 1$$

Let us examine now the case in which the thermodynamic function is entirely unknown. In Clapeyron's graphical process, the path described by a substance can always be traced on the paper by measuring directly the volume and the pressure for a sufficient number of points along the path, whether the thermodynamic function be known or not. When φ and s are chosen as coördinates the position of the point corresponding to any physical state of the substance can also be determined directly from experimental data.

Let us suppose first that the specific heat at constant volume of the substance is constant, as is the case for a certain number of bodies, and let us find what would be in this hypothesis, the general equation of the curves of constant volume. By putting $V=\text{constant}$ or $dV=0$ in equation (12) and replacing $\frac{dT}{T}$ by: $\frac{d\varphi}{\varphi}+\frac{ds}{s}$, we shall obtain the differential equation :

$$(c-K)\frac{d\varphi}{\varphi}+(c-2K)\frac{ds}{s}=0$$

Integrating and denoting the arbitrary constant by *N*, the general equation to the curves of constant volume is :

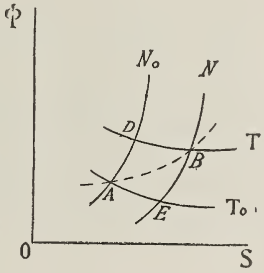
$$\varphi^{c-K}s^{c-2K}=N$$

On the other hand : $\varphi s=KTE$ is the general equation of the isothermals. The value of the constant *N* depends only upon the volume *V*, so that as soon as the experimental data *V* and *T* are given, these equations will furnish the corresponding value of φ and s, provided however that the value of the constant *N* be known for any given value of the volume *V*.

This determination can be made as follows : let V_0 and T_0 be the experimental data corresponding to the initial state of the substance. The point representing this state, is on the isothermal : $\varphi s=KT_0E$; but it can be chosen anywhere on this isothermal, because the three equations to the thermodynamic surface involve always an arbitrary constant, as seen in the case of a perfect gas. Let *A* be the chosen point (fig. 7) ; φ_0 and s_0, its coördinates ; then the value of the constant *N*, corresponding to the initial value of the volume, is given by the equation :

$$N_0=\varphi_0^{c-K}s_0^{c-2K}$$

7



Let the substance describe any path, such as *AB* and let *V* and *T* be the experimental data corresponding to any point, such as *B* ; the coördinates φ and s of this point will be determined by the intersection of the two curves :

$$\left.\begin{array}{ll} & DBT:\ \varphi s=KTE \\ \text{and} & EBN:\ \varphi^{c-K}s^{c-2K}=N \end{array}\right\}$$

N being given a value corresponding to that of the volume *V;* to find this value of *N*, it must be noticed that the isothermals AET_0, *DBT* and the curves of constant volume ADN_0, *EBN*, form a curved quadrilateral *AEBD*, whose area is equal to the external work done by the substance, if it were made to describe the closed path *AEBD*. The amount of this work can be easily computed from the experimental data and the area of the quadrilateral can also be obtained analytically from the equations of its sides:

$$\left.\begin{array}{ll} AE: & \varphi s = \mathrm{KT_0E} \\ DB: & \varphi s = \mathrm{KTE} \\ AD: & \varphi^{c-\mathrm{K}} s^{c-2\mathrm{K}} = \mathrm{N_0} \\ EB: & \varphi^{c-\mathrm{K}} s^{c-2\mathrm{K}} = \mathrm{N} \end{array}\right\}$$

Since the last equation involves the unknown constant *N*, the area of the quadrilateral will be obtained in terms of *N*, and by equating said area to the external work previously computed in terms of *V* and *T*, we shall obtain an equation giving the unknown constant *N* in terms of the experimental data.

In short *N* can be considered as known, as soon as the volume *V* is given, so that the two equations:

$$\left\{\begin{array}{l} \varphi^{c-\mathrm{K}} s^{c-2\mathrm{K}} = \mathrm{N} \\ \varphi s = \mathrm{KTE} \end{array}\right.$$

can be regarded as giving the value of the coördinates φ and s in terms of the experimental data *V* and *T*. These equations enable us to find the position of the point corresponding to any given physical state of the substance, without having to know its thermodynamic function, provided only that its specific heat be known.

The equation to the curves of constant volume can also be made use of, for the determination of the thermodynamic function in terms of φ and s; for, since we know how to find the value of the constant *N* corresponding to any given value of the volume *V*, it may be possible to express *N* in terms of *V* by an empirical function: $\mathrm{N} = \psi(\mathrm{V})$. In this case, the general equation to the curves of constant volume can be written:

$$\psi(\mathrm{V}) = \varphi^{c-\mathrm{K}} s^{c-2\mathrm{K}}$$

This equation gives *V* in terms of φ and s; hence it is one of the three equations involved in the thermodynamic function.

All that has been said in this paragraph concerning the volume *V*, applies also to the pressure *P*, provided the specific heat at constant volume *c*, be replaced by the specific heat at constant pressure *C*. The general equations to the curves of constant pressure would be:

$$\chi(\mathrm{P}) = \varphi^{\mathrm{C}-\mathrm{K}} s^{\mathrm{C}-2\mathrm{K}}$$

($\chi(P)$ being a function obtained empirically), and the complete thermodynamic function of the substance would then be:

$$\left\{\begin{array}{l} \chi(\mathrm{P}) = \varphi^{\mathrm{C}-\mathrm{K}} s^{\mathrm{C}-2\mathrm{K}} \\ \psi(\mathrm{V}) = \varphi^{c-\mathrm{K}} s^{c-2\mathrm{K}} \\ \mathrm{KTE} = \varphi s \end{array}\right.$$

This form of the thermodynamic function applies only to the case in which the specific heats are constant.

In the general case, the specific heats vary with the physical state of the substance; but as this variation is always comparatively small, the sheet of paper can be divided into a sufficient number of regions, so that either one of the specific heats of the substance may be regarded as constant inside of any one of these regions. Then the equations given above will hold true, provided that the specific heat be given a special value for each region.

Another method consists in finding first the value of the specific heat in terms of the volume and the temperature; since the variation of c is slow, it will be sufficient to take only in consideration the first and second powers of V and T, so that it can always be assumed that:

$$c = a + b\mathrm{V} + k\mathrm{T} + d\mathrm{T}^2 + e\mathrm{VT} + f\mathrm{V}^2$$

a, b, k, etc., being constant coefficients determined empirically.

The differential equation to the curves of constant volume being still:

$$(c - \mathrm{K})\frac{d\mathrm{T}}{\mathrm{T}} = \mathrm{K}\frac{ds}{s}$$

or, by replacing c by its value:

$$\left(\frac{a + b\mathrm{V} + f\mathrm{V}^2 - \mathrm{K}}{\mathrm{T}} + k + e\mathrm{V} + d\mathrm{T}\right)d\mathrm{T} = \mathrm{K}\,\frac{ds}{s}$$

We shall obtain by integration, V being constant:

$$(a + b\mathrm{V} + f\mathrm{V}^2 - \mathrm{K}) \log \mathrm{T} + (k + e\mathrm{V})\mathrm{T} + \tfrac{1}{2}d\mathrm{T}^2 = \mathrm{K} \log s + \text{constant}.$$

Replacing T by its value $\frac{\varphi s}{\mathrm{KE}}$, the result will be the equation of the curves of constant volume, involving only one unknown constant, which can be determined by the method given above.

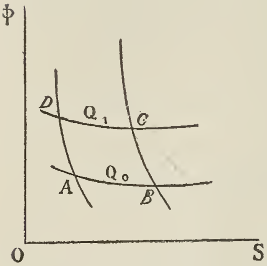
Conclusion.

15. The object we have been trying to fulfill in this short study, was to determine which is the best system of coördinates to adopt in graphical representations of thermodynamical phenomena. Evidently, the best system is the one in which the value of each variable depending upon the phenomenon can be obtained graphically; hence, each one of these variables must be represented by a geometrical magnitude depending only upon the form and position of the path described by the substance with respect to said system of coördinates.

The system of coördinates φ, s seems to possess this property to a higher degree than the system P, V, which is usually adopted and known as Clapeyron's system.

It is true that in the latter system, the location of the point representing any state of the substance, is obtained directly from the experimental data P and V, while in the system φ, s the point has to be located by a more or less indirect way; but when the path of the substance has been traced in Clapeyron's system, it does not give any information relating to the phenomena (except the value of the external work, but this work can usually be computed without difficulty); if it is desired to know more about the transformation, it is necessary to trace first all the isothermals and adiabatics; this is a long work, these curves being irregular curves in the system P, V. On the contrary, when φ and s are chosen as coördinates, the path itself is sufficient to give any information concerning the phenomenon, because the various physical variables depending upon the transformation are given by geometrical magnitudes determined by the path itself, and also because the isothermals and adiabatics, instead of being irregular, are geometrical curves whose equations are known, being the same for any substance; so that the curves: $\varphi s =$ constant, and: $\varphi s^2 =$ constant, need to be traced but once for all; they can be reproduced as many times as necessary by the blue-print process or by any other printing process.

8.



The use of the coördinates φ and s simplifies also the demonstration of most of the theorems of thermodynamics; let us take, as an example, Carnot's theorem.

If a substance describes a closed path formed by two adiabatics AD, CB (fig. 8) and by two isothermals DC, BA, and if the amount of heat absorbed and abandoned by the substance be denoted respectively by H_1 and H_0, the expression $\frac{H_1 - H_0}{H_1}$, which is called the *economical coefficient* of the cycle, is independent of the nature of the substance, and is equal to $\frac{T_1 - T_0}{T_1}$, T_0 and T_1 being the temperatures corresponding to the isothermals.

Since there is no transmission of heat along the adiabatics AD and CB, the amounts of heat H_1 and H_0 correspond respectively to the isothermals DC and BA. We have seen that:

$$EH = \int s d\varphi + 2\int \varphi ds$$

the equation to the isothermals being: $\varphi s = \mathrm{KTE}$, the integration gives:

$$\mathrm{EH} = \mathrm{KTE}(\log \varphi + 2 \log s)$$

Hence:

$$\mathrm{EH}_1 = \mathrm{KT}_1\mathrm{E}(\log \varphi_{\mathrm{D}} s^2_{\mathrm{D}} - \log \varphi_{\mathrm{C}} s^2_{\mathrm{C}})$$
$$-\mathrm{EH}_0 = \mathrm{KT}_0\mathrm{E}(\log \varphi_{\mathrm{B}} s^2_{\mathrm{B}} - \log \varphi_{\mathrm{A}} s^2_{\mathrm{A}})$$

But the equation to the adiabatics being: $\varphi s^2 =$ constant, we have also: $\varphi_{\mathrm{C}} s^2_{\mathrm{C}} = \varphi_{\mathrm{B}} s^2_{\mathrm{B}}$ and $\varphi_{\mathrm{D}} s^2_{\mathrm{D}} = \varphi_{\mathrm{A}} s^2_{\mathrm{A}}$, so that by dividing:

$$\frac{\mathrm{H}_1}{\mathrm{T}_1} = \frac{\mathrm{H}_0}{\mathrm{T}_0}$$

which can be written:

$$\frac{\mathrm{H}_1 - \mathrm{H}_0}{\mathrm{H}_1} = \frac{\mathrm{T}_1 - \mathrm{T}_0}{\mathrm{T}_1}$$

Thus, the demonstration of the theorem consists simply in the analytical measurement of areas, and the reason of it is that the heat of transformation H, which is the unknown quantity, is represented graphically by areas. This is not the case in the usual graphical methods, and Carnot's Theorem can only be demonstrated indirectly, by showing first that the economical coefficient of Carnot's cycle is independent of the nature of the substance, then computing its value for a perfect gas. One can object to this method that a perfect gas is only a theoretical substance, having no real existence.

The use of the coördinates ϕ and s, does not imply any hypothesis upon the nature of the motion constituting heat, as ϕ and s can be regarded simply as two auxiliary variables, without attributing to them any special significance.

Another advantage of expressing the thermodynamic function in terms of ϕ and s, is that each one of the specific heats of the substance can be obtained separately from said function, while the ordinary form of the thermodynamic function $\mathrm{F}(\mathrm{P}, \mathrm{V}, \mathrm{T}) = 0$ furnishes only the difference between the two specific heats $(\mathrm{C} - c)$. Finally, if heat is really a vibratory motion of the particles of matter, the state of this vibration at any time is obtained from the experimental data, by solving the thermodynamic function with respect to ϕ and s.

ART. IV.—*On the Application of the Schroeder-Le Chatelier Law of Solubility to Solutions of Salts in Organic Liquids;* by C. E. LINEBARGER.

IT has been found by two scientists, working independently, that, by means of thermodynamical considerations, the solubility of a substance may be shown to be the same in all solvents; the mode of deduction employed by each as well as the nature of the experimental proof offered is quite different. Schroeder* established these two equations:

$$l = \frac{\rho}{2}\frac{T_0 - T}{T_0 T}, \qquad (1)$$

and

$$\frac{Q}{T} = \frac{\rho}{T_0} = \text{constant}, \qquad (1\ bis)$$

in which *s* represents the solubility (defined by the ratio of the number of the molecules of the dissolved substance to the total number of molecules making up the saturated solution); ρ, the latent heat of fusion of a kilogram of the dissolved (solid) substance; T_0, the absolute point of fusion of the dissolved substance; T, the temperature at which saturation takes place; and Q, the heat of solution of a kilogram-molecule of the solid substance in almost saturated solution. Experiments carried out with solutions of *para*-di-brom-benzene in carbon disulphide, benzene, and mono-brom-benzene; of naphthaline in benzene, mono-chlor-benzene, and carbon tetrachloride; of *meta*-di-nitro-benzene in benzene, mono-brom-benzene, and chloroform: corroborated fully the statement that "*the solubilities at equal intervals from the temperatures of fusion for different solid bodies and in different solvents are the same.*"

For alcoholic solutions, however, this law was found not to obtain even approximately; this is undoubtedly due to the circumstance that the alcohols are made up of associated molecules, although Schroeder did not take this view of the matter, perhaps because, at the time of the appearance of his paper, our knowledge of the molecular state of liquids was exceedingly slight.

The law was further tested by Schroeder, by determining the solubility of *para*-di-brom-benzene in mixtures of chloroform and benzene, which was found to be very nearly the same as in either of the pure solvents.

The formula developed by Le Chatelier† runs thus:

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* Zeitschr. f. phys. Chem., xi, 449, 1893.

† Comptes rend., cxiii, 638, 1894.

$$0{\cdot}002 \text{ Log nép } s - \frac{L}{t} + \frac{L}{t_0} = 0, \qquad (2)$$

in which s has the same signification as in equation (1); L is the latent heat of solution of a molecule of the dissolved substance in a large amount of the nearly saturated solution; t is the temperature of saturation, and t_0 the point of fusion. This formula leads at once to the conclusion that "*the normal curve of solubility of a given body should be the same in all solvents, because the equation contains no term having reference to the solvent.*"

In a subsequent "Note," Le Chatelier communicated the solubilities of sodium chloride in fused sodium carbonate, and barium chloride; also of lithium sulphate in fused calcium sulphate, lithium carbonate, and sodium sulphate, these data being found entirely in accordance with the law enunciated.

Neither Schroeder nor Le Chatelier claims that the law in question expresses more than an approximate relation between the quantities upon which it has a bearing. Le Chatelier ascribes any exceptions to its generality to differences in the latent heats of solution, which may vary from solvent to solvent. The law should, then, be restricted in its government to chemically similar compounds, and, indeed, it is seen that the compounds, experimented upon by each observer, belong to the same general classes,—the normal organic preparations (Schroeder), and the salts (Le Chatelier). But when we consider groups of chemical substances of differing natures, we perceive that all the regularity of the phenomenon, which has been formulated into a law, disappears; the very fact, that there exist substances, which do not unite with certain others to form the homogeneous mixtures commonly called solutions, is sufficient to warrant the restriction of the law to quite narrow limits. Nearly all inorganic salts are not at all, or, at most, but sparingly soluble in the vast number of organic liquids. Unhappily, our quantitative knowledge of the solubility of salts in organic liquids is very limited; yet perhaps enough data may be collected to permit of the drawing of theoretic conclusions. The object of this paper is to discuss in the light of the Schroeder-Le Chatelier law, the data we possess on the solubility of inorganic salts in normal organic liquids. The importance of this law, which, in its enunciation, is one of the widest-reaching in the domain of solutions, makes it very desirable that it be applied to all cases, in order that it may be ascertained to what degree its approximation towards truth may come.

The greater part of the determinations of the solubilities of salts in organic liquids has been done with the alcohols, especially ethyl alcohol, as solvents. The choice of such solvents is unfortunate, since, aside from the difficulty experienced in getting and preserving them in a state of purity, they are made up of associated molecules; and this circumstance introduces very serious complications, for not only is the relative proportion of associated molecules different at different temperatures, but also the dissolved substance must have some influence on the degree of molecular association of the solvent, the combined result being that the nature of the solvent varies infinitely. Accordingly, from reasons that are obvious, only "normal" liquids, that is, such liquids as possess the same molecular mass in the liquid as in the gaseous state, will be considered in what follows. By thus eliminating the difficulty arising from the use of associated liquids, it may be possible to get matters into a clearer light. In what follows, no pretensions are made to discuss all the data on the solubility of salts in organic liquids; only such data as seem to have the stamp of reliability will be considered.

Étard* in the course of his extended investigations on the solubility of substances, determined through wide ranges of temperature the solubilities of the salts, mercuric and cupric chlorides, in a number of normal liquids, mostly esters. As in this case the solvents are chemically very similar, it seems likely that, if the above law is at all applicable to the solubilities of salts in organic liquids, Étard's data will permit of its ascertainment.

According to Étard, the solubility of corrosive sublimate in ethyl ether is as follows,—the numbers directly under the temperatures being the number of parts of the salt contained in 100 parts of the saturated solution:

—47°	—40°	—35°	—30°	—19°	0°	13°	83°	100°	115°
5·6	5·8	6·1	5·9	5·6	5.8	5·8	8·4	8·7	9·0

From —47° to +60°, that is, throughout a temperature interval of more than 100°, Étard states that the solubility is the same; the average of the above first seven data is 5·8, which represents the mean solubility for the temperature interval just mentioned. If this be recalculated in molecular proportions, it comes out that 100 molecules of the saturated solution contain 1·65 molecules (of normal size, i. e. corresponding to the formula $HgCl_2$) of the salt. Above 60°, however, the solubility increases with rise of temperature (see Table I for recalculated data).

Similar phenomena were observed in the case of the solubility of corrosive sublimate in acetic ether, the data of which are these:

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*Ann. de chim. et de phys., VII, ii, 560.

—50°	—20°	—14°	—6°	0°	7°	19°
39·6	40.5	40·2	40·0	39·5	39·9	40·2

In an interval of more than 70°, the solubility seems to be constant, 100 parts of the saturated solution containing on an average 40·0 parts of salt, or, calculated in molecular proportions, 17·80 molecules of salt are in 100 molecules of the solution. Above 40° the solubility augments with rise of temperature as shown thus:

45°	66°	100°	131°	150°	180°
41·6	44·0	47·8	50·1	57·0	59·3

Étard gives also the solubility of mercury chloride as well as of copper chloride in other ethers; I will not reproduce the data as presented by him, but will throw them into tabular form, after having made the calculations necessary to change them into solubilities defined by the ratio of dissolved molecules to the total number of molecules contained in the solution.

TABLE I.

Solubility of Mercuric Chloride in Organic Liquids.

Names of Liquids,	—50°	—47°	—40°	—35°	—30°	—20°	—19°	—14°	—6°	—3°	—0°	+7°	13°	19°
Ethyl Ether,		1·65	1·65	1·65	1·65		1·65				1·65			
Ethyl formiate,						10·48				10·48				
Ethyl acetate,	17·80					17·80		17·80	17·80		17·80			17·80
Methyl acetate,						16·51								
Amyl acetate,														
Ethyl butyrate,														

TABLE I, Continued.

Names of Liquids,	20°	22°	24°	45°	46°	48°	55°	66°	71°	83°	100°	115°	131°	150°
Ethyl Ether,										2·45	2·52			
Ethyl formiate,			10·48		10·48									
Ethyl acetate,				18·78				20·33			22·92		25·02	30·09
Methyl acetate,			15·56				16·23							
Amyl acetate		9·70				9·82								
Ethyl Butyrate,	5·81						6·26		7·05					

TABLE II.

Solubility of Copper Chloride in Ethyl Acetate and Ethyl Formiate.

	—20°	+20°	24°	37°	40°	50°	72°
Ethyl formiate..	5·88		4·33	4·21		4·08	
Ethyl acetate....		1·98			1·66		0·85

The data given in Tables I and II cannot be said to confirm the predictions of the law under discussion. The solubility of mercuric chloride in acetic ether and in ethyl formiate is indeed nearly the same; and so is that of copper chloride in acetic ether, and of mercuric chloride in ethyl ether. These cases are, however, exceptional, and can be as likely due to chance as to law. Now, as it may be laid down as a general rule that, no matter in how many instances a "law of Nature" may be confirmed, one exception is sufficient to disprove that generality which is taken to be the very essence of law, it is apparent that the truth of the "law" in the case in hand is very doubtful.

Arctowski* has investigated what may be termed the complement of the case studied by Étard (loc. cit.), for he determined the solubility of three very similar—as regards their chemical constitution—salts, viz: the chloride, bromide, and iodide of mercury, in carbon disulphide. Arctowski communicates his results in the same form as does Étard. To permit of direct comparison with our "law," I have recalculated his results in molecules, the data being given in Table III.

Table III.

Solubility of the Halide Salts of Mercury in Carbon Bisulphide.

Mercuric.	−76¼°	−21°	−10¼°	0°	8°	13½°	19½°	25°	29°
Chloride,			0·003	0·004	0·005		0·099	0·011	0·016
Bromide,			0·011	0·018	0·024	0·029	0·038		0·041
Iodide,	0·008	0·013	0·017	0·029	0·039	0·044	0·050	0·056	0·079

Here again we see no confirmation of the "law" in question. The solubilities of the salts are in direct proportion to their molecular masses, and the curves with temperatures on axis of abscissas and solubilities on axis of ordinates are very nearly parallel.

In order to increase our knowledge of the solubilities of salts in organic liquids, and to augment our store of data with which to compare the law in question, I have made a number of determinations of the solubility of several salts in benzene and ethyl ether; the results of this work are given in Tables IV and V.

Table IV.

Solubility of Cadmium Iodide, Mercuric Chloride, and Silver Nitrate in Benzene.

Temperatures.	10°·7	11°·4	16°·0	35°·0	38°·8	40°·5
Cadmium iodide,			0·01	0·02		
Mercuric chloride,	0·11	0·12			0·23	0·25
Silver nitrate,				0·01		0·02

Table V.

Solubility of Cadmium Iodide in Ethyl Ether.

Temperatures.	0°	15°·5	20°·3
Cadmium iodide,	0·03	0·04	0·05

These data also cannot be said to be favorable to the law.

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* Zeitschr. f. anorgan. Chemie, v, 263, 1894.

It is evident from all the data which have been exhibited in the preceding tables, that no trace of the applicability of the Schroeder-Le Chatelier law is to be found. It may, now, be urged that in our definition of solubility as the number of molecules of dissolved substance contained in 100 molecules of the solution, the value of the molecular mass of the dissolved substance has rather arbitrarily been assumed to be equal to that which it has in the gaseous condition, although nothing positive in regard to the real size of the molecule in the dissolved state is known ; if the molecular mass of the substance in the gaseous state be doubled, tripled, quadrupled, etc., when it is in solution, the number, expressing the solubility in the manner here adopted, must be changed correspondingly. But even if our knowledge of the molecular state of salts dissolved in organic liquids was sufficient to permit of the introduction of this correction, its amount would not be large enough to account for the very considerable differences in solubility of even the same salt in different, yet chemically similar, organic solvents, as any one can convince himself by a simple calculation. We conclude then, that the law enunciated by Schroeder, and by Le Chatelier, although approximately true for the cases investigated by them, is not applicable to the case of inorganic salts in normal organic solvents.

Chicago, November 26th, 1894.

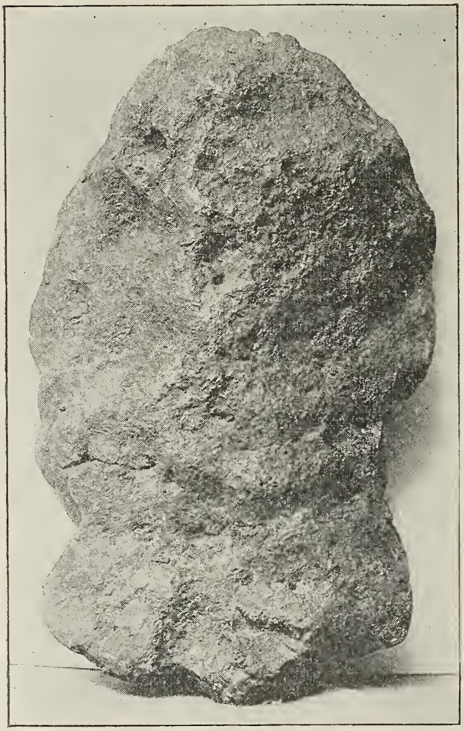
ART. V.—*Preliminary Notice of the Plymouth Meteorite;*
by HENRY A. WARD.

THE Plymouth meteorite was found in the year 1893 by Mr. John Jefferson Kyser, while plowing in a field on his farm about five miles southwest of the town of Plymouth, Marshall County, Indiana. Mr. Kyser had, about the year 1872, found in the same field another, larger mass of the same iron. This mass was pear-shaped, about four feet in length by three feet in its widest diameter, narrowing to six or eight inches at its upper end. It lay for a year or two so near the surface of the ground as to be seriously annoying in plowing the field. On that account, Mr. Kyser, aided by his son, dug a deep hole by the side of the mass and buried it to the depth of one and one-half to two feet beneath the surface, where it should thenceforth do no more damage.

The account of this I had last June from the son, Mr. John M. Kyser, now city clerk of Plymouth. Mr. Kyser well remembers the circumstance of the finding of the large piece and assisting his father in burying the same; and he further thought that, notwithstanding the removal of certain landmarks (a fence and tree), in the field, he would still be able to locate it very closely. This he subsequently undertook to do by trenching, but was unsuccessful in finding the mass. I was, myself, present and assisted in a further search for it in September last, using a surveyor's magnetic needle, with the hopes of the same being attracted to the mass and discovering it, but all to no purpose. Mr. Kyser seems to feel very confident of his knowledge of the immediate vicinity of the mass where he buried it 22 years ago, but is unable to prove its presence by re-discovery. Nor has he the aid of another eye-witness, his father having died soon after the original finding and burying as above mentioned.

The smaller piece which was, as before said, found in 1883, was presented by Mr. Kyser, Sr., to Mr. W. S. Adams who, at that time kept a plow factory in the city of Plymouth. It was retained in their family until last November, when it was brought to Ward's Natural Science Establishment in Rochester, N. Y. by Mrs. Adams from whom I procured it.

1.



The mass, as represented in the accompanying cut (fig. 1) is a lengthened, tongue-like form, not unlike a rude Mound-builder's axe. Its greatest length is 12½ inches; its width 7⅜ inches; its thickness in the middle about two inches, from which, in the greater part of its length it slopes in a somewhat even manner to a thin, rounded edge.

Its surface is deeply eroded by oxidization, so that, although sound and free from scales, it shows no signs of an original crust. The characteristic pittings of meteorites are also by the same cause rendered somewhat feeble, although still quite clearly visible. We have cut a number of thin slices from the mass. These etched in dilute nitric acid give very clear Widmanstätten figures, which are well shown in the accompanying cut (fig. 2.) There are, further, several small nodules of troilite.

2.

A careful analysis of this iron has been very kindly made for me by Mr. J. M. Davison of the Reynolds Laboratory of the University of Rochester, and I give the same below.

Analysis of Plymouth Meteorite.

Fe	88·67
Ni	8·55
Co	0·66
Cu	0·24
P	1·25
Graphite	0·11
S	0·07
	99·55

This iron, herein briefly noticed, is interesting in many ways, and it is much to be regretted that the large mass, of which the record seems to me to be entirely reliable, cannot be re-discovered.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Diammonium.*—The suggestion of Curtius, the discoverer of hydrazine or diamide, that there should be a hypothetical radical diammonium which bears the same relation to diamide that ammonium does to ammonia, has been verified by this chemist in connection with Schrader; they having prepared a large number of double salts containing this diammonium radical. Diamide itself H_2N-NH_2 is extremely unstable and its separate existence is yet somewhat uncertain; while its hydrate $N_2H_4 . H_2O$ is very permanent. Moreover, diamide is also unlike ammonia in the fact that it is a diacid base while ammonia is monacid. The normal hydrazine chloride is ClH_3N-NH_3Cl and the sulphate is $(H_3N-NH_3)''SO_4$. The analogy thus shown between diammonium and the bivalent metals of the alkali-earths, is further strengthened by the sparing solubility of its sulphate and its inability to form alums with the sulphates of the alumina group. On the other hand, however, certain properties of diammonium show that it resembles closely the alkali metals. Thus its hydrate generally acts as a monacid base. Its chloride $N_2H_6 . Cl_2$ is decomposed below 100° into hydrogen chloride and $N_2H_4 . HCl$, which cannot be made to lose more hydrogen chloride without destruction of the base. The hydrate $N_2H_4 . (H_2O)_2$ can exist only in solution. On evaporation it passes into the hydrate $N_2H_4 . H_2O$, which boils without decomposing. Ammonia gas displaces only half the acid of the sulphate $N_2H_4 . H_2SO_4$ leaving the stable sulphate $(N_2H_4)_2H_2SO_4$. Moreover only one nitrate $N_2H_4 . HNO_3$ appears to exist and only one thiocyanate $N_2H_4 . SCNH$. The authors conclude that diammonium may act as a univalent radical $(N_2H_5)''$ and also as a bivalent one $(N_2H_6)''$, the salts of the former being the more stable. Double salts of diammonium sulphate with the sulphates of copper, nickel, cobalt iron, manganese, cadmium and zinc have been obtained, all of which are anhydrous. They are readily thrown down as precipitates on mixing strong solutions of the metallic sulphate and diammonium sulphate. The latter may be either the sulphate $N_2H_6SO_4$ or $(N_2H_5)_2SO_4$. While the former of these sulphates is difficultly soluble the latter is deliquescent; yet the sparingly soluble double salts always contain the latter sulphate. Moreover salts of the type $R''SO_4 . (N_2H_4)_2$ and $R''SO_4 . (N_2H_4)_3$ have been obtained, the former containing zinc or cadmium, the latter nickel or cobalt. All attempts to obtain alums containing the diammonium sulphate $N_2H_6 . SO_4$ have been unsuccessful.—*J. prakt. Ch.*, II, 1, 311, September, 1894. G. F. B.

2. *On Nitrogen Trioxide.*—The actual existence of the trioxide of nitrogen or nitrous anhydride N_2O_3, appears to have been established by Lunge and Porschnew. Although the oxides

N_2O_2 and N_2O_4 show scarcely any tendency to unite at the ordinary temperature, the authors find that at $-21°$, these oxides combine in exact molecular proportions to form N_2O_3 which condenses as an indigo-blue liquid; 98·3 per cent of the trioxide having been obtained in one experiment. It is perfectly stable at and below this temperature; but at a slightly higher temperature, even under pressure, it begins to decompose, the dissociation becoming almost complete on conversion of the liquid into gas. Hence it would seem that the trioxide is not capable of existing in the gaseous state; although certain facts observed in the investigation seem to indicate that a residue of N_2O_3 molecules may escape dissociation and may exist side by side with the molecules of N_2O_2 and N_2O_4 into which the trioxide is decomposed.—*Zeitschr. anorg. Chem.*, vii, 209, September, 1894.

G. F. B.

3. *On the Physical Properties of Nitrogen Monoxide.*—The physical properties of carefully purified nitrogen monoxide have been studied by VILLARD. The gas was obtained pure either by the decomposition of its hydrate or by fractioning the liquid oxide; the gas in the latter case being passed through suitable purifying and drying agents. It was then liquefied and allowed to boil to expel the dissolved gases. As thus obtained, it is free from the less liquefiable gases, its maximum vapor pressure is independent of the volume of the vapor, and a small increase of pressure causes complete liquefaction. The densities of the gas and of the liquid at various temperatures are given as follows:

Temperature	0°	5°	10°	17·5°	26·5°	32·9°	34·9°	36·3°
Density of liquid	0·9105	0·885	0·856	0·804	0·720	0·640	0·605	0·572
Density of gas	0·0870	0·099	0·114	0·146	0·207	0·275	0·305	0·338

The critical temperature of pure N_2O is 38·8°, the critical volume is 0·00436, the critical density 0·454 and the critical pressure 77·5 atmospheres.—*C. R.*, cxviii, 1096, May, 1894. G. F. B.

4. *On the use of the Refractive Index for determining Critical Temperatures.*—By a careful observation of the interference bands, CHAPPUIS has been able to note the changes which take place in the index of refraction of a liquefied gas in the vicinity of its critical temperature. For this purpose the liquid was contained in a cylindrical cavity in a steel prism, having apertures closed by optically plane and parallel glass plates; the whole being immersed in a liquid whose temperature could be maintained constant. By means of a pair of Jamin mirrors, two beams of light, starting from a Billet compensator, pass through the liquid in the prism, traversing in their course the enveloping bath, the sides of which also are made of plane parallel glass. When liquid carbon dioxide is used, the refractive index is constant and the bands remain stationary; beyond this temperature the refractive index increases rapidly and the bands fall. At 31·61° the curve of the index shows a vertical tangent; and the intersection of this curve with the straight line which represents the index above this temperature, is the critical point of the

index. The uncorrected results vary between 31·60° and 31·62° only, and the corrected value for the critical point is given as 31·40°; in close agreement with Amagat's value 31·35°.—*C. R.*, cxviii, 976, April, 1894. G. F. B.

5. *On the Constants of Refraction of Carbonyl Compounds.*—In order to ascertain the influence exerted by the presence of a number of carbonyl groups in a molecule upon its molecular refraction, NASINI and ANDERLINI have determined the constants of refraction of several carbonyl compounds. Mond and Nasini had attributed the exceptionally high molecular refraction of nickel tetracarbonyl to the fact that in this substance nickel is an octad. But Gladstone had expressed the opinion that the equally high molecular refraction of ferropentacarbonyl, is due rather to the peculiar arrangement of the carbonyl groups than to the presence of iron as a decad. The substances examined were quinone, diacetyl, dipropionyl, tetrachlorotetraketohexamethylene, dibromodichlorotetraketohexamethylene, leuconic acid and potassium croconate; the last two being examined in solution in water, and the others (excepting the second and third) in solution in benzene. The measurements were made for the line $H\alpha$ and the results calculated both for the formula $M(\mu-1)/\delta$ and the formula $M(\mu^2-1)/(\mu^2-2)\delta$. It was observed that the experimental values agreed well with the calculated ones. If, however, the atomic refraction of potassium be taken as 8·1 as given by Gladstone, the observed molecular refraction of potassium croconate becomes 58·20 for the first formula given above; so that if the ordinary constant be assigned to the carbonyl groups, the atomic refraction of potassium must be taken as 22·5 for the first, and 12·40 for the second, of these formulas. Since the measurements made on the other carbonyl compounds show that the presence of several carbonyl groups causes no abnormal increase in the molecular refraction, the authors attribute the abnormally high molecular refraction of this substance to the metal alone; though they admit that the anomalous results sometimes obtained with such compounds may be due in part to the fact that they were made in solution.—*Gazzetta Chim. Ital.*, xxiv, i, 157; *J. Chem. Soc.*, lxvi, ii, 301, August, 1894. G. F. B.

6. *On the Electrolysis of Copper Sulphate in Vacuo.*—It is a well recognized fact that the electrolytic deposition of copper from a solution of its sulphate does not conform rigorously to Faraday's law; Gray having shown that the deposit of metal is heavier the higher the current density and the lower the temperature. This appears to be due to the fact that copper is slightly soluble in a copper sulphate solution. Since Schuster had suggested that this solution of the copper is due to the oxygen present in the copper sulphate solution, GANNON has made a comparison between the masses of copper deposited in two voltameters in series, from one of which the air was exhausted. His results show that with a neutral solution, the deposit of copper in the vacuum tube is higher than that in the one under the atmos-

pheric pressure; although the percentage difference is not constant. On adding a little free sulphuric acid to the air solution, however, this difference becomes more constant and is higher than before. On adding the acid to both voltameters the percentage difference becomes constant within the limits of experimental error. In this case, where the current density rises above 0·01 ampere per square centimeter of active kathode, there is no practical difference between the two deposits. For densities below this value however the vacuum deposit is appreciably higher than the air deposit. If a curve be drawn to represent the deposits obtained in a vacuum at different current densities, it will be observed to be more regular than the air curve, and to be approximately a straight line for densities below 0·01 ampere per square centimeter.

In a paper following this, SCHUSTER gives the details of certain experiments made by him some years ago, proving that when copper is placed in a copper sulphate solution containing free sulphuric acid, and the tubes are exhausted of air, the diminution in the weight of the copper is quite insignificant compared with what takes place in the presence of air. In sulphuric acid alone the metal behaves similarly.—*Proc. Roy. Soc.*, lv, 66, 84, January, 1894. G. F. B.

7. *On the Propagation of Electromagnetic Waves in Ice and on the Dielectric Power of this Substance;* by M. BLONDLOT.—In a previous note (*Comptes Rendus*, July 25, 1892) I enunciated the following proposition:—The length of the waves which an electromagnetic oscillation can emit is the same whatever be the insulating medium in which the experiment is made; in other words, the wave-length depends on the oscillator alone, just as in acoustics the wave-length of a pipe depends only on the length of the pipe.

The confirmatory experiments described in the Note cited referred to oil of turpentine and to castor oil; the law holds perfectly for both these substances, and everything leads to the belief that this will be the same for other dielectrics.

There is, however, a doubt about ice, in consequence of the exceptional properties ascribed to it. The experiments of M. Bouty (*Comptes Rendus*, March 7, 1892) show in fact that ice has a dielectric power of 27, that is to say incomparably greater than that of all other substances. Suspecting that the law relative to the propagation of waves might not apply to a dielectric so different from the others, I resolved to submit the question to experiment.

For these investigations I availed myself of the intense and prolonged frosts of the winter of 1892–93. M. M. Dufour has helped me in carrying them out, which the rigour of the cold rendered difficult and even painful. I thank him for his extreme kindness on this occasion.

The method which I adopted was the following, which, with slight modifications necessitated by the solid character of the dielectric, is the same as that I used in the case of turpentine and castor oil.

Electromagnetic waves were transmitted along two tinned copper wires 2·5 millim. in diameter stretched horizontally and parallel to each other at a distance of 0·8 meter. A resonator of gilt copper is placed in a fixed position between the wires; the portion of the transmitting wires beyond the resonator is contained in a wooden trough 4 meters in length. The trough being filled with liquid, the position is sought at which a movable bridge must be placed, joining the wires beyond the resonator to cause the spark to disappear; the distance from the bridge to the resonator is then a quarter of the specific wave-length of the resonator; the position of the bridge is accurately noted.

That done, I surround the part of the resonator forming the condenser with a water-tight bag of parchment-paper which I fill with distilled water, and then freeze this water; the layer of air is thus replaced by one of ice. Measuring the wave-length afresh, it is found to be considerably greater than in the first experiment, having become $\frac{141}{100}$ of what it was.

The trough is then filled with water which is frozen, and then the position of the bridge for disappearance of the spark is again sought. For this purpose the ice at the distant end of the trough is broken and progressively removed. I ascertained that this position is *exactly* the same as in the first case, when the dielectric was air.

The experiment four times repeated, varying each time the capacity of the condenser, always gave the same result. The proposition relative to the wave-length is therefore true for ice as well as for other dielectrics. Hence, as shown in my previous Note, Maxwell's relation that the dielectric power is also equal to the square of the refractive index also holds for electromagnetic waves in the case given.

The preceding results, partly unforeseen, led me to determine the dielectric constant of ice, using electromagnetic undulations. The experiment cited above gave all the data necessary for this determination.

For if λ and λ^1 are the wave-lengths corresponding to a given resonator, working respectively in air and in a substance of dielectric power K, we have

$$\frac{\lambda'}{\lambda}=\sqrt{K}.$$

As stated above, I found

$$\frac{\lambda'}{\lambda}=\frac{141}{100},$$

whence

$$K=2 \text{ in round numbers.}$$

The experiment repeated a dozen times always gave the same result. I consider the relative error does not exceed $\frac{1}{20}$, for the plate of ice was almost entirely free from air bubbles. According to this, ice does not present exceptional dielectric properties.

It remains to be explained how MM. Bouty and A. Perot obtained values of a totally different order for the dielectric power of ice. In the first place, in M. Bouty's method the charge and discharge were enormously slower than in my experiments. Is it not probable, then, that the physical magnitudes measured by M. Bouty and myself were in themselves very different. In any case we know at present too little about the dielectric properties of bodies to be surprised at the divergences of numbers obtained by two methods so dissimilar, however great they are.—*Comptes Rendus*, October 8, 1894.—*Phil. Mag.*, xxxviii, 578, Dec., 1894.

8. *Rotation of magnetic lines.*—E. LECHER describes in the Wiener Berichte an experiment performed to test whether, when a magnet turns about its magnetic axis, the lines of force remain at rest or turn with the magnet. A magnet was divided by an equatorial plane into two parts which could turn independently. It was possible to obtain from the two extremities of the magnet an induced current of such a magnitude as cannot be explained by the cutting of the rotating lines of force by the extremely short brushes employed. These currents can be explained if we suppose that a rotating magnet cuts its own lines of force which remain fixed in space.—*Nature*, Nov. 22, 1894, p. 84.

J. T.

9. *Magnetization of iron and nickel wire.*—KLEMENCIC has measured the permeability of iron steel and nickel wire with the rapidly alternating currents employed by Hertz. He employed the method of a thermal junction previously described by him and obtains the following values.

Soft iron	$\mu = 118$
Hard steel	$\mu = 115$
Bessemer steel	$\mu = 77$
Nickel	$\mu = 27$

—*Ann. der Physik und Chemie*, No. 12, pp. 705–720. J. T.

10. *New Storage Battery.*—In researches on the condensation of electrolytic gases by porous bodies, particularly by metals of the platinum group, M. L. CAILLELET and E. COLLARDEAU find that platinum and palladium in the spongy condition and ruthenium, iridium and gold in the finely divided state form poles which condense electrolytic gases and hence produce a gas battery, which on connection of the poles is capable of giving up the stored energy for a short period. The storage capacity is vastly increased by subjecting the poles to great pressure during charging. With spongy platinum and iridium a storage capacity can be obtained which is greater than the capacity of lead accumulators per unit of weight. With finely divided palladium, a storage capacity of 176 ampere-hours per kilograms of palladium was obtained at a pressure of 600 atmospheres. The storage capacity of an ordinary lead accumulator is about 15 ampere-hours per kilogram of lead.—*Comptes Rendus*, Nov. 12, 1894.

J. T.

11. *Resemblances between the grouping of figures on soap films and the arrangement of stars and nebulæ.*—In a leading article, Professor QUINCKE, of Heidelberg, draws attention to the remarkable resemblances between the figures produced on oily films by the operation of water, and the grouping of stars and nebulæ. He suggests that the tendency of modern physics is to ignore any qualitative differences between infinitely great and infinitely small distances. The great masses of the fixed stars in infinite space and the little masses of the infinitely near molecules in the soap films must react upon each other according to the same laws. The protoplasm of organic nature also resembles in structure and movement phenomena, the structure and movements observed on oily films.—*Ann. der Physik und Chemie,* No. 12, 1894, pp. 593–632. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Glacial succession in Europe.*—The following quotations from the third edition of Geikie's The Great Ice Age,* will present to our readers in concise form the latest views of the author upon the glacial succession in Great Britain and Europe, and the chief data upon which the interpretation is based.

I. PREGLACIAL TIMES.†—The earliest indications of the approaching Ice Age are met with in the marine deposits of the Pliocene system. The older Pliocene deposits introduce us to a time when the waters of the North Sea were tenanted by a fauna which is clearly indicative of genial climatic conditions. And similar testimony to the warmth of the period is furnished by the contemporaneous marine lacustrine and terrestrial accumulations of other regions of Europe. In those days the sea occupied considerable tracts in the east and south of England, in Belgium, Holland, Northern and Western France, and the coast-lands of the Mediterranean. As time rolled on, however, the genial conditions gradually passed away. The southern forms slowly retreated from the North Sea, while at the same time northern and boreal types came to occupy their place. Similar migrations were in progress farther south, many British and boreal forms finding their way into the Mediterranean. Upon the land like changes

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* The Great Ice Age and its relation to the Antiquity of man; by James Geikie, third edition, largly rewritten, pp. 850. (Edward Stanford). London, 1894.

† The general reader will quite understand what is meant by the term "preglacial," but I ought to mention that it has been applied by geologists to certain deposits which underlie the "lower boulder-clay" of the regions in which these deposits occur. But, as we have learned, many accumulations of so-called "lower boulder-clay" are not the products of the earliest epoch of glaciation, and the fossiliferous beds which sometimes underlie them are, therefore, not necessarily of preglacial age. I apply the term exclusively to deposits which were laid down before the earliest appearance of glacial conditions in temperate latitudes. These, so far as our present knowledge goes, are the only accumulations which we are justified in classing as preglacial.

were brought about—the luxuriant flora and the great mammals of the Pliocene retreating gradually before the approaching winter of the Glacial Period.

II. First Glacial Epoch.—Eventually a thoroughly arctic fauna lived in the North Sea. Great snow-fields at the same time came into existence, and a gigantic glacier occupied the basin of the Baltic.* The mountainous parts of the British Islands, we can hardly doubt, must likewise have been ice-clad, but of this there is no direct evidence. Farther south the Alpine Lands were swathed in snow and ice, and great glaciers occupied all the mountain-valleys and piled up their terminal moraines upon the low-grounds at the foot of the chain. In Central France very considerable glaciers also descended from the great volcanic cones of Auvergne and Cantal, and deployed upon the plateaux. And probably in many other mountain-districts similar conditions obtained.

III. First Interglacial Epoch.—Eventually cold conditions passed away. The arctic fauna retreated from the North Sea, and at the same time dry land occupied the southern part of that sea up to the latitude of Norfolk at least. Across this new-born land flowed the Rhine and other rivers. A temperate flora, comparable to that now existing in England, clothed the land in our latitude, while the hippopotamus, elephants, deer, and other mammals became denizens of our country. In other parts of Europe similar genial conditions obtained—conditions which, to judge from the flora, were even more genial than are now experienced in the same regions. A luxuriant deciduous flora occupied the valleys of the Alps, and flourished at heights which it no longer attains. That flora was accompanied by a mammalian fauna (North Italy) which embraced among other forms *Elephas meridionalis.* From the amount of river-erosion effected during this epoch we may gather that the stage was one of long duration. By-and-by, however, cold conditions again supervened—the temperate flora disappeared from England, and was gradually replaced by arctic forms.

IV. Second Glacial Epoch.—The appearance of that arctic flora and the immigration into the North Sea of arctic mollusks heralded the approach of the greatest of the European ice-sheets. This enormous *mer de glace* covered all the northern part of the Continent and flowed south into Saxony. At the same time the Alpine glaciers reached their greatest extension, while in all the other mountains of Europe snow-fields and glaciers made their appearance. In extraglacial tracts, as in Southern England and Northern France, and in many other regions, the formation of rock-rubble was in active progress, and much movement of such superficial accumulations took place. These physical changes

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* The limits reached by this earliest "great Baltic glacier" are not known. In Southern Sweden, however, it occupied a wider area than the great Baltic glacier of the fourth glacial epoch, its northern limits lying at least thirty miles farther north than those reached by the latter.

were necessarily accompanied by great migrations of flora and fauna—arctic alpine plants coming to occupy the low-grounds of Central Europe, and northern animals ranging down to the shores of the Mediterranean.

V. Second Interglacial Epoch.—The enormous morainic accumulations and fluvio-glacial gravels of the second glacial epoch are sufficient evidence of its prolonged duration. Eventually, however, it passed away and the climate by degrees became temperate and even genial. The arctic-alpine flora and northern fauna retreated from the low-grounds and were replaced by temperate and southern forms. The character of the plants which then occupied North Germany and Central Russia is suggestive of a milder and less extreme climate than is now experienced in those regions—and the mammalian fauna of the epoch, which included the hippopotamus and *Elephas antiquus*, was in keeping with the flora. Britain would appear to have been connected with the Continent at this time, and land-passages probably joined our Continent to North Africa. Again, however, the climate began to deteriorate, accompanied by renewed migrations of flora and fauna, and as the third glacial epoch approached, much low-lying land in Northern and Northwestern Europe was submerged. The long duration of this interglacial phase is shown by the great depths to which the rivers of the epoch succeeded in eroding their valleys.

VI. Third Glacial Epoch.—At the climax of this epoch a most extensive ice-sheet again overwhelmed the major portion of the British Isles and a vast area of the Continent. It did not, however, attain the dimensions of its predecessor. From the Alps great glaciers again descended to the low-grounds, where they dropped the terminal moraines of the "inner zone." These moraines form most conspicuous objects, and extend in curving lines between the highly denuded moraines of the first and second glacial epochs. Like these they are accompanied by well-marked sheets and terraces of fluvio-glacial gravels. Many of the other mountains of Europe were similarly snow-clad and glaciated, while rubble-drifts accumulated in extraglacial regions.

VII. Third Interglacial Epoch.—The third glacial epoch eventually passed away like its predecessors and was gradually succeeded by temperate conditions. Of this change the most direct evidence we have is that furnished by the youngest interglacial beds of the Baltic coast-lands. It is probable, however, that a considerable proportion of the old alluvial deposits of Britain and Ireland, which have hitherto been classed as of post-glacial age, really belong to this interglacial epoch. Amongst these are the clays, etc., with Irish deer, red-deer, etc., which underlie the older peat-bogs. In the Baltic area the interglacial beds contain in some places arctic forms, in others a temperate marine fauna, in yet others they have yielded mammoth, woolly rhinoceros, horse, Irish deer, and urus. It is obvious that these beds cannot be strictly contemporaneous. Some probably belong to the beginning, others to the middle of the third interglacial epoch, while others again may pertain to its close. They show us clearly, however, that after the disappearance of glacial conditions the Baltic became tenanted by a temperate North Sea fauna, while the adjacent lands supported a corresponding terrestrial fauna and flora.

VIII. Fourth Glacial Epoch.—In the early stages of this epoch the low-grounds of Scotland were submerged to the extent of 100 ft. at least, while an arctic marine fauna lived round the coasts. Eventually the various mountain-districts of our islands were cased in snow and ice, large glaciers filling all the Highland fiords and calving their icebergs in the sea—a condition of things implying a snow-line not exceeding 1,000 to 1,600 ft. in elevation. But the greatest development of ice was witnessed in the Baltic area. The Scandinavian peninsula once more supported an ice-sheet that broke away in icebergs at the mouths of all the fiords of Western Norway. Finland was well-nigh overwhelmed, while the Baltic basin was occupied by a great ice-stream which invaded North Germany and Denmark. Later on, as the ice-sheet melted away, a wide area in Scandinavia was submerged in a cold sea which communicated widely with the Baltic. In the Alps large glaciers flowed for long distances down the great valleys, but came far short of attaining the dimensions reached by those of the preceding glacial epoch. At the same time small local glaciers appeared in the high valleys of some of the mountain-ranges of Middle Europe.

IX. Fourth Interglacial Epoch.—At the climax of this epoch temperate conditions prevailed, and extensive forests of deciduous trees spread far north into regions where such trees no longer flourish. The British Isles now formed part of the Continent. The cold sea had retreated from Scandinavia, and the Baltic was converted into a great lake. Eventually, however, submergence again ensued, but the sea, which now invaded Scandinavia and communicated with the Baltic, was tenanted by a fauna indicative of more genial conditions than obtain at present.

X. Fifth Glacial Epoch.—This epoch is characteristically represented by local or valley moraines in the British Isles, the position of which indicates that the snow-line reached in Scotland an average height of 2,500 ft. The disappearance of the genial conditions of the preceding temperate epoch was marked by the submergence of the Scottish coast-lands to a depth of about fifty feet below their present level. Here and there in the northwest of Scotland, glaciers reached the sea and dropped their moraines on the beaches of the period. To the same epoch may be assigned the formation of most of the corrie rock-basins of the British Isles—each of these basins marking the site of a glacier of more or less limited size. The submergence in Scotland probably commenced in the preceding temperate epoch, as it did likewise in

Scandinavia. In the Alps the fifth glacial epoch is marked by the moraines of the so-called "second postglacial stage"—moraines that indicate a renewed advance of the glaciers of that region.

XI. Fifth Interglacial Epoch.—This epoch was heralded by the re-emergence of the land and the retreat of our valley-glaciers. Again the British area attained a wider extent than at present, but we cannot tell whether it became united to the Continent. The upper "buried forests" in the peat-bogs of Northwest Europe show that this epoch was characterized by drier conditions and a remarkable recrudescence of forest-growth—conditions recalling those of the preceding interglacial epoch.

XII. Sixth Glacial Epoch.—To this epoch belong our latest raised-beaches, which indicate a limited submergence not exceeding, in Scotland, twenty to thirty feet. The climate once more became humid and less favorable to forest-growth. Hence forests decayed while peat-bogs extended their area. The snow-line stood at an elevation in Scotland of 3,500 ft.—and thus nourished a few small glaciers in our loftiest mountain-groups.

XIII. The Present.—Marked in Britain by the retreat of the sea to its present level, and by the return of milder and drier conditions and the final disappearance of permanent snow-fields.

It will be observed that in this short résumé I have abstained from the use of the term "postglacial." The word has been applied to deposits of such widely different ages that it has ceased to be of any value for classificatory purposes. From late Pliocene down to the close of the Pleistocene time we have the record of a continuous series of geographical and climatic changes. Early in the cycle the glacial and interglacial phases attained their extreme development. The climax once passed, each successive cold and genial epoch declined in importance. In a word, the climatic and geographical changes became less and less marked as the cycle drew to a close. From the point of view of the present it seems absurd to speak of "fifth" and "sixth" glacial epochs, seeing that these epochs were marked only by the presence in Britain of limited snow-fields and small local glaciers. When either of these epochs is contrasted with the conditions that obtained in early glacial times they would seem to be more properly described as temperate epochs. But they undoubtedly belong to one and the same series of alternating cold and genial conditions, and from this larger point of view cannot be designated otherwise than glacial.

In the following tabular statements the glacial and interglacial succession is given in ascending order, beginning with the lowest beds—the successive stages being indicated in the several tables by the same numbers.

Glacial Succession in British Isles.

1. Weybourn crag and Chillesford clay.	1. Marine deposits with pronounced arctic fauna.
2. Forest-bed of Cromer.	2. Temperate flora; *Elephas meridionalis, E. antiquus. Rhinoceros etruscus, Hippopotamus, &c.*
3. Lower boulder-clays and associated fluvio-glacial deposits.	3. Ground-moraines, &c., of most extensive ice-sheet.
4. Marine, fresh-water, and terrestrial accumulation; basin of Moray Firth; basin of Irish Sea; Lanarkshire, Ayrshire, Edinburghshire, &c.; Hessle gravels; Sussex beach-deposits, &c.; Settle Cave, &c.	4. Northern and temperate flora and fauna; *Elephas primigenius*, *Rhinoceros tichorhinus;* reindeer, &c.; hippopotamus, *Elephas antiquus*, *Rhinoceros leptorhinus*, Irish deer, grisly bear, lion, hyæna, &c.
5. Upper boulder-clay and associated fluvio-glacial deposits.	5. Ground-moraine of ice-sheet which extended south to the Midlands of England.
6. Fresh-water alluvia underlying oldest peat-bogs; probably a considerable proportion of our so-called "postglacial" alluvia.	6. Temperate flora and fauna; Irish deer, red deer, *Bos primigenius*, &c.
7. Boulder-clays and terminal-moraines of mountain-regions; 100-ft. beach of Scotland; arctic plant-beds.	7. Morainic accumulations of district- and large valley-glaciers; arctic marine fauna; snow-line at 1.000 to 1,600 ft.; arctic flora.
8. Lower buried forest.	8. Temperate flora and fauna.
9. Peat overlying "lower buried forest"; Carse-clays and raised beaches; valley-moraines and corrie-moraines.	9. Small glaciers in mountain-regions; snow-line at 2,400 to 2,500 ft.
10. Upper buried forest.	10. Temperate flora and fauna.
11. Peat overlying "upper buried forest"; low-level raised beaches; high-level valley-moraines and corrie-moraines.	11. Small glaciers in the most elevated regions; snow-line at 3,500 ft.

Glacial Succession in Northern Europe.

1. Lowest boulder-clay of Baltic coast-lands.	1. Ground-moraine of earliest Baltic glacier.
2. Alluvia underlying lower diluvium of Hanover, Brandenburg, &c.	2. Temperate flora and fauna, including *Cervus elaphus*, *C. capreolus*, *Bos*, sp., *Rhinoceros*, sp., &c.
3. Lower diluvium of Central and Southern Germany, Holland, Central Russia.	3. Ground-moraines, &c., of most extensive *mer de glace.*
4. Fresh-water and marine deposits of Baltic coast-lands, Grünenthal, Rixdorf, Kottbus, Moscow, &c.	4. Northern and temperate floras and faunas; mammoth, *Elephas antiquus*, Irish deer, horse, &c.
5. Upper diluvium of Central Germany, Poland, West Central Russia; second boulder-clay of Baltic coast-lands.	5. Ground-moraines, &c., of ice-sheet which flowed some 40 or 50 miles south of Berlin.
6. Fresh-water and marine deposits of Baltic coast-lands.	6. Northern and temperate floras and faunas.
7. Youngest boulder-clay of Baltic coast-lands; terminal moraines in South Norway and Sweden, Baltic Ridge, and Finland. Arctic plants under oldest peat-bogs of Denmark, Norway, Sweden, &c.; *Yoldia*-clays, &c.	7. Accumulations of last great Baltic glacier; submergence in Scandinavia; adjacent lands clothed with arctic flora.

8. *Ancylus*-beds of Baltic area; older buried forests generally; *Littorina*-beds of Baltic area in part.	8. Temperate flora and fauna; climate at climax of stage more genial than now; conditions become more humid in later stages.
9. Peat overlying older buried forests; calcareous tufas, &c.; *Littorina*-beds in part; large valley-moraines in Norway.	9. Humid climate; glaciers here and there reach heads of fiords.
10. Younger buried forests.	10. Temperate flora and fauna; drier conditions.
11. Peat overlying younger buried forests; high-level terminal moraines in Norway.	11. Humid climate; relatively small glaciers.

GLACIAL SUCCESSION IN CENTRAL AND SOUTHERN EUROPE.

1. Lowest ground-moraines; terminal moraines opposite mouths of great valleys; plateau-gravels (Alpine Lands). Oldest morainic accumulations of Central France (?).	1. Accumulations of first glacial epoch.
2. Hötting breccia; lignites of Leffe, &c.; so-called Upper Pliocene alluvia of Central France.	2. Flora indicates warmer conditions than now obtain in those regions; *Elephas meridionalis*, *Rhinoceros leptorhinus*, &c.; valleys deeply eroded.
3. Ground-moraines; terminal-moraines of outer zone; high-level gravel terraces (Alpine Lands); "Ceppo" of North Italy; Pleistocene conglomerate of Ligurian coast-lands; torrential gravel terraces of South-west Italy; erratics of raised beaches (France); older moraines of Urals, Carpathians, and mountains of Central Europe; of Central France, Pyrenees, Corsica, Appenines, Balkan Peninsula, &c.; lower breccias of Gibraltar; and rubble-drift, in part, of other regions.	3. Accumulations of epoch of maximum glaciation.
4. Lignites of Switzerland, Bavaria, &c.; alluvial deposits; beach accumulations underlying rubble-drift (Northern France); terraces cut in older breccias of Gibraltar.	4. Temperate flora; *Elephas primigenius*, *E. antiquus*, *Rhinoceros Merckii*, *Bos primigenius*, *Cervus elaphus*, &c.; valleys deeply eroded.
5. Ground-moraines; terminal moraines of inner zone; low-level gravel terraces (Alpine Lands); valley-moraines in other mountain-regions; rubble-drifts in part.	5. Accumulations of third glacial epoch.
6. Alluvial deposits, &c. (?)	6. Not yet recognized.
7. Terminal moraines in large longitudinal valleys of the Alps; small valley-moraines in the higher valleys of other mountain-regions.	7. Accumulations of fourth glacial epoch = "first postglacial stage" of glaciation.
8. Alluvial deposits, &c. (?)	8. Not yet recognized.
9. Terminal moraines in higher valleys of Central Alps.	9. Accumulations of fifth glacial epoch = "second postglacial stage" of glaciation.
10. Alluvial deposits, &c.	10. Not recognized.
11. High-level moraines in Western Alps.	11.

2. *Changes of level in the region of the Great Lakes in recent geological time;* by FRANK B. TAYLOR. (Letter to J. D. Dana.)—"*First,* as to the probable place of the highest shore line on the north coast of Lake Superior. It seems to me that when we take full account of all that is now known about the highest shore line in the regions adjacent to Lake Superior we are bound to conclude, pending further exploration, that this line probably attains an altitude of at least 1200 to 1300 feet above sea level in the Nipigon region at the north-northwestern extremity of the lake, and at least 1100 to 1200 feet on the northeastern side at Lake Missinaibi. The facts upon which this opinion rests are as follows: The altitude of the Herman beach of "Lake Agassiz" (ancient Gulf of Winnipeg) is 1055 feet at Lake Traverse, and 1220 feet at the international boundary. On the east side of Red river in Minnesota this beach rises a little more rapidly. On the southeast side of Beltrami island in northeastern Minnesota it occurs at 1087 feet and on the northwest side at 1195 feet. At Duluth, 1134 feet, and at Mt. Josephine on the northwest coast of Lake Superior, 1207 feet. Near L'Anse and again near Marquette on the south coast, 1190 feet. Near Sault Ste. Marie 1014 feet. Near Cartier, Ontario, about 1200 feet, and at the ancient Nipissing strait at North Bay, Ontario, 1140 feet on the north and more than 1220 feet on the south side.

It is noticeable that the lowest level of the line in this list is at Sault Ste. Marie. If the highest shore line passes downward to the north from this place, or even on a level, it must cut off the supposed straits to the north of Lake Superior. But considering the high altitude of the shore line in all the regions bordering the lake, Green Bay only excepted, the chance of this seems extremely small. The highest beach, rising northward from 1134 feet at Duluth to 1207 feet on Mt. Josephine, (supposing Lawson's observations at the latter place to be correct) must meet the beach which passes northward from Sault Ste. Marie somewhere in the north, because they are the margin of one water plane. It seems almost certain, therefore, that the highest beach must rise more rapidly northward from Sault Ste. Marie than it does from Duluth. For it starts from a level about 120 feet lower. I am bound to conclude, therefore, for the present that the highest shore line rises at least 1½ to 2 feet per mile northward from Sault Ste. Marie and keeps well up along the north shore, leaving the open straits to the north, as stated in my paper. (As I remember Prof. Lawson's figures, the Missinaibi pass is about 1044 feet above sea level and the Kenogami pass 1109 feet.) I see no escape from this conclusion, then, unless it be by some abrupt and very exceptional dip of the ancient water plane downward to the north. It would appear, therefore, that the mean height of the highest shore line in the Superior basin can hardly be less than 1100 feet or more than 1200. On present data the most probable mean that I can name for the whole basin is about 1150 feet. I think this estimate is conservative and likely to prove too low rather than too high.

Second. As to the origin of the highest beach, I believe that it was all made at sea level and that the Iroquois beach in the Ontario basin, the highest beach in the northern parts of the Huron and Michigan basins with that of the Superior basin, and also the upper beach of the Red river and Winnipeg basin, are all one continuous beach and of the same age in all parts. In the Michigan and Huron basins this beach slopes downward toward the south and passes under the present lake level, thus leaving Lake Erie with all its beaches and also the Chicago outlet entirely above that plane. The Erie beaches are undoubtedly the shores of an ice-dammed lake of the glacial recession. It was much the largest lake produced in this way. But there were other smaller, shorter lived ones at the south ends or sides of all the basins. The Ontario basin was probably also partly filled by a large temporary lake of this kind, emptying through the Mohawk valley. But the record it may have left has been wiped out by the later marine invasion which made the Iroquois beach.

Third. As to the relations of Niagara, Lake Erie, etc., I have the data to show conclusively that the present period of the great cataract's activity began at a point a few rods above the cantilever railroad bridge. Before that time the outlet of the upper lakes was eastward over Nipissing pass and down the Ottawa river, and greater Niagara was replaced for a long period of time by a very much smaller stream (the "Erigan" river), which drained only the Erie basin and possibly not all of that. This smaller stream made the narrower, more shallow gorge of the whirlpool rapids, extending from Foster's flat below the whirlpool up to the cantilever bridge. The time which was required to do this must have been many times longer than Mr. Gilbert's estimate of the age of the whole gorge from Lewiston up. I should say that the multiplier would have to be tens rather than units. As a measure of the duration of postglacial time, therefore, I do not see how the gorge can have any value worth mentioning. But without meeting this demand, it goes far enough to show that postglacial time must have been much longer than the current estimate.

But to go a step farther, there is considerable evidence to show that the greater Niagara had another earlier period of postglacial activity, during which it cut out the gorge from Lewiston to Foster's flat. Overhanging Foster's flat is the old fall ledge of the greater cataract with the narrower gorge of the smaller stream cut back on the south side. At this old ledge the great cataract ceased for a long period of time, and when it returned the smaller stream had cut back in the interval to the cantilever bridge. Thus the great cataract has been intermittent in its activity. It has had two active periods separated by the long, almost indefinitely long, period during which the falls of the smaller stream carried on the work. And all this *plus* a short period for the Chicago outlet has been since the ice age. There is some evidence in the beaches of the north pointing to this earlier period of the cataract. But this episode of the gorge is not yet so strongly established as the other two.

Fourth. A word as to the nature of the changes that have produced these great alterations of land altitude. They are so extensive, so great, and above all so *recent* as to be almost appalling when one thinks of them.

Of the whole amount of apparent elevation along the line of the parallel of 46° 30′, which passes close to Duluth, Sault Ste. Marie and North Bay, I think I can make out fairly well that between 600 and 800 feet of it are due to a change of the *secular* kind, while the rest is of the *paroxysmal* sort, I have always embodied this distinction (which is derived from Dana's Manual of Geology) in my working hypothesis, and with good effect. I am quite sure that it was the secular factor that changed the outlet of the upper lakes this last time and brought Niagara into its present state of activity—in consequence of a secular relative, differential, northward elevation. It seems probable that the earlier episode of Niagara was also due to the same factor. But the order of relative change was probably then in the opposite direction. I believe that maximum northern relative elevation coincided with maximum glaciation, as you have said. But I believe, further, that maximum relative northern submergence coincided with the climax of the postglacial warm epoch now passing off. Relative northward elevation has been in progress for some time past and we are now advancing again toward a climax of cold."

3. *Introduction to Geology as historical science.* Einleitung in die Geologie als historische Wissenschaft. Beobachtungen über die Bildung der Gesteine und ihren organischen Einschlüsse. I Theil: Bionomie des Meeres. II Theil: Die Lebensweise der Meeresthiere. III Theil: Lithogenesis der Gegenwart (by Johannes Walther), pp. i-xxx and 1055. (Gustav Fischer), Jena, 1893–1894.—The author describes the method employed in this "Introduction to Geology" as the *ontological method* of investigation, which consists in the interpretation of the events of the past by the phenomena of the present. The aim he has held before him while constructing this elaborate work has been to bring together from many sources, from periodicals, monographs and special treatises, all the facts bearing upon the general question of the formation of rocks and upon the conditions under which organisms have lived and died and been fossilized.

The work is divided into three parts: The first (Bionomie des Meeres), on the marine conditions of life, was briefly noted when it first appeared in 1893.* It is an elaborate description and classification of the zones of life-habitat of the ocean following the system of classification proposed by Haeckel† and gives a very convenient and apparently exhaustive synopsis of the facts with full references to sources.

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* This Journal, III, vol. xlvi, p. 240.

† Planktonstudien, Jena, 1890.

The second part (Die Lebensweise der Meeresthiere, pp. 197–532) treats of the mode of life of sea animals. In its 335 pages are brought together the facts known about the geographical distribution, bathymetric range and other conditions of adjustment to conditions of life environment of the organisms whose remains could be preserved as fossils. The facts are classified in sections for each of the larger groups of organisms, the classes or branches. Here also references to original sources are liberally given.

The third part (Lithogenesis der Gegenwart, pp. 535–1055) describes the methods of formation of rocks on the present surface of the earth. The first section is devoted to the statistics of Lithogeny or dynamical geology, classified under the heads of Weathering, Ablation, Transportation, Corrosion, Deposition, Diagenesis and Metamorphism. The second section describes and classifies the various areas of the present surface of the earth, (Du Faciesbezirke der Gegenwart) distinguished by differences of climate or physical surface as affecting the geological formations or phenomena. In the last section the outlines of a comparative Lithology are discussed under such headings as the correlation of facies, the equivalency of rocks, changes of facies.

Although there is little original in the book, a large amount of statistics scattered over a very wide range of literature are brought together, concisely stated and classified in such a way as to be helpful and suggestive to the geological student, to which end the full references to original sources and the good indexes at the close contribute no small share. H. S. W.

4. *Alabama, Geological Survey—Geological Map of Alabama with explanatory Chart.* E. A. Smith, State Geologist and Assistant. Two large folio sheets. 1894.—The map presents in clear and yet not too strong colors the geological features of the State, with division of the scale as fine as the classification in the reports. The Chart presents an admirable synopsis of the important features of the geological conditions of the State. In the first column names, synonyms, classification and common fossils are given for each of the recognized formations, opposite each division in the second column are given thickness, lithological and topographical characters, area and distribution, in a third column, useful products followed by a fourth describing the soils, characteristic timber growth and agricultural features, and a final column in which are listed the Reports in which each of the formations is described, making a convenient index to the geology of the State for the general reader as well as the geologist.

5. *Manual of Geology;* by James D. Dana.—The new (fourth) edition of this work, entirely rewritten and much enlarged, will be ready about the middle of January.

6. *Bulletin of the Department of Geology, University of California.* A. C. Lawson, Editor, Berkeley, Cal.—This work has been noticed in this Journal, vol. xlvii; p. 147, 1894, and we are now in receipt of Nos. 5, 6 and 7.

No. 5. *The Lherzolite-Serpentine and associated rocks of the*

Potrero San Francisco; by CHAS. PALACHE.—This presents the results of a study of this rock both in the field and in the laboratory. The facts obtained show that it is the result of alteration of a very basic igneous rock intruded into the San Francisco sandstone.

No. 6. *On a rock from the vicinity of San Francisco containing a new Soda-Amphibole;* by the same author.—The rock consists of fine grains of albite. Through this is thickly sprinkled the amphibole in small acicular crystals, in simple forms. The optical relations determined in thin section are $b = \mathfrak{b}$, $c : \mathfrak{a} = 11° - 13°$ in front: Pleochroism strong: $\mathfrak{a}$=sky-blue to dark blue, $\mathfrak{b}$=violet, $\mathfrak{c}$=yellowish brown to greenish yellow. Absorption $\mathfrak{a} \geqq \mathfrak{b} > \mathfrak{c}$. Is often zonally built. A chemical analysis gave the following results:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O		Sum.
·55·02	4 75	10·91	9·46	tr.	9·30	2·38	7·62	0·27	?	=	99·70

A consideration of the molecular ratios of the oxides from this analysis shows them to be

$$\begin{array}{ll}\mathrm{SiO_2} & \cdot918\\ \begin{array}{l}\mathrm{Al_2O_3}\\ \mathrm{Fe_2O_3}\end{array} & \left.\begin{array}{l}\cdot046\\ \cdot068\end{array}\right\}\cdot114\end{array}\qquad \begin{array}{l}\mathrm{FeO}\\ \mathrm{MgO}\\ \mathrm{CaO}\end{array}\;\left.\begin{array}{l}\cdot131\\ \cdot233\\ \cdot043\end{array}\right\}\cdot407\qquad \begin{array}{l}\mathrm{Na_2O}\\ \mathrm{K_2O}\end{array}\;\left.\begin{array}{l}\cdot123\\ \cdot003\end{array}\right\}\cdot126$$

whence $(Na, K)_2O : R_2O_3 : SiO_2 :: .126 : \cdot114 : 480 :: 1\cdot05 : 0\cdot95 : 4$
and $RO : SiO_2 :: \cdot407 : \cdot437 :: 1 : 1$.

From which it appears that the mineral is a mixture of the actinolite $(Ca, Mg, Fe)SiO_3$, the glaucophane $NaAl(SiO_3)_2$ and the riebeckite $Na\overset{III}{Fe}(SiO_3)_2$ molecules. The author proposes for it the name *crossite* after Mr. Whitman Cross of Washington.

The propriety of giving new names to indefinite mixtures of isomorphous molecules is at best a very doubtful one, unless from constancy and frequence of occurrence there is a positive demand for such a term. By far the larger part of the work of chemical mineralogy in the last few decades has been ridding the terminology of just such synonyms; and one needs only to glance at the index to the recent edition of Dana's Mineralogy to become convinced of this fact. The best usage seems to require that definite mineral molecules once established should receive definite names, and isomorphous mixtures should be classed under the one prevailing.

No. 7. *Geology of Angel Island;* by F. L. RANSOME.—This is a very careful and excellent study of the geology and petrography of a small island in San Francisco bay. The island consists in the main of the San Francisco sandstone which is folded, and intruded with serpentine and a basic igneous rock classed by the author under fourchite. It is accompanied by a detailed geological map and plates, and DR. G. H. HINDE adds a chapter on the idiolarian chert found on the island. L. V. P.

7. *Mineral Resources of the United States.* Vol. IX. Calendar Year, 1892, 850 pp. Washington, 1893. Vol. X. Calendar Year, 1893, 810 pp. Washington, 1894. DAVID T. DAY, Chief of Division of Mining Statistics and Technology (U. S. Geol.

Survey, J. W. Powell, Director).—The latest volumes of this valuable series are Nos. IX and X for the years 1892 and 1893 respectively. They have been issued under the able editorship of Mr. David T. Day, and like the earlier volumes, contain a large amount of interesting and useful data in regard to the present condition and recent growth of the mineral industries of this country.

8. *Physikalische Krystallographie und Einleitung in die krystallographische Kenntniss der wichtigeren Substanzen;* von Paul Groth. Dritte vollständig neu bearbeitete Auflage, I und II Abtheilung, physikalische und geometrische Eigenschaften der Krystalle, 528 pp. 8vo. Leipzig, 1894 (Wm. Engelmann).—Ever since the publication of the first edition in 1876, the *Physikalische Krystallographie* of Professor Groth has been the standard work in this subject for the mineralogists of all lands. In the second edition, issued in 1885, the work was rewritten throughout and much enlarged, and the same is true to even greater extent of the present third edition. The author's keen mind and long experience as a teacher have enabled him to present the subjects of crystallography and the general physics of crystals with rare clearness and system, as all know who have used the earlier editions. This is conspicuously true of the work in its present form, which contains much that is new and suggestive particularly in the discussion of the symmetry of crystals and their classification based upon this. Two parts of the third edition only have thus far appeared, but the third, upon the methods of calculation applied to crystals, instruments and methods of investigation, is promised in a few months.

9. *A Manual of Microchemical Analysis;* by Professor H. Behrens, of the Polytechnic School in Delft, Holland, with an introductory chapter by Professor John W. Judd of the Royal College of Science, London. 246 pp. 8vo. London and New York, 1894 (Macmillan & Co.)—Workers in Petrography and all who have occasion to use the now well developed microchemical methods will welcome this admirable volume. The original contributions of the author to this subject are well known, but his work on *Mikrochemische Methoden* is not readily accessible to the English student and hence this translation made by him will be highly appreciated. The value of the work is increased by the fact that the author's manuscript has been revised by Prof. J. W. Judd, who with the assistance of Mr. A. E. Tutton, has also seen it through the press. A brief but interesting introduction, in part historical, in part descriptive, has been added by Professor Judd.

10. *Handbuch der Mineralogie;* von Dr. C. Hintze. Achte Lieferung, pp. 1121–1280. Leipzig, 1894 (Veit & Co.).—The eighth part of Hintze's great work has appeared recently. It embraces the close of the Pyroxene group, the Amphibole group and the opening pages on the species beryl.

III. BOTANY.

1. *Lehrbuch der Botanik.* Dr. FRANK, Berlin, 8vo, two volumes, pp. 669, and 431 (1892 and 1893).—Professor Frank's text-book follows the usual course of treatment, but gives great prominence to the subject of physiology. This part of his work makes the treatise of great value. The topics are fully treated and the essential matters are kept in their proper relations, so that the general result is symmetrical. The questions with which Professor Frank has specially busied himself in his original work, are discussed in an exceedingly interesting manner and with due perspective. In a few instances, it seems on the first reading, as if the author had stated some of his own conclusions in too positive a form for the requirements of a text-book for the general student, but, as above said, the treatise is symmetrical. G. L. G.

2. *Lehrbuch der Botanik.* Dr. K. GIESENHAGEN, Munich, 8vo, pp. 335, 1894.—The author has prepared this text-book with reference to the needs of students who are reviewing their work before examination. It is, therefore, a comprehensive volume in which the whole ground is covered in such a manner as to refresh one's memory with regard to the results of personal laboratory exercises in histology and physiology, supplementing this by sufficiently full treatment of systematic and economic botany. The newer results have been incorporated with the older in a well-proportioned and well-balanced manner, so that the work gives a clear and sound exposition of the present state of our knowledge. The author has carried his work on under the advice and with the assistance of Dr. Goebel, Professor of Botany in Munich. G. L. G.

3. *Lehrbuch der Botanik.* Dr. F. PAX, Leipsic, 8vo, pp. 365.—This is the ninth edition of Prantl's well-known work, already noticed in this Journal. The revision has been thorough. In the histological and physiological portions changes demanded by recent investigations have been made, and important modifications have been made throughout the systematic part. It may be remembered that the earlier editions gave a good deal of prominence to species: in this edition, only those are referred to which are of interest in economic botany, especially in medicine. The number of illustrations has been increased from 326 to 355. The improvement in the engravings since the first edition has been very great. G. L. G.

4. *Lehrbuch der Botanik.* Dr. E. STRASBURGER, Dr. F. NOLL, Dr. H. SCHENK, Dr. A. F. W. SCHIMPER, Jena, 8vo, pp. 558, 1894.—Professors Strasburger and Schimper with the two Privatdocents associated with them in botanical teaching in Bonn, have carried successfully to completion the very hazardous experiment of preparing a composite text-book. The dangers which confront such an undertaking are obvious. Each specialist is likely as we say to magnify his office, and give a disproportionate amount of space to the results which have been recently attained

in his part of the field. It is exceedingly difficult to secure under such circumstances anything which approaches careful editing. Distortions of a serious character are very likely to result. Furthermore it is very hard to avoid duplication, even when the conferences and friendly discussions have been frequent and critical. But the outcome of this experiment has been successful in a high degree. Professor Strasburger has given the subject of histology the fruits of his long and ripe experience in investigation and teaching. Within the comparatively narrow limits of 130 pages, he has compressed without too much condensation, all the essential facts of general and special anatomy of the external parts and the internal structure. It is only when one looks over this part of the volume a second time that he begins to realize how much grain free from chaff has been made ready for the student. Moreover all the material has been arranged in an orderly and attractive manner. Dr. Noll has considered the subject of physiology in a comprehensive fashion, dealing with the principal phenomena presented by all the organs of flowering and flowerless plants. He has presented his facts fully, but without prolixity. The style is clear, and the illustrations like all which are given in the volume, are of a high order considered both from a scientific and a pedagogic point of view. We think he has done well to give so much prominence to the experimental side of the subject. Dr. Schenck and Professor Schimper divide the field of systematic botany between them, the former taking the Cryptogams, and the latter the flowering plants. It is enough to say that the work is satisfactory in every respect. New and admirable figures, many of them of the highest excellence, illustrate the remarkably clear text. As might be expected, the subject of adaptive modifications, although touched but lightly, has assumed a peculiar charm at the hands of Professor Schimper. A good deal of new light is thrown on the subject and the whole of it is invested with a deep interest. Returning for a moment to the matter of illustrations, attention must be called to the beauty and accuracy of the colored figures which represent poisonous plants. It is to be hoped that a translation into English of this admirable work will soon be in the hands of English-speaking students.

G. L. G.

5. *A Student's Text-Book of Botany;* by SYDNEY H. VINES, M.A., Professor in the University of Oxford. First Half, 8vo, pp. 480. London, 1894.—The author has based his work on the well-known *Lehrbuch der Botanik*, of PRANTL, which, as will be seen in another notice, has reached its ninth edition in Germany. But the changes which he has made, are so numerous as to transform this into a new treatise; the metamorphosis is almost complete. A great deal of new matter designed for the advanced student has been skillfully interwoven, bringing the whole well up to the most advanced knowledge of minute details. It is to be remembered that there are scores of trained workers now engaged in minute investigations in different parts of the field

covered by this volume, and that the results of their investigations are swelling the periodical literature of the science at a startling rate. It is indeed high praise to confess that a symmetrical résumé like this is fairly abreast of the times.

One feels inclined to criticise the free use of the new terminology adopted and in part suggested by Professor Vines, although there can be little doubt of the utility of the introduction in an advanced work of this sort of the new terms which are employed so generally in monographs; the work serves as an excellent technical dictionary. But we own that we should have been glad to see from Professor Vines, whose scholarship would have carried great weight, a reform in the terminology. Our language has, of course, lost its plasticity, and few new terms can be constructed out of English stems and roots; we are driven back to Greek for our materials and these serve every purpose; but it seems as if the new terms demanded by the advance of knowledge could be framed with some regard to euphony. Perhaps no one in English-speaking countries is so well prepared as Professor Vines to undertake this task, and perhaps he will take it in hand when he thinks the time is ripe. G. L. G.

6. *Practical Physiology of Plants;* by FRANCIS DARWIN, F.R.S. and E. HAMILTON ACTON, M.A., Cambridge, 1894, 8vo, pp. 321.—This is an outline of directions for experimenting. Explicit directions are given for conducting, generally with simple apparatus, the more conclusive experiments in nearly all parts of the field. As is quite proper, the character of the results are seldom announced; the student must find out for himself. In Detmer's Practicum and in the work of Oels, the student is generally helped towards his result by a brief statement of what he may expect to discover if he is successful, and this is a good plan for a certain class of students. But there is no question that the method used by Mr. Darwin and Mr. Acton is pedagogically correct, and is capable of giving excellent results. The only drawback to physiological experimenting at the hands of students, who are simultaneously pursuing other subjects, is the great amount of time which is generally consumed while plants are growing or reacting, and the consequent difficulty of arranging hours so as to make a close economy of time. The student should receive some hints as to what he might be getting ready for the next study while he is patiently waiting for something to happen to the plants which he has in hand, just as in the chemical and physical laboratory he is taught to keep many things going at the same time. It seems, on first reading, that the authors have arranged the work admirably in order to secure the greatest economy of every moment. This we are putting to a practical test.

G. L. G.

7. *A practical Flora for Schools and Colleges;* by O. R. WILLIS, New York, 8vo, pp. 349, 1894.—After a very brief statement of the subdivision of the subject of Botany, Professor Willis begins with an analytical key to the natural orders, and thence

passes to a description of certain orders. It is not easy to see the principle which guided him in the choice of subjects; in fact, it seems as if hardly any principle at all had been followed, but leaving this aside, it must be stated that a great amount of useful material has been brought together, and in such form as to be readily utilizable by a teacher. The work is a convenient handbook of Economic Botany. There are some unfortunate omissions, but, on the whole, there is a larger mass of well-arranged facts made ready for the hand of the teacher than we remember to have seen in any English treatise on the subject. The name of the valuable work seems to us a misnomer. Certainly it does not suggest to instructors that in these pages they can find the information regarding useful plants, in search of which they range through cyclopedias of every sort. G. L. G.

8. *Pflanzen-Teratologie, systematisch geordnet.* Dr. O. PENZIG, Genoa, 1890, and 1894.—The first volume of Professor Penzig's masterly work, comprising the polypetalous dicotyledons, was published four years ago; the concluding volume, in which are considered all the other groups of plants in which monstrosities have been thus far detected, was finished in June of this year, and has just been issued. The minuteness of Professor Penzig's search for recorded cases of monstrosities is shown by references to some of the most obscure sources, such as local journals and the like, and his care in stating the appearances of the distortions has been such as to place in the hands of the reader exact and yet much abbreviated descriptions which can be safely used in generalizations. On the part of the author there has been no attempt to state theoretical views in connection with the special cases, except where such treatment appears absolutely necessary; but he gives, in a clearly written preface to the second volume, a sound and clear exposition of modern speculations in regard to this interesting subject. With this treatise and with the philosophical work of Dr. Masters, the student of this subject is well-equipped. G. L. G.

9. *Practical Botany for Beginners;* by F. O. BOWER, F.R.S., Professor of Botany in the University of Glasgow, London, 1894, 8vo, pp. 275.—With the caution given in the preface, this laboratory manual, an abridgement of the larger Course of Practical Instruction in Botany, can be recommended without reserve. The caution is worth heeding in many quarters. "Type-teaching in Biological Sciences appears at present to be inevitable in elementary classes; it lies chiefly with the teacher to avoid the evils which are apt to arise from it. In order to use this book with proper effect, his knowledge should extend far beyond the area of the work here specifically described, and the larger edition may help him towards this end. By grasping every opportunity of comparison of the type selected with allied forms which show differences of detail, he will then be able to guide the pupil to distinguish essentials from secondary details, and to check the dangerous tendency of beginners towards generalization from too limited an area of fact." G. L. G.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *New Tables of the Planets.*—Prof. Newcomb in his report as Superintendent of the Nautical Almanac announces the substantial completion of the work of determining the fundamental constants of astronomy and the elements and masses of the major planets from Mercury to Saturn inclusive. He hopes to have the tables from Mercury to Mars inclusive completed by the end of the fiscal year. The tables of Jupiter and Saturn were completed by Dr. Hill during the last fiscal year. This leaves only Uranus and Neptune to be worked up.

Prof. Newcomb takes this occasion to present a general report upon the nature and objects of this work. The best of existing tables, those of Leverrier are by the lapse of time and by the lack of homogeneity in the elements employed, quite unsuited to the present needs of astronomers. There was needed a partial or complete reduction of all good observations of the sun and planets made since 1750. The actual number of separate meridian observations of the sun and the three planets Mercury, Venus, and Mars used by Prof. Newcomb was 62,030, against 10,893, used by Leverrier. The work of computation required to utilize all these observations and determine simultaneously the 23 unknown quantities involved can be appreciated only by those who have experience in such work. This immense labor has been secured by means of extra appropriations of $3,000 to $4,000 annually, together with such economy in the regular work of the Almanac office as was practicable.

Prof. Newcomb speaks of the increased demand for accurate positions of a much larger number of fixed stars than have heretofore been given in the Ephemeris. This increase is greatly needed, and in making it, we hope that the additional stars will be selected after consultation with the superintendents of the British, German and French Almanacs. A common list of stars may or may not be desirable. If a common list is not desirable, the differences in the lists should be for explicit reasons.

2. *Ostwald's Klassiker der exakten Wissenschaften.* Leipzig (Wm. Engelmann).—This series of classical scientific memoirs continues to grow in value as it grows in size. The papers, selected for republication, are well chosen and the originals being for the most part difficult of access, the library becomes of the first importance to the student in the subjects which it embraces. The latest additions are as follows:

No. 54. Anmerkungen und Zusätze zur Entwerfung der Land und Himmelscharten von J. H. Lambert (1772) 93 pp.

55. Ueber Kartenprojection: Abhandlungen von Lagrange (1779) und Gauss (1822) 101 pp.

56. Die Gesetze der Ueberkaltung und Gefrierpunktserniedrigung. Zwei Abhandlungen von Sir Charles Blagden (1788). 49 pp.

57. Abhandlungen über Thermometrie von Fahrenheit, Réaumur, Celsius (1724, 1730–33, 1742). 140 pp.

58. Chemische Abhandlung von der Luft und dem Feuer von Carl Wilhelm Scheele (1777) 112 pp.

59. Otto von Guericke's neue "Magdeburgische" Versuche über den leeren Raum (1672) 116 pp.

OBITUARY.

LEWIS R. GIBBES.—Dr. Lewis R. Gibbes, a scientist of very varied learning, died on the 21st of last November at Charleston, S. C., in the 85th year of his age. He was born in Charleston on the 14th of August, 1810. He entered on a course of medical study in 1830; but before the close of 1831 he was appointed Tutor in Mathematics in the College of South Carolina, at Charleston. At the revolution in the College, of December, 1834, when, owing to opposition to the President, Dr. Cooper, all the officers were requested to resign, he was set adrift with the rest. But in the new organization which followed the next day, Mr. Gibbes was made Professor of Mathematics. He resigned his position the following year, and in 1836 visited Paris for the purpose of completing his medical education, and gratifying his desire for knowledge in other directions. In 1838 he was again a Professor in the Charleston College, teaching mathematics, physics, chemistry and mineralogy. Botany and some departments of Zoology were also among his special studies. He published various papers on the Crustacea of the American coast, and showed his comprehensive knowledge of the subject by his revision, in 1850, of the species in the various United States collections, to which he added valuable notes and descriptions of new species. His encyclopedic tastes and knowledge are further shown by his astronomical work, especially between 1845 and 1854, when he published, besides other related papers, one on a comparison and discussion of all the observations made in the United States on the transit of mercury of May, 1845, and in 1849-50, while engaged in observing occultations of fixed stars by the moon, devised and constructed an occultator for the purpose "of obtaining the approximate times of disappearance and reappearance with less labor than by calculation."

As President Shepherd in his tribute to Dr. Gibbes, says: Astronomy was his passion, but he cultivated nearly every phase of our complex modern science, and cultivated none that he did not dignify and adorn. As a teacher he was lucidity itself. He not only taught so that he might be understood by the pupil, but so that he could not be misunderstood. He ever manifested a spirit of absolute consecration to his ideal as a scientist, an insatiable quest of knowledge, undiminished even in the view of death, and respect and reverence for the eternal verities of the Christian faith.

The death of FATHER DENZA, Director of the Vatican Observatory, is announced by telegraph.

JANUARY OPENING SALE OF MINERALS.

SPECIAL ANNOUNCEMENT

We expect to place on sale on January 2d, at noon, all of the minerals secured by Mr. English during his recent European Trip. This great display will doubtless attract mineralogists from far and near, and be the greatest exhibition of brand new minerals in America for a long time. We refer our customers to our advertisements last month for an account of a large number of the most important of these accessions; briefly summarized they were:

FROM RUSSIA: Dioptase, 16 specimens; Topaz, Alexandrites, Beryls, Emeralds, Crocoites, Uvarovite.

FROM GREECE: Realgar, fine groups; Orpiment.

FROM HUNGARY: Twins and rosettes of Hematite (new); fibrous Orpiment; Grossularite groups; Amethyst groups.

FROM BOHEMIA: Cassiterite groups, very fine lot; transparent green Obsidian; Carlsbad Twins of Orthoclase.

FROM STYRIA: Exquisitely beautiful Flos Ferri.

FROM TRANSYLVANIA: Wire, leaf and crystallized Golds.

FROM SPAIN: Crystallized Cinnabars; Aragonite and Dolomite in loose crystals.

FROM NORWAY: Wire Silver, one magnificent $80 museum specimen, several smaller; Xenotime in monster crystals.

MISCELLANEOUS: Cimolite pseudomorphs after Augite; clear masses of Sanidin; Crystallized Niccolite (!); crystallized HESSITE (!); Lumachelle; splendid lot of Manganites.

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THIRD SERIES.

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WITH PLATE II.

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NEW ARRIVALS OF MINERALS.

Leadhillite. Prof. Foote has just visited the "Beercellar Mine" at Granby, Mo., where he was fortunate enough to secure from the mine owners, several fine specimens of this rare species. By working over the dump and through purchases from former workmen, a few others were obtained. The mine caved in, in the spring of '94 and it is the opinion there that it will not be reopened. Crystals, some of good green color, 25c. to $10.00.

Calcite. Prof. Foote bought the entire collection of the discoverer of the famous cave that furnished so large a part of the Missouri exhibit in the mining building at Chicago.

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AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. VI.—*On the Relation of Gravity to Continental Elevation;* by T. C. Mendenhall.

[Read at the November meeting of the N. A. S.]

Nearly all of the earlier determinations of the force of gravity in the United States were made in the vicinity of the Atlantic Ocean, not more than one or two stations in the Mississippi Valley having been occupied previous to the year 1890. A determination had, however, been made on the Pacific Coast, at San Francisco, and pendulums had been swung for the same purpose on the summit of Mount Hamilton, at the Lick Observatory.

The development in the Coast and Geodetic Survey of the system of gravitation measure by means of half-second pendulums, to which reference has already been made in previous papers, made it possible, at a vastly less expenditure of time and labor, to execute an extensive series of gravity determinations as near as might be along the 39th parallel, extending from ocean to ocean, thus following nearly the line of the great trans-continental arc.

In the year 1893, an officer of the French Geographic corps, Colonel George Defforges, widely known for his investigations in connection with gravitation, visited this country, bringing with him pendulums which he had swung at several European stations, for the purpose of occupying the fundamental stations of the Coast and Geodetic Survey, and observing at a few isolated points which might be available during the period of his stay. Colonel Defforges swung his pendulums at several stations previously occupied by Coast Survey observers, and at one or two stations in the interior at which the Coast Survey had not before observed. These fundamental stations, in connection with those already occupied by the American observers, made it possible to form a general idea of the variations of gravity along the trans-continental line and to compare such variations with elevations above the sea.

At a meeting of the National Academy in April, 1894, the writer presented a brief résumé of these results, including a diagram showing the departures of actual gravity from what might be called normal values.

During the summer of 1894 a very extended series of gravitation observations were made, by the new pendulum apparatus of the Coast and Geodetic Survey, by a party in charge of Assistant George R. Putnam. An examination of the details of the results of this series of observations proves that they were very carefully executed, and must be regarded as having a high value from the standpoint of accuracy. The results are of very great interest, and the special point to which attention is now called is the relation of this series of relative values of the force of gravity along this great continental arc to the various elevations above the sea of the stations at which the work was done. Below is a list of the stations occupied, arranged in the order of their longitude, beginning with Washington, near the Atlantic Coast, and ending with San Francisco, Cala.

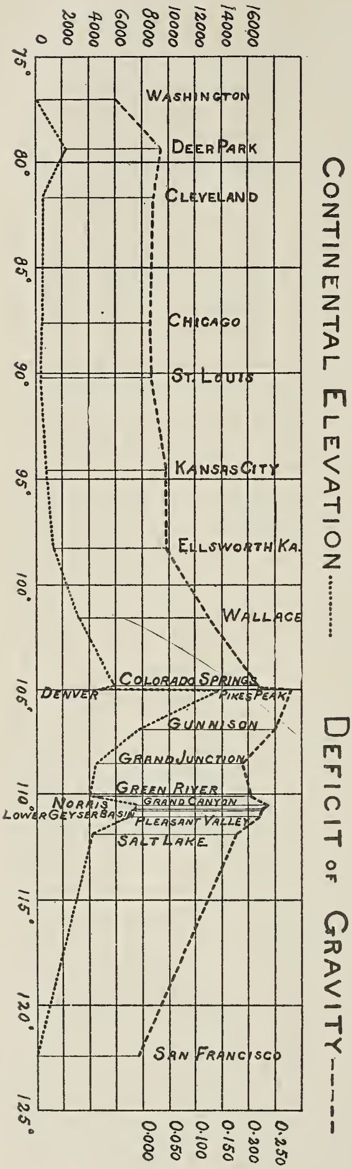
Abstract of preliminary results of relative gravity observations with half-second pendulums.

Station.	Lat.	Long.	Elevation in feet.	g observed.	$g_{,}$ at Sea Level.	$g_{,,}$ Helmert.	$g_{,}-g_{,,}$
Washington	38° 53′	77° 00′	46	980·098	980·101	980·047	+·054
Deer Park	39 25	79 20	2515	979·921	980·068	980·094	—·026
Cleveland	41 30	81 40	689	980·227	980·268	980·280	—·012
Chicago	41 47	87 36	597	980·265	980·300	980·306	—·006
St. Louis	38 38	90 12	504	979·987	980·017	980·024	—·007
Kansas City	39 06	94 35	913	979·977	980·031	980·066	—·035
Ellsworth	38 44	98 14	1470	979·912	979·999	980·033	—·034
Wallace	38 55	101 35	3281	979·742	979 934	980·049	—·115
Colorado Spgs.	38 50	104 49	6063	979·475	979·831	980·042	—·211
Denver	39 41	104 57	5375	979·595	979·910	980·117	—·207
Pike's Peak	38 50	105 02	14140	978·940	979·769	980·042	—·273
Gunnison	38 32	106 55	7679	979·328	979·778	980·015	—·237
Grand Jct.	39 04	108 30	4570	979·620	979·887	980·063	—·176
Green River	39 00	110 05	4079	979·622	979·861	980·057	—·196
Grand Canyon	44 43	110 29	7828	979·885	980·344	980·571	—·227
Norris	44 44	110 43	7466	979·925	980·362	980·572	—·210
Lower Geyser Bas.,	44 33	110 48	7219	979·918	980·341	980·556	—·215
Pleasant Valley	39 51	111 02	7187	979·499	979·920	980·132	—·212
Salt Lake	40 46	111 54	4340	979·790	980·044	980·214	—·170
San Francisco	37 47	122 26	375	979·951	979·973	979·946	+·0265

It will be seen that there was no great variation in latitude among these stations, and that in longitude they are quite well distributed, except that there remains for the time being a break of a little more than ten degrees between Salt Lake and San Francisco. It is to be hoped that the Coast Survey will in the near future be able to fill up this break. The elevations above sea level are also given, together with the force of gravity at each station. These values of the force of gravity must be accepted only tentatively, as it will appear that they are all made to depend upon the value at Washington. This value was adopted after an examination of several values for this point, some of which were not very satisfactory absolute measurements, and others the result of relative determinations at Washington and various absolute stations in Europe. It is not believed that the error of the assumed value is very great, and hence the table of values given may be considered as very close approximations to the absolute results. Relatively the degree of accuracy is, of course, very much higher.

Now the question of the existence at any point of an excess or deficiency of the force of gravitation is one which depends, of course, purely upon definition. Strictly speaking there can be no excess or deficiency of gravity at any point on the surface of the earth, for it must be whatever it is; but if comparisons be made of actual values with a theoretical distribution of the force of gravity some interesting conclusions can be drawn from an examination of the excesses and deficiencies. Accepting any spheroid, as Clark's spheroid of 1866, and assuming any distribution of gravity that may be chosen, the theoretical values may be calculated for any point on the surface of the earth, and the difference between these theoretical values and those actually observed would naturally lead to some conclusion as to the correctness of the theory of distribution which had been adopted. However, the greater part of the deviation of the observed values of the force of gravity at the several points given in the table above, from the values as distributed over Clark's spheroid, in accordance with the generally accepted formula, is due to the elevation of these points above the sea level. Now in order to bring such observations at elevated points into the same category as those observed at or near the surface of the imaginary spheroid, it is necessary to reduce them to the sea level, and in doing that we are obliged to take account not only of the actual diminution of the force of gravity due to the greater distance of the point from the center of the earth, but also the attraction of the continental mass which lies above the spheroidal surface. This correction is usually made by the application of a formula due to Bouger and used by him many years ago for making reductions of observations made by the Peruvian expedition of the French Academy. This formula is :—

$$\frac{dg}{g}=2\frac{h}{r}\left[1-\frac{3}{4}\frac{\delta}{\Delta}\right]$$



And it will be seen that it involves the relation between the density of the elevated mass and the mean density of the earth. It is usual to assume this relation as being equal to one-half; that is, to assume that the density of the surface material is one-half that of the mean density of the earth, and hence that it is about 2·75. On this hypothesis the excess of the force of gravity when reduced to the sea level over that as computed for the theoretical spheroid, by the use of Helmert's formula, is obtained, and the difference between these two quantities will be found in one of the columns of the table given above. It will be seen that nearly all of these differences are negative; that is to say, that the gravity as actually observed at the various points across the Atlantic is less than it should be in acccordance with the hypothesis above referred to. The accompanying diagram shows these variations in a very much simpler way than they can be exhibited in the table, and by plotting side by side the elevations of the several points and the difference in the observed and computed force of gravity referred to, the relation between the two is shown in a very striking manner. It will be observed that the two lines representing these quantities run side by side very closely, indicating beyond a question a distinct relation between the deviations in the force of gravity and the continental elevation. It will be seen that even where small changes only take place in proceeding from point to point they are, almost without exception, in the same direction in both curves. The proper interpretation of this fact is perhaps not easy. In the formula of Bouger, which is made use of in this reduction to the sea level, the only quantity that can be at all in doubt, or at least seriously in doubt, is the term involving the relative density of the surface matter to that of the earth itself, the other terms referring only to the decrement of gravity due to elevation. It might at first seem, therefore, that an adjustment of this term could be made which would harmonize the theoretical value of gravity and the observed values; that is to say, it might appear that it would be only necessary to alter our hypothesis in regard to the density of the surface matter of the earth in order to remove the discrepancies that are shown in the table and are exhibited so vividly in the diagram. When this is attempted, however, it is seen that no reasonable hypothesis with regard to the density of the continental mass of the earth will account for these differences. Indeed, to account for them would require the assumption that the density of the surface matter was not only not one-half of the mean density of the earth, but that it was not even so much as one-third of the mean density, or possibly not one-fourth, and in some cases, indeed, that it must be nothing at all, so that it is difficult to make the hypothesis accord with the facts.

It may be well to remark that the studies of the trans-continental system of triangulation, which is now nearly completed along the 39th parallel, seem to show that the figure represented by Clark's spheroid is in very close agreement with the reality as developed by this scheme, so that no large discrepancies in the value of the force of gravity can be expected to result from any possible error in the representation of the geoid by this figure.

These results are certainly of much interest and importance to geologists, and it seems that they may, when the subject is sufficiently thoroughly investigated by further determinations widely and properly distributed, throw considerable light on the internal structure, and the formation of that part of the earth lying nearest the surface. They evidently demonstrate the great value and scientific interest of gravity determinations, conducted as skillfully and as rapidly as have been these under the direction of Mr. Putnam.

In connection with this subject, it may be of interest to add that during this campaign a number of comparisons were made of the half-second pendulum system, which was generally used throughout the work, and the system of quarter-second pendulums for gravity purposes exhibited and described at a previous meeting of the Academy. These little pendulums, not more than five or six centimeters in length, have proved, under the test to which they were thus submitted, to be quite accurate and reliable in their performance, and their lightness and convenience in transportation will doubtless render them of considerable service in future gravity campaigns where the conditions of travel and observation are difficult and trying. It was also observed, by very careful comparisons of the periods of the pendulums of both types, both before and after the campaign made at the base station at Washington, that there was almost, if not quite, no sensible wearing of the agate knife edges, thus demonstrating the efficiency of the combination of plane and edge which was a year or two ago first presented to the National Academy.*

Art. VII.—*Observation upon the Glacial Phenomena of Newfoundland, Labrador and Southern Greenland;* by G. Frederick Wright.

Dr. F. A. Cook's expedition to the Arctic regions in the summer of 1894 met with many reverses, ending in the loss of the Steamer Miranda and of the valuable collections which had been made by the naturalists on board. But the opportunities for glacial investigation were on the whole as good as could have been reasonably expected. The delays afforded nearly a week for observations in Newfoundland, and about the same length of time at three different points in Labrador, namely at Henley Harbor, St. Charles Harbor, and the Punch Bowl, while two weeks were at our disposal in Greenland in the vicinity of Sukkertoppen in latitude 65·25, where the inland ice sends a projection down to within fifteen miles of the open sea. Besides spending a week in camp at the edge of this portion of the inland ice, we made an excursion up Isortoki Fiord to a distance of twenty-five miles, having oppor-

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* Since the above was written I have received a letter from Mr. Putnam in which he informs me that he has since added two or three stations to the list as given above. He also makes the important suggestion that a similar line of gravity stations should be run across the southern part of the country. "We would then," he says, "get in another latitude a variety of conditions not found in the past season; a sea coast free from the mountains, along the Gulf Coasts an immense area of deposits, farther to the west a long, rising swell comparatively little disturbed with mountains, and beyond a great depression below sea level." It is earnestly hoped that he may be allowed to execute this interesting piece of work.

tunity to study the phenomena along each side to that point, and to get extensive views of the inland ice and of the country bordering it.

The glacial phenomena of Newfoundland have been very carefully studied by Mr. Alexander Murray and fully recorded in his paper before the Royal Society of Canada in 1882, published in the Proceedings and Transactions of that year, Sec. iv, pp. 55–76. I have little to add to what he has written, except to set the facts in their connection with those observed in Labrador and Southern Greenland, so as to assist in forming certain general conclusions.

The west coast of Newfoundland presents a nearly straight face to the sea, running about N.N.E. and S.S.W. The southwestern portion of the western coast rises in Cape Arguille to a height of 1800 feet. The rounded or sloping escarpments usually face to the westward, as if the ice-movement from that direction had covered the whole island.

The southeast and east coast is deeply indented with numerous large bays which for the most part trend in lines nearly parallel with the western face of the island. Grand Pond, whose surface is 116 feet above tide, has a depth of more than 1000 feet, its bottom being 988 feet below sea-level. The evidences of former occupation by glacial ice are universal in the island ; glacial striae being found not only in the valleys opening out into the Atlantic, but upon the highest headlands. In the vicinity of St. John's the direction of the scratches varies, according to Murray, from N. 64 E. to S. 76 E. upon the higher lands, which are from 300 to 600 feet above the sea. On the summit of Signal Hill, which is about as high a point as there is upon the peninsula of Avilon, the direction of the scratches is S. 86 E. At Torbay, a few miles north, at 300 feet above tide, the scratches are S. 76 E. On the Great Belle Island in Conception Bay the direction is N. 38 E., or very nearly in line with the axis of the bay. At Topsail Head, however, which lies on the south side of the bay, just opposite the island, and 650 feet above tide, the scratches point, according to Murray, N. 43 W. It seems to me, however, a fair question, whether the direction of movement was not here S. 43 E., bringing it nearly in line with the scratches upon the rocks on the highlands between Topsail Head and St. John's.

So far as I could learn, the transported material in the vicinity of St. John's is local, the bowlders on Signal Hill being all traceable to outcrops a few miles west, where the land is very nearly upon a level with the summit of the headlands. Taken altogether, and in connection with the phenomena in Nova Scotia and Labrador, and with the soundings of the surrounding sea, there seems every reason to accept the conclusion of Mr. Murray, that the glacial phenomena of Newfoundland belong to a general movement which filled the Gulf of St. Lawrence and extended some distance out upon the Atlantic plateau in this latitude. 1st. The glacial scratches which appear near the summits of the highlands are often at right angles to those appearing in the shallow valleys, indicating a movement, at the climax of the period, which was largely independent of local features. At St. John's there is a considerable accumulation of till upon the southeast side of the harbor up to about 200 feet; but there are very few indications of any vigorous movement of ice along the axis of the harbor. It was with difficulty that I found any indications of movement at all underneath this till. The whole appearance was that the harbor had been filled with nearly stagnant ice, having but a slight movement making very fine scratches in the direction of the axis of the upper part of the harbor, which was northeast, or about at right angles to the scratches upon Signal Hill, and to those near the summit of the hill upon the south side of the harbor.

2. The depth of Grand Pond (988 feet below sea-level) coincides with numerous other facts indicating a preglacial elevation. In Conception Bay the general depth of the water is from 100 to 140 fathoms; but the depth across the mouth is only 80 fathoms, indicating a bank which is most likely a terminal moraine. The mouth of Holyrood Bay is crossed by a similar bank, convex on the inside, and is covered by only thirteen fathoms of water, while it suddenly deepens on both sides to forty fathoms. As is well known, also (see especially a paper by Prof. J. W. Spencer, Geol. Soc. of Am., vol. i, p. 68), the shallow water surrounding Newfoundland, and extending to Nova Scotia, is intersected by a deep channel extending from the Saguenay River down the St. Lawrence and through the Gulf, south of Anticosti Island, to the margin of the plateau which suddenly breaks off into the profounder depths of the Atlantic Ocean, about 200 miles from the present land margin. This channel is, throughout its entire length, more than 1200 feet in depth, reaching towards its mouth a depth of nearly 2000 feet. Throughout its entire length, also, it is pretty sharply bordered by a margin of shallow water less than 500 feet in depth.

3. Along the coast of Labrador the most instructive feature of the scenery is its subdued character, especially when contrasted with the west coast of Southern Greenland. From the Straits of Belle Isle to Hamilton Inlet the entire coast came within reach of our vision. Everywhere the land rises pretty rapidly to heights of from 1000 to 2000 feet. But though the rocks

are of Laurentian age, consisting of granite and gneiss, which would naturally weather into sharp peaks, the summits present everywhere a flowing outline. So far as we observed, there was not a single needle-shaped peak to interrupt the monotony of the scene. At St. Charles Harbor and at the Punch Bowl we spent several days in wandering over the hills near the shore, some of them rising to an elevation of nearly 1000 feet. But it was with the greatest difficulty that any glacial scratches were found upon the rocks, while the absence of till and of transported bowlders was equally remarkable. Similar absence of these characteristic glacial signs was noted by Prof. Carl Kenaston, who accompanied Mr. Bryant to the great falls on Grand River, nearly 200 miles inland. Still there can be no question that this whole region was enveloped in glacial ice. The absence of till probably accounts largely for the absence of scratches; for in that inclement climate disintegration of granitic rocks proceeds at a very rapid rate; so that we have few freshly exposed surfaces that have not suffered considerable disintegration. At Henley Harbor, which opens southward upon the Straits of Belle Isle, large granite bowlders were found upon the Devil's Dining Table, a remnant of an extensive basaltic eruption, which rises 250 feet above the sea-level. But around St. Charles Harbor and the Punch Bowl, it was very difficult to find any bowlders at all. The natural explanation would seem to be that we are here so near the center of a great glacial movement that all the sharp peaks were worn down, and the material carried away to points nearer the margin of the movement. It seems altogether likely that an ice-front stretched along near the border of the continental plateau as far as the banks of Newfoundland. But glacial conditions were, most likely, a concomitant of the elevation, so that the confluent glaciers spread out there upon the continent as they did in the interior portions of America.

Passing to Southern Greenland, one is deeply impressed by the great contrast in the scenery, though the geological formations are essentially the same. We had a view of the Greenland coast from the vicinity of Frederickshaab to the vicinity of Holstenborg, a distance of about 300 miles. While from Sukkertoppen, in lat. 65° 25′, we were able to make extensive tours into the interior up the fiords and along the channels and to make a minute study of a considerable section. The rocks are principally gneiss, with occasional veins of granite and trap. But instead of the flowing contour characteristic of the mountainous border of Labrador, the scenery of this part of Greenland as viewed from the ocean is extremely picturesque—needle-like peaks of Laurentian rocks running up at frequent intervals to heights of from 2000 to 4000 feet.

Nothing in the Alps or the Rocky Mountains is more characteristic of the forms assumed by such rocks under subaerial erosion than the numerous sharp peaks to be found all along this part of Southern Greenland. One has not far to go in the interior, however, to find the same subdued topography already noticed in Labrador. Upon penetrating Isortok Fiord 25 miles, the peak of Nukagpiak rises 4180 feet. From its flanks a projection of the inland ice-sheet can be seen 15 or 20 miles to the north. This ice-field is penetrated by two or three nunataks of about the same height with this mountain. But the elevated region intervening between this point and the eastern ice is characterized not by sharp peaks, but by truncated masses that have been rounded and smoothed by glacial, rather than by subaerial erosion.

On the contrary, the island of Sukkertoppen, which is about five miles in diameter, and still farther north the island of Sermersut, which is about ten miles in diameter and rises to an elevation of 3300 feet, present on every side a continuous line of conical peaks which show every characteristic mark of having been sculptured mainly by water and subaerial agencies. As seen from the channels to the southeast, their outline, when thrown against the glowing sky of the north at midnight, is the most picturesque I have ever witnessed,—to be compared with that of the Teton Mountains when seen from the east or the west, and with the Aiguilles around the upper part of the Mer de Glace; while the view is scarcely less impressive when seen from some of the adjoining heights. They present none of the characteristics of a region which has been completely covered with glacial ice. If they have ever been so covered, an enormous time must have elapsed since the recession of the ice-sheet on that part of the coast.

But while it is not probable that the ice ever covered these marginal peaks, it is clear that at one time glaciers extended through all the fiords and filled all the channels to the very border of the sea. This is indicated both by glacial striæ and by transported bowlders. In Isortok Fiord, which is now open back into the interior for 50 or 60 miles, and is bordered all the way by mountains 2000 or 3000 feet high containing local glaciers, glacial groovings are magnificently displayed near its mouth, where I had opportunity to observe them upon a scale scarcely inferior to that witnessed on Kelley Island, in the western end of Lake Erie, or in the vicinity of Victoria on the Island of Vancouver. (See illustrations in the Ice Age of North America, pp. 156, 237–245.) So powerful was the movement of ice at this point that it did not confine itself to the direct axis of the fiord, but pushed obliquely upwards toward a low promontory several hundred feet above sea-level, while the flank of this promontory facing to the southeast was marked by two or three clearly defined moraines composed mostly of pretty well rounded bowlders. Below the 200-foot level these had evidently been partially rearranged by wave action. But there was here a large amount, also, of till running down to the water's edge which had not been thus modified. This deposit of till was larger than any other which I saw in Greenland.

In the fiord at Ikamiut, about 20 miles north of Sukkertoppen, and directly east of the Island of Sermersut, the glacial phenomena were of the most significant kind. This fiord extends back from the open channel about eight miles, where it is met by the perpendicular ice-front of an extensive glacier which here projects from the inland ice. The height of this ice-front is from 100 to 200 feet, and the width of the fiord two and a half miles, but for about a third of its distance the ice terminates on gravel deposits that had been laid down in front of it. On the northern side of the glacier the ice is much broken, rendering it impossible for one to traverse it. The motion of the ice, however, is evidently very slow; for, though the front is perpendicular, the icebergs that break off from it are small and few, even when compared with those from the Muir Glacier in Alaska, and the water from the subglacial streams is only slightly colored by the glacial sediment.

We ascended this glacier along its southern edge for a distance of six miles, reaching an altitude of 1800 feet, where a very sharp and high *nunatak* divided the glacier which was here from six to eight miles wide.

Upon looking back over the space we had traversed we could see that at the head of Ikamiut fiord the glacier encountered a mountain rising 4000 feet which caused it to divide and put off two branches, one to the northwest and one to the southwest. The southern fiord leads directly down to Sukkertoppen, and is twice as long as that leading to Ikamiut.

From our point of view we could easily see that the southern fiord was much more encumbered by floating ice than the northern. From this point, also, the rugged and angular contour of the mountains along the coast were strikingly noticeable. Upon looking to the east the ice-cap, covered with freshly fallen snow, stretched away beyond the nunatak as far as the eye could see. We were looking out upon the same ice-field which we beheld two weeks before from Nukagpiak, at a right angle on the south side of Isortok fiord and twenty miles distant.

Among the most impressive phenomena upon this glacier were the majestic swells in the ice as it broke against the mountain barrier between the two fiords. In vast masses separated by long fissures the ice turns to the right and to the left towards the head of the fiords, while opposite the mountain barrier it is pushed up in a smooth dome-shaped protuberance, so that when we were in the depression between the descent from the ice-field to the ascent towards the mountain, the appearance was almost exactly like that which often confronts one in a "sag" in a rolling prairie.

Above the height of 1500 feet the glacier was so covered with fresh snow that there was little opportunity for observation. Below this level there were numerous superglacial streams of large size, which eventually plunged into moulins several hundred feet deep. The surface of the ice from which the fresh snow had melted contained a large amount of fine dust corresponding, I suppose to Nordenskiöld's *kryokonite*. In shallow depressions this was occasionally an inch or two in depth. We estimated that, over considerable areas, the average thickness of the dust was a quarter of an inch. The height and bareness of the surrounding mountains favored such an accumulation, as the winds had free access to them. Unfortunately our specimens were lost, so that I have not been able to compare the dust found here with that described by Nordenskiöld and Holst; but the general appearance was similar to their specimens.

Numerous moraines, coming principally from the northern side of the glacier, joined to form two main lines before reaching the head of Ikamiut fiord. These stood considerably above the general level of the ice. One of the moraines was spread out over a width of fully a quarter of a mile,—that appearing to be the distance to which the stones had rolled transversely in the process of the lowering of the level of the ice in recent times by ablation. The number of perfectly rounded pebbles six inches or more in diameter interspersed a mile or more back from the front with this morainic debris upon the surface of the ice was such as to attract special attention.

Ikamiut fiord presents one of the best object lessons conceivable illustrating the process which went on everywhere in mountainous regions during the closing stages of the ice invasion. The fiord runs nearly east and west. The flanks of the mountain upon the north side of the fiord facing the sun, are entirely free from ice up to the border of the glacial front; but those upon the south side facing the north sustain a number of local glaciers fed by comparatively small neve-fields and extending varying distances towards the water's edge. The glacier nearest the mouth of the fiord comes down to within about 1000 feet of the sea-level, a second, farther up the fiord, reaches down to within about 500 feet of sea-level, a third descends still nearer, while a fourth comes to the water's edge close to the ice-front of the main glacier. Still farther eastward, and higher up the mountain, a glacier is moving directly against the general ice movement. The face of the rocks upon the south side of the fiord are very plainly striated in the direction of the axis of the fiord up to a height of 1000 feet or more; while the present local glaciers are now producing scratches in numerous places at right angles to those produced when the fiord was full of ice, and a little above the head of the fiord the scratches produced are directly opposite to those which were made at the time of the maximum extension.

There is very little till to be found anywhere along this part of the Greenland coast, and when one considers the indications of the former extension of the ice down the fiords he is surprised at the small number of bowlders upon the surface. It is probable, however, that the bowlders have been largely dumped into the fiords. The moraine upon the main glacier, though very large, could easily disappear in the great depths of Ikamiut fiord after the ice had melted away. In the vicinity of Sukkertoppen there were a few bowlders of light colored granite so different from the gneiss of the vicinity as to furnish indubitable evidence of transportation by ice from a considerable distance in the interior.

I could find no indications of high terraces along this part of the Greenland coast. In a few protected places, however (at Sukkertoppen and Ikamiut and at the locality already referred to on the Isortok fiord), there was an arrangement of large numbers of rather small subangular bowlders which indicated a limited amount of water action up to a height of 200 or 300 feet. At Ikamiut shells were found in abundance in a terrace about 50 feet above tide-level. I saw no evidences of "englacial" till. The perpendicular face of the glacier seemed to be pure ice.

The most important inferences to be drawn from the foregoing facts are:

1st. That the ice-sheet of Southern Greenland formerly sent glaciers down through all the fiords, filling them to a height of about 2000 feet, and pushing even to the very margin of the continent. Greenland, therefore, like the rest of the world has had its ice age which has already partially passed away.

2d. During the maximum of the ice extension the mountains bordering the sea in Southern Greenland formed innumerable nunataks. The ice was not thick enough to cover them in solid mass, and there is no probability that the ice extended far out into Davis Straits.

3d. On the other hand, it is pretty evident that in Labrador and Newfoundland all the mountains were completely covered with glacial ice, which extended far out over the bordering continental plateau. But this was at that time probably elevated above the sea-level, so that it is doubtful if the ice ever extended far into the sea. The facts point to considerable preglacial elevations of land followed in Labrador, at least, by a period of extensive depression below the present level, and subsequent partial elevation.

4th. The freshness of the glacial striæ in exposed places and the small amount of modification which has taken place in the topography since the retreat of the ice sustains the abundant evidence elsewhere found of the recent date of the glacial period; while the indications of recent changes of level point to terrestrial rather than astronomical causes to account for the vicissitudes of the glacial period.

Art. VIII.—*On the Recurrence of Devonian Fossils in strata of Carboniferous Age*; by Henry S. Williams.

[Read before the Geological Society of America at Baltimore, December, 1894.]

The fossils which form the subject of the following remarks were brought to my notice by Dr. J. C. Branner during the progress of the Geological Survey of Arkansas. They were collected by various members of the survey from a dark colored limestone and associated calcareous shales at Spring Creek, a few miles west of Batesville. The first batch of fossils sent me were in a rotten-stone, originally a sandy limestone, and seemed to be identical with the *Leiorhynchus quadricostatum* of the Devonian rocks of New York, which led to my reporting them to be of Devonian age. Afterwards fossils from the same ledge were sent which were reported in my correspondence to be of undoubted Carboniferous age. As the presence of Devonian rocks was looked for but had not been definitely proven the find was of considerable interest, but the confusion in my identifications led naturally to suspicion of either mixing of the evidence or error in the identifications.

McChesney* had previously described a few fossils as coming from dark shales near Batesville, Ark., and probably of Hamilton (Devonian) age (*Nucula Vaseyana*, *Nucula? rectangula* and *Pleurotomaria nodomarginata*). And the black shales met with in the same part of the State and farther west, have

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* Descriptions of fossils, Chicago Acad. Sci., vol. i, pp. 37, 40 and 47.

been supposed to be equivalent to the "black shales" of Tennessee and of Devonian age.

More fossils were collected and the Arkansas geologists examined the locality with special care but with the result of confirming the singleness of the horizon from which the fossils came and the certainty of the duplicity of the testimony of the fossils themselves. Finally, Drs. Branner, Penrose and I went together and examined the locality with special care and sent in a collector, Mr. Weller, to make full collections of the fossils of the neighborhood, and the materials are now being elaborated for a full report of the fauna. On account of the importance of the facts this preliminary announcement is made.

The geological age of the Spring Creek limestone is established to be younger than the Batesville sandstone and older than the Boone chert, of the Arkansas survey nomenclature, which makes it equivalent to the Warsaw or St. Louis limestone of Missouri and the Mississippi Valley sections in general. Three kinds of evidence confirm this determination: The stratigraphy of the immediate neighborhood of Spring Creek, and second the correlation of the fauna with faunas of the same general region of higher and lower horizons, and third the comparison of the species of the fauna with those of a different geological province whose age is established on independent evidence. The stratigraphical evidence is as follows:

The locality is in the northern part of Arkansas, geologically on the southern slope of the Ozark uplift, which centers in southeastern Missouri, where the upper paleozoic terranes lie with a general dip southward and southwestward, with thin upper edges graded toward the north so that outcrops are of older and older rocks on passing northeastward from Spring Creek, a point a mile or so west of Batesville. There is a fault near the point where the fossils come from running northeasterly, the southeasterly mass has fallen below the northwesterly mass. The Spring Creek limestone is on the northwest side of the fault hence the occurrence of the Devonian types cannot be explained as having been caught in a fault, since the other side of the faulted rock has been dragged down, leaving more recent and not older rocks at the same horizon on the opposite side.

The strata underlying the Spring Creek limestone was shown to be the Boone chert (= Keokuk-Burlington of Missouri, Illinois, Iowa, etc.). The Batesville sandstone above it contains a fauna closely like the fauna of the St. Louis limestones in some of its species. At Mountain view some of the same species are reported from a similar stratigraphical position. In its more western exposures, according to the interpretation of the Arkansas geologists, the same interval is occupied by the Fayettville shales. There is common agreement on the part of all the geologists of the survey who have studied the region that the stratigraphical position of the Spring Creek limestone is between the Batesville sandstone (= Chester-St. Louis horizon) and the Boone chert (= Keokuk-Burlington horizon).

The second method of determination is by identification of the fauna with other faunas of known age. The general Carboniferous age is clearly indicated by the presence of *Productus* of the types of *cora* and *semireticulatus*, of Spirifers of the *S. bisulcatus* type of the Carboniferous limestone of England and elsewhere, and further by the identity of several of the species with those in the neighboring formation containing only faunas of the upper formations of the Mississippian series ("Subcarboniferous"). The species are not in general strictly identical with species of any of the typical divisions of the Mississippi Valley Carboniferous, and it is necessary to use the third method of correlation to reach greater precision than a general correlation with faunas of neo-Carboniferous age.

According to the third method we compare the species with faunas of other regions whose age is determined, and this reveals some of the more interesting features of the case. Upon making close identification of the fauna it is found that one of the most characteristic and abundant species in the fauna of the Spring Creek limestone is identical with Walcott's *Rhynchonella Eurekensis** of Lower Carboniferous limestone of Secret cañon road Cañon and the Cañon of Pinto Park of Eureka District, Nevada. This is a unique species, no Rhynchonella like it is reported from North America, but it is represented by several European species from Devonian horizons, or more ancient (cf. *R. Dumonti* Gosselet, Devonian of Ardennes; *R. princeps* var. Barrande; *R. livonica* v. Buch, Wenukoff, Tab. V, fig. 3. Russian Devonian). It resembles also the striated varieties of the recent *Rhy. psittacea. Pleurotomaria nodomarginata* McChesney, referred to above, or a very closely allied form is among the Spring Creek species. Walcott identified the same species in the Secret Cañon road Cañon locality in Nevada.

When the fauna is compared with the fauna of Eureka district three-fifths of the genera are the same, and many of the species closely allied. The same close generic resemblance is seen on comparing the former with the Baird shale described by J. P. Smith† from the U. S. Fisheries in Shasta County, California, and both these western faunas are peculiar in holding species which are of markedly Devonian type, though the

* Monograph, Paleontology of the Eureka District. p. 223.

† Journal of Geology, vol, ii, Sept.-Oct., 1894, p. 594.

majority of the species are so typically Carboniferous as to leave no doubt of their Carboniferous age.

In describing the Lower Carboniferous fauna of the Eureka district Mr. Walcott says:

> There is also a certain commingling of upper Devonian species with the lower Carboniferous fauna. We find *Discina Newberryi*, *Macrodon Hamiltonia*, *Grammysia Hannibalensis*, *G. arcuata*, *Sanguinolites Aeolus*, *Pleurotomaria nodomarginata* associated with common Carboniferous species.—*Pal. Eureka District*, p. 8.

The same commingling of species is noted by J. P. Smith.* He states that 29 of the 84 species of the Baird shales of Shasta County, California, are identical with the

> forms described by Walcott from the lower Carboniferous of the Eureka district, and in this Baird shale fauna are such Carboniferous species as *Productus Burlingtonensis*, *P. giganteus*, *P. Nebrascensis*, *P. punctatus* and *P. semireticulatus*, *Spirifer lineatus* and *S. striatus*. But in the California fauna 15 species are found which are known Devonian fossils of Eastern America.

In my manuscript report on the Arkansas fauna to Dr. Branner, I had suggested the relationship between the Spring Creek and Eureka faunas, and Mr. Smith who had read it before writing his paper on the Shasta faunas noticed the confirmation his species furnished of this interpretation. The Shasta and Eureka faunas find an unmistakable representative in the fauna of the Spring Creek limestones of Arkansas, and the fact that they differ from the ordinary Carboniferous faunas of the Mississippi Valley in the particulars which associate them with these faunas west of the Rocky Mountains is a strong argument for the theory that this Spring Creek fauna migrated into the seas over Arkansas from the west, was there only temporarily and was soon withdrawn or destroyed, leaving only this solitary record of its existence in the series of the Mississippi Valley. Thus all the evidence in hand points to the Carboniferous age of the Spring Creek limestone, and there are sufficient reasons for referring it to the lower third of the Carboniferous (the Mississippian); and its correlation with an horizon about equivalent to the Warsaw, St. Louis, or the Spergen Hill formations is strongly suggested.

As a general fauna, this Arkansas fauna is more closely allied to those of Eureka District, Nevada and of Shasta County, California, than to any other fauna in the Mississippi Valley or farther east. Both of these western faunas, although presenting species of Devonian type commingled with the Carboniferous species are separated by considerable thickness of strata from

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* Journal Geol., vol. ii, p. 597.

the latest Devonian horizon of the local section; by three thousand feet of conglomerate in the Eureka District, and by some, at present, unknown amount of sediments in Shasta County, California.

The second point requiring verification is the presence of actual Devonian species in this limestone of Carboniferous age. There are two species both of which are represented by numerous specimens in the same strata with the Carboniferous species: they are *Leiorhynchus quadricostatum* Vanuxem, and *Productella lachrymosa*, varieties *stigmata*, *onusta*, etc. Hall.

The first of these species was reported by Meek from the White Pine Mountains, Eureka District (=White Pine shale of Walcott) in 1877.*

The age of these shales, was, in the same report (p. 201), referred to the Devonian by Hall and Whitfield on the evidence of this species and a *Lunulicardium* (*L. fragosa*, Meek sp.) and an *Avicula* (*A. equilatera*), while the beds immediately above were called Carboniferous without hesitation. Walcott noted the mixture of the Devonian and Carboniferous† species in this White Pine shale, but concluded from study of the section that the beds in question covered a fauna uniting the two systems but of pre-Carboniferous age (p. 6).

The second species in some of its varieties is also reported by Walcott from Upper Devonian limestones of the Eureka District‡ associated with many typical eastern Devonian species. The *Rhynchonella Eurekensis* Walcott, found in the Lower Carboniferous limestones of the Eureka District above, and separated from the White Pine shales by 3000 feet of quartzite conglomerate, is associated with the two above-mentioned Devonian species in the Spring Creek limestone of Arkansas. The two species *L. quadricostatum* and *P. lachrymosa*, have been regarded by Meek, by Hall, Whitfield and Walcott as Devonian species. They are characteristic of Devonian rocks of New York, although the *Leiorhynchus* has been reported, with early Carboniferous species in Pennsylvania, as it has in Nevada. Not only the species but the subgeneric types in both cases are Devonian; both *Productella* and *Leiorhynchus* are characteristic Devonian modifications of the genera *Productus* and *Rhynchonella* respectively. These two species then are not only characteristic Devonian species but Devonian subgenera, and where seen in Nevada they are still below the fauna with which the general fauna of the Spring Creek limestone is correlated in the Nevada sections.

* Geol. Expl. Fortieth Par., vol. iv, p. 79.

† Paleontology of the Eureka District, p. 5.

‡ l. c, p. 132.

The contrast between the Nevada and the Arkansas sequence is seen in the fact that in the Arkansas section, the faunas above and below the Spring Creek limestone are typically Carboniferous and do not present admixture of Devonian forms, while the Nevada and, from present reports also, the California sections from Devonian far into Carboniferous time present remarkable commingling of Devonian with Carboniferous types. The 3000 feet of conglomerate in Nevada, reported by Walcott as separating the White Pine shale from the Carboniferous limestone with *Rhynchonella Eurekensis*, suggests the cause of the appearance of this western fauna in the Arkansas region, i. e. an elevation of the western area sufficient to cause diversion of the ocean currents and shifting of such species as endured the transport into the Mississippi Valley area. In the Appalachian province the Devonian species are still more sharply distinct from the Carboniferous forms than in the Mississippi Valley.

These are the facts in the case: in northwestern Arkansas is found a fauna in the Spring Creek limestone which by its stratigraphical position and general fossil contents is shown to be of Carboniferous age, separated by at least two well defined and distinct faunas (the Kinderhook-Chouteau and the Burlington-Keokuk) from the latest Devonian fauna of the Mississippi basin province, but containing several species which in the more eastern Paleozoic sections are, both specifically and subgenerically, Devonian forms.

One of the species is known only from a Carboniferous horizon of the western part of the continent, and others are distinctive of more western faunas in which the commingling of Devonian and Carboniferous species is conspicuous.

The recurrence of the Devonian species in the Arkansas Carboniferous rocks is most readily explained as a case of migration of species from a region in which they had continued to live unchanged, into a region from which they had for a long time been absent or into which they had never before entered. It is an example of the living on of species in one locality long after they had become extinct or were replaced by other species in another region. This is not an anomalous fact; the Australian land fauna is a remarkable illustration of the same law. Deep sea dredgings have shown the same fact in regard to some of the abyssal species which are of Eocene or Cretaceous type, ancient characters having been preserved in the ocean depths while they have been superseded by evolved successors in other environments. But the interesting point in this Arkansas case is that we have here a suggestion as to the cause of the unchanged continuance of the species. The recurrent Devonian species were evidently associated with a generalized as contrasted with a specialized fauna.

The faunas of the Devonian and Carboniferous in Nevada and California are peculiar for showing a very long continuance of the same general fauna, with changes by the accession of new species as time progressed, but with remarkable persistence of early species unchanged. Walcott called attention to the fact in his Nevada faunas. The great thickness of Devonian rocks shows not only long range of species but such mingling as to bring species supposed to be characteristic of Upper Devonian in the east down at the base of the series in Nevada. In the Appalachian series we find the opposite to be the fact, the faunas are much broken up into distinct zones, with very few species tying together the successive faunas. And this breaking up of the faunas is plainly associated with oscillating levels and general passage from pure marine conditions up to brackish water, and finally by the closing of sedimentation upon elevation of the bottom above the sea-level. This is shown by the passage from limestones of the Lower Devonian into shale, sandstone and conglomerate—in the succession of deposits that followed.

Taking the first full appearance of a characteristic fauna as indicative of common horizon for each of the separate provinces, we observe that in the Appalachian province the Devonian species are more closely restricted to the Devonian age. In the Mississippi province, after the Devonian stage is sharply closed, this case of recurrence is seen well up in Carboniferous faunal succession, while in the western continental border there was a mixture of Devonian and Carboniferous species all along the way till the characteristic Carboniferous species were present in full force in the prevalent fauna. This later and later removal of the earlier types from the prevalent faunas as we pass westward across the continent is coördinate with the continental expansion occurring at the same time. The conclusion seems evident that the cutting off of the Devonian species was in some way associated with the progress of the continental border westward during later Devonian and the first half of Carboniferous time. The coal measure conditions, were as early as the Warsaw and St. Louis limestones in Pennsylvania, if not still earlier, and limestone had ceased to be a factor in the deposits in northern Pennsylvania and New York, before the Chemung began. In the Mississippi Valley limestones continue up to the Chester, and then the sands, conglomerate and coal measure condition suddenly appear.

Before we reach the central ridges of the Rocky Mountains the limestone conditions are prevalent till the upper coal measure time, and still further west there are no indications of any continental lands sufficient to disturb the reign of the marine faunas till near the close of the Carboniferous age. Thus in the Appalachian province diversity and alternation of deposits is marked by numerous successive and distinct faunas; in the western continental border province uniformity of prevailing calcareous sedimentation for long periods is marked by the abnormally long continuance of many of the Devonian species; while the central continental province midway between the two is marked by the unmistakable recurrence of Devonian species far up in the midst of Carboniferous sediments.

While theoretically such a fact might be expected, this unique case of recurrence furnishes us with the evidence connecting the three distinct geological provinces, and makes it possible to correlate, with more than ordinary precision, the chronological horizon of the several widely separated faunas. This series of observations furnishes a demonstration of the hypotheses that the persistence of species without modification is associated with continuance of uniformity of conditions of environment, and that change in the successive faunas of geological time is associated with the change and rearrangment of the conditions of environment to which the fauna is subjected.

Art. IX.—*Constituents of the Cañon Diablo Meteorite;* by Orville A. Derby.

A specimen of the Cañon Diablo meteorite obtained from Mr. E. E. Howell of Washington and stated to be one of the original lot brought from Arizona by Dr. A. E. Foote, has been treated in the laboratory of the Commissão Geographica e Geologica de São Paulo by the fractional method of Prof. E. Cohen with the following results. The chemical analyses accompanying this paper have been kindly made for me by Dr. Guilherme Florence, assistant to the Commission.

The specimen, weighing nearly 200 grams, was a perfect meteoric individual; that is to say, it presented no fractural surfaces, but everywhere the rough pitted surface of meteoric masses. In appearance it suggested a metallic bleb broken or weathered out of friable, or more easily decomposable, material. An examination of a considerable number of specimens of all sizes in Mr. Howell's collection shows this to be a general characteristic of the Cañon Diablo group. Nothing in the shape and aspect of the masses suggests the occurrence of planes of slight cohesion (presumed to be the limits of crystalline individuals, such as in a paper now in press, I have described under the name of Wollaston Planes, in the Bendegó mass) and which, by facilitating fracture either in the original place of formation, or in the act of falling, have probably produced the approximately plane faces and angular edges that characterize that meteorite. Such faces and edges might be expected on the Cañon Diablo masses on the hypothesis of their being fragments of a single homogeneous mass, which seems to be required by the conditions under which they were found. A rough, jagged and pitted surface is however common to all of them, showing a perfect individualization and suggesting on a large scale, the small, irregular metallic masses scattered through the stony matrix of a mesosiderite. Referring them to a single original mass, the hypothesis may be ventured that, on its arrival in our atmosphere, this was not homogeneous but consisted of a large mesosiderite with unusually large metallic nodules that became separated by the explosions attending the fall, and probably also by subsequent decay and disaggregation of the stony matrix.*

After freeing the specimen as far as practicable from its rust crusts by scraping after a soaking in strong acid, it was treated with cold hydrochloric acid of a strength of 1 to 10. The solution was effected slowly with evolution of gas and a separation of a variety of grains with a metallic aspect and of a light, black residue resembling coal dust. A vein-like mass some three millimeters thick, that showed through the rust crust with the appearance of the pencil-like inclusions of troilite in the Bendegó meteorite, extended for about a centimeter into the mass and not being acted upon by the acid, came away in fragments. After fourteen weeks of treatment with frequent changes of acid, the action almost ceased although a considerable mass still remained undissolved. This had much the shape and appearance of the original meteorite though much more irregular and jagged, and represents a nucleal portion less soluble than the generality of the mass.

The undissolved residue was separated by screening through fine bolting cloth, sorting under the lens, and with a magnetized knife point, into the following groups: vein matter consisting

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*I was also shown in Washington schistose masses of iron oxide found in the same region, whose connection with the meteorite was considered doubtful. These closely resemble the thicker masses of rust crust formed on the Bendegó meteorite and like it, as is well seen in sections prepared by Mr. Diller, show minute particles with a metallic luster which are almost certainly grains of schreibersite, as that mineral has been separated from the rust crust of both Bendegó and São Francisco do Sul. In view of its occurrence it can hardly be doubted that these Canon Diablo specimens are due to secondary alteration of the meteorite. As the iron masses in general have only a thin rust crust, indicating considerable resistance to oxidation, it may be suggested that these thicker masses of oxide may perhaps come from original pyrite as in the case of São Francisco do Sul.

of massive schreibersite with cohenite; irregular jagged fragments resembling the large nucleal piece and bristling with needles of rhabdite (*zackige Stücke* of Cohen?); taenite; coarse schreibersite and cohenite from the general mass and not from the vein (a considerable part of the schreibersite was free but the grains of cohenite were so charged with it that no satisfactory separation of the two could be effected); fine magnetic residue for the most part schreibersite in the form of rhabdite needles but with fine particles of taenite; granular schreibersite and cohenite, and a black, coal-dust-like residue highly charged with rhabdite. The separation could not be completely made except for the jagged pieces and coarser taenite, schreibersite and cohenite. In the finer material the two last were so lumped together that neither by sorting nor by gravity or magnetic methods could they be satisfactorily separated. An attempt to separate the light, coaly matter by the use of the Thoulet solution was only partially successful, as a small amount of the black particles were carried down with the heavy metallic grains and a larger portion of these were retained by the spongy, coaly particles. The proportions given below, calculated for the dissolved portion after deducting the nucleal piece and the vein matter, are therefore only approximate.

Original specimen	195 grams	
Large jagged nucleal piece	9·1855	
Vein matter, schreibersite and cohenite	2·971	
Small jagged pieces	1·4105	0·78%
Taenite	1·872	1·02
Coarse schreibersite and cohenite	7·5835	4·14
Fine magnetic residue mainly schreibersite, in part acicular (rhabdite), with some taenite and cohenite	1·4945	0·82
Fine non-magnetic residue with rhabdite	0·517	0·28
Dissolved	169·966	92·95
		100·00

An analysis of 100^{cc} of the solution corresponding approximately to 0·5 grams of the meteorite (except for the copper determination which was made with 500^{cc}) gave:

Fe	91·264%
Ni and Co	8·252
P	0·440
Cu	0·044
	100·000

This result agrees fairly well with the composition of kamacite (Fe 93·11, Ni and Co 6·89) according to the formula $Fe_{14}Ni$

as given by Cohen. As the proportion of phosphorus and copper is higher than in the greater part of Cohen's analyses* in which for the most part weaker acid was employed, it may be presumed that the elements rich in nickel, taenite, schreibersite and the coaly substance, were more strongly attacked, giving an enrichment in nickel. Making allowance for this circumstance, the dissolved portion may be considered as consisting essentially of normal kamacite.

The large jagged piece which was only attacked with extreme slowness by cold acid of a strength of 1 to 10 was tried with acid 1 in 5 without much better results in the cold. On heating on the water bath vigorous action commenced and continued even after the acid was much diluted. At times the action would continue in the cold after removal from the bath, at others it would almost cease in the hot acid and only recommence with vigor on the addition of a considerable quantity of fresh acid. At other times the action would continue until the acid was completely exhausted and a precipitate began to appear in the solution. These variations in the action of the acid indicate a lack of homogeneity and varying degrees of solubility in different parts of the mass. The residue was similar to that of the original mass except that cohenite was almost entirely lacking. The principal contrast in the two residues was in the greater relative abundance of rhabdite and the less abundance of granular schreibersite and of the coaly matter in that of the jagged piece. The coaly matter was evidently partially destroyed by the action of the hot acid and the residue was entirely freed from it by treatment with strong, cold acid, a white flocculent skeleton remaining.

The large piece was broken up as follows:

Original specimen				9·1855 grams	
Taenite				0·029	0·31%
Schreibersite	granular	0·0075	0·08%	0·033	0·35
	acicular	0·0255	0·27		
Non-magnetic residue				0·325	0·34
Dissolved				9 094	99·00

An analysis of the solution gave the following result (copper was determined in the whole solution, the other elements in 100^{cc}:)

Fe	94·32
Ni and Co	5·78
P	0·15
Cu	0·05
	100·30

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* Annalen d. K. K. naturhistorischen Hofmuseums, vi, 1891, p. 131; vii, 1892, p. 143; ix, 1894, p. 97.

This composition agrees very nearly with that of the "zackige Stücke" of Toluca given by Cohen, and like that shows a higher proportion of iron and a lower proportion of nickel and cobalt than the general mass of the meteorite and of normal kamacite. The occurrence of rhabdite is not noted in the case of Toluca but may perhaps be presumed from the relatively high percentage of phosphorus.

The non-magnetic residue consisted mainly of rust particles and some dirt evidently derived from laboratory dust. Nothing of any interest that could be referred to the meteorite could be detected in it by microscopic examination.

The small jagged pieces were dissolved in copper-ammonium chloride with the view of determining the amount of carbon but owing to an accident this determination was lost, and only the relative proportion of granular (1·84 per cent) and of acicular (1·16 per cent) schreibersite was determined. The amount of the coaly residue was apparently greater than with the treatment with acid. The higher proportion of schreibersite may be referred in part to the slighter action of the solvent, by which more of the original content is recovered, but it is also evident that this mineral, particularly in the acicular form of rhabdite, is more abundant than in the generality of the meteoric mass.

An analysis of taenite, which was dissolved in copper-ammonium chloride, gave:

Schreibersite	1·65
Fe	66·46
Ni	30·28
Co	0·68
Cu	0·32
P	0·30
	99·69

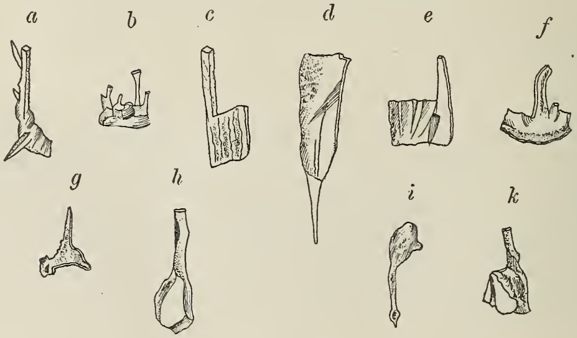
In composition as well as in physical aspect (thin, tin-white flexible lamellæ) this agrees very closely with the group rich in nickel and free from carbon of Toluca, Wichita, etc. as given by Cohen. With Toluca also it agrees in the presence of a determinable amount of copper. The phosphorus of the above analysis indicates, as Prof. Cohen has already remarked, that schreibersite is not wholly insoluble in the Cu-Am chloride.

Two analyses of cohenite were made, No. I being the free grains from the general solution of the mass and No. II the vein matter. Both were dissolved in copper-ammonium chloride and the percentages calculated for the difference in weight after deducting the considerable residue of undissolved schreibersite, separated with the magnet from the carbon, which was determined by burning in a stream of hydrogen and weighing as carbonic acid.

	I.	II.
Fe	92·88	91·67
Ni and Co	1·33	2·43
P	0·48	0·09
C	5·33	6·07
	100·02	100·26

The phosphorus is undoubtedly due to a slight action of the solvent on the schreibersite, which as already remarked is not wholly insoluble in copper-ammonium chloride. This result agrees very well with the analyses of cohenite given by Weinschenk and Cohen and with an unpublished analysis of that of Bendegó by Dafert. In appearance the cohenite grains agree with those of Bendegó although they are richer in inclusions of tabular schreibersite. Owing to the general distortion of the crystals and the rounded character of the faces, no measurements could be made, but the forms are undoubtedly identical with those of Bendegó, on which Hussak succeeded in demonstrating that they belong to the cubic system.

Three distinct forms of iron and nickel phosphide occur which although differing greatly in appearance and somewhat also in chemical composition, are probably different phases of a single mineral species. The most abundant individually are the acicular forms known as rhabdite, though, owing to their minute size, they do not equal in weight the granular and tabular forms known as schreibersite. Both are generally distributed throughout the mass, the schreibersite form being particularly abundant, included in, or adherent to, the surface of the cohenite grains, while the rhabdite needles are especially concentrated in the less soluble metallic portions and in the



spongy, coal-like particles. Both are distinctly crystalline and, as shown in the annexed figure, may occur in the same individual. As Cohen has already shown the chemical identity of the two types, no further proof seems necessary that schreibersite and rhabdite belong to the same mineral species, for which the former name, being the older, should be retained. Diligent search was made without success for crystals that would admit of measurement, the rhabdite individuals being too minute and those of the schreibersite type too much distorted and with strongly rounded faces. The general appearance of the latter type is strongly suggestive of distorted crystals of the cubic system, while the rhabdite needles are apparently tetragonal prisms, although they might also be distorted members of the cubic system. On crystals which will be described later, separated from the São Francisco do Sul mass, Dr. Hussak succeeded in proving that the crystalline form of schreibersite is really tetragonal.

The third form of phosphide occupies the center of the vein mass being enclosed between walls of cohenite. This is massive and extremely brittle, breaking with a conchoidal fracture and in color and general appearance strongly resembling arsenopyrite.* As shown by the analysis below (No. III) the composition differs from that of the typical schreibersite of the same meteorite in the relative proportions of the iron and nickel. The phosphorus is also higher in the complete analysis and approaches more nearly to what Prof. Cohen considers as the normal proportion, but in a separate determination (No. IV) the proportion is nearly the same as in the normal granular schreibersite with a slight admixture of rhabdite needles, Nos. III and IV of the vein matter. In all the material was freed from taenite and cohenite by treatment in copper-ammonium chloride, and in No. II special care was taken in the washing to make sure that the copper found in I and III previously executed; really belonged to the substance and did not come from this solvent.

	I.	II.	III.	IV.
P	12·82	13·17	14·58	12·98
Fe	54·34	51·25	66·72	
Ni	31·48	33·68	17·54	
Co	0·67			
Cu	0·20	0·17	0·13	
Sn		1·18	tr.	
	99·45	99·45	98·97	

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* The cohenite of the walls of the vein also forms a massive crust covered however with crystalline faces on its outer surface.

The most reliable published analyses of meteoric phosphide, or phosphides, show very variable relative proportions of iron and nickel and cobalt even in the same meteoric mass and as regards phosphorus, a larger group with about 15 to 16 per cent and a small group with about 12 to 13 per cent. The above analyses place Cañon Diablo in the latter group. Copper is only reported in two, Schwetz and Seeläsgen, both of which have been reanalyzed by Cohen with very different results and without copper, which possibly, however, was not looked for. Tin has not been reported, possibly because the solution has usually been made in aqua regia in which it would only appear through a special research. In the present case the solution was made in plain nitric acid and the tin appeared as oxide and was verified by blowpipe tests. The proportion in No. III was certainly as great as in No. II, but was not determined for fear of losing the slight residue before a qualitative test could be made. Curiously enough it did not appear in Nos. I and IV, possibly from the accidental presence of enough chlorine in the nitric acid to dissolve the small amount of stannic oxide as fast as it formed. If this was not the case, it must be presumed that the tin does not belong to the schreibersite but to another mineral that is not generally distributed throughout the meteoric mass, so that it only appears in certain portions of the residue.

As in the course of this investigation, which was mainly undertaken for the purpose of verifying the reported existence of the diamond in the Cañon Diablo meteorite, nothing resembling that substance, or any other form of free carbon, could be detected, it was suspected that possibly the polishing effect produced by the residue of the dissolved mass and attributed to the presence of diamond dust might be due to schreibersite. Owing to the minuteness of the grains and their extreme brittleness, it is difficult to determine the hardness accurately and the figures given (7·01 to 7·22) may be too low. The means at hand were too crude for an accurate test, but apparently distinct scratches were produced on a cleavage plane of topaz and a depolishing effect on the polished face of a cut sapphire. Specimens have been submitted to Mr. George F. Kunz with a request to test the hardness with more perfect appliances, and probably he will report upon them.

The non-magnetic residue consisted for the most part of irregular, black, coke-like particles full of needles of rhabdite. These dissolve quietly in strong hydrochloric acid, setting free the crystals of rhabdite. In strong nitric acid under the microscope there is a rapid evolution of gas that tears the particles to pieces, scattering the rhabdite and leaving an extremely light, whitish flocculent skeleton.

In the following analysis this coaly residue was treated with strong nitric acid for a few minutes until the black color disappeared and an attempt was made to collect the escaping gas. As, however, abundant red fumes appeared, it was concluded that the gas came from the acid and it was allowed to escape. The great deficiency in the following analysis indicates, however, that a gaseous constituent may have been set free from the substance. The heavy residue was separated by decantation and divided with the magnet into rhabdite and a non-magnetic portion consisting of rust particles and grains of sand evidently from laboratory dust, or dirt on the original rust covered surface of the meteorite. Nothing of interest that could be referred to the meteorite could be observed in it under the microscope. The light, flocculent residue collected on an asbestus filter was burned and determined as carbon by collecting and weighing the gas given off. The other constituents were determined in the nitric acid solution. The numbers given below can only be considered as approximative, as the separation by decantation may not have been complete and there may have been some loss in the mechanical separation of the heavy residue. Still after making all due allowances for defects in the process of analysis, the deficiencies are too great to be accounted for in this manner and must be attributed to one or more undetermined constituents, possibly gaseous. The result obtained is as follows:

Fe	7·11
Ni and Co	37·47
Cr	tr.
Cu	2·84
P	0·88
C	5·60
Rhabdite	11·65
Non-magnetic residue	8·30
	68·30

The phosphorus can probably be referred to a partial solution of the rhabdite and the traces of chromium may perhaps indicate an admixture of daubréelite. The whitish flocculent substance giving carbonic acid on burning is very extraordinary, though something similar seems to have been observed by Tschermak (as quoted by Flight, History of Meteorites, p. 163,) in the Goalpara meteorite. As a similar residue with the same aspect and behavior with acids and with a strong nickel reaction in the borax bead was obtained in small quantities from Bendegó, efforts are now being made to obtain a sufficient amount for a more careful study of this curious substance.

The non-magnetic residue of the above analysis contained all the non-soluble and non-magnetic residue of the original mass treated, together with all the dirt accumulated throughout the long process of treatment. Nothing of interest that could not be referred with almost absolute certainty to the later source could be observed in it in a careful microscopic examination. Evidently the mass treated did not contain diamonds or anything remotely suggestive of them.

ART. X.—*β-Bromvalerianic Acid*, $CH_3-CH_2-CHBr-CH_2-COOH$; by JOHN G. SPENZER, Cleveland, O.

THE first step in the preparation of β-bromvalerianic acid was the preparation of propylideneacetic acids by the action of hot, caustic soda solution on ethylidene propionic acid.

To one volume of pure propylideneacetic acid contained in a small cylinder having a well ground stopper, 1½ volumes of hydrobromic acid saturated at 0° C. were added, on shaking a clear solution resulted, it was allowed to remain quietly for 24 hours at the ordinary temperature; the monobromide had now risen to the surface of the hydrobromic acid as a light brown colored layer. The cylinder was now vigorously shaken from time to time, to bring any unaltered propylideneacetic acid, which might be dissolved in the monobromide into intimate contact with the hydrobromic acid. After this occasional shaking had been continued for four or five days, the contents of the cylinder formed two distinct layers, the reaction was ended and all the propylideneacetic acid had been quantitatively changed into β-bromvalerianic acid. The cylinder still stoppered was now placed in ice water, to cause the new acid to solidify, this, however, did not occur; it was then placed in a freezing mixture of ice and salt, and on agitating slightly the monobromide at once congealed to a solid mass of fine needles lying on the surface of the hydrobromic acid. The cylinder stood for 15 hours at a temperature of 15° C.; then the crystalline cake was broken through with a glass rod, distributed through the hydrobromic acid and brought into a platinum cone, where it was allowed to dry, being washed with small successive portions of ice water, in order to remove the greater part of the mineral acid.

The contents of the cone were now brought on to a watch glass and placed in a vacuum over sulphuric acid and caustic potassa; a dry sandy, white substance resulted, which was powdered and recrystallized out of petroleum ether. So produced, the β-bromvalerianic acid is, after drying, perfectly pure, as the analysis proves:

0·233 g. of the substance dried in a vacuum gave 0·2410 Ag Br.

Calculated for $C_5H_9BrO_2$.	Found.
44·20% Br.	44·20% Br.

β-bromvalerianic acid melts at 59° to 60° C., the melting point not altering in the least by repeated determinations on the same sample. It dissolves readily in ether, chloroform, carbon disulphide, less easily in benzene and petroleum ether, and is almost insoluble in water of 0° C. If the cold, saturated solution of the monobromide in petroleum ether be allowed to evaporate spontaneously it crystallizes out in beautiful, colorless, 8-sided prisms.

The crystals set up after Naumann's System give the following crystallographic measurements:

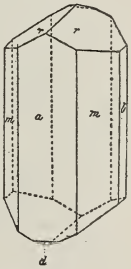
β-Bromvalerianic acid.

Crystal system : Monosymmetric.

$$\acute{a} : \bar{b} : \acute{c} = 1{\cdot}4688 : 1 : 0{\cdot}4900$$

$$\beta = 79^\circ\ 58'\ 45''$$

Observed forms: $m = \{110\}\infty P$, $a = \{100\}\infty \bar{P}\infty$, $b = \{010\}\infty \bar{P}\infty$, $r = \{011\} \bar{P}\infty$, $d = \{\bar{1}01\} + P\infty$, $e = \{101\} - P\infty$



The crystals are mostly 2 to 5^{mm} long by 1 to 2^{mm} wide and possess a valerianic acid like odor.

Some crystals are without $\{\bar{1}01\} + P\infty$, as also $\{100\}\infty \bar{P}\infty$, while $\{101\} - P\infty$ was only observed once.

The faces were almost always smooth and polished giving excellent reflections.

The following angles were measured and calculated:

		Measured.	Calculated.
r : *r* =	(011) : (011) =	*51° 31′	------
a : *m*	(100) : (110)	*55 21 30″	------
r : *m*	(011) : ($\bar{1}$00)	*99 1	------
m : *m*	(110) : (1$\bar{1}$0)	110 43	110° 41′
m : *b*	(110) : (010)	34 47	34 39 30″
r : *b*	(011) : (010)	64 6	64 14 30
a : *b*	(100) : (010)	89 58	90
a : *d*	(100) : ($\bar{1}$01)	99 2	99 12
r : *m*	(011) : (1$\bar{1}$0)	74 2	74 26
a : *e*	(100) : (101)	61 59	62 44
r : *d*	(101) : ($\bar{1}$01)	36 33	36 29
r : *m*	(011) : (110)	63 33	63 28
r : *d*	(011) : ($\bar{1}$01)	31 8	31 45
d : *m*	($\bar{1}$01) : ($\bar{1}$00)	80 11	80 48

The plane of the optical axes stands at right angles to the clinopinacoid and is only slightly inclined towards the orthopinacoid.

A cleavage could not be found. Obtuse bisectrix = $\bar{b}$ axis.

ART. XI.—*The Inner Gorge Terraces of the Upper Ohio and Beaver Rivers;* by R. R. HICE.

IN all discussions of the terraces of the upper Ohio region a sharp distinction has been drawn between the Upper Rock benches, and the terraces lining the inner gorge, first, in the character of the alluvium connected with each and, secondly, in their structure.

The alluvium of the Upper Rock bench on the Beaver river (below the glacial boundary), consists of clayey deposits, with occasional pockets of gravel. On the Ohio, above the mouth of the Beaver, the proportion of gravel is greater, but below that stream the deposits partake more of the clayey character, reaching however a much greater thickness than is generally found on the Beaver.

The alluvium of the inner terraces, on the contrary, is almost entirely gravel, with a large proportion of metamorphic material, with its immediate origin in the morainic deposits a few miles northward. It cannot be mistaken for, or confused with, the gravels found on the higher benches, from which it is distinguished (1) in the character of its deposition, (2) in the proportion of metamorphic material, (3) in the shape of the pebbles, (4) in the apparent greater age of the higher gravels. These distinctions when once noted are not easily mistaken, and taken together form a certain guide, irrespective of difference in elevation above present stream level.

The distinguishing feature of the upper terraces is the ever present rock shelf. Prof. White in speaking of the most prominent of the upper terraces says a rocky escarpment leads up to at every point where it is seen.* In point of fact, the true character of the upper terraces has been generally recognized, in that they represent fragments of the bed of the stream, left in the original excavation of the valley. They are thus the earliest records we have of the cutting stream, and evidence has been heretofore presented, both of a general and local character, to show that the original stream flowed to the north, and has been reversed.

On the other hand, it has been assumed heretofore, that the distinctive mark of the terraces of the inner gorge was the absence of any included rock shelf. This assumption presupposes that the inner gorge differs from the upper, wider, and older valley, in its freedom from any remnantal benches, and from their supposed absence it has, in turn, been assumed that the cutting of the inner gorge was a short, quick, continuous

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* For principal papers relating to subject, see list at close of paper.

action; that, when renewed activity had been given the cutting stream, excavation proceeded without break, until the bottom of the now buried channel was reached. A more careful examination of the inner terraces shows, however, that to some extent at least, the prevailing notions regarding them are not correct. There are points, it is true, where the current descriptions seem, in some features, entirely accurate, but it is believed that sufficient is now known to show that the broad generalizations that have been drawn are incorrect.

Passing up the Ohio from the Pennsylvania and Ohio State line, the inner terraces alternate from side to side of the stream, and no appearance of an included rock shelf has been noticed until Raccoon Creek is reached. On this part of the Ohio the inner terraces, so far as observed, are made up bodily of alluvium, the gravel appearing to extend from the top of the terrace to the bottom of the now buried channel.

At the mouth of Raccoon Creek we find the alluvium reaching to the height of the "third" terrace (about 120 feet above river level) and along the river front it presents an unbroken escarpment of gravel and bowlders. Raccoon Creek, which is quite a rapid stream, shows, however, that the apparent uniformity in terrace material is a mistake. As this stream emerges from the narrow valley it has cut for itself, into the trough of the Ohio, we find it does not follow its natural course, but, turning abruptly up the larger stream, it has cut for itself a narrow cañon through a rather massive sandstone. The direct course of the stream we find cut off by the alluvial deposit, and evidently the old channel of the creek, which was cut when the now buried channel of the Ohio was being excavated, was, on the coming of the alluvium, filled to the terrace level, and when the Ohio re-excavated its channel in the gravel, Raccoon Creek was turned in its new course and has cut the channel we now find, which is in no way comparable in size with the valley cut for many miles by the same stream. How far the rock here underlying the terrace extends we have yet no means of knowing.

Crossing the Ohio to the next fragment of inner terrace we come to the point where the inner terraces have their greatest development on the upper Ohio. On both sides of the Beaver river the terraces attain a height of one hundred and twenty feet above stream level. On the lower, or Beaver, side it extends from a point about two miles below the mouth of the Beaver up the Ohio, and thence up the Beaver for about one mile. Where Two Mile run cuts across the terrace a modern channel has been cut through the ferriferous limestone, which here underlies the terrace in a broad, flat bench. How far this rock bench extends cannot be told. It at no point shows on the escarpment of the terrace, and wells have been sunk at Beaver, one mile up the stream, that reach river level without finding rock. It may be, however, these wells lie in the course of the buried channel.

Two hundred yards from the mouth of the Beaver we find that stream flowing over the soft shales that overlie the Homewood sandstone. Of the extent of this bench, which here lies at stream level, nothing is known. On the eastward a rock escarpment cuts it off, to the west it is covered with alluvium. Towards the Ohio it is cut off by the buried channel of that river, and up the Beaver it is covered by the impounded waters of that stream. It seems most probable, however, that it is but a small triangular bench, lying between the buried channels of the Ohio and Beaver rivers and the rock escarpment, here rising on the eastern bank of the Beaver.

On the eastern bank of the Beaver, at Rochester, the rock is seen passing under the higher portion of the terrace. The Rochester terrace is triangular in shape, bounded by the Ohio and Beaver rivers on the two sides, and the bounding hill of the valley on the northeast. The face of the escarpment along the Ohio has been cut by the railroad and no rock is seen. It is impossible therefore to assign any dimensions to the rock shelf seen on the Beaver side.

Passing up the Ohio we find a rock bench showing along the railroad cut below Baden and extending, almost continuously, to Legionville. Here the rock shelf is plainly visible, and even in a cursory examination it is evident that, measuring from the bottom of the buried channel, almost the whole terrace is rock in place.

The terrace at Economy, extending from Legionville to the Allegheny County line, has long been considered entirely gravel. Wells have been sunk at the town of Economy to river level without finding rock, yet a short distance below the town a quarry has been worked, right on the escarpment of the inner terrace. Of the extent of the rock shelf we have yet no means of knowing.

Returning to the Beaver and passing up that stream, we first come to a small rock bench about twenty-five feet above stream level, occurring at the mouth of Brady's run. This stream at its mouth, is now flowing in a rock channel, while a half mile up the stream it has a buried channel fifty feet, or more, in depth. The old channel evidently passed into the Beaver higher up that stream, and the present channel is a post terrace one.

Passing up the Beaver to the upper end of Beaver Falls, we reach a point where the Beaver, passing out of the narrow gorge in which it is confined for some eleven or twelve miles, flows in a modern channel for about two miles. From records it is known that the buried channel passes to the westward of the present stream in a long curve and is crossed by the present river, nearly at right angles, about one and a half miles below, thence the buried channel, now passing beneath New Brighton, makes a sweep to the right and the present channel passes into it a half mile further on.

The modern channel, from where it leaves the old one, at the upper end of Beaver Falls, flows in a shallow trough, cut in a rock bench left in the original cutting of the inner gorge, and this modern channel represents the post-terrace work of the Beaver. This stretch of the Beaver presents, in many respects, the best place to study the inner rock benches, for a rock escarpment is present for much of the distance. On the New Brighton side, from the point where the new channel enters the buried one, rock is seen in a low shelf extending under the inner alluvium and reaching to the point where the old channel is crossed by the modern one. Above this point the river runs close to the hill bounding the valley on the east, until Eastdale is reached, at the upper end of the modern channel, where quite a large shelf is seen, extending under the whole of the inner terrace at that point. On the western side of the stream, passing upwards, we find a rock bench, corresponding to the one at New Brighton. It occupies the triangle lying between the present stream, Walnut Bottom Run, and the western bounding hill, having a frontage of about one-fourth mile on the Beaver and one-half mile on the Walnut Bottom Run side. About one-half mile above the mouth of Walnut Bottom Run rock is again seen in place, extending continuously to the point of junction with the buried channel. This shelf is nowhere seen on the Walnut Bottom Run side, but is well defined by wells, and is known to extend about one mile in a southwesterly direction, being but a few feet below the surface until Twelfth Street is reached, from which point it falls rapidly, owing to the proximity of the buried channel.

In the narrow gorge which extends from Beaver Falls to Wampum, it was not expected that any fragments of inner rock benches could be found, but an examination of the gravel deposit at Clark's Run (Homewood) shows that it is resting on a rock bench. In changing the line of the P. & L. E. R. R. it was thrown into the hill, and the necessary cutting disclosed a bench consisting of the soft shales underlying the Homewood sandstone.

Passing out of the narrow gorge at Wampum, we have passed into the glaciated region, and the inner benches are somewhat harder to trace. The character of the inner gorge also changes, becoming wider than at any point below. This is due to the character of the strata cut, here being much softer than below where the gorge is cut in hard sandstones.

A short distance above Wampum a bench is seen, extending some distance, and, crossing the river to Moravia (east side), a corresponding bench is seen. The river at this point makes a sharp reverse curve, cutting from side to side of the valley, so that these two benches are really one, cut across by the river. The bench at Moravia reaches well to the confluence of the Shenango and Mahoning rivers.

Along the Mahoning river rock in place is frequently seen, and some of the inner terraces are undoubtedly of this character. The same is true of the Shenango valley, but neither of these streams have yet been studied or mapped.

A glance at a map will show we have followed the Ohio river from the Ohio and Pennsylvania line to a point but fifteen miles below the confluence of the Allegheny and Monongahela rivers, a distance of twenty-four miles, and the Beaver river its entire length, a distance of twenty-two miles. The following table gives the terraces on the rivers studied and the occurrences of rock where noted above. The flood plain is not given except where underlaid by rock.

On the Ohio.

Georgetown,	south	side river,	No rock observed.
Below Industry,	north	side river,	“ “
“ “	south	“	“ “
Above “	north	“	“ “
Raccoon Creek,	south	“	Underlaid by rock.
Beaver,	north	“	“ “
Bridgewater,	“	“	“ “
Rochester,	“	“	“ “
Monaca,	south	“	No rock observed.
Baden,	north	“	Underlaid by rock.
Aliquippa,	south	“	No rock observed.
Economy,	north	“	Underlaid by rock.
Shannopin,	south	“	No rock observed.

On the Beaver.

Brady’s run,	west	side river,	Underlaid by rock.
Fallston,	“	“	No rock observed.
New Brighton,	east	“	Underlaid by rock.
Beaver Falls (1),	west	“	“ “
“ “ (2),	“	“	“ “
Eastdale,	east	“	“ “
Homewood,	west	“	“ “
Wampum,	“	“	“ “
Moravia,	east	“	“ “

It will be noticed there are twenty-two observed terraces, and of these fourteen are underlaid by rock benches, to a greater or less extent. The first four, and those of Monaca, Aliquippa and Shannopin are not favorably situated to show the presence of an included rock shelf; no stream cutting them in such a way as to reveal their structure.

It has not been possible in all cases to assign even approximate limits to the observed rock benches. At Raccoon, Beaver, Rochester and Economy it is evident they underlie but a portion of the terrace and there is as yet no data that will enable any estimate of proportion of included rock shelf to entire terrace to be made. At New Brighton the rock extends only under the lower terrace, and whether it underlies more than that portion of the terrace lying between the buried and modern channels of the river has not yet been determined. At Beaver Falls the limits of the rock are well defined, and estimating from the bottom of the buried channel, one-half of the whole terrace would seem to be rock. At Eastdale the rock rises practically to the surface, and fully nine-tenths of this fragment is rock. At Homewood the rock underlies the whole of the gravel deposit and constitutes one-half of the whole (the gravel here rising to the level of the outer rock bench). At Wampum the greater portion of the terrace seems to be rock. The shelf shows for some distance along the river front and rises almost to the level of the terrace, which is also true at Moravia. In the terrace extending from Baden to Legionville the railroad cutting shows rock reaching practically to the surface and constituting at least four-fifths of the entire terrace.

It will thus be seen that the data for forming an estimate is not sufficient to judge accurately, yet it must be evident that the included rock benches form no insignificant portion of the inner terraces, and reduces by that amount the immense quantity of alluvium which it has been supposed made up the terraces. From the present data the writer believes the proportion of rock will be found over, rather than under, one-half of the entire volume of the terraces, measured from the bottom of the buried channel.

The attempt to correlate the rock benches has not been entirely satisfactory. Taken as a whole the benches on the Beaver (Moravia, Wampum, Homewood, Eastdale, Beaver Falls, New Brighton) lie at about the same elevation above present stream level (30′ to 40′). The benches on the Ohio (Economy, Baden, Rochester, Beaver, Raccoon) lie at a somewhat higher elevation above stream level (50′±), yet it seems they belong to the same series found on the Beaver. The Ohio is flowing over its buried channel in this region and has eroded its post-terrace channel deeper than the Beaver, which has been cutting a new rock channel within about two miles of its mouth, and that through the hard Homewood sandstone.

This view of the benches is in harmony with the facts as shown on the Beaver. The rock benches at Beaver Falls and New Brighton, where the Beaver is cutting its new channel, lie nearer stream level than the benches at Wampum and Moravia, where the Beaver is re-excavating its buried channel. It may also be added that the greatly increased fall of the Beaver in the last four miles of its course where it drops down from the rock channel into its buried one, and thence into the Ohio, is sufficient to compensate for the greater elevation of the benches on the Ohio.

It would seem therefore that sufficient is now known to justify the conclusion that the cutting of the inner gorge is to be subdivided into two periods. (1) The time required to cut from the level of the lowest of the upper rock benches to the level of the inner rock benches, when erosion seems to have approached a base level, and (2) a second period of cutting from the inner rock benches to the bottom of the buried channel. The first period evidently much the longer. The bench at Homewood, for example, is some seventy feet above the bottom of the inner gorge (the bottom of the buried channel), and about one hundred feet below the lowest of the upper benches. The work of erosion in the first period was here through the Homewood sandstone in great measure, while the cutting of the second period was in shales to a great extent; the lower portion of the gorge is also narrower than the upper portion. It seems safe to say, therefore, the first period represents two-thirds to three-fourths of the entire work of excavation, and probably a larger proportion in time.

After the excavation of the buried channel, the next chapter of the river history was the silting of the valleys to the top of the inner terraces. It is not purposed in this paper to discuss the inner alluvium, further than to call attention to a mistake regarding it, evidently due to a study of the gravel escarpments, without examination of the structure back from the face. It has been described as quite coarse, ranging up to two feet in diameter, and the impression prevails that it is uniformly of this character, from top to bottom, and from escarpment to the base of the hills bounding the inner gorge.

It seems evident, and generally admitted, that the alluvium should be considered as a whole, from the top of the highest terraces, to the bottom of the buried channel. The records that determined the existence of the buried channel were not sufficient to furnish any knowledge of the character of the filling, and it is only recently any real knowledge has come to light, and rendered it possible to form a correct idea of the filling material and consequently of the stream that deposited it.

The writer has records, more or less complete, at four points, one on the Ohio and three on the Beaver. The first of these is at Dam No. 6 (Merrill) on the Ohio, near the mouth of Raccoon Creek. This set consists of a series of drill holes in a line across the river, at regular intervals of one hundred feet. Only two holes reach bed rock, one hundred and two hundred feet respectively from the northern bank of the river. All the other holes are deeper, but in no case reach rock. In all cases after passing through the immediate bed of the stream, the alluvium is much finer than shown by the escarpment of the terraces.

The next record is at the mouth of Wallace's run. No accurate records of strata are at hand, if indeed any were kept, but it is well established that in passing through the 60′ of alluvium the material grew successively finer, and about twenty feet of it, immediately overlying the rock bottom, consisted of a very fine silt.

The third set of soundings reach rock in all but one hole, and consist of test wells sunk to determine the foundation for piers, about one-half mile below the mouth of the Connoquenessing. The records of all these wells agree and it is possible to form from them an accurate knowledge of the stratification of the filling of the buried channel at that point. Three distinct strata are recognized, the top of each horizontal, and conformable to each other, but non-conformable to the rock bottom on which they lie. Immediately overlying the rock bottom is a layer of fine silt, reaching in the middle of the channel a thickness of twenty-five feet, but thinning out to nothing on the sides. The top is horizontal and the thinning at the sides is due entirely to the rising of the rock bottom. Overlying the silt is a fine sand, eight to ten feet in thickness This also abuts against the rock at each side. Overlying this in turn is a fine gravel. The top of this stratum has been slightly eroded by the present stream, but it lies conformably on the sand stratum. Over the gravel is a thin deposit of river detritus.

The last of the records is at the railroad bridge between Wampum and Moravia. This set is incomplete, as the wells do not reach rock, but as far as they go they entirely agree with the others in the successively increasing fineness of the filling material, from the surface downward.

It should also be said that in a number of excavations about Beaver Falls and New Brighton "quicksand" has been frequently reported, and it is recognized by all persons conversant with deep excavations in the buried channel, that the material grows finer as excavation proceeds.

If we examine the structure of the terraces as revealed by excavations in the midst of them, we find them in harmony with the character of the filling of the buried channel. A well at Beaver Falls commenced at the top of the terrace, and excavated over eighty feet to rock, showed first a few feet of coarse material, followed by coarse gravel, which in turn grew finer until it corresponded with the gravel found in the buried channel. At Beaver, after passing through a few feet of the coarser material, the same is true, reaching, as we know from old wells, to the present level of the Ohio. At Georgetown, after passing through eight feet, no more "bowlders" were found to present river level.

It is not intended to convey the impression that the terraces, or rather the alluvial portion of them, are made up bodily of the finer material, for it is believed there are evidences from the escarpment that in the middle of the valleys the upper half of the filling is coarser than the average, but it is evident the stream depositing the alluvium had by no means the transporting power heretofore assigned it. In the refilling of the inner gorge the depositing stream was not a torrential current, but at first was quite sluggish, depositing fine silt only, gradually increasing in carrying power until the whole of the inner alluvium was deposited, but apparently at no time of sufficient eroding power to remove the deposit just previously made.*

Beaver, Pa., Jan. 5, 1895.

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* The literature of subject is quite scattered, the principal papers are:—

T. C. Chamberlin, U. S. Geol. Survey, Bull. 58, pp. 24–37; Bull. Geol. Soc. A., vol. i, pp. 472–473; p. 479; this Journal, vol. xlv, p. 195; vol. xlvii, p. 247. G. F. Wright, U. S. Geol. Survey, Bull. 58, pp. 76–78, pp. 81–86; Ice Age in N. A., pp. 287–289, pp. 335–339; this Journal, vol. xliv, pp. 368–371; xlvii, p. 161; Am. Geol., vol. xi, pp. 195–199. Dr. Alfred T. King, "Ancient Alluvium of the Ohio Valley and its Tributaries," January, 1854. Frank Leverett, this Journal, vol. xlii, p. 210; vol. xlvii, p. 247. P. Max Foshay, this Journal, vol. xl, p. 401; Bull. G. S. A., vol. ii, p. 457. I. C. White, Second Geol. Survey Penna., vol. Q, pp. 10–14; vol. QQ, pp. 10–12; vol. QQQ, pp. 17–18. J. J. Stevenson, Second Geol. Sur. Penna., vol. K, pp. 11–19. J. P. Leslie, Sec. Geol. Sur. Penna., vol. Q, pp. xxv. B. C. Jillson, Trans. of Academy Sci. and Art, Pittsburg, vol. i, pp. 1–25. E. W. Claypole, Trans. Geol. Soc. Edinburgh, 1887, p. 42. R. R. Hice, Bull. Geol. Soc. Am., vol. ii, p. 457; Science, vol. xxii, p. 170.

ART. XII.—*The Glacial Land-Forms of the Margins of the Alps;* by HUGH ROBERT MILL.

[From the Geographical Journal, January, 1895.]

AT the close of the sixth meeting of the International Geological Congress, which was held at Zurich during August and September, an excursion occupying a week was arranged in order to afford an opportunity of examining the remains of ancient ice-action far beyond the reach of actual glaciers on both the southern and northern slopes of the Alps. This trip was planned and directed by Professors Penck and Brückner and Dr. Du Pasquier, who, from their previous knowledge of the localities to be visited, had drawn up a guide in the form of a pamphlet of 86 pages, entitled "Le Système glaciaire des Alpes," which is published in vol. xxii of the Bulletin of the Neuchâtel Society of Natural Sciences.

The special object was to exhibit the part played in the formation of the land surfaces at the base of the Alps by the moraines or glacial formations, strictly so called, of the great Ice Ages, and also of the intermediate fluvio-glacial deposits of moraine material which had been rearranged by water on the retreat of the ice. To these was added involuntarily, rather too much experience of the "pluvio-glacial" conditions which several days of steady rain at the beginning and at the end of the excursion induced on the steep surfaces of the clay slopes over which Professor Penck led his followers.

The main point of interest to the glacial geologist was the proof afforded by the sections of the occurrence of at least three successive periods of great glaciation separated by relatively long intervals, during which the vast volumes of water liberated by the melting ice dispersed and rearranged the moraine material. To a geographer the interest centered rather in seeing how the scenery and structure of great stretches of country were determined by the heaping up upon the plains of extensive systems of low hills—low, that is, when compared with the Alps, for some of them exceed a thousand feet in height—differing entirely from the mountains of elevation lying beyond them. These hills and fluvio-glacial plateaus represent the amount of glacial erosion and transport; they are the rubbish heaps of the mountain sculpture. Their effect on the broad geographical features of the alpine border is very clear in determining the lines of communication. The amount of weathering they have undergone, according to the different ages of the deposits, decides the character of the soil, which in turn reacts on the vegetation and appeals directly to the eye, the general aspect of the landscapes of the first glaciation differing in a marked degree from those of the last. Unfortunately, the weather was throughout unsatisfactory for photography, and the attempts made to take comprehensive views were failures, as had been expected. Some fair results were, however, obtained in detailed sections, which are of geological rather than geographical interest.

The excursionists met at Lugano on Monday, September 17, when thirty-seven members assembled, including representatives of Austria-Hungary, Germany, France, Russia, Norway, Holland, Switzerland, Italy, the United States, England, and Scotland. The weather was hopelessly wet, the one interesting result of which was to throw into the shade the distinguishing peculiarities of the Italian lakes, and reveal the essential similarity of their scenery to that of the English lakes and Scottish lochs. Professor Penck explained, and in some cases subsequently demonstrated, that the lower ends of the North Italian lakes were dammed by glacial accumulations, thus raising their level far above the rim of the rock-basins which contain their deeper water, and accounting for such peculiarities as the "recurved hook" of Lugano.

A somewhat exciting boat-trip down the rapid Ticino landed the geologists at a fine section where the river had cut deeply through its moraine bar. Here, so far as sky or soil or vegetation were concerned, one might have been in Scotland instead of Italy. The steep bowlder-clay slope, grown in part with the common coltsfoot, when ascended, led to a level moorland, the poor soil of which was covered with heather, not shrubby as in more northern latitude, but composed of long separate flower-stems with exceptionally large heads of blossom. In the distance sombre pine woods crowned the hillocks, but at a turn of the path maize and sorghum were found as common field-crops, and the similarity to northern lands disappeared.

On Monday evening the party reached Ivrea by steam tramway from Santhia, and the whole of Tuesday was occupied in seeing, as well as the mist would allow, the vast glacial amphitheater which surrounds the town, and in crossing the steep ridge of the Serra and the ferretto-covered slopes of moorland which succeed it to Biella, whence Milan was reached not long before midnight.

The morainic amphitheater is both the largest and most typical of the southern slopes of the Alps. Two ramparts of moraine material diverge nearly at right angles from the mouth of the narrow valley of the Dora Baltea, gradually diminishing in height, and these are finally united by an arc of moraines convex to the south, so that the whole completely surrounds a central plain, the two little lakes occupying the center of which overflow by the Doire, which cuts across the southern barrier. The eastern side of the amphitheater includes the largest moraine hill of the system, so large that it by no means belies its name of the *Serra*. It is a ridge more than 12 miles long, and in its highest part more than 1300 feet above the bottom of the depression, towards which the sides slope at an angle of 20°. The accumulation is the result of several glaciations, the *moraine externe*, or early bowlder-clay, being covered with a red weathered crust of *ferretto*, the intercalation of which between the older and newer moraines is one of the proofs of the occurrence of an interglacial period.

A railway journey next morning allowed a fine forenoon to be spent in driving from Lonato to Salo, on the Garda Lake, through moraines and fluvio-glacial formations—some of them compact conglomerates. Here the successive glaciations were very clearly shown in several sections, the lower moraine of the earlier Ice Age having its pebbles much weathered; in some cases even the granites had crumbled into clay, retaining only their original form. Above this came a layer of conglomerate formed of ice-scratched pebbles stratified by running water, and on the top a fresher bowlder-clay much less weathered than that below.

Coming up the Garda Lake at night, the contrast between physical and political geography was finely shown by the uniform cliff walls and continuous water-surface broken by the long beam of the electric search-light at the Italian frontier station, which swept the lake all night for the prevention of smuggling.

On Thursday, September 20, the excursion left Riva by rail at 6·20, and had an excellent opportunity, on the journey to the Brenner line at Mori, of seeing that ice is not the only agent which is capable of producing scenery by the accumulation of detritus. The landslip-covered plateau of Loppo, with its lake formed in a hollow of the dolomitic detritus, and the still more extensive piles of landslip material about Mori, contrasted and compared in many ways with the glacial phenomena seen farther south. The Austrian Railway Company had provided, free of charge, an observation car at the end of the train, from which a good view was obtained of the deltaic wilderness through which the lateral tributaries entered the Adige, and of the extraordinary fertility of the alluvial flats, where maize and vines in alternate narrow strips covered almost all the available land. Later the porphyrite gorges marked the passage across the center of the range, and beyond the Brenner saddle carriages were provided at Matrei to allow of a more detailed examination of the terraces of the Sill valley than would be possible from the train. The vastness of this accumulation of moraine, fluvio-glacial deposit, and moraine again, may be judged from the fact that it fills the ancient valley of the Sill, and that the modern river had to cut down through more than 300 feet of it before coming to the underlying rock, into which the river bed has now worn its way to some depth. As the road winds along the face of the steep slope of the clay gorge, it affords a view of the railway on the opposite side far below, cut in the hard rocks close to the river, while the slope above is so unstable that it remains in many places bare of vegetation, and wattled fences have been run along in zigzags to bind the clay and reduce the risk of damage to the roadway by sudden falls. In the moraine material the action of sub-aërial denudation has produced a number of "fairy chimneys," the *Erdpyramiden*, or earth-pillars, with which the name of Tyrol is usually associated in elementary text-books of geology; but they are neither so large nor so picturesque as those of the Finsterbach, the view of which so well repays the labor of the arduous climb from Botzen to the Ritten plateau.

Two nights were spent at Innsbruck, and the whole of Friday the 21st was devoted to the study of the sections along the mountain slope of the left side of the Inn. Here the interglacial deposits were seen in their most impressive form. A steep climb along a clay slope of unquestionable moraine, crowded with highly polished and striated pebbles, showed an overhanging cornice of compact breccia resting on the moraine, and itself a hardened water-bedded deposit. Mayr's great quarry in this reddish breccia is a prominent object as seen from Innsbruck, and has supplied a great part of the stone which, from its hardness and durability, causes the newer streets of that town to recall the clear-cut buildings of Aberdeen. Above Mayr's quarry comes a nearly level plateau—the top of the terrace of accumulation—1000 feet above the flat floor of the valley, and similar in its features to the terrace of the Wippthal, through which the Sill cuts its way, as seen from Schönberg. As the quarry is carried farther back the loose material above the hard breccia is cleared away in advance, and so a series of excellent sections of the upper moraine is exposed. The intercalation of this mass of breccia, several hundred feet thick, is a proof of the comparatively long duration of the interglacial period in which, according to Penck, it was formed as a talus or scree on the shores of the ancient Inn lake.

The remarkable terrace which breaks the steep slope of the mountains on both sides of the Inn valley is only found between the Oetzthal and the Zillerthal, from each of which glacial accumulations had blocked the main valley, thus giving origin to a lake which, invading the lower Wippthal also, allowed the interglacial deposits to form on its margins, which are now represented by the top of the lateral terrace.

From Innsbruck the excursion proceeded by rail along the Inn valley into Bavaria, then by a branch line across the glacial amphitheater of the Inn, and the monotonous plain south of Munich to Deisenhofen, whence the Isar was reached on foot. The contrast of the uniform levels and low moraine hills of this northern slope, with their ranges of rather dwarfish pines in monotonous plantations, was sharp when compared with the more abrupt slopes and richer vegetation of the southern side. The true plateau character of this country appeared when, after a walk of several miles along a straight and absolutely level road, a break in the line of trees in front showed the swift Isar flowing almost at our feet, and a steep path descending the gorge to its shore. Crossing the river we reached Höllriegelskreut, and saw a succession of sections demonstrating the triple glaciation and intermediate genial periods. Next day a trip was made from Munich to the Würmsee, or Lake of Starnberg; but the weather proved so unfavorable that, for the first time on the excursion, the full programme for the day as planned by the leaders could not be carried out. It was possible, however, to visit a remarkable surface of interglacial conglomerate at Berg, which has been enclosed and placed under cover by the German and Austrian Alpine Club, a body which has rendered inestimable services to the scientific visitor, as well as the tourist and climber, along the whole line of the Eastern Alps. This surface is so strongly glaciated that the rock is polished as if by a lapidary, and the internal structure of every constituent pebble is clearly seen. The characteristic striæ are there, showing how the glacier, long since shrunk back to the obscurity of the central Alpine ridge, had advanced over the hardened mass of cemented pebbles sorted out by water from an earlier moraine, and cut by its intense erosive power through pebbles and matrix alike. The Würmsee is deeper below the general level of the plain than the surrounding hills are high above the surface, and it is entirely surrounded by the interglacial deposits known as *Deckenschotter*, in which it seems probable that the whole basin was eroded beneath the pressure of the last great ice-sheet.

In concluding this short account of a delightful and memorable excursion, it may be of advantage to define the nomenclature and summarize the general theoretical conclusions arrived at by Drs. Penck, Brückner, and Du Pasquier.

Glacial deposits, so far as they occur in the Alps, are divided into two classes—the *glacial*, or moraines properly so called; and the *fluvio-glacial*, or alluvia formed by the action of running water on moraines. The latter are usually clearly stratified, but contain many pebbles marked by glacial striæ. Fluvio-glacial deposits are always being formed on the outer slopes of moraines, forming a gentle slope leading from the edge of the morainic amphitheater to the plain of the enclosed depression. A complex of glacial and fluvio-glacial deposits of contemporaneous origin corresponds to each phase of the cessation of glaciation. Thus in a single glacial series there may be a succession of complexes, one partially superimposed on another, and each corresponding to a definite stage of retreat or advance of the ice. The fluvio-glacial deposits in a single glaciation are spoken of as inter-stadiary.

Under the deposits of relatively recent glacial accumulation which are characterized by trifling superficial alteration due to weathering, two other glacial series are found distinguished from each other and from the most recent series by highly weathered layers or by evidence of great erosion, showing the existence of a long sub-aërial period between each epoch of glaciation. These periods are termed interglacial in distinction to the brief interstadiary periods which occur in the course of a single glaciation. Amongst the interglacial deposits of the neighborhood of the Alps, at least on the north of the chain, *loess* must be included. *Lehm* is a product of alteration of loess, mainly distinguished by the absence of carbonate of lime.

The more ancient moraines are often weathered externally into a brick-red crust, termed *ferretto* by the Italian geologists. The moraines so coated always occupy the outer side of morainic amphitheaters, and are therefore called *external moraines* in distinction to the more *internal moraines*, which form the inner slopes and in part rest upon the more ancient. This is not a mere case of superposition, but of actual enclosure, the external moraine extending around as well as partially under the internal. The alluvia of the most ancient glaciation are termed *plateau alluvia* (Deckenschotter), those of the intermediate glaciation *high-terrace alluvia* (Hochterrassenschotter), and those of the most recent stage *low-terrace alluvia* (Niederterrassenschotter).

I cannot conclude without an expression of gratitude to Professor Penck, for his great kindness and tireless patience in not only showing, but making sure that every member of the excursion saw and understood, the various features which he explained.

Art. XIII.—*Distribution of the Echinoderms of Northeastern America;*[*] by A. E. Verrill. (Brief Contributions to Zoology from the Museum of Yale College, No. LVIII.)

About 200 species of Echinoderms are now known from the Atlantic Ocean, adjacent to the North American coast, north of Cape Hatteras. Of these, over 100 species have been discovered in recent years, since the deep sea dredgings were undertaken. The "Challenger," 1873; the "Blake," 1880; the "Fishhawk," 1880–1882; and the "Albatross," 1883–1887, each brought to light many new forms. Those dredged by the "Challenger" were, however, not described until 1889. Those collected by the two steamers last named, as well as several derived from previous explorations, were mostly described by me, from 1878 to 1885. Many of these necessarily brief descriptions appeared in this Journal, from time to time, in this series of "Brief Contributions to Zoology."[†] It seems desirable, therefore, to bring together here all the species, with a brief review of their distribution, as known at present. Of the 200 species now recognized, about 137 may be classed as deep-water species, as they rarely if ever occur in less than 50 fathoms. About 116 species are found in depths greater than 500 fathoms. Many of these have a wide range in bathymetrical distribution, some of them ranging from less than 100, to more than 1000 fathoms. The same is true of some of the shallow water species. About 58 species have been found to occur only at depths greater than 500 fathoms; these may be classed as true abyssal species. Many of our species also have a wide geographical range. A considerable number occur on the eastern side of the Atlantic and in the Arctic Ocean. Several extend southward to the West Indies, and some even to the Indian and Pacific Oceans.

More complete details in regard to the distribution will be given in connection with the general lists of each class. The general distribution in depth may be illustrated by the following table:—

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[*] Abstract of a paper read before the National Academy of Science, Dec. 31, 1894.

[†] Especially in Nos. 38, 39, 42, 49, 50, 51, 55, 56, 57.

Other species were described by me in the Proc. U. S. Nat. Museum, vol. ii, p. 165, 1879; vol. viii, p. 423, 1885; and in vol. xvii, pp. 245–297, 1894.

Many were figured and described, in "Results of the Explorations made by the steamer Albatross, in 1883," in the 11th Annual Report of the Commissioner of Fish and Fisheries, 1885.

In this article the localities indicated by station numbers and by latitude and longitude, unless otherwise stated, are those of the United States Fish Commission.

Bathymetrical Distribution of N. E. American Echinoderms.

Fathoms.	Aster.	Ophiur.	Crin.	Echin.	Holoth.	Total.
0–50	26	17	1	5	25	74
50–100	37	20	2	12	12	83
100–500	35	30	2	17	9	93
500–1000	24	26	2	10	11	73
1000–2000	22	26	1	12	13	74
2000–2600	7	7	2	0	5	21

It will be seen from the above table that the species of Echinoderms are more numerous between 100 and 500 fathoms than in any other zone of depth. It is also in this zone that many species occur in the greatest abundance of individuals. This is largely due to the fact that off much of our coast, a profuse fauna is sustained at those depths by the direct influence of the Gulf Stream, as shown in several of my former articles.

A brief statement of some of the results and conclusions, arrived at from the study of this group, may be given here, leaving a more detailed discussion of the subject for another occasion.

1. The abyssal genera and families are mostly very widely diffused over the three great ocean basins.

2. The species belonging to abyssal genera are usually restricted in range to particular regions or to a single ocean.

3. Those genera and species having the greatest bathymetrical range are also generally the most widely distributed geographically. Some of these species range from very shallow water to 1000 fathoms or more, and may extend geographically into all the great oceans.

4. Some of those species belonging to the intermediate depths (100 to 500 fath.), known as the "continental zone," often have a very wide geographical range. Many of them extend to European waters, and some even to the Pacific.

5. Many of the most peculiar and remarkable new genera belong to the continental zone, or even between 50 and 200 fathoms.

6. Many peculiar and conspicuous genera and several remarkable families are nearly or quite confined to the abyssal zone.

7. Abyssal genera are often endowed with special structures adapted to the peculiar physical and biological conditions in which they live, especially to the food upon which they feed and to the soft mud or ooze in which most of them live more or less buried.

8. The abyssal species in many cases appear to be capable only of very slow dispersion, as compared with shallow water species. This is, at least in many cases, due to the fact that

many of them do not have free-swimming larvæ, but bring forth well developed creeping young; as, for example, the Pterasteridæ, Solasteridæ, Echinasteridæ, Astrophytonidæ, etc.

In other cases the eggs are so large as to indicate that the larvæ (though unknown) are unlike those of shallow water species and not free-swimming.

9. It is, therefore, probable that many of the strictly abyssal species do not have the benefit of the transporting agency of ocean currents, which so rapidly transport the free larvæ of most shallow-water species. If that be the case, they can only extend their range by the extremely slow process of creeping by means of their ambulacral feet, which, on the soft ooze of the sea bottom, must be a very slow process.

10. We must, therefore, conclude that the widely diffused abyssal genera, many of which now occupy all the great ocean basins, and in many cases range from the Arctic to the Antarctic Oceans, are of very great antiquity, and that there has been ample time, since they occupied the deep sea, for the minor differences characteristic of species to originate in different geographical regions, as a result of casual variations that have been conserved by isolation, perhaps aided in some cases by "natural selection."

11. In the majority of cases, however, there is no evident utility in the characters that separate one abyssal species from another of the same genus, for the differences are generally slight modifications of form and color; arrangement, shape and size of the spines, granulations, pedicellariæ, etc. Such differences can hardly be of protective value in the darkness and quietness of the depths in which they live.

*Systematic List of the Starfishes, with their Bathymetrical and Geographical Distribution, expressed in a condensed form.**

ASTERIOIDEA.

Family Archasteridæ (Viguier, 1878) emended, Sladen.

Benthopecten spinosus Verrill.

Benthopecten spinosus Verrill, this Journal, vol. xxviii, p. 218, 1884; Explorations made by the Albatross in 1883, in Annual Report, U. S. Comm. of Fish and Fisheries, pp. 519 [17], 543 [41], 1885; Proc. Nat. Mus., vol. xvii, p. 245, 1894.

Pararchaster semisquamatus var. *occidentalis* Sladen, Voyage of the Challenger, vol. xxx, p. 10, 1889.

Pararchaster armatus Sladen, op. cit., p. 19, pl. 1, figs. 5, 6; pl. 4, figs. 5, 6, 1889.

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* In this list, as a matter of convenience, I have followed pretty nearly the arrangement and nomenclature adopted by Mr. Sladen in his classical work on the Starfishes collected by the Challenger. (Report on Scientific Results, Zoology, vol. xxx, with a vol. of plates).

In doing this I do not necessarily approve of all the changes of names made by him. In several cases I decline to follow him and others in the resurrection of the ante-Linnæan names given by Linck. To do this systematically would produce endless confusion.

Bathymetrical range, 721 to 2021 fathoms. Most common in 1200 to 1600 fathoms. It was taken at 60 stations, between N. lat. 42° 47′ and 35° 10′, by the U. S. Fish Commission. Off the coast of Portugal (t. Sladen).

The genus *Pararchaster* Sladen (1889) is synonymous with *Benthopecten* (1884). This is a strictly deep-sea genus, none of the species occurring in less than 400 fathoms. It is found in all the oceans. The following additional species were described by Mr. Sladen:—

B. spinosissimus (Sl.) V., Atlantic	425	fath.
B. simplex (Perrier) V., Caribbean	1323	"
B. antarcticus (Sl.) V., Southern Ocean	1675	"
B. pedicifer (Sl.) V., " "	1600–1900	"
B. semisquamatus (Sl.) V., Pacific	565–1875	"

All the above species are closely related. Mr. Sladen also described a single young specimen, taken off Delaware Bay by the Challenger, as a variety (*occidentalis*) of *B. semisquamatus*. The type of the latter was from off Japan.

This supposed variety appears to me to agree in all respects with many young specimens of our *B. spinosus*, judging from Mr. Sladen's detailed description. The two species are evidently very closely allied.

PONTASTER HEBITUS Sladen.

Pontaster hebitus Sladen, Voyage of the Challenger, vol. xxx, p. 33, pl. 8, figs. 1, 2; pl. 12, figs. 1, 2, 1889; Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 247, 1894.

Archaster tenuispinus Verrill, Proc. U. S. Nat. Mus., vol. ii, p. 203, 1879; Rep. Com'r of Fish and Fisheries, vol. xi, for 1883, p. 543, pl. 13, fig. 38, 1885 (perhaps not of Düben and Koren).

B. range, 85 to 250 fath. This species is known only from the Banks off Nova Scotia and Newfoundland. It is very closely allied to *P. tenuispinus* of northern Europe, if not identical.

Mr. Sladen records twelve species and several varieties of *Pontaster*, not including *P. sepitus*. Seven species occur in the Atlantic. Others are found in the Indo-Pacific and Southern Oceans, mostly at great depths. Mr. Perrier has also described several additional forms that appear to belong to the same genus. Three of these are from the West Indian seas.

PONTASTER FORCIPATUS Sladen.

Pontaster forcipatus Sladen, Voyage of the Challenger, xxx, p. 43, pl. 8, figs. 3, 4; pl. 12, figs. 3, 4, 1889; Verrill, Proc. Nat. Mus., vol. xvii, p. 247.

B. range, 828 to 1396 fath. 1240 to 1700 fath. (Sladen). Taken at 45 stations, between N. lat. 41° 28′ and 36° 34′.

Mr. Sladen (op. cit., p. 47) has described a variety (*echinata*) of this species, taken off Marion Island, S. lat. 46° 46′, in 1375 fathoms.

Allied species are found in all the great oceans.

PONTASTER SEPITUS Verrill.

Archaster sepitus Verrill, this Journal, vol. xxix, p. 151, Feb., 1885; Expl. by the Albatross in 1883, pp. 519, 543, 1885.
Pontaster sepitus Verrill, Proc. Nat. Mus., vol. xvii, p. 247, 1894.

B. range, 368 to 858 fath.

Taken at several stations between N. lat. 41° 53′ and 39° 40′.

DYTASTER GRANDIS Verrill.

Archaster grandis Verrill, this Journal, vol. xxviii, p. 218, 1884.
Dytaster madreporifer Sladen, op. cit., p. 70, pl. 3, figs. 3, 4; pl. 32, figs. 5, 6, 1889.
Dytaster grandis Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 248, 1894.

B. range, 475 to 2620 fath. Most common between 1200 and 1600 fathoms. Taken at 36 stations between N. lat. 41° 13′ and 36° 34′.

The genus *Dytaster* Sladen is found in all the great oceans. Mr. Sladen described seven species, none of them from less than 800 fathoms.

D. exilis var. *carinata* Sl., op. cit., p. 69, was taken off Maryland, in 1700 fathoms. The typical *D. exilis* was from off Valparaiso, in 1375 fath. I have not been able to satisfy myself that the var. *carinata* Sl. is distinct from the young of *D. grandis*.

PLUTONASTER AGASSIZII Verrill.

Archaster Agassizii Verrill, this Journal, vol. xx, p. 403, 1880.
Plutonaster rigidus Sladen, op. cit., p. 91, pl. 14, figs. 3, 4; pl. 15, figs. 3, 4, 1889; also var. *semiarmata*, op. cit., p. 94.
Plutonaster bifrons (part) Sladen, op. cit., p. 88, 1889 (very young example).
Plutonaster Agassizii Verrill, Proc. Nat. Mus., vol. xvii, p. 248, 1894.

B. range, 182 to 1700 fath. Most common in 300 to 1200 fathoms. Taken at 103 stations between N. lat. 41° 53′ and 35° 45′ 23″.

Very closely related to *Pontaster bifrons* Sl. from off the European coasts, and to *Pontaster intermedius* (Perrier sp.), of the West Indian region.

Mr. Sladen recorded eight species of this genus: one from the Mediterranean; one from the South Pacific; all the others from the Atlantic. Most of the species inhabit only great depths.

PSEUDARCHASTER INTERMEDIUS Sladen.

Pseudarchaster intermedius Sladen, Voyage of the Challenger, vol. xxx, p. 115, pl. 19, figs. 3, 4; pl. 42, figs. 5, 6, 1889; Verrill, Proc. Nat. Mus., vol. xvii, p. 249, 1894.
Archaster Parelii Verrill, this Journal, vol. vii, p. 500, 1874 (not Düben and Koren); vol. xxiii, p. 140, 1882; Rep. U. S. Com'r Fish and Fisheries, vol. xi, p. 543, pl. 13, fig. 37, 1885 (var. with narrow rays).

B. range, 85 to 1608 fath. Most common between 150 and 500 fath. Taken at 33 stations between N. lat. 44° 26′ and 37° 59′ 30″.

This species is very closely allied to *P. discus* Sladen, from off the west coast of S. America in 147 fath., and to *P. tessellatus* Sl., from the Cape of Good Hope.

Variety, *insignis* nov.

A few specimens, much larger than usual and with coarser granules, represent a marked variety or perhaps a distinct species. For the present it may be best to consider it a variety.

Radii, 75^{mm} and 23^{mm}. Upper surface and marginal plates granulated nearly as in the typical form, except that the granules are somewhat larger. Actinal plates covered with unequal, coarse, irregular, angular, fusiform granules, some of those on the middle of each plate longer and larger, spiniform. Lower marginal plates with a median row of small, appressed, fusiform spines much larger than the granules. Adambulacral spines longer and larger than in the type-form, those on the ventral side of the plates, 12–16; the largest, thick and blunt, or clavate. Jaw-spines thick, blunt, angular, longer and more prominent than in the type, those on the actinal surface in two regular rows of about 8 each.

B. range, 100 to 1356 fath. Nova Scotia to N. lat. 40° 09′ 30″.

PSEUDARCHASTER CONCINNUS Verrill.
Proc. U. S. Nat. Mus., vol. xvii, p. 250, 1894.

B. range, 1188 to 1791 fath. In one instance recorded as from 123 fathoms, but probably erroneously. Taken at 3 stations between N. lat. 41° 28′ 30″ and 41° 07′.

Family PORCELLANASTERIDÆ Sladen.

CTENODISCUS CRISPATUS Dub. and Koren.
Asterias crispatus Retzius, Dissert. Asteriarum, p. 17, 1805.
Ctenodiscus polaris Müll. and Trosch., Syst., p. 76, pl. 5, fig. 5, 1842.
Ctenodiscus crispatus Duben and Kor., K. Vet. Akad. Handl., p. 253, 1844; Stimpson, Invert. G. Manan, p. 15, 1853; Lütken, Grönl. Echinod., p. 45, 1857; Verrill, Proc. Bost. Soc. Nat. Hist., vol. x, p. 345, 1866.
Ctenodiscus corniculatus Perrier, Stell. du Mus., p. 380, 1875; Duncan and Sladen, Echinod. Arctic Sea, p. 49, pl. 3, figs. 17–20, 1881; Sladen, Voy. Chall., p. 171, 1889.*

B. range, 5 to 632 fath. Most abundant from 50 to 150 fath. Taken at numerous stations in Massachusetts Bay, Gulf of Maine, Bay of Fundy, etc. It extends to Greenland, Spitzbergen, and Northern Europe. Circumpolar. Allied species occur in the South Atlantic and South Pacific.

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* This is an instance in which certain writers have resurrected Linck's antebinomial names to displace those given under the Linnæan system. In this I cannot concur.

PORCELLANASTER CÆRULEUS Thoms.

W. Thomson, Voy. Challenger, Atlantic, vol. i, p. 378, figs. 97, 98, 1877; Sladen, Voy. Chall., vol. xxx, p. 134, pl. 20, figs. 1 to 7, 1889; Verrill, Expl. by the Albatross in 1883, p. 543, pl. 14, figs. 40, 41, 1885.

B. range, 662 to 1917 fath. Most common from 900 to 1500 fath. Taken at 42 stations between N. lat. 41° 28′ and 37° 50′. Found also off the European coasts.

This genus is found at great depths in all the oceans. About 10 species are known.

Family ASTROPECTINIDÆ (Gray, 1840) emended.

ASTROPECTEN AMERICANUS Verrill.

Archaster Americanus Verrill, this Journal, vol. xx, p. 402, 1880.

Astropecten Americanus Verrill, Proc. Nat. Mus., vol. xvii, p. 255, 1894.

B. range, 43 to 296 fath. Most common from 63 to 150 fath. Taken by the U. S. Fish Comm. at 72 stations, from N. lat. 40° 23′ to 35° 38′. Allied species occur in all seas. *A. mesacutus* Sl., from the East Atlantic, seems to be the nearest related.

ASTROPECTEN VESTITUS Lütken.

Asterias vestita Say, Journ. Philad. Acad., vol. v, p. 143, 1825.

B. range, shallow water. Cape May (Say.). It is not uncommon farther south.

ASTROPECTEN ARTICULATUS Müll. and Trosch.

Asterias articulatus Say, Journ. Acad. Nat. Sci., Philad., vol. v, p. 141, 1825.

Astropecten articulatus Müll. and Trosch., Syst. Aster., p. 72, 1842; A. Agassiz, North American Starfishes, p. 114, pl. 19, figs. 1–8, 1877.

B. range, 4 to 43 fath. Taken at several stations off Cape Hatteras, and as far north as 35° 42′. Common farther south, in shallow water. West Indies.

LEPTOPTYCHASTER ARCTICUS Sladen.

Astropecten arcticus M. Sars, Reise Lofoden og Finmarken, Nyt. Mag. Nat., vol. vi, p. 161, 1851.

Archaster arcticus Verrill, this Journal, vol. xvi, p. 214, 1878.

Leptoptychaster arcticus, var. *elongatus*, Sladen, op. cit., p. 189.

Leptoptychaster arcticus Sladen, op. cit., p. 189; Verrill, Proc. Nat. Mus., vol. xvii, p. 255, 1894.

B. range, 50 to 965 fath. (1350 fath., Sladen). Most common in 85 to 200 fathoms; rare at greater depths. Taken at 23 stations, from N. lat. 45° 14′ to 38° 29′. It always occurred in small numbers. It is also found off the northern coasts of Europe. Two closely allied species are found in the Antarctic Ocean.

PSILASTER FLORÆ Verrill.

Archaster Floræ Verrill, this Journal, vol. xvi, p. 372, 1878; Expl. by the Albatross, in Ann. Rep. U. S. Com'r Fish and Fisheries, vol. xi, p. 542, pl. 13, fig. 36, 1885.

Psilaster Floræ Verrill, Proc. Nat. Mus., vol. xvii, p. 255, 1894.

B. range, 53 to 452 fath.; in one instance in 984 fath. (perhaps an error). Most common in 150 to 350 fath. Taken by the U. S. Fish Comm. at 70 stations between N. lat. 44° 47′ and 38° 27′. It has also been sent by the Gloucester fishermen, from several localities on the various Banks off Nova Scotia, in 60 to 230 fath.

This is closely allied to *P. Andromeda* of Northern Europe (40 to 690 fath.), and may eventually prove to be identical. Several allied species are known from the East Atlantic, Indian, and Pacific Oceans.

BATHYBIASTER ROBUSTUS Verrill.

Archaster robustus Verrill, this Journal, xxix, p. 383, 1885; Expl. by the Albatross in 1883. pp. 519, 541, 1885.

Phoxaster pumilus Sladen, op. cit., p. 236, pl. 15, figs. 3–6; pl. 40, figs. 7–11, 1889 (Young).

Bathybiaster robustus Verrill, Proc. Nat. Mus., vol. xvii, p. 256, 1894.

B. range, 705 to 1467 fath.; 1240 to 1700 (Sladen). Taken at 33 stations between N. lat. 41° 28′ and 35° 10′.

This is closely allied to *B. pallidus* from off the Scandinavian coast. An allied species occurs in the South Pacific and Antarctic Oceans, in 75 to 245 fath.

LUIDIA CLATHRATA (Say).

Asterias clathrata Say, Journ. Acad. Nat. Sci., Philad., vol. v, p. 142, 1825.

Luidia clathrata Lutken, Vidensk. Meddel., p. 37, 1859; A. Agassiz, North American Starfishes, p. 117, pl. 20, 1877; Verrill, this Journ., vol. iii, p. 438, 1872.

B. range, 1 to 48 fath. Most common in less than 20 fath. Taken at 18 stations, from N. lat. 37° 31′ to 35° 12′. Common in shallow water southward to Florida, West Indies, and Rio Janeiro, Brazil. Rare north of Cape Hatteras.

Allied species occur in all tropical seas.

LUIDIA ELEGANS Perrier.

Luidia elegans Perrier, Arch. Zool. Expér., p. 256, 1876; Verrill, this Journal, vol. xx, p. 403, 1880; Expl. by the Albatross, in Ann. Rep. U. S. Fish Comm., vol. xi, p. 543, pl. 13, figs. 39, 39^a, 1885.

B. range, 53 to 146 fath. Most common from 60 to 120 fath. Taken at 34 stations between N. lat. 40° 16′ and 35° 10′ 40″. Seldom obtained entire. Appears to extend to the West Indies.

Family GONIASTERIDÆ or PENTAGONASTERIDÆ.

PENTAGONASTER EXIMIUS Verrill.

Proc. Nat. Mus., vol. xvii, p. 264, 1894.

B. range, 80 to 122 fath., rare. Taken at two stations, N. lat. 44° 27′ 30″ and 42° 25′ 40″.

Closely allied to the following species.

PENTAGONASTER GRANULARIS Perrier.

Asterias granularis Retzius, K. Vet. Akad. Nya. Handl., vol. iv, p. 238, 1783.
Astrogonium granulare Müller and Trosch., Syst., p. 57, 1842; Verrill, Expl. by the Albatross in 1883, p. 542, pl. 18, figs. 48, 48^a, 1885.
Goniaster granularis Lütken, Vidensk. Medd. nat Foren., p. 146, 1865.
Pentagonaster granularis Perrier, Revis. Stell. du Mus., p. 224, 1876; Sladen, Voy. Challenger, vol. xxx, p. 268, 1889.

B. range, 72 to 471 fath. Rarely taken below 150 fathoms. Taken at several stations between N. lat. 44° 28′ 30″ and 41° 47′. Also taken by the Gloucester fishermen on the Banks off Nova Scotia. Occurs off the coasts of Norway and Great Britain.

PENTAGONASTER SIMPLEX, sp. nov.

B. range, 640 fath. Off Martha's Vineyard.

Greater radius, 20^{mm}; lesser radius, 13^{mm}; thickness at margin, 45^{mm}. Form pentagonal, with the sides slightly incurved; rays short-triangular, terminated by a somewhat prominent, rounded apical plate, situated on the upper side. Usually twelve superior and fourteen inferior marginal plates; these are uniformly covered with rather fine, crowded, angular granules, except on the middle of each plate, where there is a smooth, rounded area above and below. Abactinal plates very regular in form and arrangement; those of the radial areas are hexagonal, with the median row distinct and bordered by about three parallel rows on each side. Those of the triangular interradial areas are rhombic, somewhat smaller and less regular; all the plates are covered with numerous small, crowded, angular granules, often thirty to forty on the larger plates. Actinal plates mostly rhombic, flat, regularly arranged, and covered with fine, rounded granules which are not closely crowded. Adambulacral spines decidedly longer and larger than those adjacent. Each adambulacral plate bears a single marginal row of three or four somewhat elongated, blunt or clavate spines, and outside of these a somewhat stellate group of seven to nine shorter, thicker, blunt spinules, one of which usually occupies the center of the group. Jaw-spines numerous, short, thick, angular, similar to the larger adambulacral spines.

A single specimen (No. 13,363) was taken at station 1124.

PENTAGONASTER PLANUS, sp. nov.

B. range, 156 fath. N. lat. 39° 53′, off Martha's Vineyard.

Greater radius, 50^{mm}; lesser radius, 35^{mm}; thickness at margin, 8^{mm}. Form pentagonal, with the sides slightly incurved; rays very short, triangular, and obtuse, with the tip turned up and terminated by a small, conical plate. Marginal plates large, median ones nearly square, usually fourteen in the dorsal series and sixteen in the ventral series, all uniformly covered with rather coarse, rounded granules, standing a little apart, the margins of the plates with a regular row of granules of about the same size. Abactinal plates flat, mostly rather large, rounded or hexagonal, with some small, rounded ones interspersed; all are uniformly covered with rather coarse, spaced granules, like those of the marginal plates, so that the whole of the upper surface has a remarkably uniform granular coating. The larger plates often bear fifty to seventy granules; the small intermediate plates frequently carry but nine to twelve. Actinal plates large, rhombic, uniformly covered with coarse, angular granules, distinctly larger than those of the marginal plates. Adambulacral plates numerous and crowded, similar to the actinal plates, but slightly larger and longer, the length increasing somewhat toward the ends of the rays. Each plate usually bears three or four marginal spines in a simple row; outside of these there are usually nine to twelve thicker, obtuse, angular spines, forming four irregular, longitudinal rows, the outer ones smallest. Jaws covered with numerous blunt, angular spines, similar to the actinal spines, but larger. One specimen (No. 13,362) was taken at station 1098.

ODONTASTER HISPIDUS Verrill.
Odontaster hispidus Verrill, this Journal, vol. xx, p. 402, 1880; Proc. Nat. Mus., vol. xvii, p. 263, 1894.

B. range, 43 to 1230 fath. Taken at many stations between N. lat. 44′ 28° 30″ and 39° 53′.

No very closely allied species is known.

The genus *Gnathaster* (Sladen, 1889) appears to be identical with this. Among the recorded species are the following:

Odontaster pilulatus (*Gnathaster* Sl.) Magellan St.
O. elongatus (*Gnathaster* Sl.) Southern Ocean.
O. singularis (*Astrogonium* M. and Tr.) W. S. America.
O. miliaris (*Astrogonium* Gray) N. Zealand.
O. paxillosum (*Astrogonium* Gray) Australia.
O. dilatatus (*Pentagonaster* Per.) N. Zealand.
O. meridionalis (*Astrogonium* Smith) Southern Ocean.
O. Grayi (*Calliderma* Bell) Magellan Str.

ISASTER BAIRDII Verrill.
Archaster Bairdii Verrill, this Journal, vol. xxiii, p. 139, 1882.
Isaster Bairdii Verrill, Proc. Nat. Mus., vol. xvii, p. 258, 1894.

B. range, 351 to 721 fath. Taken at 6 stations between N. lat. 42° 55′ 30″ and 39° 47′ 07″.

No other species of this genus is known.

PARAGONASTER FORMOSUS Verrill.

Archaster formosus Verrill, this Journal, vol. xxviii, p. 383, 1884; Expl. by the Albatross in 1883, pp. 519, 543.

? *Paragonaster cylindratus* Sladen, op. cit., p. 314, pl. 51, figs. 3, 4; pl. 53, figs. 3, 4, 1889.

Paragonaster formosus Verrill, Proc. Nat. Mus., vol. xvii, p. 257, 1894.

B. range 1396 to 2021 fath. Taken at 15 stations between N. lat. 41° 07′ and 37°.

The type of *P. cylindratus* Sl. was from south of Cape Verde Islands, in 1850 fath.

A West Indian species (*P. subtilis* = *Goniopecten subtilis* Perrier), appears to be closely allied to ours. It was taken in 955 fathoms by the "Blake" Exp.

HIPPASTERIA PHRYGIANA Ag.

Asterias phrygiana Parelius, K. Norske Vid. Selskabs Skrifter, vol. iv, p. 425, pl. 14, fig. 2, 1770: Gmelin, Linné, p. 3163, 1788.

Asterias equestris Pennant, Brit. Zool., vol. iv, p. 130, 1776; Lamarck, Anim. sans vert., vol. iii, p. 242, 1815.

Hippasteria plana Gray, Ann. and Mag., vol. vi, p. 279, 1841; Synopsis Starf. Brit. Mus., p. 9; Perrier, Arch. de Zool., Exper. vol. v, p. 86, 1876; Sladen, Voy. Challenger, vol. xxx, p. 341.

Goniaster equestris Forbes, British Starfishes, p. 125, fig., 1841.

Astrogonium phrygianum Müll. and Trosch, Syst. Asteriden, p. 52, 1842; Lutken, Vidensk. Meddel., pp. 70, 105, 1857; Sars Norges Echinod., p. 44.

Goniaster phrygianus Norman, Ann. and Mag. Nat. Hist., vol. xv, p. 123, 1865; Verrill, Proc. Boston Soc Nat. Hist., vol. x, p. 356, 1866.

Hippasteria phrygiana Agassiz. Sea Side Studies, p. 113; Verrill, Check List., p. 14, 1879; Expl. by the Albatross, in Ann. Rep. U. S. Fish Comm., vol. xi, p. 542, pl. 17, fig. 47, 1885.

B. range, 20 to 224 fath.; in one instance, off George's Bank, in 471 fath. Most common from 50 to 150 fath. Newfoundland to Cape Cod, off Chatham Light. Taken at numerous stations in Massachusetts Bay, off Cape Ann, Gulf of Maine, Bay of Fundy, and off Nova Scotia, on hard bottoms. It occurs also on the European coasts and in the Arctic Ocean.

No other species of the genus is known.*

Family GYMNASTERIDÆ.

PORANIA (CHONDRASTER) GRANDIS Verrill.

This Journal, vol. xvi, p. 371, 1878; Expl. by the Albatross in 1883, in Ann. Rep. Fish Comm., vol. xi, p. 542 (*pars.*), pl. 15, fig. 44, pl. 16, fig. 44^a, 1885 (not figs. 45, 45^a).

B. range, 220 to 538 fath. East of George's Bank and off Martha's Vineyard, N. lat. 39° 53′ 30″.

This large species is not a typical *Porania*. In several of my former articles it was not distinguished from the following

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* Perrier, Sladen, and others have resurrected one of Linck's ante-binomial names (*planus*) for this species. This proceeding appears to be entirely unwarranted and unnecessary.

species, which is similar in size and general appearance. The present form has a thinner margin with the plates poorly developed. The marginal spines are more or less abortive. The long, slender dorsal papulæ are confined to two petaloid bands on each ray, leaving the median area bare. There are two adambulacral spines on the inner edge of each plate, side by side, and an outer transverse series of two or three. The integument is firm, thick, and glabrous, and when dried it shows numerous microscopic spicules on the surface. The radial grooves are conspicuous and numerous; one runs from between all the adambulacral plates and marginal plates. The rudimentary abactinal and actinal plates are much less developed than in the next species.

The above characters warrant the establishment of a new subgenus, or perhaps a genus, for this species. I propose to name it *Chondraster*.

PORANIA INSIGNIS, sp. nov.

Porania grandis (pars) Verrill Explorations made by the Albatross in 1883, p. 542, pl. 15, figs. 45, 45^a, 1885.

B. range, 65 to 373 fath. Most common in 100 to 250 fath. Chiefly in the warm area. Taken at numerous stations, from N. lat. 41° 28′ 30″ to 36° 38′ 30″. It has, also, been taken several times by the Gloucester fishermen, on the Banks.

A large pentagonal species with convex disk and short rays. Radii of an average specimen 70^{mm} and 34^{mm}. Dorsal surface smooth, with a tough, leathery integument, without visible plates or spines, except a cluster of small spinules around the "anal" pore. Papulæ conspicuous, elongated; they are most abundant along the sides of the rays, but do not form very definite bands, though the median line of the rays is mostly bare; a single or double row of papulæ extends along the margins, between the upper and lower marginal plates, which are somewhat prominent, but covered by thick cuticle. The lower plates carry a row of three or four sharp, conical, skin-covered spinules, which form the sharp edge of the disk; distally the number decreases to two, and finally to one. Each adambulacral plate bears a transverse row of three or two stout, short, divergent spines, in irregular alternation; they are somewhat webbed at base; the outer one is stoutest and often gouge-shaped or even double at the blunt tip. Each jaw bears two oral, partly webbed, skin-covered, short spines, and two or three on each side. The actinal radial furrows are strongly marked; they run from between all the marginal plates, but only between alternate adambulacral plates.

Young specimens of this species, when 15 to 20^{mm} in diameter, have more or less numerous, small, scattered, simple spines, both on the dorsal and ventral plates; these plates are distinctly visible, beneath the cuticle, when dried, and the upper marginal plates are relatively larger than in the adult. The papulæ are few and scattered. In this stage, it agrees in all respects with the genus *Marginaster* Perrier and *Lasiaster* Sladen, both of which are probably the young of *Porania* or *Poraniomorpha.*

Four allied species of this genus are known from the Southern Ocean; of these *P. glabra* Sl., from off Kerguelen I., in 30 to 127 fath., seems nearest to our species; *P. pulvillus* (Müll.) Norm., of northern Europe, is also allied to this.

PORANIOMORPHA SPINULOSA Verrill.
Porania spinulosa Verrill, Proc. U. S. Nat. Mus., vol. 2, p. 202. 1877.
Poraniomorpha spinulosa Verrill, Expl. by the Albatross, p. 542, 1885.

B. range, 80 to 640 fath. Rare below 400 fath. Most common in 150 to 250 fath. In one instance, off Cape Hatteras, taken in 48 fath. Off Cape Cod in 80 and 118 fath. Taken at 42 stations from 41° 80′ 30″ to 35° 12′ 30″, mostly in the warm area.

Var. *rudis:* A variety of this species has small divergent groups of longer and somewhat enlarged spinules on more or less of the actinal interradial plates, while the rest of the plates have the normal small spinules.

Var. *inermis:* This variety lacks the marginal spines on the infero-marginal plates, except near the ends of the rays.

There is considerable variation, also, in the number of spines on the jaw-plates.

A very large specimen, with the radii 80^{mm} and 46^{mm}, taken in 90 fathoms, off Martha's Vineyard, has thick, tumid margins, with the infero-marginal plates forced downward to the under side; many of these plates along the disk are destitute of marginal spines, or have them in a more or less aborted form; toward the tips of the rays the marginal spines become normal, but stouter than in smaller specimens.

This is closely allied to *P. rosea* Duben and Koren, of northern Europe.

PORANIOMORPHA BOREALIS Verrill.
Asterina borealis Verrill, this Journal, vol. xvi, p. 213, 1878; Verrill, Expl. made by the Albatross in 1883, in Ann. Report U. S. Fish Comm., vol. xi, pl. 18, figs. 46, 46^a, 1885.
Porania borealis Verrill, Check List, 1879; Ann. Report U. S. Com'r. of Fish and Fisheries, for 1882, vol. x, p. 659, 1884.

B. range, 64 to 225 fath., rare. Belongs to the cold area. Taken at 4 stations, from 44° 26′ to 39° 49′ 30″. Also in the Gulf of Maine, in 110 fathoms, 1874. Fishing Banks, N. lat. 45° 25′, W. long. 57° 10′, in 170 fathoms.

The specimen from the Banks is much larger than any of the others. Radii 35^{mm} and 23^{mm}. The dorsal papular pores are very numerous and conspicuous over most of the dorsal surface, in large clusters. The ventral plates are nearly uniformly covered with slender needle-shaped spinules of nearly uniform size, no groups of larger spinules being present on them.

The spinules, above and below, as well as the adambulacral spines, are decidedly longer and more slender than in *P. spinulosa.* The upper marginal plates are conspicuous, swollen, elongated vertically, but have no special spines.

A row of papulæ, between the upper and lower plates.

RHEGASTER ABYSSICOLA, sp. nov.

B. range, 2045 fathoms, N. lat. 37°, W. long. 71° 54′.

Greater radius, 35^{mm}; lesser 14^{mm}; elevation at center, 17^{mm}. Form five-rayed, stellate, with the disk flat beneath, tumid above, and indented by a distinct groove at the interradial angles. Rays tumid at base, with the distal part roundish, slender, and uniformly tapered. Abactinal plates rather large, concealed by the cuticle, and everywhere bearing small, blunt, well-separated, simple spinules, which are more or less covered by the integument. Papulæ small, scattered singly over most of the dorsal surface. The lower marginal plates are small, somewhat prominent, and bear an irregular group of six or eight small, sharp spinules, which form a distinct border along the under edge of the disk and basal half of the rays, but disappear gradually before reaching the tips of the rays. Actinal plates entirely concealed by the integument; each one bears a divergent group of four to six or more small, sharp, rather stout spinules, which are unequal in size. Each adambulacral plate usually bears an obliquely transverse row of about five somewhat long, subacute spinules, of which the middle ones are a little longer than the others, and in some cases the row is double; the innermost is borne upon the inner angle of the plate, which projects somewhat into the furrow. The ambulacral feet are large, biserial, and furnished with well-developed terminal suckers. The inner end of each jaw bears four rather stout, sharp spines, similar to those of the adambulacral plates.

A single specimen (No. 8140) was taken at station 2226, off Delaware Bay.

Two allied species (*R. Murrayi* Sl. and *R. tumidus* (Stuxb.) Sl. are found at moderate depths on the northern European coast; the last also occurs in the Arctic Ocean.

Family ASTERINIDÆ.

ASTERINA PYGMÆA Verrill.
This Journal, vol. xvi, p. 372, 1878.

B. range, 52 to 92 fath., Gulf of Maine. Allied species are found in nearly all seas.

TREMASTER MIRABILIS Verrill.
Proc. U. S. Nat. Mus., vol. ii, p. 201, 1879; Expl. by the Albatross in 1883, pl. 18, fig. 51, 1885.

B. range, 150 to 250 fath., rare. Known only from the Banks off Nova Scotia and Newfoundland, from N. lat. 47° 6′ to near George's Bank. All the specimens have been received from the Gloucester fishermen.

No other species of this remarkable genus is known.

[To be continued.]

ART. XIV.—*Lower Cambrian Rocks in Eastern California;* By CHAS. D. WALCOTT.

[Read before Geol. Soc. America, Baltimore meeting, Dec. 27, 1894.]

THE only Lower Cambrian rocks of California known to me occur in the White Mountain range of Inyo County, east of Owen's Valley, with the single exception of one small mass west of Big Pine, which is in the foothills of the Sierra Nevada. That portion of the White Mountain range lying near the Waucobi Canyon is commonly referred to as the "White Mountain range," while the portion to the south is called the "Inyo range." Prof. J. D. Whitney refers to the ranges (Inyo and White Mountain), stating that little is known of the geology except that, from Bend City for twenty-five miles north, their western base and slope seem to be made of slate and other stratified rocks generally dipping to the southwest and often much contorted. These slates are said to alternate with beds of limestone. In these rocks a single fossil was discovered, opposite Camp Independence, by Dr. Horn. This species was considered by Mr. Gabb as identical with a Triassic species which had been found in the Upper Trias of the Alps. From this Professor Whitney identified the strata along the western flanks of the Inyo and White Mountains with the rocks of Washoe, which were referred to the Trias.*

On a map issued by the California State Mining Bureau in 1891,† eight areas of limestone are indicated on the line of the White Mountain and Inyo ranges. Some of these are described in the report of the State Mineralogist for 1888.‡ In his report

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* Geol. Surv. California; Geology, vol. i, 1865, p. 459.

† Preliminary Mineralogical and Geological Map of the State of California, 1891.

‡ California State Mining Bureau; Eighth Ann. Rep. State Mineralogist for 1888.

on Inyo County Mr. W. A. Goodyear, who was an assistant in the State Survey under Prof. J. D. Whitney, speaks of the Inyo and White Mountain ranges as a part of the great Paleozoic formation which occupies so extensive an area in the Great Basin. He also describes,* in the form of an itinerary, a geological exploration of parts of the range, noting the occurrence of various stratified rocks and granites.

During the summer of 1894, accompanied by Mr. F. B. Weeks, I crossed the range over the toll-road leading from Big Pine to Piper's ranch, in Fish Lake Valley, and penetrated into it from the western side in Waucobi, Black and Silver canyons.

The ascending section exposed in the ridge on the north side of Black Canyon is as follows:

1. Gray and yellowish, arenaceous limestone, occurring in low hills above the Quaternary .... 200 ft.
2. Massive, bedded, compact, fine-grained, often saccharoidal, light-gray, siliceous and arenaceous limestone (strike N. 10° W. mag., dip 20° E.).

   At 100 feet from base of this division a dike of basalt 40 feet in thickness cuts through and displaces the limestone in the vicinity of the dike, so as to give it a dip of from 70° to 80° E. Above the dike the dip of 20° is very quickly resumed.

   At 160 feet from the base a band of white limestone occurs, which contains numerous small concretions of limestone.

   At 230 feet above the dike occurs a band of shaly limestone, which has buff-colored partings; and irregular, buff-colored, sandy laminations occur in thin layers in the thick-bedded limestone.

No. 2 may be subdivided as follows:

a. Light-gray and white limestone	500 ft.
b. Buff and gray, more arenaceous limestone, with a band of cherty limestone 20–25 feet thick at 125 feet from its base	170 ft.
c. Gray, arenaceous limestone, cherty at top	115 ft.
d. Shaly and thick-bedded, sandy limestone, cross-bedded in places, with yellowish-buff layers, also with two bands of brown, thick-bedded and shaly quartzite	145 ft.
e. Massive, bedded, coarse, arenaceous, gray limestone, passing into buff-colored and cherty beds above	85 ft.
f. Buff-colored, shaly limestone	5 ft.
g. Bluish-gray, banded limestone	30 ft.

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* Loc. cit., p. 290.

h. Gray, arenaceous limestone, with bands of buff-colored, mostly thick-bedded limestone	70 ft.	
i. Thick-bedded, bluish-gray limestone	10 ft.	
j. Brownish and buff-colored, calcareous sandstone, with inclosed brecciated, thin-bedded brown sandstone	5 ft.	
k. Dark, banded quartzite	30 ft.	
l. Massive, bedded, gray, arenaceous limestone	225 ft.	
Total of No. 2		1,525 ft.
3. Dark, irregular, thin-bedded, siliceous slates, with interbedded, dark, quartzitic sandstone (dip 25–30 E. mag., strike N. and S.)		635 ft.

The section is terminated at this point by a fault line.

On the north side of Silver Canyon, No. 3 is well exposed, and is estimated to have a thickness of 2,000 feet. Above this a series of limestones and calcareous and siliceous shales occurs, and some interbedded, dark, quartzitic sandstones, that extend upward 1,000 feet. Near the base a massive, bedded limestone 100 feet in thickness occurs, in which great quantities of Lower Cambrian corals (*Archæocyathinæ*) occur. This series is capped by about 200 feet of compact, thin-bedded, arenaceous argillite, with interbedded layers of dark-brown, fine-grained quartzite.

The entire section, briefly summarized from summit downward, is as follows:

4. Upper arenaceous beds	200 ft.
3. Alternating limestones and shales	1,000 ft.
2. Siliceous slates and quartzites	2,000 ft.
1. Siliceous limestones	1,700 ft.
Total	4,900 ft.

In round numbers the section exposed in the White Mountain range, between White Mountain peak and Waucobi Canyon, is 5,000 feet in thickness.

No fossils were found in the lower limestone. Numerous annelid trails occur in the lower siliceous series, and in the slaty portion near the summit heads of Olenellus were found. In places the lower portion of the upper limestone series is almost a solid bed of different forms of the *Archæocyathinæ*. *Ethmophyllum whitneii* Meek is very abundant, and the genera *Protopharetra*, *Coscinocyathus*, and probably *Archæocyathus* occur. Ethmophyllum ranges throughout the limestone series into the base of the shales in Tollgate Canyon, where it is associated with Cystidean plates and fragments of Olenellus. On the north side of Silver Canyon the Archæocyathinæ are so abundant in the limestone that it may practically be called a Lower Cambrian coral reef. This reef was traced for nearly thirty miles, and the same types are also known to occur in the Silver Peak range, about twenty-five miles to the eastward.

So far as known to me, this is the oldest of the Cambrian faunas known in the western portion of the United States. Just what its relations to the Olenellus fauna of central Nevada and British Columbia are I am unable at present to state, except that I believe it to be older than the Olenellus fauna of central Nevada.

It is not impossible that a fauna will be found in the lower limestone, but in the hasty reconnoissance in which I was engaged, only a portion of one day was given to the examination and measurement of the section. I hope in the future to extend the study of the White Mountain range, as Mr. Fairbanks has written me that he has discovered *Fusilina cylindrica* in the southern end of the range, east of Keeler, which is about fifty miles south of Tollgate Canyon. If the section is unbroken, the Middle and Upper Cambrian and Ordovician faunas should be found before reaching the Carboniferous horizon, discovered by Mr. Fairbanks.

ART. XV.—*On the* PITHECANTHROPUS ERECTUS, *Dubois*,* *from Java;* by O. C. MARSH. (With Plate II.)

A RECENT discovery of great interest is recorded in the memoir here cited. In many respects, this discovery appears to be one of the most important since the Neanderthal skull was brought to light in 1857, and hence the main facts concerning it deserve early notice in this Journal. This memoir of forty pages contains a full description, with illustrations, of part of a skull, a molar tooth, and a femur, found in the later Tertiary strata of Java, and pertaining to a large anthropoid ape, which is believed to represent a new genus and family intermediate between the *Simiidæ* and *Hominidæ*. This would make it a veritable "missing link" between the higher apes and man, the discovery of which has so long been confidently predicted by many anthropologists.

The locality of these remains was near Trinil, in the precinct Ngawi of the Madiun province, in central Java. The three specimens, the tooth, the skull, and the femur, were

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* PITHECANTHROPUS ERECTUS. Eine menschenaehnliche Uebergangsform aus Java. Von Eug. Dubois, Militairarzt der niederlaendisch-indischen Armee. Mit zwei Tafeln und drei in den text gedruckten Figuren. 4to, Batavia, 1894.

found at different times, in the same horizon, and all imbedded in the same volcanic tufa. The tooth was found first, in September, 1891, in the left bank of the river Bengawan, about a meter below the water level of the river during the dry season, and twelve or fifteen meters below the plain in which the river had cut its bed. A month later, the skull was discovered, only a meter distant from the place where the tooth lay, and both apparently pertained to the same individual. In August, 1892, the left femur also was found, about fifteen meters distant from the locality where the other specimens were imbedded. Subsequent researches in the vicinity, for additional remains, were unsuccessful.

The fossils thus secured have been carefully investigated by Dr. Dubois, who regards them as representing a distinct species and genus,* and also a new family, which he names the *Pithecanthropidæ*, and distinguishes mainly by the following characters:

Brain cavity absolutely larger, and, in proportion to the size of the body, much more capacious than in the *Simiidæ*, yet less so than in the *Hominidæ*. Capacity of the skull about two-thirds the average of that of man. Inclination of the nuchal surface of the occiput considerably greater than in the *Simiidæ*. Dentition, although somewhat specialized, still of the simian type. Femur equal in its dimensions to that of man, and like that adapted for walking in an upright position.

Of this skull, the upper portion alone is preserved, the line of fracture extending from the glabella backward irregularly to the occiput, which it divides somewhat below the upper nuchal line. The cranium seen from above is an elongated oval in outline, dolichocephalic; and is distinguished from that of other anthropoid apes by its large size and its higher arching in the coronal region, as shown below in figure 2. The greatest length from the glabella to the posterior projection of the occiput is 185^{mm}. The greatest breadth is 130^{mm}, and the smallest, behind the orbits, is 90^{mm}. The cranium in its original condition must have been of somewhat larger dimensions. The upper surface of the skull is smooth, and the sutures all appear to be obliterated.

This dolichocephalic skull, with an index of 70°, is readily distinguished from that of the Orang-utan, which is decidedly brachycephalic. The absence of the characteristic cranial crests will separate it from the skull of the adult Gorilla. In

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* The generic name used (*Pithecanthropus*) has already been employed by Haeckel, in 1868, for a hypothetical form, which walked erect, and had a greater intellectual development than the anthropoid apes, but did not possess the faculty of speech.

its smooth upper surface and general form, it shows a resemblance to the skull of the Chimpanzee, and still closer to that of the Gibbons (*Hylobates*).

A figure of the present specimen and the skull of a Gibbon for comparison are shown in figure 1, Plate II. These figures and those that follow are reproduced directly, but not all successfully, from illustrations in Dr. Dubois's memoir.

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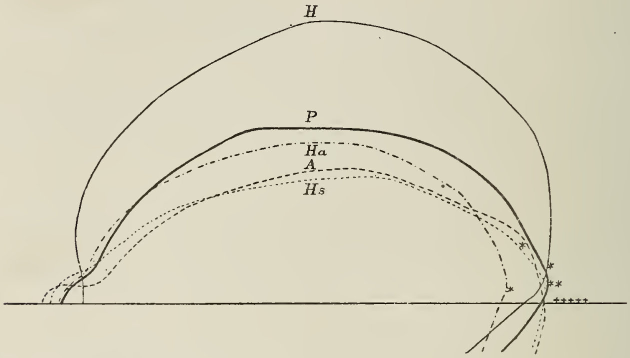


FIGURE 2.—Longitudinal outlines of crania.
H. European man; P. *Pithecanthropus;* Ha. *Hylobates agilis;*
A. Chimpanzee; Hs. *Hylobates syndactylus.* (After Dubois.)

The tooth, the first specimen found, is the last upper molar of the right side, and is in good preservation. It indicates a fully adult, but not very old, animal. The crown is subtriangular in form, with the corners rounded, and the narrowest portion behind. The antero-posterior diameter of the crown is $11{\cdot}3^{\mathrm{mm}}$, and the transverse diameter $15{\cdot}3^{\mathrm{mm}}$. The grinding surface of the crown is concave, and much less rugose than in existing anthropoid apes.

The femur, which is from the left side, is in fair preservation, although it was somewhat injured in removing it from the surrounding rock. It belonged to a fully adult individual. In form and dimensions, it resembles so strongly a human femur that only a careful comparison would distinguish one from the other. The bone is very long, its greatest length being 455^{mm}. The shaft is slender and nearly straight. The general form and proportions of this femur are shown in figure 3, Plate II, with a human femur for comparison.

These precious remains, the skull, tooth, and femur, are described by Dr. Dubois, with full details, and for these the anatomical reader will look to the memoir itself. The conclusions drawn by the author from these fossils are so comprehensive, that they will be carefully weighed by anthropologists of every nation. It is only justice to Dr. Dubois and his admirable memoir to say here, that he has proved to science the existence of a new prehistoric anthropoid form, not human indeed, but in size, brain power, and erect posture, much nearer man than any animal hitherto discovered, living or extinct.

The brief review here given of the main facts relating to this discovery, together with the figures reproduced from the memoir, will afford the reader some idea of the importance of this latest addition to the known allies of primæval man, if not to his direct ancestry. Whatever light future researches may throw upon the affinities of this new form that left its remains in the volcanic deposits of Java during later Tertiary time, there can be no doubt that the discovery itself is an event equal in interest to that of the Neanderthal skull.

The man of the Neander valley remained without honor, even in his own country, for more than a quarter of a century, and was still doubted and reviled when his kinsmen, the men of Spy, came to his defense, and a new chapter was added to the early history of the human race. The ape-man of Java comes to light at a more fortunate time, when zeal for exploration is so great that the discovery of additional remains may be expected at no distant day. That still other intermediate forms will eventually be brought to light no one familiar with the subject can doubt. Nearly twenty years ago, the writer of the present review placed on record his belief that such missing links existed, and should be looked for in the caves and later Tertiary of Africa, which he then regarded as the most promising field for exploration in the Old World. The first announcement, however, has come from the East, where large anthropoid apes also survive, and where their ancestors were doubtless entombed under circumstances favorable to early discovery. The tropical regions of both Asia and Africa still offer most inviting fields to ambitious explorers.

Yale University, New Haven, Conn., January 21, 1895.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

Chemical Abstracts.

1. *On a new mode of preparing Hydrogen phosphide.*—The supposition that phosphorus does not combine with hydrogen directly, founded on the early experiments of Fourcroy and Vanquelin, has been shown by Retgers to be erroneous. After he had established the great readiness with which arsenic unites with moderately heated hydrogen, he inferred that ordinary phosphorus would also combine with this gas, were it not for its low fusing point, 44°. He was led, therefore, to use red phosphorus, whose melting point is much higher. And he found that when dry hydrogen is passed over red phosphorus contained in a glass tube, at a gentle heat, direct combination readily takes place and the issuing gas inflames spontaneously in the air. Evidently the non-spontaneously-inflammable gaseous phosphide of hydrogen must contain a certain amount of spontaneously-inflammable liquid phosphide; and by conducting, the evolved product through a U-tube placed in a freezing mixture, this latter phosphide was obtained separately. In addition, the solid phosphide is also produced and is deposited as a yellow mass just beyond the heated portion of the tube. On removing the source of heat, the evolved gas soon ceases to take fire on contact with the air and is almost pure hydrogen. The author thinks this process much preferable to the older methods of preparing hydrogen phosphide, not only because of the ease with which it may be operated, but also because it affords an excellent example of the formation of the three hydrogen phosphides by direct synthesis.—*Zeitschr. anorg. Chem.*, vii, 265, September, 1894. G. F. B.

2. *On a Hydrate of Sodium Trioxide.*—By the action of ordinary alcohol upon sodium peroxide, Tafel has obtained a new substance of rather remarkable composition. When the alcohol is poured on the peroxide, a part of the latter enters into combination to form a strongly alkaline solution, while the rest, about equal to this in amount, changes its color from pale yellow to pure white and becomes a fine granular powder, totally unlike the peroxide in appearance. It is soluble in water, but with much less rise of temperature. While the peroxide is stable even at high temperatures evolving no oxygen below redness, the new substance evolves oxygen copiously on simple warming; and if heated rapidly in a test tube explodes violently with the production of flame. If the dry powder be touched with a heated rod, the escaping oxygen sets the particles into a rapid whirling motion, with a very considerable rise of temperature; the action extending throughout the entire mass, pure dry oxygen being continuously evolved. On heating still more strongly, the residue melts and evolves vapor of water, leaving ordinary sodium hydrate. On analysis it afforded

the composition $HNaO_2$, being formed according to the equation:

$$Na_2O_2 + C_2H_5OH = C_2H_5ONa + HNaO_2$$

The author regards the new substance as the hydrate of sodium trioxide, Na_2O_3; and therefore gives it a doubled formula, $H_2Na_2O_4$. In ice-cold water it dissolves unchanged, but at higher temperatures the solution slowly evolves oxygen. If alcohol be present, the evolution of gas increases and the solution deposits crystals of the hydrate of sodium peroxide $Na_2O_2(H_2O)_8$, discovered by Vernon Harcourt. By hydrogen chloride, it is converted into sodium chloride, hydrogen peroxide and oxygen gas. In preparing this new substance, the author finds 12 grams sodium peroxide and 200 c.c. of ice-cold absolute alcohol, convenient quantities to employ. After shaking them well together, the liquid is filtered off, and the white sandy product—separated from any undecomposed peroxide—is washed with cold alcohol and ether and placed in a desiccator.—*Ber. Berl. Chem. Ges.*, xxvii, 2297, September, 1894. G. F. B.

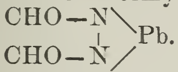
3. *On a pure white Stannic sulphide.*—A new form of tin disulphide has been prepared by SCHMIDT which is pure white in color and which is readily soluble in ammonium carbonate. To prepare it, metallic tin is dissolved in hydrochloric acid, and the stannous chloride is converted into stannic chloride by means of nitric acid; the excess of acid being removed by evaporation. After dilution, the tin sulphide is thrown down by hydrogen sulphide in the ordinary yellow form. It is washed, separated from traces of arsenic by solution in hydrogen chloride and reprecipitation, and digested with ammonium hydrate in excess for some days. The clear solution is neutralized with dilute sulphuric acid, when an almost pure white precipitate is obtained. On dissolving this in ammonium carbonate and neutralizing with sulphuric acid the precipitate is pure white. It is very bulky and is in a different state of hydration or of molecular aggregation from ordinary stannic sulphide. Upon drying it becomes amber-yellow and is no longer soluble in ammonium carbonate.—*Nature*, li, 85, November 1894. G. F. B.

4. *On the Properties of Liquid Ethane and Propane.*—The properties of the gaseous hydrocarbons ethane and propane in the liquefied condition have been studied by HAINLEN in Lothar Meyer's laboratory. The propane was obtained pure by the process of Köhnlein which consists in heating propyl iodide to 130° in a sealed tube with aluminum chloride. After twenty hours, the tube was allowed to cool and was afterwards placed in a freezing mixture; it could then be opened without danger and the gas be transferred to a gas-holder. It was condensed to a liquid in a U-tube surrounded with solid carbon dioxide, and then was distilled over into a special boiling point apparatus, which consisted of a glass tube closed at the lower end, having a side tube by which the gas entered, and provided at top with a stopper through which a thermometer and the exit tube passed. Solid carbon dioxide surrounded the upper half of this tube and a layer

of felt the lower half; the propane condensing above and collecting below. By removing the felt the liquid boiled, at first irregularly; but it finally became steady and the corrected temperature-reading was found to be −37° at 760^{mm}. The vapor pressures at different temperatures from −33° to +12·5° were determined by placing the liquid propane in one leg of a U-tube and air in the other; the two being separated by mercury and the pressure estimated from the compression of the air. From 12·5° to 102° the pressure was measured in a Cailletet apparatus. It was found that at −33°, the pressure was 1·8 atmospheres; at −19°, 2·7; at —15°, 3·1; at —11°, 3·6; at —5°, 4·1; at −2°, 4·8; at +1°, 5·1; at 5·5°, 5·9; at 12·5°, 7·1; at 22°, 9; at 53°, 17; at 85°, 35; and at 102°, 48·5 atmospheres. The critical temperature of propane is 102° and the corresponding critical pressure 48·5 atmospheres. Hence, propane may be sealed safely in glass tubes when surrounded with solid carbon dioxide, and thus preserved. It is colorless and much more viscous than liquid carbon dioxide. Its density at 0° is 0·536, at 6·2°, 0·524, at 11·5°, 0·520, and at 15·9°, 0·515. The examination of liquid ethane was more difficult owing to its lower boiling point. The gas was prepared from ethyl iodide and the zinc-copper couple of Gladstone and Tribe. Although a mixture of solid carbon dioxide and ether was found insufficient to liquefy ethane, liquid ethylene afforded the necessary low temperature and the ethane readily condensed to a liquid in the boiling point apparatus, where its temperature was determined by means of a thermo-element. When in regular ebullition, its boiling point was found to be −89·5° at 735^{mm} pressure. The determination of the pressure at different temperatures was effected in a modified Cailletet apparatus. The critical temperature was found to be 34·5° and the critical pressure 50 atmospheres. The meniscus became hazy at 32° and disappeared completely only at 40°. At 31°, the pressure is 11 atmospheres; at —20°, 14·5; at —11°, 18·3; at 0°, 23·3; at +15°, 32·3; and at +34·5°, 50. The density of liquid ethane at 0° is 0·446, and at 10·5°, 0·396.—*Liebig's Annalen*, cclxxxii, 229, October, 1894. G. F. B.

5. *On the Effect of Low Temperatures on Chloroform.*—An interesting example of the anomalous behavior of substances at very low temperatures has been observed by Raoul Pictet in the case of chloroform. In the preparation of this substance in the pure state by crystallization at −69° he made use of two copper refrigerators, of capacities of 2½ and 32 liters respectively. In the first series of experiments, the former only was used. About 2 kilograms of commercial chloroform in a glass cylinder was placed in the refrigerator and cooled to −120°, as indicated by an ether thermometer. The chloroform appeared turbid at −40° or −50°, and was filtered and again cooled. At −68·5°, the cooling ceased and very transparent crystals of chloroform appeared on the walls of the tube. Owing to the anæsthetic advantages of the pure chloroform thus obtained, attempts were

made to secure larger quantities, by operating in the larger vessel. But it was found that here the chloroform could be cooled to −81° without a trace of crystallization. Indeed chloroform crystals produced in the smaller vessel at −68·5°, dissolved at once when placed in the larger one at −81°. Finally the whole tube with crystals on its walls and liquid surrounding them, was immersed at −68·5° in the liquid chloroform at −81°. And although the thermometer fell from the higher to the lower temperature, the crystals actually dissolved before the observer's eyes. The author accounts for this result on certain theories of his own concerning radiation.—*Nature*, li, 20, November, 1894. See also *C. R.* cxix, 554, 1894. G. F. B.

6. *On Symmetrical Di-ethyl hydrazine.*—Although the discoverer of hydrazine, Curtius, succeeded in obtaining the symmetrical di-benzyl hydrazine and Fischer the unsymmetrical di-ethyl hydrazine, yet it is only recently that the symmetrical di-ethyl derivative of hydrazine $C_2H_5NH.NHC_2H_5$, or symmetrical hydrazo-ethane, has been isolated. This has been done by Harries in the laboratory of the University of Berlin, by a somewhat indirect though in practice quite simple series of reactions. As the first step, a remarkable hydrazine derivative was first prepared by acting on di-formyl hydrazine with sodium and then decomposing the product with lead acetate. In this derivative one hydrogen atom of each amidogen radical was replaced by the radical formyl and the other by lead; its constitution being  $\begin{array}{l}CHO-N\diagdown \\ \qquad\;\; | \quad Pb \\ CHO-N\diagup\end{array}$ When warmed in a sealed tube with ethyl iodide, together with sand and magnesia, the lead atom is replaced by two ethyl groups. The substance thus obtained, a volatile liquid, is then treated with fuming hydrogen chloride, which removes the formyl groups and produces the hydrochloride of symmetrical di-ethyl hydrazine; the free substance passing over at 85° on distillation with potassium hydrate. It is a liquid with an agreeable ethereal odor which reduces Fehling's solution with great energy and also silver nitrate even in the cold. Toward certain oxidizing agents, especially yellow mercuric oxide, it reacts violently, yielding mercury di-ethyl and azoethane $C_2H_5N{=}NC_2H_5$.—*Ber. Berl. Chem. Ges.*, xxvii, 2276, September, 1894. G. F. B.

7. *On Carbazide and Di-urea.*—In conjunction with Curtius, Heidenreich has produced two remarkable nitrogen compounds, one of which is carbazide or carbonyl nitride CON_6 and the other is di-urea $CO(NH.NH)_2CO$. The former is produced by the action of sodium nitrite on the hydrochloride of carbohydrazide. It is a colorless oil which explodes violently on being touched. The latter is obtained when the compound $\left\{\begin{array}{l}NH{\cdot}COOC_2H_5 \\ NH{\cdot}COOC_2H_5\end{array}\right.$ is heated to 100° with hydrazine hydrate in a sealed tube. It is crystalline and very stable and acts like a strong monobasic acid. —*Ber. Berl. Chem. Ges.*, xxvii, 2684, October, 1894. G. F. B.

8. *Phosphorescence at Low Temperatures.*—RAOUL, PICTET and ALLSCHUL exposed tubes containing sulphides of calcium, strontium and barium to a strong sunlight for definite periods of time and then placed them in liquid nitrous oxide, the temperature of which was estimated at −140°. After remaining in the freezing mixture for twelve minutes they were taken out and the renewal of the phosphorescent appearance was observed. At first no light could be observed, gradually, however, light appeared in the warmer portions of the tubes and extended to lower portions. After five minutes the tubes became as bright as they were before they were placed in the freezing mixture. To determine the limits of the phenomena the tubes were placed in alcohol cooled to −80°, as the tubes took the temperature of the alcohol the phosphorescence diminished and totally disappeared at −65°. The portions of the tube above the alcohol phosphoresced strongly. Before the colored phosphorescence, whether blue, green or orange, entirely disappeared, the tubes assumed a yellow color.—*Zeitschrift fur physikalishe Chemie*, vol. xv, part 3, p. 386. J. T.

9. *Telegraphing without wires.*—At a meeting of the Physical Society held in Berlin, Nov. 16, Professor Rubens gave an account of experiments on this subject. On the banks of the Wannsee near Potsdam two electrodes were sunk in the water at a distance of 500 meters from each other and a current of fifty-five accumulators was sent through them. From each of the boats connected by a cable an electrode was immersed in the water and a telephone inserted into the connection. When the current of the accumulators was broken an effect was perceived in the telephone at a distance of 4·5 kilometres. Small islands lying between the boats and the shore had no influence on the transmission of the signals.—*Nature*, Dec. 20, 1894. J. T.

10. *Calculation and measure of small coefficients of Self-induction.*—In the study of electric waves, the oscillators and resonators have, in general, small coefficients of self-induction and it becomes important to obtain an accurate value of these coefficients. Max Wien discusses the various mathematical formulæ for parallel wires, circles, rectangles, etc., and gives an experimental method also of determining the values of the coefficients. The student will find an interesting use of Maxwell's geometrical mean distance in the paper.—*Ann. der Physik und Chemie*, No. 13, 1894, pp. 928–947. J. T.

11. *Self-induction in iron wires.*—KLEMENCIC shows that in general the magnetic permeability is different in the circular and axial directions. Iron wires may be said to be magnetically double refracting. In soft iron the permeability is smaller around the axis than in the direction of the axis. Hard iron in the process of drawing, obtains a stronger permeability axially than in the circular direction. This is also the case with Bessemer steel.—*Ann. der Physik und Chemie*, No. 13, 1894, pp. 1053–1061.
J. T.

12. "*On the Photographic Spectrum of the Great Nebula in Orion*," by J. NORMAN LOCKYER, C.B., F.R.S. Abstract from the Proc. Roy. Soc., lvi., 285.—The paper consists of a description and discussion of photographs of the spectrum of the Orion Nebula, taken with the 30 inch reflector at Westgate-on-Sea in February, 1890, of which a preliminary account was communicated to the Royal Society at the time. Fifty-four lines are tabulated as belonging to the spectrum of the nebula, nine of them being due to hydrogen. The complete discussion has led to the following general conclusions:—

1. The spectrum of the nebula of Orion is a compound one consisting of hydrogen lines, low temperature metallic lines and flutings, and high temperature lines. The mean temperature, however, is relatively low.*

2. The spectrum is different in different parts of the nebula.

3. The spectrum bears a striking resemblance to that of the planetary nebulæ and bright line stars.

4. The suggestion, therefore, that these are bodies which must be closely associated in any valid scheme of classification, is confirmed.

5. Many of the lines which appear bright in the spectrum of the nebula appear dark in the spectra of stars of Groups II and III; and in the earlier stars of Group IV, and a gradual change from bright to dark lines has been found.

6. The view, therefore, that bright line stars occupy an intermediate position between nebulæ and stars of Groups II and III is greatly strengthened by these researches.

13. *Elementary Lessons in Electricity and Magnetism* by SILVANUS P. THOMPSON. New edition, revised throughout with additions, 628 pp. New York and London, 1895 (Macmillan & Co.)—The first edition of Thompson's Lessons, published in 1881, is well known as one of the best elementary books on Electricity and Magnetism ever presented and, with later reprints, it has had well deserved success. The present new edition contains all the good features of the earlier ones, while the large amount of new matter added makes it fresh and new throughout. Thus for example, to the subject of Electric waves a special chapter is devoted in which the work of Hertz and others is clearly, if briefly, presented. Many new illustrations are introduced; these representing the lines of force in various electric fields, e. g. in electrostatic induction, etc., will be particularly helpful to the student. The work in its present form deserves high commendation. A criticism might be offered by the teacher using the book to the arrangement of matter in some cases, but there may be room here for some difference of opinion.

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* Roy. Soc. Proc., vol. xliii, p. 152, 1887.

II. GEOLOGY AND MINERALOGY.

1. *Note on the Florida Reef;* by A. AGASSIZ. (Letter to J. D. Dana dated Tampa Bay, Florida, Dec. 27, 1894)—You will be interested to hear that I have just returned from a ten days' trip to the Florida reefs, which I was anxious to examine again, in the light of the experience gained by my visit to the Bahamas and Bermudas; I think I shall be obliged materially to change my ideas of the mode of formation of the Keys, and to give up the Marquesas as a true Atoll. After having seen at the Bermudas the mode of formation of the Sounds, I have become satisfied that the Marquesas are a Sound. But the Florida Sounds do not, I think, owe their origin to subsidence, but merely to the mechanical and solvent action of the sea. It is interesting to trace on the large scale charts of the Coast Survey the mode of formation of Key Biscayne Bay, composed of two sounds, followed by Barns Sound, and finally to the westward, by the Bay of Florida, itself only a series of disconnected sounds indicated by isolated keys and bars. The same thing is going on at the Pine Islands, Key West, Boca Chica, Boca Grande, Ballast Key, and is especially well seen in Key Largo, the Marquesas, to the west of the principal line of Keys being a remarkably well preserved sound of an elliptical shape. To my great surprise I found that Lower Matecumbe was edged by an elevated reef about 2 feet above high water mark! and this elevated reef I was able to trace all along the shores of the Keys to the east of Indian Key as far as Soldiers Key, off the central part of Key Biscayne. I examined this elevated reef also at Indian Key where its highest point is 8 feet above high water mark, at several points on Key Largo, Old Rhodes, Elliott Key, and, as the most easterly point, Soldiers Key. No trace of this elevated reef could be detected north of Cape Florida, Key Biscayne being entirely covered by siliceous sands, just as the beaches of limestone sands cover great tracts of the Keys to the westward and hide the underlying elevated reef. Shaler speaks of having traced this reef at Old Rhode's and having followed it to the Miami River as an elevated reef. I was quite surprised on examining a bluff about ten feet in height, extending eastward from Cocoanut Point toward the mouth of the Miami River, to find that it consisted of *æolian rocks* which have covered the elevated reef in many places. On the low shores these æolian rocks are honeycombed and pitted and might be readily mistaken for decomposed reef rocks; but they contain *no* corals. This looks as if the lower southern extremity of Florida, the Everglade tracts, was a huge sink into which sands had been blown forming low dunes which have little by little been eroded, and which former observers had mistaken in some localities for reef rock. The material for these dunes coming from the (now elevated) reef at a time when it was either a fringing or a barrier reef along the former coast line of Florida, all of which, back of the reef, has little by little been eroded

by the mechanical and solvent action of the sea leaving only an occasional outcrop of the elevated reef as observed by Agassiz and Shaler. The outer line of reef has also been elevated. For I think Tuomey was right in looking upon the outcropping reef rock of Sand Key as an elevated reef, if I remember rightly what he says; while Professor Agassiz mistook it, as well as the traces of the elevated reef he saw along some of the Keys, for a recent reef consisting of beach rock into which large masses of corals had been thrown by hurricanes. But in this I now think both he and I were mistaken. It was however a natural view to take of the formation of that reef for one who was not familiar with the peculiar aspect of the elevated reefs of Cuba. From the Pine Keys and the Islands to the West, and including the Marquesas, there is nothing exposed but beach rock, stratified at a slight angle seaward on the sea faces of these Keys; and even that is only casually exposed,—the greater part of the southern beaches of the Keys being covered by coralline and coral sand completely hiding the substratum. Behind this beach rock, æolian rocks stretch northward and have formed the Keys.

2. *The Geological Society of America. 7th Annual meeting.*—The winter meeting of the Geological Society was held in Baltimore Dec. 27, 28, and 29, 1894, in the geological rooms of the Johns Hopkins University. It was a representative gathering, geologists from all parts of the county east of the Rocky mountains attending; and the number of papers presented for reading (48) was so great that it was found necessary to make two sections in order to have them all read during the meeting. The Presidential address was delivered in Levering Hall at the evening session and was one of the most important contributions of the meeting. It was an account of his recent glacial studies in Northern Greenland, by Professsor T. C. Chamberlin as a member of the Peary expedition which went to Greenland during the last summer. The lecture was illustrated with some sixty stereopticon slides. "The feature that first impresses the observer on reaching the glaciers of the far North," said the lecturer, "is the verticality of their walls. Southern glaciers terminate in curving slopes. Next to the verticality of the edges, the most impressive feature is the pronounced stratification of the ice. It appears that stratification originated in the nucleus of deposition, emphasized by winds, rains and surface melting; that the extended stratification may have been intensified by the ordinary processes of consolidation; that shearings of the strata upon each other still further emphasized the stratification and developed new horizons under favorable conditions; that basal inequalities introduced new planes of stratification, accompanied by earthy debris, and that this process extended itself so far as even to form minute laminæ. A glacier is, essentially, made up of large, interlocking granules that have been developed from the snow crystals and pellets of the original snowfall. In the growth and the changes of these granules the secret of motion may lie. The glaciers drop

their material in front, and so sometimes build up their own pathway before them; thus, it is easy to understand how they may advance over sandy soils without abrading or disrupting them. All along the coast, from Southern Greenland to Inglefield Gulf, there are stretches of mountains that are very angular and irregular, and show no evidences of ever having been overridden by the ice. There are other stretches of the coast that seem to have been once covered by the ice, as their contours are subdued. It would appear, therefore, that the ice once pushed out to the coast line a portion of the western coast, and failed to do so along the other portion. The general conclusion is that no great extension of the Greenland ice has formerly taken place, and, hence, that the theory that the glaciation of our own region had its source in Greenland is without support."

G. F. WRIGHT, presented a paper on *Observations on the Glacial Phenomena of Newfoundland, Labrador and Southern Greenland* which is given in full in this Journal. H. F. REID discussed *Variations in velocity of glaciers* incident to varying amount of snow, pointing out vividly the effect of decrease in snow-fall in the withdrawal of the ice front with increasing rapidity, while increase of snow fall would result in advance of the glacier beginning only after considerable accumulations to the mass, and increasing in rate of advance as the increased snow fall continued. C. H. HITCHCOCK spoke on *Highland level gravels in northern New England*, which he interpreted as evidence of glacial lake beaches, 1000 and more feet in altitude in New Hampshire. WARREN UPHAM read papers on *Discrimination of glacial accumulations and invasion*, and *Climatic conditions shown by North American interglacial deposits.* Two papers based upon study of the altitudes of old beach lines and morainal drift in New York State were read by H. L. FAIRCHILD, of which the following abstracts are communicated by the author.

Glacial Lakes in western New York, Lake Newberry, the successor of Lake Warren, by H. L. FAIRCHILD.—If the reader will place before himself a map showing the hydrography of western and central New York, he will observe that the divide between the St. Lawrence and the Ohio-Susquehanna waters passes near the south ends of the so-called "Finger Lakes." The valleys of these present lakes with their northward drainage end abruptly in the high land south, the old valleys in that direction being choked with moraine drift. The same is true of several other valleys between the Tonawanda on the west and the Onondaga on the east, in which no water is now ponded.

All these north-south valleys were, during the retreat of the ice sheet, the site of extinct lakes, the water of which was held up by the barrier of ice on the north to the height of the col south, and so forced into southern drainage. Granting the capacity of glacial ice to serve as barrier to water, only a glance at the topography is sufficient to show the the necessity of such lakes. The positive evidence is found in the abandoned stream channels south of all the cols, the terraces and water inscriptions upon the valley sides north of the cols, and particularly the many large deltas formed by the lateral streams debouching into the extinct lakes at the high levels.

Eighteen of these extinct lakes are recognized from the topography, the Attica lake (the flooded Tonawanda valley) being the most western, and the Tully valley lake (the flooded Onondaga valley) the most eastern. Data have been gathered by personal observation and measurements of several of the more important lakes. The Ithaca lake was the largest and deepest, being at its maximum over 1100 feet deep, five to ten miles wide and about thirty miles long, overflowing by the Six Mile Creek and Catatonk valleys to the Susquehanna at Owego. The Watkins lake with its outlet by Horseheads to the Chemung at Elmira was in dimensions but little under the Ithaca lake. A fine delta at Watkins gives the maximum level of the water and several lower levels. The Dansville, the Conesus, the Naples, and the Hammondsport lakes have been carefully studied. Some of these have a complex but interesting history.

With the removal of the ice barrier by the melting and recession of the ice, the local glacial lakes were lowered until they were merged into the great body of glacial water which buried all western New York, north of the dividing ridge, to a depth of several hundred feet. At first this was the "Warren" water, having its outlet at the low divide south of the present Lake Michigan, near the site of Chicago. The beaches of this water have been traced by Mr. Gilbert, Mr. Spencer and Mr. Leverett to a point east of Buffalo, and at an elevation of 860 feet or more, with a differential rise toward the northeast. This indicates a depression of western-central New York following the ice-retreat. If Messrs. Upham and Spencer are correct in their estimates of the depression, then the Horseheads outlet of the glacial Watkins lake was certainly below the Chicago outlet of the Warren waters, and the uncovering of the Seneca Valley gave a new and lower outlet. There could have been no other escape for the waters unless there was a low uncovered pass into Hudson's Bay, which is not believed. In memory of a former distinguished worker in the field of glacial geology this lower lake is called Lake Newberry.

The further withdrawal of the ice sheet finally uncovered the valley of the Mohawk, and opened a still lower outlet, producing the episode of Lake Iroquois.

R. D. SALISBURY read a paper on "*The Surface Formations of Southern New Jersey.*" The following abstract was prepared by him for this Journal. The series of deposits considered in this paper have heretofore been grouped under the name of "Yellow Gravel." It is found that the series of sands and gravels which have been referred to by this general name are divisible into several distinct formations. Of these formations there are certainly three, probably four, and possibly five. The oldest of these several formations finds its northernmost extension in the Sand Hills north of Monmouth Junction. It caps various high hills in Monmouth County, where it reaches its greatest elevation. Southward the formation becomes lower and at the same time much more continuous. In general it is essentially continuous south of the line where the Middle Marl bed comes to the surface. This formation has essentially the same dip as the Cretaceous beds beneath. That it is not strictly conformable with the Cretaceous is shown by the fact that it overlies different members of the Cretaceous series in different areas. The relations are such as to show that the main part of the deformation of the Cretaceous beds took place after this oldest "Yellow Gravel" formation was laid down. Professor W. B. Clark has reached the conclusion that this formation is Miocene. After it was deposited, there was a period of uplift accompanied by deformation. This was followed by a long period of erosion, during which a large part of the formation, especially to the north, was destroyed by subaërial agencies. During this time of erosion central Jersey was reduced to a peneplain. Subsequently the central and southern parts of Jersey were again submerged, and there was deposited on the peneplain, the second member (the Pensauken formation) of the "Yellow Gravel" series. Above the Pensauken sea stood a considerable number of hills capped by Miocene. The Pensauken is best developed along the trough-like depression which extends from the vicinity of Trenton northeastward to Raritan bay. The Pensauken formation is made up of constituents which came from very diverse sources. The Triassic shale, and most, if not all the formations of the highlands of northern New Jersey made their contributions, as well as the Cretaceous and Miocene. All decomposable constituents of the formation are completely decayed. This formation originally reached at least as far north as the Watchung Mountains. During the uplift which followed the deposition, there was slight deformation, the elevation being greatest in the region which suffered greatest uplift after the deposition of the Miocene beds. Erosion followed, and a well developed system of drainage was established on the Pensauken surface. Subsequently subsidence and a considerable degree of submergence followed, so that much of the Pensauken formation (its lower parts) and the valleys which were cut in it, received a new mantle of loam and gravel. This is known as the Jamesburg formation. Subsequent to the deposition of the Jamesburg, the Trenton gravels were deposited in the Delaware valley, during the last glacial epoch which affected New Jersey. About the eastern and southern coasts of the state there is a broad, ill defined terrace, having a general altitude of about forty-five feet, which may or may not correspond in age with the Trenton gravels. This broad terrace is certainly much younger than the body of the Jamesburg formation, though it may represent no more than a halt in the emergence which followed the deposition of the body of that formation. The correlation of these various subdivisions with formations which have been heretofore recognized is not now attempted. There is some reason to believe that the Pensauken is considerably older than the oldest glacial drift. The two formations come together in but one area, and there the relations are not unequivocal. The general constitution of the Pensauken formation would ally it quite as closely with the Lafayette as with the Columbia of the regions farther south, but this is not regarded as a sufficient basis for so correlating it. It may be Pleistocene, antedating the earliest drift by a short interval only. The Jamesburg formation contains occasional glaciated bowlders. It is believed to be later in origin than the earliest glacial drift, and to be earlier than the latest glacial drift. Little erosion has taken place since it was laid down. Whether this is the result of a shortness of time, or of insufficient elevation, is not yet certain.

C. D. Walcott, in a paper on *The Appalachian type of folding in the White Mountain Range, of Inyo County, California*, gave an account of the discovery of the overturned synclinal-anticlinal structure in the White Mountain range, situated east of the Sierras, similar to that existing in the Appalachian Mountains in occupying a similar position to those on the opposite side of the continent. In a second paper (*Lower Cambrian Rocks in Eastern California*), he gave an account of the discovery of Lower Cambrian rocks and fauna in the same range. These two papers will appear in full elsewhere in this Journal. Arthur Keith gave an interesting analysis of the structure of the Southern Appalachians in a paper on *New structural features in the Appalachians.* His paper reviewed the generalizations of long standing in regard to Appalachian structure, stated and analyzed the late generalizations, such as effect of bedding planes, of superincumbent load, of initial basins of deposit, and of transmission of thrust, upon structure. Finally, statement was made of newly discovered structures, such as fan structure, cross folds, cross shear zones, secondary system of folding and the distribution of metamorphism; and a theory was advanced to account for these features that the crystalline rocks moved against the sediments, chiefly along the shear-zones, and deformed them most in the southwestern Appalachians.

F. B. Adams presented an excellent paper entitled *A further contribution to our knowledge of the Laurentian*, which was fully illustrated by lantern views with the novelty of projecting the enlarged rock sections directly upon the screen. Prof. Adams showed that essentially two types of rock structure are to be found in the metamorphosed Laurentian rocks, one a purely clastic one, the other one in which recrystallization has taken place and the importance of these in discriminating the origin of these rocks was pointed out.

G. K. Gilbert, in a paper on *the formation of lake basins by wind*, *The Tepee Buttes*, by G. K. Gilbert and F. P. Gulliver, described peculiar geological formations examined by him in Colorado. Shallow lakelets reaching ½ a mile in greatest diameter, were observed in the arid regions in eastern Colorado along the

Arkansas River valley, often near the highest points in the surface topography, and were interpreted as hollows scooped out by winds blowing in one direction persistently, during dry weather and filled by rains, becoming lakes and finally drying up to mere hollows in the surface. The name "Tepee Buttes" is given to conical hills left after surface degradation of the approximately horizontal Cretaceous strata, composed of central cylindrical cones of limestone chiefly made up of fossil shells in the midst of the soft, thinly bedded shales. N. S. SHALER read a paper *On certain features in the jointing and veining of the Lower Silurian limestone near Cumberland Gap, Tenn.*,—gash veins, in dense dolomitic limestone, 1^{mm}. in diameter and an inch to a few inches in length, filled by calcite, but the rock strata not faulted, folded or displaced. H. S. WILLIAMS, read a paper on *Devonian fossils in Carboniferous strata* which appears in full in the present number of this Journal. The large number of papers on Petrography and allied subjects determined the formation of a petrographical section which held a separate meeting on Friday.

In addition to the papers above referred to the following were presented, some of them, in the absence of the authors, being read by title only.

H. P. CUSHING—The faults of Chazy Township, Clinton Co., N. Y.

W. J. MCGEE—Remarks on the geology of Arizona and Sonora.

WALTER H. WEED and LOUIS V. PIRSSON—Geology of the Highwood Mountains, Montana.

CHARLES R. KEYES—Genesis and structure of the Ozark uplift.

J. W. SPENCER—The geographical evolution of Cuba.

T. C. CHAMBERLIN—Notes on the glaciation of Newfoundland.

C. W. HALL—The Pre-Cambrian floor in the Northwestern states.

J. F. KEMP—The crystalline limestones, ophiolites and associated schists of the eastern Adirondacks.

DAVID WHITE—The Pottsville series along New River, West Virginia.

WILLIAM B. CLARK—The Cretaceous deposits of the Northern half of the Atlantic coastal plain. The marginal development of the Miocene in eastern New Jersey.

G. K. GILBERT—Stratigraphic measurement of Cretaceous time.

E. T. DUMBLE—Notes on the Cretaceous of Western Texas and Coahuila, Mexico.

N. H. DARTON—Sedimentary geology of the Baltimore region.

R. P. WHITFIELD—On new forms of marine algæ from the Trenton limestone, with observations on *Buthograptus laxus*, Hall.

W. S. BAYLEY—Spherulitic volcanics at North Haven, Maine. The peripheral phases of the great gabbro mass of northeastern Minnesota. The contact phenomena at Pigeon Point, Minnesota. (Simply exhibition of specimens.)

ALFRED C. LANE—The relation of grain to distance from margin in certain rocks. Crystallized slags from copper-smelting.

ROBERT BELL—On the honeycombed limestones in the bottom of Lake Huron.

LEON S. GRISWOLD—On the nomenclature of the fine-grained siliceous rocks.

ALFRED E. BARLOW—On some dykes containing "Huronite."

WALDEMAR LINDGREN—The characteristic feature of the California gold quartz veins.

SAMUEL WEIDMAN—On the quartz-keratophyre and its associated rocks of the Baraboo Bluffs, Wisconsin.

EDWARD B. MATHEWS—The granites of Pike's Peak, Colorado.

N. H. DARTON and J. F. KEMP—A new intrusive rock near Syracuse, New York.

G. P. MERRILL—On the decomposition of the granite rocks of the District of Columbia.

B. WILLIS—Ancient physiography as represented by sediments.

B. K. EMERSON—Serpentine pseudomorphs after olivine, formerly called quartz-pseudomorphs, Middlefield, Mass. Skeleton crystals of salt which have been called chiastolite and later spinel, from the Trias, Westfield, Mass. Radiating puckering of corundum crystals around allanite, Pelham, Mass.

C. H. SMYTH, JR.—The crystalline limestones and associated rocks of the Northwest Adirondack region. H. S. W.

3. *Manual of Geology. Treating of the Principles of the science with special reference to American Geological History;* by JAMES D. DANA. 4th edit., pp. 1088, with 1575 figures and two double-page maps. New York, 1895. (American Book Company).—Dana's Manual, in this new edition, is a wholly rewritten work, a total revision having become necessary in consequence of the great progress in the science during the last twenty years, and especially in the geology of the Continent of North America. In the Preface the author remarks that North American Geology is still its chief subject; and adds:

"The time-divisions in this history, based on the ascertained subdivisions of the formations, were first brought out in my Address before the meeting of the American Association at Providence, in 1855;* and in 1863, the 'continuous history' appeared in the first edition of this Manual, written up from the State Reports and other geological publications. The idea, long before recognized, that all observations on the rocks, however local, bore directly on the stages in the growth of the Continent derives universal importance from the recognition of North America as the world's type continent—the only continent that gives, in a full and simple way, the fundamental principles of continental development."

The general arrangement of the work remains the same as in the earlier editions, except that Dynamical Geology is made to precede Historical. Moreover the Dynamical part commences with a chapter on "Chemical Work"; and the subject of Mountain-making and Earth-shaping, with which it closes, is treated under the general heading of "Hypogeic Work," the results, whatever the agency concerned, whether external or internal, being consequent on subterranean movements.

In the preparation of the Historical part of the Manual, the author, besides availing himself of all recent geological reports and other related publications, carried on an extensive correspondence with the chief geologists of the country; and further, in the paleontological parts, each of the chief divisions of the subject was prepared with the assistance of specialists familiar with the latest results of investigation.

The following are the principal changes in connection with the subdivisions of geological time.

Paleozoic time is divided at the close of the Lower Silurian, into two sections:

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* Republished, with added notes, in this Journal, II, xxii, 305, 1856.

(1) The EOPALEOZOIC, characterized by almost universal seas over the Continental areas, by the display of Invertebrate marine life under nearly all its grander divisions, and by the first appearance of marine Vertebrates—all eminently thalassic features; and by the appearance of the earliest of terrestrial plants and Invertebrates.

(2) After the making in North America of the Taconic Mountain system and the attendant raising of land above the sea along the wide Atlantic border, the NEOPALEOZOIC, characterized by the increasing emergence of the land of eastern North America, and also by the further emergence of life, until, through the progressing developments, a great semicontinent existed, that of *eastern* North America covered with forests and populated by Amphibians and Reptiles, along with gigantic Insects and various inferior species.

The Devonian era is made to commence with the Oriskany period; and the Catskill period, hitherto the last, is dropped, the deposits being now regarded by workers in the field, as a sea-shore phase of the Upper Devonian. In the first edition of this work (and still earlier in 1855), the Subcarboniferous, Carboniferous and Permian periods were made to represent one age or era, and the age was named the Carboniferous; but in this new edition, since the double use of the name Carboniferous is objectionable, Renevier's term, Carbonic, first published by him as the name of the era in 1874, is substituted. The name Subcarboniferous is retained because it has priority, D. D. Owen having formally proposed it for the period in his final quarto report, of 1852, on the Geological survey of Wisconsin, Iowa and Minnesota.

The American Cretaceous period is divided into epochs based on the Cretaceous series of Texas and the Continental Interior, which in general is sufficiently fossiliferous to serve as the basis of time-divisions. Those of the Lower Cretaceous are named the Trinity, Fredericksburg and Washita epochs, from Prof. R. T. Hill's Texas section; and those of the Upper, the Dakota, Colorado, Montana and Laramie, from the Cretaceous of the Continental Interior, after the grouping of Eldridge. Moreover the Laramie is divided into the Lower Laramie, and the Denver group or Upper Laramie.

It is brought out in this connection that Mesozoic time, like Paleozoic, ended in North America in the making of a great coal-bearing formation, and as the coal period closed there followed mountain-making on a grand scale and world-wide disappearance of species; and that further, as, after the Paleozoic, the emergence from the water of the eastern half of North America took place, so, after the Mesozoic, there was the final emergence of the western half. The Post-cretaceous mountain system of the Rocky Mountains is called the Laramide, and it is described as extending from near the Arctic seas to Central America; and as having probably its counterpart in South America, along the line of the Andes.

Under the Quaternary, the three periods are, as before, the Glacial, Champlain and Recent, and the same grand continental or epeirogenic movements, first appealed to by the author in 1855, are still recognized as distinguishing them. The Glacial period is divided into three epochs (1) The Early Glacial, or that of the Advance of the ice to its maximum extension; (2) the Middle Glacial, or that of the First retreat; and (3) the Later Glacial, or that of the Final retreat.

Evidence is presented connected with the distribution of birds and other species, proving that during the Glacial period the Antarctic lands were emerged, and that the Antarctic continent, so made, spread northward until more or less closely connected with Australia, New Zealand, South America, Madagascar, and Southern Africa, so that it added to the efficiency of high latitude elevation in giving a glacial climate to the period. The work also states evidence for believing that the semiglaciated condition of South Africa, India and perhaps Australia, in the later Permian, was probably due to similar Antarctic conditions.

Through the Historical Geology, the history of an era is followed by a review of the geological and biological progress made during it, thereby illustrating the stages in Continental growth, and briefly the stages in the history of living species. In the closing chapter of the work, making the last of the series on the Progress in the Earth's life, the author sets forth in a more general way his views on evolution. Referring,—under the heading "Augmentation of variations by interbreeding fundamental in evolution" —to the augmentation of variations by selective breeding, and the strange diversity of results thus educed, he says: "it is perceived that the law of nature here exemplified is not like produces like, but like with an increment," and that "consequently the law of nature, as regards the kingdoms of life is not permanence but change, evolution." Two following paragraphs have the headings: "Natural selection not essential to evolution, variation being effectual without it" (that is the variation that goes forward under the slow and sure processes of free nature); "Natural selection a means of determining the successive floras and faunas of the world, a prominent cause of the geographical distribution of species." Moreover, a "tendency upward" in the Animal Kingdom is stated to be a necessary consequence, under favorable conditions, of the existence of a cephalic nervous mass or ganglion. The theory advocated is essentially the Lamarckian, Evolution by variation," not "Evolution by Natural selection."

The illustrations in the work have been increased in number by more than 400, making the total over 1575, and to them is owing in part the increased size of the volume. They include a bathymetric map of the Atlantic and Pacific oceans, another of the Arctic ocean, a temperature oceanic chart, a map of the Great Lakes; seven maps illustrating the supposed geographical condition of the North American Continent at different times in its history from the Archæan to the Quaternary, a map of the

Yellowstone Park, and others, besides very large additions to the figures of fossils.

This edition is issued thirty-two years after the first, twenty-one after the second, and fifteen after the third. In the preparation of the third, the Historical Geology was only partly revised.

4. *Manual of the Geology of India*, chiefly compiled from the observations of the Geological Survey, by H. B. MEDLICOTT and W. T. BLANFORD.—*Stratigraphical and Structural Geology.* Second edition, revised and largely rewritten by R. D. OLDHAM, Superintendent Geological Survey of India. 543 pp. large 8vo. with maps, plates and illustrations in the text, Calcutta, 1893.—This new edition of the Manual of the Geology of India appears in a single volume. While the size of the Manual has been reduced by omission of less important parts and by condensations, the latest results of the survey of India have been incorporated, and a new colored geological map of the country is among its illustrations. The many peculiarities in the geological structure and orographic history of India make the study of the work of great importance to the geologists of other lands and especially to those of America. The addition of 20,000 feet to the height of the Himalayas after the Miocene period was a marvelous event in geological history; and the great fault-plane of a reversed (or up thrust) fault, "along the whole length of the Himalayas," against which the fresh water Siwalik beds of the Pliocene were deposited to a thickness of several thousand feet (now constituting the Subhimalayas) and other related facts, present orographic problems of profound interest. (On the colored map, a narrow yellow band, extending along the north margin of the great alluvial plain of the Ganges and the south margin of the mountains indicates the position of the Siwalik Hills.) It adds to that interest that while these great changes were in progress in the mountain region, Peninsular India, the lower region, from 500 to over 1000 miles in width, lying between the Himalayas and the Indian Ocean, underwent little change. "The only prominent event which can be attributed to this period is the origin of the western Ghâts."

5. *Recurrence of Ice-Ages.*—PROF. T. MCK. HUGHES, of Cambridge, England, in a paper read before the Cambridge Philosophical Society (Proc. Phil. Soc. 1893–94, 72. 98) entitled "Criticism of the Geological evidence for the recurrence of Ice-Ages," makes the following statements in the course of his concluding remarks. "I have criticised the principal cases in which it has been contended that we have evidence of glacial action in ancient bowlder deposits, and have shown, by reference to actual specimens of the rocks in question, that, not only is the evidence of Paleozoic or Mesozoic glaciation in Britain inconclusive, but that the negative can be proved in all cases hitherto adduced.

Being thus warned against taking on trust evidence for glacial action in ancient times founded upon the form or the condition of the surface of the rock, I venture to throw doubts on the inference that the faceted stones of Copitz near Pirna, are of glacial origin. I give the results of some of my own explorations among the ancient bowlder clays of Wetzikon, and other localities. I point out that the Cambrian-scratched stones of Norway are in regions that are still under the influence of glacial conditions in spite of the mild influences of the gulf stream. I then give a sketch of the distribution of bowlder-bearing beds in India, Australia and Africa, but have no evidence from personal observation to offer respecting them. I admit that the consensus of many competent observers renders it difficult to believe that these beds do not exhibit evidence of glacial origin."

III. BOTANY.

1. *Mechanism of the movements of the stamens of Berberis.*—CHAUVEAUD (Comptes rendus, July 2), suggests a new explanation of the curvature of the filament of Barberry, in response to touch or other irritation. He first calls attention to the inadequacy of one of the more widely accepted explanations, namely, that the movement is in consequence of the expulsion of water, showing by a simple experiment that water does not escape from a severed filament. He says that if a stamen be cut off at its base, and held in a dry place, it is possible, after it has recovered and straightened itself, to excite a new bending and after a second straightening to cause a second bending; all of which would not be likely to take place if there was at each movement a true expulsion of water.

According to the author, the following is the anatomical structure of the filament of *Berberis aristata.* Besides the fibrovascular bundle there is a special tissue which occupies about two-thirds of the transverse section and about two thirds of the length. This tissue is formed of narrow, elongated cells which are packed closely. This tissue possesses, especially towards the extremities of the cells, minute intercellular spaces. The transverse walls of its cells are thin, but the longitudinal walls, on the contrary, are thick, with thin places arranged longitudinally. This elastic tissue is covered by a layer which is practically continuous with the epidermis on the internal face and the sides of the filament and which may be called the motile tissue. But this motile layer differs from the rest of the epidermis in many ways. Its cells are rounded and thin-walled on their outer aspect, but notably thicker on the inner or deeper aspect. The contents differ widely from those of the other epidermal cells, being much more opaque. At the bottom of each cell of this layer, there is, when the organ is at rest, a peculiar thickening of the protoplasm into a sort of band. Under the influence of irritation, mechanical, physical, or chemical, the protoplasm reacts. This band suddenly stretches, curves into a bow, and while its ends touch and draw on the side walls, its convexity is pressed against the outer wall, resulting in a shortening and thickening of the cell. This causes a slight but yet sufficient deformation, and produces a curvature of the filament toward the interior of the flower.

The contractile movements of these cells are very rapid. They demand for their manifestation perfect integrity of the tissue. When the tissue is acted on by Osmic acid, for fixation of the contents of the cells, it presents totally different appearances according to the phase of activity immediately preceding the employment of the reagent. In a state of rest, the protoplasm forms a dark band at the bottom of each motile cell. When the filament is cut longitudinally, these bands give the impresssion of a sort of ribbon, as long as the sensitive portion. But if the filament was in a state of tension when it was fixed, these bands are more or less detached and curved, and present an undulating appearance. These colored and fixed segments of protoplasm are very distinct from the rest of the cell contents, and can be readily photographed.

These intracellular changes had been previously noticed, but had been regarded as enlargements and diminutions of an intercellular substance readily susceptible to changes in the amount of water in the cell. G. L. G.

2. *The Harvard Botanical Museum.*—The accuracy of the glass models of plants and the analytical details of their flowers, made by the botanical artists, Messrs. L. and R. Blaschka, has rendered it possible to exhibit all the morphological relations of more than two hundred North American genera. Above four hundred species from North, South, and Central America are now arranged in such order as to display affinities in a manner perfectly intelligible to every observant visitor. The minutest details are given on an enlarged scale, so that the position and character of the embryo in even the smallest seeds are fully and faithfully presented. All peculiarities of the essential organs and floral envelopes are displayed with absolute fidelity.

The success attending this venture has encouraged the installation of other specimens illustrating all the relations of plants to their surroundings, and to animals; in short, a full presentation of the Biological features of vegetation. In this biological section, the department of economic botany has, of course, its proper place and is to claim its proportion of space. The coöperation of the Director of the Museum of Comparative Zoölogy, at Cambridge, of the Director of the new Museums at Philadelphia, and of the Curator of the Peabody Museum, places in hand sufficient material for the realization of this comprehensive scheme, so far as the Phanerogams are concerned. In the installation of the Cryptogamia, Professors Farlow and Thaxter have given indispensable assistance, and some of their specimens are already in the cases.

From present appearances about two years will elapse before all the relations of plants to their environment can be satisfactorily exhibited, but the systematic and economic departments are now open. The phytopalæontological exhibit will be in the same building, but on a lower floor. G. L. G.

3. *On the amount of absorption of water by roots.*—M. Lecomte (Comptes rendus, July 9), makes the following interesting statement regarding *Musanga Smithii*, an Urticaceous tree, found in French Congo. The tree attains a height of sixty to seventy-five feet, is much branched, and has compound leaves. One of these trees, having a diameter of a foot and a half, was cut down five feet from the ground, and a groove was made to convey the water for collection. The tree was "felled" at five P. M. Jan. 6, 1894, when the atmosphere was saturated with moisture, but when there was no rain falling. At seven in the morning ($9\frac{1}{4}$) nine and one quarter liters of sap had collected, but it is certain that some was lost during the experiment. Subsequent experiments showed that the amount steadily diminished during the day, thus :

1st, from 6 P. M. to 7 A. M. at rate of 0.711, each hour.
2d, from 8 to mid-day, " " 0.587, " "
3d, from noon to 4 P. M " " 0.360, " "

The author says that the gorilla is acquainted with this property of the species in question, since he tears the branches off, and quenches his thirst at the wounds he makes. G. L. G.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Science.*—The well-known weekly Journal, Science, after a brief period of suspension has recommenced as a new series. The first number, issued January 4th, in the interest and variety of its contents speaks well for its future. It is now under the direction of an editorial committee constituted as follows : Mathematics, Prof. S. Newcomb ; Mechanics, Prof. R. S. Woodward ; Physics, Prof. T. C. Mendenhall ; Astronomy, Prof. E. C. Pickering ; Chemistry, Prof. Ira Remsen ; Geology, Prof. J. LeConte ; Physiography, Prof. W. M. Davis ; Paleontology, Prof. O. C. Marsh ; Zoölogy, Prof. W. K. Brooks, Dr. C. Hart Merriam ; Botany, Prof. N. L. Britton ; Physiology, Prof. H. P. Bowditch ; Hygiene, Dr. J. S. Billings ; Anthropology, Prof. D. G. Brinton, Major J. W. Powell ; Psychology, Prof. Cattell.

It is obvious that there is need in the country for a journal in the field which Science occupies and it is to be hoped that it may receive in full the support which it deserves from all interested in the progress of scientific truth. We quote a few sentences from the excellent introductory editorial by Professor Newcomb.

"At the present day one of the aspects of American science which most strikes us is the comparative deficiency of the social element. We have indeed numerous local scientific societies, many of which are meeting with marked success. But these bodies cannot supply the want of national coöperation and communication. The field of each is necessarily limited, and its activities confined to its own neighborhood. We need a broader sympathy and easier communication between widely separated men in every part of the country. Our journal aims to supply the want of such a medium, and asks the aid of all concerned in making its efforts successful. . . . , At the same time, it is intended that the journal shall be much more than a medium for the popularization of science. Underlying the process of specialization which is so prominent a feature of all the knowledge of our time there is now to be seen a tendency toward unification, a development of principles which connect a constantly increasing number of special branches. The meeting of all students of nature in a single field thus becomes more and more feasible, and in promoting intercourse among all such students SCIENCE hopes to find a field for its energies, in which it may invite the support of all who sympathize with its aim."

2. *The Astrophysical Journal:* An International Review of Spectroscopy and Astronomical Physics. Volume I, Number 1, 100 pp. January, 1895. Chicago (The University of Chicago Press.) —This Journal, which is essentially a continuation in a new form of *Astronomy and Astro-Physics*, has for its *editors-in chief*, George E. Hale, Director of the Yerkes Observatory and James E. Keeler, of the Allegheny Observatory. The *assistant editors*, are J. S. Ames, Johns Hopkins University, W. W. Campbell, Lick Observatory, Henry Crew, Northwestern University, E. B. Frost, Dartmouth College, F. L. O. Wadsworth, University of Chicago. There are also ten associate editors, leading men in this department of Science, and equally divided between this country and abroad. The first number now issued contains a number of valuable articles by Professors Michelson, Pickering, Rowland and others. The article by Rowland gives a preliminary table of Solar Spectrum wave-lengths from 3722·071 to 3911·444. Minor contributions and notes fill pages 80–87, and reviews with a list of recent publications, pp. 88–99.

That this journal will prove a great aid to scientific research in the department of Radiant Energy to which it is devoted is too obvious to require comment. It should be generously supported. The Astrophysical Journal is to be issued monthly (except in July and September) and the annual subscription is four dollars.

3. *Cloudland: A study on the structure and characters of Clouds;* by REV. W. CLEMENT LEY. 208 pp. 8vo. London, 1894 (Edward Stanford).—This is a popular discussion of the subject of clouds, presented in attractive form and with an abundance of excellent illustrations, including a number of colored plates. It would be difficult to find elsewhere so complete and systematic a description and representation of the different types of clouds and it will doubtless be of material aid to the individual observer. The latter portion of the work discusses the theory of atmospheric currents, prevailing winds, cyclones and anti-cyclones. In the illness of the author, which has prevented the completion of his work, the volume has been edited by Mr. C. H. Ley.

OBITUARY.

FREDERIK JOHNSTRUP, Professor of Mineralogy at Copenhagen, died in December 1894, at the age of seventy.

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Charles D. Walcott,

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XVI.—*The Appalachian Type of Folding in the White Mountain Range of Inyo County, California;* by CHARLES D. WALCOTT.

[Read before Geol. Soc. America, Baltimore meeting, Dec. 27, 1894.]

THAT portion of the White Mountain range of California, to the structure of which I wish to call attention, is situated between the road passing from Big Pine, Inyo County, in Owen's valley, through Waucobi Canyon to Saline valley, and the crest of the ridge a little south of White Mountain peak. The length of this portion of the range is about forty miles. South of the Saline valley road the range has received the name of Inyo range, and is so named in all reports upon it. Each observer, however, states that he does not see any reason for applying the two names to the range, as the Inyo portion is the southern prolongation of the White Mountain range. On the latest map* published of this region the entire range from Owen's Lake to the California–Nevada line, is called the White Mountain range.

Prof. J. D. Whitney† makes reference to the Inyo and White Mountain ranges, stating that little is known of their geology, except that, from Bend City for twenty-five miles north, their western base and slopes seem to be composed of slates and other stratified rocks, generally dipping to the southwest and often much contorted. Mr. G. K. Gilbert‡ crossed

---

* Map accompanying the report of Dr. C. Hart Merriam on an expedition to Death Valley, compiled under the direction of A. H. Thompson, 1892.

† Geol. Surv. California, Geology., vol i, 1865, p. 459.

‡ Expl. and Surv. west of the One Hundredth Meridian, vol. iii, Geol., 1875, pp. 34 and 169.

the range on the line of the present toll-road from Piper's Ranch to Big Pine. A sketch of the section he made shows a broad syncline on the western side, with faulting and folding in the central and eastern portions. He also gives a section of the rocks exposed on the east face of the Inyo range, at the pass between Deep Spring valley and Owen's valley.*

Mr. W. A. Goodyear, in his account of Inyo County,† notes the contorted condition of the strata, and also gives one sketch of the folding in the strata on the slope of White Mountain, north of Silver Canyon.

During the summer of 1894, accompained by Mr. F. B. Weeks, I crossed the range opposite Big Pine and penetrated into it from the western side, in Waucobi, Black and Silver Canyons, with the special purpose of determining the stratigraphic structure of the western side of the range, after ascertaining that the rocks were of Lower Cambrian age.

My first impression, when passing south through Owen's valley and looking at the west face of the range, was that, from a point twenty miles north of Bishop creek to Tollgate Canyon, the range was formed of a monocline of quartzites, argillites and limestone. The first trip into Tollgate Canyon disproved this, and furnished the data for the tentative conclusion that this portion of the range is a syncline of quartzite and limetones, very much broken by local folding and faulting. This conclusion was verified by the sections exposed in the sides of Black and Silver canyons. I shall first describe the succession of strata exposed on the western slope of the range, as the folding and faulting will thus be more readily understood. From the summit downward the section is as follows:

1.	Compact, thin-bedded, arenaceous argillite, with layers of dark-brown, fine-grained quartzite	200 ft.
2.	Alternating beds of limestone and calcareous and arenaceous shale; a massive bed of limestone, 100 feet thick, near the base	1,000 ft.
3.	Siliceous slate and compact, dark quartzite	2,000 ft.
4.	Siliceous limestone, usually in massive beds	1,700 ft.

Base unknown.

The limestone series of 2 and 4 are light-colored and contrast strongly with the dark quartzites, argillites and shales. This brings out the more prominent features of structure in bold relief when viewed from the higher points of the western spurs of the range.

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* California State Mining Bureau. Eighth Annual Report State Mineralogist for 1888, p. 282.

† In this connection see article in February number on Lower Cambrian Rocks in Eastern California.

Silver Canyon penetrates deep into the range, and about four miles from its mouth cuts across a great synclinal fold. This is outlined in fig. C, page 173. A short distance above the mouth of the canyon the siliceous argillites, with the interbedded layers of quartzite, dip to the eastward about 20°. This dip increases until the beds are in places vertical. Usually at the bed of the canyon there is still a slight eastward dip. As the strata rise on the side of the canyon they become vertical, and finally, about three and one half miles from the mouth, they are overturned to the eastward so as to assume a westward dip and to produce a rough fan structure in the section between the mouth of the canyon and the limestones. The series of argillites and quartzites is broken by minor faults and closely compressed folds. The synclinal structure is clearly shown by the limestone series. The dip of the western limb of the syncline next to the quartzite is from 70° to 80° west. This increases to about 60° near the center of the syncline. The strata of the eastern limb dip westward at about 60° at a point nearest the center, and from that down to 40° near the quartzite.

The section of the syncline exposed on the north side of Silver Canyon is over 2,000 feet in depth, and when viewed from the high ridge on the south side of the canyon, is beautifully exhibited, both in the canyon and in its extension to the northward, along the western face of the range. Frequently the eastern limb of the limestone of the syncline rises to the summit of the range, but as a whole the upper limestone syncline rests against the western side of the range for twenty miles or more north of Silver Canyon.

At the mouth of Black Canyon the lower limestone (No. 4) is exposed. It dips eastward and passes beneath the quartzite (No. 3) at an angle of from 25° to 30°. A fault breaks the section along the line of the north fork of Black Canyon, but by following the section northward about two miles and viewing it from the high ridges to the south of Black Canyon, it is seen that the dip of the quartzites above the limestone increases to the vertical, and at the western edge of the syncline formed by the upper limestone the dip is to the westward.

The lower limestone, owing to the northward pitch of the syncline, passes beneath the Pleistocene beds on the margin of the valley, before reaching Silver Canyon. In fig. B, I have theoretically restored the synclinal section of the range so as to include the lower limestone. What comes out from beneath the limestone on the eastern side of the range is unknown to me, as I was unable to reach that portion of the section. Viewed from the distance, it is apparently a dark-colored rock, very much broken up and covered with massive granitic eruptives. This is on the line north of Silver Canyon. South of Silver Canyon about five miles, the section as viewed from the high ridge south of Tollgate Canyon is diagrammatically represented in fig. A. The quartzite of the western limb of the syncline is hidden by an intervening ridge, but the syncline of the upper limestone and the two minor synclines to the eastward are clearly defined. The most easterly, on the eastern slope of the range, was not seen at near view, but it appeared to be as represented in fig. A.

The east fork of Black Canyon cuts entirely through the quartzite (No. 3) and into the lower limestone. The syncline has flattened out, and its western limb is nowhere overturned to the eastward. The quartzite (No. 3) is much contorted and broken by minor faults. This is most noticeable about midway of the section and also within a few hundred feet of the upper limestone, where there is a series of sharp anticlinal and synclinal folds, as shown in fig. D, as well as in the enlarged view, fig. E. The depth of these minor synclines is about 300 feet. They appear to have been formed largely by the slipping and compression of a series of argillaceous and thin-bedded quartzites that are between the upper limestone and other portions of the quartzite series. The upper limestones form a broad, somewhat shallow, irregular syncline, upon which, at the summit, rest about 200 feet of arenaceous shales and thin, interbedded quartzites. This shallow syncline extends southward to Tollgate Canyon, where it is much broken, as shown in the sketch made by Mr. Gilbert.* South of Tollgate Canyon there appears to be a broad, broken syncline, with the upper limestone (No. 2) at the summit.

Viewing the White Mountain range from the western slope of the Sierra Nevada, north of Big Pine, it is evident that several transverse or oblique faults break the syncline that rests on the western slope of the range. The strata are displaced on the south side of Black Canyon, and also about five miles to the north. About twenty miles north of Silver Canyon the sedimentary strata are more broken and are apparently covered by eruptive rocks that form the higher portions of the range near White Mountain peak.

The only point that I visited on the eastern side of the range was the section exposed on the northern and western side of Deep Spring valley. On the northern side eruptive granites conceal the greater portion of the sedimentary rocks, but on the western side, nearly southwest of Antelope Spring, are some very fine illustrations of open anticlinal and synclinal folding. This is shown by fig. F.

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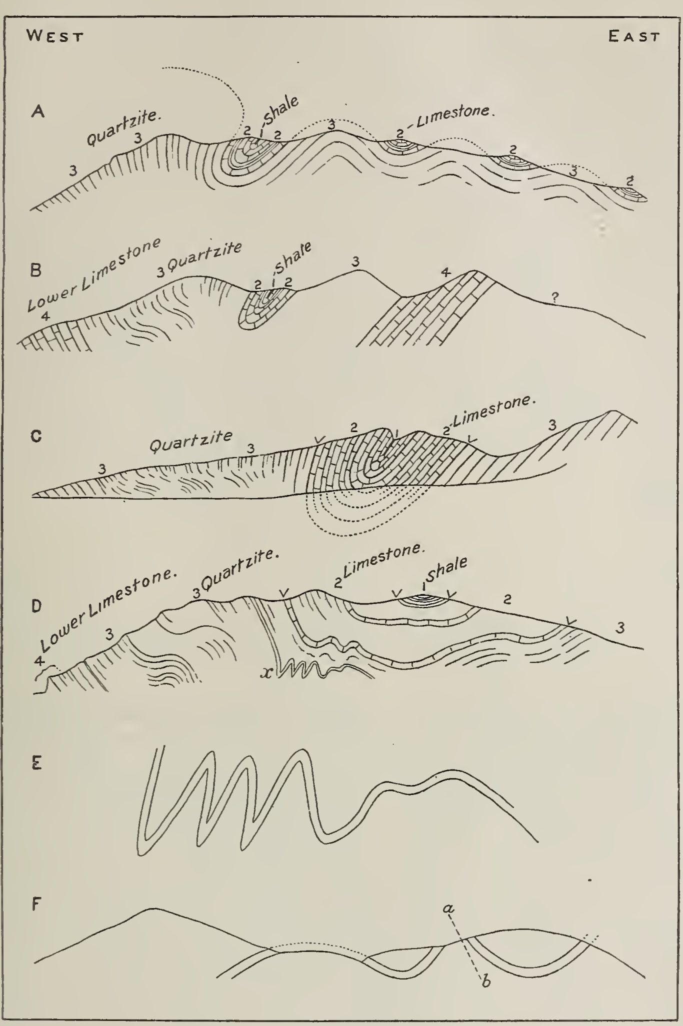
* Loc. cit.



DESCRIPTION OF FIGURES.

FIG. A.—Diagrammatic section of the White Mountain range as viewed from the high ridge south of Tollgate Canyon. 2, upper limestone; 3, quartzite and shale series.

FIG. B.—Theoretical section of range south of Silver Canyon, to illustrate character of syncline. 2, upper limestone; 3, quartzite and shale series; 4, lower limestone.

FIG. C.—Syncline on the north side of Silver Canyon. 1, upper shale; 2, upper limestone; 3, quartzite and shale series.

FIG. D.—Section on the east fork of Black Canyon. 1, upper shale; 2, limestone; 3, quartzite series; 4, upper portion of the lower limestone.

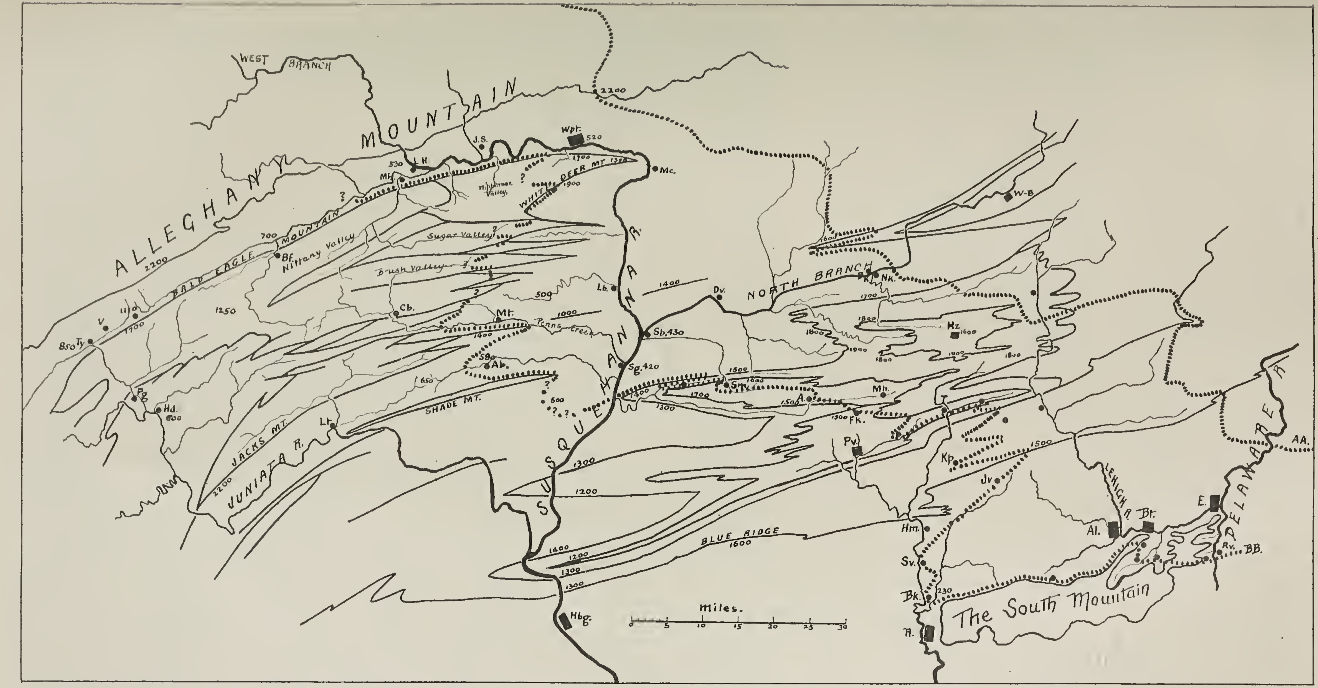
FIG. E.—Anticlinal and synclinal folds occurring at x in fig. D.

FIG. F.—Outline of folding of limestone imbedded in quartzite and shales, western side of Deep Spring valley. a–b, fault.

As seen from the western slopes of the White Mountain range, the next range to the eastward, Silver Peak, is apparently a monocline facing westward ; but from the known structure of the Great Basin ranges, such as those of the Eureka district, Nevada, the Oquirr range, Utah, and others illustrated by the geologists of the Wheeler Survey, it appears that in the broad Paleozoic area between the Sierra Nevada on the west and the early Paleozoic shoreline on the east (Colorado) a period of folding and thrust faulting was followed by a period of vertical faulting, which displaced the strata that had been folded and faulted in the preceding epoch. The extent and character of this disturbance can be determined only by a careful study of each of the mountain ranges for a distance of over five hundred miles east and west and probably a thousand miles north and south; and the great geologic problems will not be fully solved until the areal geology of the region between the 109th and 119th meridians shall have been mapped.

Art. XVII.—*Notes on the Southern Ice Limit in Eastern Pennsylvania ;* by Edward H. Williams.

The accompanying map shows what has been done during the past year, and the boundary has been extended from the Schuylkill to Lock Haven. There probably does not occur as diversified a field, and one more fortunately situated, than that which stretches from the Delaware river to the Alleghany Mountain in Pennsylvania. The measures from the Archæan to the Trias lie under all states of deformation and weathering and, forming all arrangements of mountain and valley, opposed all angles of trend and slope to the approach of the glacier. The lithological and fossiliferous characters of those measures are frequently so well marked that their fragments can be quite readily recognized under all conditions of weathering. The streams of the region run toward all points of the compass, and the Delaware, Lehigh, Schuylkill, and Susquehanna are of constantly large volume, and flow through gaps of great age as shown by their low angles, and over preglacial bottoms. The peculiar systems of parallel ridges and valleys of the region bring great differences in barometric level within small areas; so that the resistance to advance of the ice varied greatly within short distances and, at times, created a shear in the interior of the glacier. The varied river systems also distributed the glacial trash where it could be again taken up by



AA. Moraine of Lewis and Wright; BB. Southern ice limit; A. Ashland; Ab. Adamsburg; Al. Allentown; Bf. Bellefonte; Bk. Berwick; Bl. Berkeley; Bt. Bethlehem; Co. Coburn; Dv. Danville; E. Easton; Hbg. Harrisburg; Hd. Huntingdon; Hm. Hamburg; Hz. Hazelton; Jv. Jacksonville; Kp Kepner; Lb. Lewisburg; Lt. Lewistown; L.H. Lock Haven; Mc. Muncy; M.H. Mahanoy City; Mh. Mill Hall; Nk. Nescopeck; Pg. Petersburg: Pv. Pottsville; R. Reading; Rv. Riegelsville; Sb. Sunbury; Sg. Selinsgrove; Sm. Shamokin; Sv. Shoemakersville; T. Tamaqua; V. Vail; W. B. Wilkes-Barre; Wpt. Williamsport.

the advancing ice. The glacial discharges and final ablation were made under all conditions of freedom or damming, as the ice-front faced an ascending or descending valley, or rested against a ridge which it could not surmount.

In view of the fact that many writers seem to have forgotten how ice acts in its first advance over a previously unglaciated region, it seems necessary to discuss the subject. Ice erodes and accumulates and, as the country was generally covered, the erosion was of the surface covered, and the accumulations were also from that surface, which, before the advent of the ice, was more or less deeply covered with soil of decomposition. What became of this old soil and its more or less decomposed fragments? In the west, where drainage favored, they were washed away by the glacial floods in the shape of mud and sand, and so distributed that their identity is lost. It is only where drainage has been opposed by the ridges and upward sloping valleys of the Appalachian system, and all waters forced to escape sub-glacially, that we can fully study the deposits of the first glaciation.

The first advance of the ice carried a burden of rotten material. The soft underlying parts were immediately powdered, and whatever resisted immediate destruction was more or less rotted and generally oxidized; but, as it was opposed to a soft surface, its fragments were only rounded into a highly oxidized gravel that was mixed with the clays and sands of the old soil. It was only after a continuance of erosion that the solid rocks were reached and attached to the base of the ice. As this took place at a distance from the ice front, the fresher fragments were carried against the softer surfaces where the ice had as much of a cutting effect as its burden, and no scoring or grooving occurred—only a planing of the surface, as is seen at Rauch's gravel pit at Bethlehem. The fresh fragments finally reached the terminal deposits, and were mixed with the older weathered stuff; but were stirred up with it and are found at all depths, as on the crest of the ridge behind South Bethlehem, where in a rotten, unstratified deposit of great thickness, a fresh Calciferous bowlder lies near an equally fresh Lower Subcarboniferous cobble, on rotten gneiss, and under rotten and angular fragments of Potsdam. When a retreat of the ice took place, and a halt was made at a distance in the rear, the accumulations are generally of fresh fragments, and the thoroughly eroded surfaces show an abundance of groovings and striations. Those who see in this last *all* the work of glaciation, are unfortunate, in that they accept an incomplete sub-stage of the work for its entirety. Secondary advances to the former limits of glaciation frequently fail to remove portions of the former deposits, and cap them with a mass of fresh material gathered from the rear. Although there may be great differences in appearance, there may be little variation in age, and as it is generally accepted that the erosive power of the edge is slight, we may have a succession of deposits varying from a rotten gravel at the bottom to a fresh one at the surface, and all may have been formed within a short period. Rustiness of gravel, therefore, is no criterion of age, and all arguments based upon it must fall.

The bulk of the deposits is also used by some as an evidence of the duration of glaciation. This is faulty, as regards the first advance, as the first advance evidently removed the rotten surface vastly faster than it did the more resisting rocks at depth; so that comparative estimates based on thicknesses of fresh material on the one hand, and rotten or rusty stuff on the other, are valueless, unless it can be conclusively shown that the rotten and rusty deposit was fresh when formed.

Character of the Deposits.

South of Lewis and Wright's moraine the deposits are generally angular, or sub angular, and rusty accumulations from the old surface. The formations, where exposed, are generally unstriated, and the thickness of till dependent on the contour. In general the determination is made by finding fragments of formations moved out of place in a uniform direction, and independent of the slope. It is a favorable condition when a river which drains a part of the glaciated area crosses the path of another portion of the ice, as the gravels are taken from the river and distributed so as to show the direction of the movement. The broad valleys of the Mauch Chunk (Upper Subcarboniferous) formation are especially useful in marking the ice front, as the contrast between their dark red country rock and the Pottsville conglomerate on the one hand, and the Pocono (Lower Subcarb.) on the other, is so distinct that the erratics are distinguished at a distance. On the other hand, there is little difference between fine fragments of Mauch Chunk and Catskill when weathered, and the latter when leached much resembles Chemung, so that in non-fossiliferous localities the evidences are few and far between. In the event of finding distributed gravels from the rivers, they are uniformly found just over the crest of the ridges opposite to the direction from which they came. This is well shown in going south from Danville to Shamokin. In ten or twelve miles the evidences of glaciation (as shown by river gravels) can be compressed within a few hundred feet. In the valleys well-sections were very useful, and especially when force pumps were necessary from depth of water. Quicksands are found against the solid glaciated rock in the Wyoming valley and along Penn's creek west of Lewisburg. There was glacial damming in the valleys of the Lehigh, Lizard, Mahoning, and Susquehanna (main and north branch) up to 600 feet in depth; so that glacial deposits are capped by varying thicknesses of slack water clays, and flood cones were formed by torrential discharges into the emponded waters—one of them at Jersey Shore being over a mile in length, 1,000 feet wide and 170 feet high—while the escaping waters distributed gravels over high cols into other river systems, and in one case carried them to within 75 miles of the Potomac. Some points require more extended notice.

The Schuylkill gravels.

At the time when the recent State geological survey was made, the nature of glacial gravels was not so well understood as at present, and the reports on the region state that there are no glacial gravels along this river. There are no striated gravels; but extended patches of unstratified gravels occur at all points along the Little Schuylkill and the main stream, and the writer thinks that the West Philadelphia gravels may be partly glacial, as Mr. Salisbury reports finding glaciated stones at Norristown. The ice covered the whole of the extreme end of the southern coal field from Mauch Chunk to Middleport; so that the upper waters of the Little Schuylkill in the Tamenend valley north of Tamaqua, and the whole valley of Panther creek drained ice covered areas. The extension westward in the Mahoning valley was to the edge of the col between Mahoning creek and the Little Schuylkill, so that some of the glacial waters from that lobe may have reached the latter river at Zeiner's Station. Thence down the river to Port Clinton the gravels are irregularly distributed at low levels, and along the main stream south of the Blue Ridge. About half way between Hamburg and Shoemakersville the upper lobe of the ice from the Lehigh region reached the river and furnished its quota of trash, and at Berkeley the lower lobe did the same. The new Schuylkill Valley branch of the Pennsylvania R.R., cuts through varying thicknesses of unstratified gravels, and especially north of Douglassville. The contrast between the deep red of the Trias and the rusty unstratified cap can be readily seen from the train. The highest elevation above the river of these deposits south of Reading, thus far, has been 30 feet.

The Anthracite regions.

With the exception of the Southern field, west of Middleport, and, perhaps, the extreme western end of the Western

Middle field, the whole of the anthracite area was glaciated. The surface dislocations incident to mining, and the distribution of culm from the coal washings have made a survey difficult as far as connected work is concerned. Points here and there were obtained, and the intermediate line surmised from the contour of the country. As the ice was found to have been at Frackville, it must have crossed the Western Middle basin at Mahanoy Plane; but Mahanoy creek is so clogged with culm as to afford no sign of glacial deposits. As the red shale (Mauch Chunk) valley between Ashland and Gordon showed no erratics the ice did not intrude there; but at Locust Gap till was found, and a thick bed of it lines the creek of the same name at Shamokin; while in the red shale valley to the north trial shafts were sunk through a great thickness of till and bowlders. The records of shafts in many places in this region show that the first part of the work was through "gravel" or "drift." At Trevorton and down Zerbe Run gravels exist; but not as far as Dornsife, where Mahoning creek cuts through the ridge into the Susquehanna Valley. In general, glaciation is shown by the removal of the old soil. At Hazelton in the north, and Shamokin in the south there was a uniformity with which the coal beds came in workable condition to the surface, and with as great relative solidity as the enclosing sandstones. The coal strippings at and about Hazelton show plainly that the glaciation was recent, as, otherwise, the coal beds exposed so near the surface to the action of solvents would have long ere this been turned to black mud, while the sandstones would have retained a good deal of solidity. At Hazelton coal has been mined and marketed where the top rock was entirely removed by glacial action, and only a loose glacial wash capped the bed. The coal was rusty; but solid.

No striations were found over this region; but the Pottsville conglomerate on the ridge just east of Delano (1800–1900 A. T.) is planed over large areas, and large erratics of the same formation are numerous. Where the Pottsville branch of the Lehigh Valley road cuts through the ridge to the Silver Brook basin, the weight and force of the ice bent and crushed the vertical hard bands of Pottsville conglomerate, and the sandstones lying on it, as readily as it did the Hudson River slates south of the Blue Ridge.

The Susquehanna Valley.

The ice moved parallel to the north branch of this river along the Wyoming valley, and crossed it at increasing angles as it neared the main stream at Northumberland. The bed of the branch is generally solid rock, with the inequalities filled with glacial trash. Much discussion has been held regarding the Berwick gravels, and some have held that they were due to a submerged mouth of the river. As the ice went 25–30 miles south of the place, their origin is no longer in doubt; but the freshet of last May disclosed the nature of these deposits perfectly, as the torrential state of Nescopeck creek which reaches the river opposite to Berwick, cut away ten feet of the north bank of the creek at the Pennsylvania R.R. bridge; so that the north abutment was isolated and undermined. As this cut was vertical and the material compact it was seen that there was the same succession of events as shown in the Lehigh Valley at Rauch's gravel pit. There are three formations in the gravels at Nescopeck and Berwick: first, sub-glacial till so compact that a pick can scarcely be driven into it. This has a clay base and carries an abundance of rolled stones of all the formations to the north—even granite and anthracite meet in the mass. On this is a bed of modified drift of loose nature and sandy matrix with the same collection of rolled stones and of equal freshness. In fact, there is no difference in the color of the layers. As at Rauch's pit the lower inch of the gravels is a conglomerate with a limonite matrix, where the percolating waters laden with the solution of iron were stopped by the dense till below. Capping all is a layer of unstratified sand that varies in thickness greatly within a few feet, and carries streaks of gravel and glaciated cobbles and bowlders at all levels. We have, therefore, the till from the ice on the spot, and the modified drift when the ice was in retreat; but in the vicinity, and, finally, the sands, when the ice had retreated to a distance and the torrential nature of the stream had ceased; but when there still were discharged bergs bearing burden of large material. It is about 20 feet from the rock bottom of the river to the top of the sandy cap.

There are several low kames along the north branch; but their formation could not be studied from absence of cuttings.

The ice crossed the valley of the west branch from Northumberland to Muncy at the same angle as in the other branch, and the formations are similar in succession; but from Muncy westward a slack water-cap hides whatever is below, and it is only where the cuttings are fresh that the succession can be seen.

In the main valley the southern limit of the ice was where Little Mountain reaches the river. As this rises abruptly 1000 feet above the country it proved an effectual barrier to a farther southern advance. The glacier crossed the river and seems to have reached the northeastern end of Shade Mountain, as there was a slight flow southwestward over the low col of 200 feet into the Juniata at Lewistown. Evidences of glaciation are also seen in the distribution of the white Medina sandstone of Shamokin Mountain over the Salina valley to the southwest. Farther north along Penn's creek an abundance of modified drift is seen capping till of quicksands and bowlders that lie against the glaciated country rock, and all is covered with slack water clays from the Shade Mountain ice dam, or the one formed before the ice abandoned the northern end of Jack's Mountain.

Action of the ridges on the ice advance.

A glance at the map shows the numerous ridges crossing the path of the glacier. These rise sharply from the surrounding country to 600–1000 feet. The retention of a large mass of rotten gneiss on the northern slope of the South Mountain back of South Bethlehem, and where it was fully exposed to the force of the ice seemed to point to a massing of the ice in the valley, where it remained stagnant, while a shear took place and the upper part of the ice only crossed the mountain. This is also shown by the small proportion of river gravels in the till—though the glacier had just crossed the Lehigh.

In Report G7 of the late Pennsylvania survey, I. C. White describes the glacial deposits in the tier of counties along the north branch of the Susquehanna. As far as the knowledge of the subject went at that date, the report is accurate. One point is interesting in its bearing on glacial motion. In describing the gravels in Mifflin township he notes their occurrence only at comparatively low elevations above the river. The writer found this to be the case, and made a trip over Nescopeck Mountain while studying the matter. It seemed strange that the narrow strip of land lying between the Susquehanna and the mountain should be free from gravels, while to the west they were found distributed regularly over the country for many miles south of the river and in some cases 500 feet above it. The map shows that Nescopeck Mountain rises 1000 feet above the river and runs parallel to it for some miles and, at Catawissa (as Catawissa Mountain) turns southward in a series of folds, and finally resumes its former trend, as Little Mountain, and reaches the Susquehanna. At first it was thought that the mountain turned the glacier wholly from its path and forced it to scrape along its northern flank till its bend at Catawissa withdrew the resistance, when the released ice resumed its former line of motion; but the finding of till on the summit of the mountain, and also erratics from its summit that were carried across Scotch valley and over McCauleys Mountain, showed that the ice crossed it. Had this been done in the general line of motion, the abundant river gravels would have been found at all elevations over the mountain. As they stop, at the mountain foot, and as the till on the flanks and top is angular and from the immediate neighboring formations, or consists of large bowlders of the sandstones to the north, it is evident that the lower part of the ice moved parallel to the river and mountain, while the upper part crossed the ridge and probably united with the lobe that came from the east along the enclosed valley south of Nescopeck Mountain.

The glacial gravels of the Juniata valley.

While studying the deposits in the valley of the Susquehanna, the writer followed a line of drainage over the low divide between the Susquehanna at Selin's Grove and the Juniata at Lewistown; but was surprised to find on the Salina bluffs south of the river, at the latter place, a series of lenticular deposits of glacial gravels and bowlders in the depressions and on the down-river side of the elevations of those bluffs, and at heights up to 80 feet above the river. Their position pointed to an origin up the Juniata; but as I was engaged in regular work, I let that matter go for the time; but looked up the authorities and found that I. C. White, in his report for Huntingdon county in the recent survey of the State, noted their appearance in that county, and advanced four theories for their origin; but without favoring either of them; while those who worked in Mifflin and Juniata counties said nothing of the occurrence of gravels at such high elevations.

As Professor White* had also reported upon the counties along the north branch of the Susquehanna, he was in a position to speak regarding glacial deposits, and in the Huntingdon report (p. 31) he says, "Great heaps of bowlder trash, both rounded and angular, are often to be seen along the valleys of the principal streams; and these often very much resemble genuine drift heaps; but no *striated* bowlders or *striated* fragments of the country rock are to be found in the region." He further reports them at elevations above 100 feet from the river. The hypotheses advanced are various, and the only one of value is that of the melting snows of the glacial period that kept all the rivers of the State at a higher level than at present. Nothing is said of glacial occupation of the region.

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* Justice to Professor White requires the statement that his work in the recent geological survey of Pennsylvania was confined to counties widely separate from one another; so that the study of a limited portion of the Juniata valley would afford no clew to the origin of these gravels, had it not been supplemented by extended work over a large adjacent area. The writer was fortunate in having the careful and accurate work of Professor White to guide him in the study of the north branch of the Susquehanna, and has many times regretted that it was not extended to the south and west; as those regions were treated from an entirely different standpoint.

It is to be noticed that nothing is said of any difference in age between these drift heaps and those of the great moraine. There is no difference, in fact, and as the writer was happy in finding glaciated stones at Lewistown, he set the deposit down as a recent glacial formation, and as recent as the glacial gravels of the upper Susquehanna.

A glance at the map of Lewis and Wright shows that the terminal moraine approaches quite near the north branch of the Susquehanna at Williamsport. As the width of the extra-morainic deposits will average 25 miles, the writer saw, when he reached the latter place, that Bald Eagle Mountain, rising sharply 1200 feet above the river, must have required a great thickness of ice to have been surmounted, and must have formed a glacial lake similar to that in the Lehigh valley, as has been described by the writer. In proof of this the surface deposits west of Muncy changed to slack water clays and overlaid, where visible, modified and unmodified drift. A trip through the gap in Bald Eagle Mt., to the inner summit of White Deer Mt., lying three miles to the south, and making a loop with the former where they meet the Susquehanna, showed that ice had surmounted both, and, as the glacier had crossed the main Susquehanna at Fisher's Ferry, at the northern slope of Little Mt., there was at least fifty miles of the bed on the stream covered with ice over 1200 feet thick. Previous to this a line of glacial discharge had been traced up Penn's Creek to Paddy Mountain; but its origin was unknown.

Going west up the valley of the north branch of the Susquehanna, a great slack water terrace 150–170 feet high was found opposite Jersey Shore, which causes the river to make a long bend to the north and east. This was formed by a torrential discharge of glacial origin from Nippenose valley through Anti's gap in Bald Eagle Mt. Rogers has called attention to the peculiar features of the erosion of the south side of this valley, and to the "drift hill" in the gap. He also notes a similar hill in Washington gap between Sugar and Nittany valleys. The Jersey Shore terrace surprised the writer by bending to the northwest, and the stream that drains Nippenose valley was also surprising in meeting the Susquehanna in a similar way, or against the present flow of the river. Both pointed to a flow westward. A glance at the map showed that the Bald Eagle and Nittany valleys would afford an exit to deep waters, and the latter valley was first studied with the result that no signs of ice occupation were found; but it was seen that Sugar and Brush valleys had their eastern ends covered with ice, and that the northern end of Nittany valley was covered deeply with bowlder trash, as was the part adjacent to the gaps from the valleys to the east. From Bellefonte eastward to the valley of Penn's creek the surface was clear, but the glacial flow through that creek was seen to have come from Brush valley.

At Mill Hall twelve feet of slack water deposits overlie what seems to be sub-glacial till, and the Bald Eagle valley soon becomes perfectly flat and filled with debris, from which the small knolls formed by varying outcrops appeared in a submerged state. These deposits were followed continuously over the divide at 1110 A. T., or 600 feet above the river at Williamsport, and down the Juniata to Huntingdon. Where-ever they exist at great depths in the latter valley there is evidence of slack water, as below them there is a contraction of the channel, where it passes through the gaps in the numerous ridges. When we consider that the whole discharge from the central part of the state glacier passed through Bald Eagle and Juniata valleys, we can see at once that small ice dams must have been continually forming in these narrow gorges, from the floating bergs, and as these deposits are found from the present level of the river to an average of 80 feet above it, we can get an idea of the depth of the water. In one case, a dam sent cakes of ice from 300–400 feet up the slope of Warrior Ridge to make a small deposit of erratics. That the discharge was torrential is seen by the erosion of the rotten limestone at Barree on the up-stream side of the ridge, and its retention on the other side to great depths. We can imagine, therefore, during a portion of the earliest part of glacial times, a deep lake extending from Williamsport above the junction of the Susquehanna and Sinnemahoning; filling Nippenose, upper Nittany and Bald Eagle valleys, and discharging a deep torrent through the Juniata. A smaller side discharge from the same glacier went down Penn's creek to the Susquehanna; but was stopped by the ice at Shade Mt. for a time and sent down to Lewistown, on the Juniata; but afterwards was freed and allowed to reach the Susquehanna at Selin's Grove. This great glacial lake has been called by the writer, in honor of our State geologist, Lake Lesley.

Detailed sections were photographed at various places through the Bald Eagle and Juniata valleys. At the northern entrance of the former, at Mill Hall, there is a considerable flood cone attached to the southern side of the gap in Bald Eagle Mt., where the flow was turned south from the Nittany valley. Along the Central railroad of Penn., through the latter valley, there exist thick deposits of glacial drift distributed from the gaps to the east, and the larger material lies close against the Nittany Mt. on the eastern side of the valley, while the fine clays extend over the whole valley. The flood cone at Mill Hall, therefore, does not contain gravel in its upper, slack-water part; but only clay and fine fragments of the local Devonian rocks. This lies on what seems to be subglacial till; but the exposures were so small, and the time for study so short that it may have been a hard clayey modified drift. At any rate it was dense and unstratified. One argument in favor of its being till was that it lay on rotten local rock from which the old surface had been removed. Going south along Bald Eagle valley the inequalities of the valley are covered by gravel in the place of the Mill Hall drift, and that is capped by slack water sands and clays—all unstratified. This shows that the action was continuous. On crossing the divide the modified drift continues at varying thicknesses; but always unstratified, and the slack water clays of the northern side are replaced by sands and fine stuff as the torrential nature of the flow gradually ceased. An excellent section is seen in the creek at Vail—about 125 feet below the divide, and the same distance above the Juniata at Tyrone. At East Tyrone, in the yard of the Pennsylvania R. R., many fine sections are shown, and the succession is similar to those described. Huntingdon is built on a flood cone where the Juniata pours through a narrow gorge into a wide cross valley.

ART. XVIII.—*The Succession of Fossil Faunas at Springfield, Missouri;* by STUART WELLER.

Introduction.

THE rocks under consideration in this paper, are those lying above the yellow Chouteau limestone in the region in question. They consist of beds of gray limestone, more or less crystalline in the various strata, with scattered bands of lenticular chert concretions. No results of careful stratigraphical work, based on palæontological evidence, have ever been published in connection with this region, and though the rocks have been correctly considered as equivalent to that part of the Mississippian Series known in Illinois and Iowa as the Burlington and Keokuk Groups, the subdivisions of the strata have never been properly pointed out. The object of the present paper is to dissect out the various sub-faunas, to note their order of succession and the relations which they hold to each other.

During the summers of 1892 and 1893 the writer made quite extensive collections of the fossils from the quarries and other exposures in and about Springfield. From the study of these collections, the whole series of strata has been divided into twelve zones, which can be distinguished by their faunas.

The limits of these zones, however, are not sharply defined, as lower faunas change to the ones above through gradual transitions.

As the fauna of the Keokuk beds in Illinois and Iowa has been shown to be simply a later product of the same line of development which took place during the deposition of the Burlington beds, so here in Southwest Missouri, the upper faunas, which represent the Keokuk, are only a continuation of the development seen in the lower beds. Prof. H. S. Williams has suggested the name Osage Group* for this whole series of strata in Missouri, while Mr. C. R. Keyes has adopted the name Augusta Group† for the same deposits. With the exception of the lowest beds, the Springfield limestones resemble their more eastern equivalents in Illinois and Iowa, both in lithological and in faunal characters.

The great difficulty experienced in this study, has been the lack of any continuous section comprising all the beds of the group, such as is shown in the Mississippi River section. Some twenty-five localities were studied, and from them more or less complete collections of the fossils were made.

Most instructive in the way of showing the succession of the faunas, is a series of sections along the Gulf railroad, from Jones Spring, four miles southeast of Springfield, to the Gulf railroad shops in the city, then turning to the south and extending along Wilson Creek to Mackey's quarry. These sections show the succession from near the base of the Burlington up into the Keokuk. Along this line the rocks dip gradually to the west, and in the successive cuts and quarries, starting from Jones Spring, successively higher beds are exposed. At one point, a short distance east of Springfield, a slight fault disturbs the regularity of the line of sections, otherwise it is continuous. Besides this series of sections, other more or less isolated outcrops were studied.

There being no continuous section, and the element of dip being uncertain, no accurate estimate of the aggregate thickness of these beds can be made, but they probably extend through one or two hundred feet.

Description of Zones.

Zone I.—This zone can be readily recognized wherever it occurs. Its lithological characters are, in general, distinct from any of the succeeding beds. It is a fine-grained, gray or bluish limestone, quite hard, and with a more or less marked conchoidal fracture. Some lenticular chert nodules occur

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* Bull. U. S. Geol. Surv., No. 80, p. 109. Washington, 1891.

† Iowa Geol. Surv., vol. i, p. 59. Des Moines, 1893.

scattered through the limestone. Its geological position is immediately above the yellow Chouteau limestone, and in some places it even seems to be a continuation of the Chouteau, with no sharply fixed dividing line ; the yellow, sandy Chouteau gradually changing in color and texture till it becomes this hard gray limestone. Also the two faunas are blended so that the association of organic forms occurring here, is transitional between the Chouteau and the true Burlington. The zone is characterized by a brachiopod fauna.

At Spout Spring (Station 21), the following fauna was collected a few feet above the yellow Chouteau.*

***Spirifer biplicatus* Hall.
†*Productus lævicostus* White.
Productus sp.
**Terebratula burlingtonensis* White.
†*Spirifer lineata* Martin.
†*Spirifer suborbicularis* Hall.
†*Chonetes illinoisensis* Worthen.
†*Orthis swallovi* Hall. ?
Spiriferina sp.
**Phanerotinus paradoxus* Winchell.
**Entolium circulus* Shumard.
†*Productus punctatus* Martin.
†*Productus burlingtonensis* Hall.
†*Terebratula cf. hastata* Sowerby.
Loxonema sp.

The most abundant species, *S. biplicatus*, is described from the Kinderhook. The remaining forms are partly Chouteau and partly Burlington. The species which range downward are comparatively rare.

Collections have also been made from this zone near Pierson Creek, east of Springfield (Station 17). Here the fossils are from an horizon higher above the Chouteau than at Spout Spring, but the lithological characters are similar, except that the limestone contains much more chert. The following species were collected at this locality.

†*Chonetes illinoisensis* Worthen.
†*Orthis burlingtonensis* Hall.
Spiriferina sp.
†*Spirifer suborbicularis* Hall.
**Spirifer biplicatus* Hall.
**Spirifer marionensis* Shumard.
†*Spirifer grimesi* Hall.
†*Athyris lamellosa* L'Eveille.
Phillipsis sp.
†*Derbyia keokuk* Hall. ?

The fauna differs in some respects from the Spout Spring fauna, and more nearly resembles the true Burlington.

At an exposure on Sac Creek (Station 20), other collections were made which may be referred to this zone. The beds are of an higher horizon than either of the preceding localities, being up very close to the crinoidal limestone of the Burlington beds proper. In this fauna species of higher range are more common but lower forms are still present. The following species were collected.

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* Species marked * are forms having a downward range, and those marked † range upward. In all the lists the species are arranged according to their relative abundance, the most abundant being placed at the beginning of the list.

Chonetes illinoisensis Worthen.
Spirifer biplicatus Hall.
Syringothyris carteri Hall.
Spirifer suborbicularis Hall.
Rhynchonella sp.
Spiriferina sp.
Terebratula sp.
Orthis burlingtonensis Hall.
Orthis swallovi Hall.
Strophomena analoga Phillips.
Derbyia keokuk Hall.
Athyris lamellosa L'Eveille.
Productus burlingtonensis Hall.
Spirifer lineata Martin.
Athyris incrassatus Hall.
Spirifer grimesi Hall.
Productus lævicostus White.
Productus punctatus Martin.
Spirifer forbesi Norwood and Pratten.
Platyceras sp.

Spirifer biplicatus, a lower form which was abundant in the Spout Spring fauna, is still one of the common species. *Spirifer grimesi* which is the most characteristic brachiopod of the Burlington limestone, is rare in this whole zone.

The contact between Zone I and the overlying beds is generally quite well defined lithologically, but in some cases the transition between the two is gradual.

Zone II.—The lithological characters of the beds of this zone are decidedly different from those below. Here we pass into beds of rather coarse, crystalline limestone, composed largely of broken crinoid fragments, the fauna is a typical Burlington one.

At Jones Spring (Station 1), these beds are exposed lying directly upon the more compact limestone of Zone I. The following fauna was collected at this station.

Spirifer grimesi Hall.
Spirifer keokuk Hall. ?
Productus sp.
Athyris lamellosa L'Eveille.
Chonetes illinoisensis Worthen.
Straparollus latus Hall.
Spirifer suborbicularis Hall.
Strophomena analoga Phillips.
Orthis burlingtonensis Hall.
Zaphrentis centralis Worthen.
Platyceras sp.
Productus sp.
Syringothyris plenus Hall.
Orthis swallovi Hall.
Productus burlingtonensis Hall.

In a quarry at the Valley Water Mills (Station 18), the following species were collected, lying immediately above Zone I.

Spirifer grimesi Hall.
Athyris incrassatus Hall.
Orthis swallovi Hall.
Strophomena analoga Phillips.
Straparollus latus Hall.
Athyris lamellosa L'Eveille.
Spirifer forbesi Norwood and Pratten.
Derbyia keokuk Hall.
Platyceras sp.
Zaphrentis centralis Worthen.
Syringopora harveyi White.

In a quarry at Edward's Spring (Station 19), in strata a short distance above those containing the last fauna described under Zone I, these beds are well exposed. Here the two zones are not sharply defined lithologically, but the lower one grades gradually into the upper. Two more or less distinct beds are recognized in this quarry. From the lower of these the following fauna was collected.

Productus sp.
Straparollus latus Hall.
Productus sp.
Spirifer sp.
Strophomena analoga Phillips.
Agaricocrinus planoconvexus Hall.
Spirifer keokuk Hall.
Spirifer suborbicularis Hall.
Derbyia keokuk Hall.
Orthis swallovi Hall.
Dichocrinus striatus Owen and Shumard.
Pleurotomaria montezuma Worthen.
Syringothyris plenus Hall.
Platycrinus sp.
Chonetes illinoisensis Worthen.

In the upper bed the fauna is somewhat different.

Spirifer suborbicularis Hall.
Productus sp.
Chonetes illinoisensis Worthen.
Orthis swallovi Hall.
Batocrinus pyriformis Shumard. ?
Spirifer lineata Martin.
Zaphrentis centralis Worthen.
Platyceras sp.
Productus burlingtonensis Hall.
Spirifer keokuk Hall. ?
Spirifer grimesi Hall.
Syringothyris plenus Hall.
Spirifer forbesi Norwood and Pratten.
Spirifer sp.
Terebratula cf. hastata Sowerby.
Athyris lamellosa L'Eveille.
Dichocrinus striatus Owen and Shumard.
Athyris trinuclea Hall. ?

Most of the species occurring in this zone are typically Burlington forms. A few are limited to this horizon while others begin here and only reach their maximum development higher up.

Zone III.—In this zone the limestone is very similar to, and is a direct continuation of Zone II. At Station 2 these beds are exposed, and their position above Zone II can be readily seen. The following fauna was collected.

Syringothyris plenus Hall.
Spirifer grimesi Hall.
Orthis swallovi Hall.
Productus burlingtonensis Hall.
Orthis burlingtonensis Hall.
Spirifer suborbicularis Hall.
Athyris incrassatus Hall.
Spirifer sp.
Eucladocrinus pleurovimineus White.

At Station 14 the following species were collected from the same zone.

Syringothyris plenus Hall.
Spirifer grimesi Hall.
Productus burlingtonensis Hall.
Athyris incrassatus Hall.
Spirifer suborbicularis Hall.
Spirifer sp.
Productus punctatus Martin.
Spirifer pseudolineata Hall.
Orthis swallovi Hall.
Cladodus sp.
Platyceras quincyense McChesney.
Athyris lamellosa L'Eveille.
Terebratula cf. hastata Sowerby.
Dichocrinus striatus Owen and Shumard.

At Station 13, in beds of the same zone but probably at a little higher horizon, the following fauna was collected.

Syringothyris plenus Hall.
Chonetes illinoisensis Worthen.
Orthis swallovi Hall.
Spirifer grimesi Hall.
Productus burlingtonensis Hall.
Athyris incrassatus Hall.
Orthis burlingtonensis Hall.
Productus setigerus Hall.
Spirifer sp.
Spirifer suborbicularis Hall.
Metoptoma umbella Meek and Worthen.
Zaphrentis centralis Worthen.
Hadrophyllum glans White.

The distinctive character of this zone is the presence in large numbers of *Spirifer grimesi* and *Syringothyris plenus*, associated with *Orthis swallovi*, *Productus burlingtonensis*, etc. All the Chouteau species have disappeared and the fauna is typically Burlington. Exposures of the intermediate beds between this zone and the one below, have not been observed, but the change from one fauna to the other is probably very gradual, *S. plenus*, *S. grimesi*, etc., becoming more and more the predominant forms and replacing the smaller species which were abundant in Zone II.

Zone IV.—At Station 12, three distinct beds of limestone are exposed. The lowest of these is very similar in character to Zone III at Station 13, and probably lies but very few feet above it. However, there is a decided change in the fauna. *S. plenus* which was the most abundant species in the preceding zone, has almost entirely disappeared.

At Station 12, the following species were collected in the lowest bed.

Spirifer grimesi Hall.
Orthis swallovi Hall.
Orthis burlingtonensis Hall.
Athyris incrassatus Hall.
Productus punctatus Martin.
Metoptoma umbella Meek and Worthen.
Spirifer lineatoides Swallow.
Platyceras quincyense McChesney.
Platyceras equilatera Hall.

In the excavation made a few years ago at Station 6, the same three beds of limestone were penetrated as are seen at Station 12. Some fossils were obtained from here at the time, but they were not collected with reference to the present work. In the bottom of the excavation a coarse, gray, crystalline limestone, like the lower bed at Station 12, was exposed, and a great number of large, fine specimens of *S. grimesi* were collected, but no specimens of *S. plenus.*

Northwest of Springfield, in a large sunk hole (Station 15), a stratum of gray, crystalline limestone is exposed, with numerous fossils. Prominent among them is *S. grimesi*, but not a specimen of *S. plenus* was seen. The fauna as a whole is very similar to those just described and may be placed with them in Zone IV. The species collected are as follows:

Chonetes illinoisensis Worthen.
Spirifer grimesi Hall.
Orthis burlingtonensis Hall.
Spirifer sp.
Athyris incrassatus Hall.
Productus setigerus Hall.
Platyceras equilatera Hall.
Athyris lamellosa L'Eveille.
Productus punctatus Martin.
Platyceras quincyense McChesney.
Spirifer suborbicularis Hall.
Orthis swallovi Hall.
Derbyia keokuk Hall.
Zaphrentis centralis Worthen.
Rhynchonella cf. pleurodon Phillips.
Metoptoma umbella Meek and Worthen.
Hadrophyllum glans White.
Phillipsia bufo Meek and Worthen. ?

The fauna of the beds exposed at Station 16 is intermediate between the faunas of Zones III and IV. Both *S. plenus* and *S. grimesi* are abundant, though *S. grimesi* is the more common. Some other species, more characteristic of Zone IV, are present and therefore this fauna has been placed with Zone IV. The following is a list of the species collected.

Chonetes illinoisensis Worthen.
Spirifer grimesi Hall.
Spirifer sp.
Syringothyris plenus Hall.
Productus setigerus Hall.
Orthis burlingtonensis Hall.
Spirifer suborbicularis Hall.
Orthis swallovi Hall.
Productus punctatus Martin.
Athyris incrassatus Hall.
Zaphrentis centralis Worthen.
Spirifer lineatoides Swallow.
Athyris lamellosa L'Eveille.
Spirifer sp.

The whole fauna of this zone is interesting on account of the large size of the species. A constant increase in the average size of the members of the fauna as a whole, from Zone I to Zone IV is evident. In Zone I all the species are small, while in Zone IV nearly all are very large. This increase in size may be traced out even in a single species or a race. The earliest examples of *Spirifer grimesi* are generally small, but in the successively higher beds the average size increases till the maximum is reached in Zone IV. During this increase in size the specific characters remain unchanged, but above Zone IV, as the species becomes again reduced in size, the specific characters change and the race is represented by *S. logani.*

The *lineata* type of *Spirifers* also illustrates this same principle, but in this case, with the increase in size, new specific characters are assumed. The race is represented in Zones I and II by *S. lineata*, which is scarcely ever more than one-half inch in breadth. In Zone III *S. pseudolineata* occurs. This is a larger species with coarser markings. *S. lineatoides*, which is a still larger and coarser form of the same race, is limited to Zone IV. As this race decreases in size, it seems to pass through the same stages by which it attained its maximum development, but in a reverse order, for in beds above Zone IV, *S. pseudolineata* occurs which cannot be distinguished from specimens in Zone III. Other species illustrating the same principle, and reaching their maximum development at nearly the same horizon, are *Athyris lamellosa*, *Orthis swallovi*, *Zaphrentis centralis*, and *Platyceras*.

Zone V.—Lying above Zone III at Station 12, and also at Station 6, is a bed of much more siliceous limestone. This lower chert bed, as it may be designated, is constituted of variable proportions of a white, calcareous chert in lenticular masses, and limestone. The limestone is variable in character, but in general is much finer grained and harder than the beds below or above, and it often resembles very closely the fine grained limestone of Zone I. The chert, when subjected to the influence of weathering, slacks to a fine white powder. In many cases the chert masses surround a nucleus of limestone, the passage from the one material to the other being very gradual. Often fossils retaining their calcareous condition are found embedded in the chert. Like the limestone below, this also is largely made up of crinoidal remains, but perfectly preserved bodies are much more common.

At Station 12 the following fauna was collected.

Spirifer grimesi Hall.
Athyris incrassatus Hall.
Dorycrinus parvus Shumard.
Physetocrinus ventricosus Hall.
Orthis swallovi Hall.
Agaricocrinus americanus Roemer.
Platyceras sp.
Actinocrinus verrucosus Hall.
Terebratula cf. hastata Sowerby.

At Station 6 very few fossils were collected from this zone, but *Athyris lamellosa* was seen in addition to those mentioned. However at this locality we have the chert bed, with the same character of chert and limestone, lying in the same position as regards the fauna with the great development of *Spirifer grimesi*, and there can be no doubt as to the equivalence of the beds at the two localities.

In the Gulf R.R. section this chert bed is exposed at two other localities besides Station 6. At Station 3 about eight feet of this stratum is exposed. Only two species of fossils were collected here, though others are present.

Spirifer grimesi Hall.
Dorycrinus parvus Shumard.

At Station 4 this bed is again exposed. No fossils were collected here, but in the face of the quarry *Spirifer grimesi* and *Athyris incrassatus* appear to be common.

This zone may be considered as the upper limit of the true Burlington, and can be recognized by the peculiar character of the limestone and chert, as well as by its fauna. In this region *Dorycrinus parvus* is characteristic of the horizon.

Zone VI.—Lying above the lower chert bed is an horizon of rather coarsely crystalline limestone, much like that which also occurs below the chert. Nearly all the quarries along the south bank of Wilson Creek, in Springfield, are in strata of this zone. The beds however, dip to the west, and being carried below the surface, higher beds are exposed in the quarries near the Gulf R.R. shops.

At Station 3 the base of this zone may be seen resting directly upon the chert beds below. Fossils are abundant at this locality and the following species were collected.

Spirifer grimesi-logani Hall.
Zaphrentis varsoviensis Worthen.
Athyris incrassatus Hall.
Zaphrentis centralis Worthen.
Chonetes illinoisensis Worthen.
Synbathocrinus swallovi Hall.
Phillipsia bufo Meek and Worthen.
Spiriferina sp.
Platycrinus saffordi Troost.
Batocrinus subtractus White.
Batocrinus pyriformis Shumard.
Granatocrinus granulosus Meek and Worthen.
Platyceras equilatera Hall.
Athyris lamellosa L'Eveille.
Orthis swallovi Hall.
Derbyia keokuk Hall.
Productus sp.
Agaricocrinus americanus Roemer.
Batocrinus trochiscus Meek and Worthen.
Spirifer suborbicularis Hall.
Productus setigerus Hall.
Productus punctatus Martin.
Dorycrinus cornigerus Hall.
Actinocrinus multiradiatus Shumard.
Cyathocrinus iowensis Owen and Shumard.
Amplexus fragilis White and St. John.
Productus burlingtonensis Hall.

This fauna is interesting because of its transitional forms. There can be little doubt but that this horizon in Southwest Missouri may be correlated with the Burlington–Keokuk transition beds in Iowa. The fauna contains numerous crinoids, and the similarity between the forms collected here, and those described by Wachsmuth and Springer* from the transition beds at Burlington, Iowa, is very striking. The large *Spirifer* so abundant here is also a transitional form. It is the representative of what has been called *Spirifer grimesi* in the Burlington beds below, but at this horizon it begins to lengthen its hinge line and to assume the characters of *Spirifer logani* of the succeeding beds. Here however the *grimesi* type is most abundant, the individuals with elongated hinge lines being uncommon, and even in those which are present the character is not so extremely developed as it is higher up.

Above the lower beds of this zone, fossils are not so abundant. At Station 5 the following species were collected.

Spirifer grimesi-logani Hall.
Phillipsia bufo Meek and Worthen.
Athyris incrassatus Hall.
Orthis swallovi Hall.
Productus burlingtonensis Hall.
Spirifer suborbicularis Hall.
Derbyia keokuk Hall.
Zaphrentis centralis Worthen.
Platyceras fisurella Hall.
Productus punctatus Martin.
Spirifer pseudolineata Hall.
Syringothyris texta Hall.
Athyris planosulcata Phillips.
Palæacis obtusus Meek and Worthen.
Spirifer sp.
Aviculopecten magna Swallow.

Zone VII.—The next higher horizon studied, having a distinct fauna, is exposed in the upper part of the quarry at Station 7. The bed is largely composed of chert, and may be designated as the upper chert bed. The chert here is very different from that in Zone V. It is very hard and brittle and much stained with iron, and occurs in much larger and more irregular masses than in the lower bed. Both the chert and the limestone abound in fossils, but in all cases the calcareous matter of the fossils contained in the chert has been dissolved out, leaving the fossils in the form of moulds. In these impres-

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* Proc. Phil. Acad. Nat. Sci., 1878, p. 224.

sions in the chert, the finest detail of the surface markings of the shells are preserved. The limestone is coarsely crystalline and is largely composed of crinoid remains. On the decomposition of the limestone, the chert remains in the soil, often forming regular strata in the residual clay beds. Much of the fossiliferous chert, so abundant in the soil of this region, is from this horizon.

The fauna collected at Station 7 is as follows.

Agaricocrinus americanus Roemer.
Spiriferina sp.
Terebratula sacculus Martin.
Athyris incrassatus Hall.
Platycrinus saffordi Troost.
Eretmocrinus originarius Wachsmuth.
Spirifer logani Hall.
Orthis dubia Hall.
Batocrinus biturbinatus Hall.
Pentremites conoideus Hall.
Spirifer pseudolineata Hall.
Derbyia keokuk Hall.
Batocrinus sp.
Granatocrinus granulosus Meek and Worthen.
Spirifer tenuicostatus Hall.
Spirifer neglectus Hall.
Spirifer suborbicularis Hall.
Productus setigerus Hall.
Eumetria verneuilana Hall.
Batocrinus nashvillæ Troost.
Platyceras fisurella Hall.

This is decidedly a Keokuk fauna, and here we find the first appearance of a large number of new forms. Crinoids are abundant, but only the more delicate Keokuk forms are present. The crinoidal fauna does not assume the grotesque character so noticeable among the crinoids of the Keokuk Group in Iowa. The *tuberosus* variety of *Agaricocrinus americanus* is the only representative of these large forms.

Zone VIII.—The upper chert bed is succeeded by beds of crinoidal limestone similar to those which precede it. These strata may be seen at Station 8, and the fauna collected there is as follows:

Spirifer logani Hall.
Phillipsia bufo Meek and Worthen.
Zaphrentis centralis Worthen.
Productus punctatus Martin.
Derbyia keokuk Hall.
Rhynchonella mutata Hall.
Chonetes illinoisensis Hall.
Orthis dubia Hall.

At Station 9 the same horizon is exposed and the following species were collected.

Spirifer logani Hall.
Spirifer suborbicularis Hall.
Productus punctatus Martin.
Camarophoria subtrigona Meek and Worthen.
Derbyia keokuk Hall.
Terebratula sacculus Martin.

The fauna of this zone is Keokuk, though many species which were common in the chert zone, apparently are absent here. The reappearance of *Chonetes illinoisensis* is interesting, it being a form especially abundant in the Burlington beds below. Among the specimens of *Spirifer logani* the character of a lengthened hinge line is more exaggerated than in the beds below, but above this zone it is a rare species.

Zone IX.—This zone, as well as the three succeeding ones, with the exception of Zone XI, have only been seen in Mackey's quarry, Station 11. The section at this station is as follows, beginning with the lowest stratum.

1. Six feet of coarse, gray, crystalline limestone with many fossils.
2. Six inch band of lenticular chert nodules bedded in limestone.
3. Five feet of limestone similar to stratum 1, but with few fossils.
4. One foot band of chert and limestone.
5. Two feet of hard gray limestone with few fossils.
6. Eighteen inches of white oolitic limestone.
7. One foot of gray limestone. From the upper surface of this bed large stylolites, often six inches in length, extend down into the limestone. These stylolites are crowded close together and make a very conspicuous band through the quarry.
8. Three feet of gray limestone with few fossils.
9. Three to six feet to the top of the bank. A somewhat shaly gray limestone with many fossils.

Stratum 1 has been considered as Zone IX, and the fauna collected is as follows:

Orthis dubia Hall.
Athyris planosulcata Phillips.
Derbyia keokuk Hall.
Productus marginicinctus Prout.
Syringothyris sp.
Athyris incrassatus Hall.
Spirifer tenuicostatus Hall.
Chonetes illinoisensis Worthen.
Zaphrentis centralis Worthen.
Platyceras sp.
Chetetes sp.
Myalina keokuk Worthen.

Zone X.—This zone is represented by stratum 3 at Station 11, and is separated from the preceding zone by the chert band.

The fauna collected is as follows:

Athyris incrassatus Hall.
Productus punctatus Martin.
Spirifer pseudolineata Hall.
Spirifer suborbicularis Hall.
Syringothyris textus Hall.
Productus setigerus Hall.
Terebratula sp.
Conocardium indianense Miller. ?
Aviculopecten magna Swallow.

Zone XI.—The next fossiliferous stratum is the oolite bed. Few fossils were collected from this horizon at Station 11, the only species seen being *Rhynchonella mutata*. On the opposite side of Wilson Creek, however, at Station 10, this oolite bed is nicely exposed and has many fossils. The species collected at this locality are as follows:

Rhynchonella mutata Hall.
Orthis dubia Hall.
Eumetria verneuilana Hall.
Derbyia keokuk Hall.
Platyceras acutirostris Hall.
Conocardium meekanum Hall. ?
Batocrinus sp.
Pleurotomaria sp.

It is interesting to note the similarity between this fauna and that of the Spergen Hill beds in Indiana. Both faunas are made up, to a very great extent, of diminutive forms, most of the species occurring at Springfield being also present at Spergen Hill. In both localities the rock is an oolitic limestone, and the similarity of the faunas is probably due to the similarity of the environments during deposition. In Indiana these conditions were present at the beginning of the St. Louis period, but in Southwest Missouri this diminutive fauna is followed by a good Keokuk fauna.

Zone XII.—Above the stylolite band at Station 11, the first three feet are nearly barren of fossils, the only species seen being *Orthis dubia.* Above this however, in the somewhat weathered limestone, fossils are very abundant. The species collected are as follows:

Chonetes illinoisensis Worthen.
Derbyia keokuk Hall.
Orthis dubia Hall.
Athyris incrassatus Hall.
Spirifer keokuk Hall.
Spirifer suborbicularis Hall.
Phillipsia bufo Meek and Worthen.
Spiriferina sp.
Productus punctatus Martin.
Productus cora D'Orbigny.
Spirifer tenuicostatus Hall.
Zaphrentis centralis Worthen.

This fauna as a whole is Keokuk. The most interesting species is *Chonetes illinoisensis*, which was very abundant through the lower zones and then disappeared entirely. When it first reappeared it was quite rare, but in the present fauna it takes its place as the most abundant species. Specimens from the lower and upper zones are absolutely alike.

List of Stations.

1. Jones Spring, on Gulf R. R. 4 miles S. E. of Springfield.
2. Railroad cut just west of Station 1.
3. Railroad cut $\frac{1}{2}$ mile N. W. of Station 2.
4. Quarry on Gulf R. R., east of Springfield Car and Foundry Co.
5. Quarry at crossing of Gulf and Frisco railroads.
6. Excavation for gas receiver, corner of Main St. and Wilson Creek, Springfield.
7. Quarry at old brewery, near Gulf R. R. shops.
8. Quarry on east side of Wilson Creek and south of Mt. Vernon road.
9. Quarry on opposite side of creek from Station 8.
10. Ledge of oolitic limestone, $\frac{1}{4}$ mile south of Station 9.
11. Mackey's quarry, $1\frac{1}{2}$ miles S. W. of Springfield.
12. Quarry on N. Washington Ave., near the large spring.
13. Quarry $\frac{1}{4}$ mile N. E. from Station 12.
14. Quarry $\frac{1}{2}$ mile north from Station 12.
15. Sink hole in N. W. $\frac{1}{4}$, N. W. $\frac{1}{4}$, Sec. 8. T. 28, R. 22.
16. Railroad cut on Boliver R. R. at Ritter's Station.
17. Near Pierson Creek, S. W. $\frac{1}{4}$, S. W. $\frac{1}{4}$, Sec. 14. T. 29, R. 21.
18. Quarry at Valley Water Mills on Sac Creek, 4 miles N. E. of Springfield.
19. Quarry at Edward's Spring, near the N. W. corner of Sec. 6, T. 28, R. 21.
20. Ledge along Sac Creek, just north of Station 19.
21. Spout Spring, on Sac Creek N. E. of Springfield.

Chas. D. Walcott.

RANGE OF SPECIES.

ZONES.	Burlington.					Keokuk.						
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Athyris incrassatus Hall	×	×	×	×	×	×	×		×	×		×
lamellosa L'Eveille	×	×	×	×	×	×						
planosulcata Phillips						×			×			
Camarophoria subtrigona Meek and Worthen								×				
Chonetes illinoisensis Worthen	×	×	×	×		×		×	×			×
Derbyia keokuk Hall	×	×		×		×	×	×	×		×	×
Eumetria verneuilana Hall							×				×	
Orthis burlingtonensis Hall	×	×	×	×								
dubia Hall							×	×	×		×	×
swallovi Hall	×	×	×	×	×	×						
Productus burlingtonensis Hall	×	×	×			×						
cora D'Orbigny												×
laevicostus White	×											
marginicinctus Pront									×			
punctatus Martin	×		×	×		×		×		×		×
setigerus Hall			×	×		×	×			×		
Rhynchonella mutata Hall								×			×	
Spirifer biplicatus Hall	×											
forbesi Norwood and Pratten	×	×										
grimesi Hall	×	×	×	×	×	×						
keokuk Hall		?										×
lineata Martin	×	×										
lineatoides Swallow				×								
logani Hall						×	×	×				
marionensis Shumard	×											
neglectus Hall							×					
pseudolineata Hall			×			×	×			×		
suborbicularis Hall	×	×	×	×		×	×	×		×		×
tenuicostatus Hall							×		×			×
sp.		×	×	×								
Strophomena analoga Phillips	×	×										
Syringothyris carteri Hall	×											
plenus Hall		×	×	×								
textus Hall						×				×		
Terebratula burlingtonensis White	×											
sacculus Martin							×	×				
Metoptoma umbella Meek and Worthen			×	×								
Phanerotinus paradoxus Winchell	×											
Platyceras acutirostris Hall											×	
equilatera Hall				×		×						
fisurella Hall						×	×					
quincyense McChesney			×	×								
Pleurotomaria montezuma Worthen		×										
Straparollus latus Hall		×										
Aviculopecten magna Swallow						×				×		
Conocardium indianense Miller ?										×		
meekanum Hall ?											×	
Entolium circulus Shumard	×											

RANGE OF SPECIES.

ZONES.	Burlington.					Keokuk.						
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Myalina keokuk Worthen									×			
Actinocrinus multiradiatus Shumard						×						
verrucosus Hall					×							
Agaricocrinus americanus Roemer					×	×	×					
planoconvexus Hall		×										
Batocrinus biturbinatus Hall							×					
nashvillæ Troost							×					
pyriformis Shumard		?				×						
subtractus White						×						
trochiscus Meek and Worthen						×						
Cyathocrinus iowensis Owen and Shumard						×						
Dichocrinus striatus Owen and Shumard		×	×									
Dorycrinus cornigerus Hall						×						
parvus Shumard					×							
Eretmocrinus originarius Wachsmuth							×					
Eucladocrinus pleurovimineus White			×									
Granatocrinus granulosus Meek and Worthen						×	×					
Pentremites conoideus Hall							×					
Physetocrinus ventricosus Hall					×							
Platycrinus saffordi Troost						×	×					
Synbathocrinus swallovi Hall						×						
Amplexus fragilis White and St. John						×						
Hadrophyllum glans White			×	×								
Palæacis obtusus Meek and Worthen						×						
Syringopora harveyi White		×										
Zaphrentis centralis Worthen		×	×	×		×		×	×			×
varsoviensis Worthen						×						
Phillipsia bufo Meek and Worthen				×		×		×				×

Conclusion.

The facts described in the preceding paper, it is believed, satisfactorily establish the following points.

1. There is a succession of faunas in the limestones about Springfield.

2. The faunas of the lower part of the section may be correlated with the Burlington faunas of Iowa, and those of the upper part with the Keokuk faunas.

3. The whole series of sub-faunas is continuous, and the whole series of rocks should be designated by a single name. The Osage Group* is the earliest name suggested for this series of strata.

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* H. S. Williams, 1891. Bull. U. S. Geol. Surv., No. 80, p. 109.

4. In the life-history of several species, including brachiopods, a gasteropod, and a coral, the maximum development of the species, both in size and in numbers, is attained at very nearly the same time.

5. *Spirifer logani* is the genetic successor of *Spirifer grimesi.*

New Haven, Conn., Jan. 11th, 1895.

Art. XIX.—*Distribution of the Echinoderms of Northeastern America;* by A. E. Verrill. (Brief Contributions to Zoology from the Museum of Yale College, No. LIX.)

[Continued from page 141.]

Family Solasteridæ Perrier.

Solaster endeca Forbes.

Asterias endeca Retzius, K. Vet. Akad. Handl., vol. iv, p. 237, 1783; Gmelin, Syst. Nat., p. 3162.

Solaster endeca Forbes, Mem. Wern. Soc., vol. viii, p. 121, 1839; Hist. British Starfishes, p. 109. fig., 1841; Müll. and Trosch., Syst., p. 26; Stimpson, Invert. Grand Manan, p. 14, 1853; Verrill, Proc. Boston Soc. Nat. Hist, vol. x, p. 345; A. Agassiz, N. Amer. Starfishes, p. 112, pl. 17, figs. 1–5, 1877; Perrier, Stellerides du Mus., in Arch. Zool. Exper., vol. iv, p. 359, 1875; Duncan and Sladen. Echin. Arctic Sea, p. 40, pl. 3, figs. 5–8, 1881; Danielssen and Koren. Norske Nordhavs-Exp., vol. xi, p. 50, pl. 9, fig. 13, 1884; Sladen, Voy. Challenger, vol. xxx, p. 452, 1889.

B. range, 0 to 150 fath., in the cold areas. Taken at numerous stations, in 25 to 100 fath., from Newfoundland to Cape Cod. Common in the Bay of Fundy from low water to 80 fath., and off Cape Cod, 26 to 50 fath. Taken on all the fishing Banks off Nova Scotia in 40 to 150 fath. It occurs on the coasts of Greenland and Northern Europe. Probably circumpolar.

The dorsal surface is closely covered with small pseudopaxillæ, with finer spinules than in any of the following species.

This species is allied to *S. Stimpsoni* Ver., 1879, from the N. W. coast of America. *S. subarcuatus* Sl., from the Southern Indian Ocean, S. lat. 52° 04′, in 150 fath; and *S. torulatus* Sl., from north of the Kermadec Is., in 250 fath., are also closely related.

Solaster syrtensis Verrill.

Proc. U. S. Nat. Mus., vol. xvii, p. 271, 1894.

B. range, 45 to 101 fath., in the cold areas.

Taken by the U. S. Fish Comm. off Cape Cod (Sta. 264), in 80 fath.; and off Cape Sable, N. S., in 101 fath. (Sta. 85, 86, 1877). Several specimens, received from the Gloucester fishermen, were taken on the fishing Banks from George's to Banquereau, N. S., in 45 to 80 fath.

This species is easily distinguished by the even spinulation of its dorsal surface, the pseudopaxillæ being crowded and larger than in *S. endeca*. The rays are usually nine.

It appears to be allied to *S. paxillatus* Sl., from south of Japan, in 345 fath., and to *S. Stimpsoni* V., 1879.

SOLASTER ABYSSICOLA Verrill.

Solaster abyssicola Verrill, this Journal, vol. xxix, p. 152, 1885; Expl. by the Albatross in 1883, in Ann. Rep. U. S. Fish Comm., p. 541, [39], 1885.

B. range, 843 to 1537 fath. Taken at several stations from N. lat. 39° 05′ 30″ to 35° 45′ 30″.

This species is remarkable for the large number of papulæ, of rather large size, between the dorsal plates; they are longer than the spinules when expanded. The actinal plates bear stellate paxillæ, similar to those of the back. It most frequently has eight rays; sometimes seven or nine.

This appears to be allied to *S. regularis* Sl., from west of Patagonia, in 175 fath.

SOLASTER BENEDICTI Verrill.

Proc. U. S. Nat. Mus., vol. xvii, p. 273, 1894.

B. range, 841 to 1081 fath. Taken at several stations from N. lat. 40° 53′ 30″ to 35° 45′ 23″, by the U. S. Fish Comm.

Easily distinguished by the rather small and well separated dorsal pseudopaxillæ, with few small papulæ between them; by the actinal plates having small groups, mostly of two to four small spines; and by the small number of the transverse adambulacral spines. It usually has nine rays; sometimes ten.

SOLASTER EARLLII Verrill.

This Journal, vol. xvii, p. 473, 1879; Expl. by the Albatross in 1883, in Ann. Report U. S. Fish Comm., vol. xi, p. 541, pl. 13, fig. 50*b*, pl. 19, figs. 50, 50*a*, 1885.

B. range, 120 to 325 fath., in the cold areas. Taken by the U. S. Fish Comm. at a few stations between N. lat. 44° 28′ 50″ and 40° 04′. It was brought by the Gloucester fishermen from several of the Banks off Nova Scotia and Newfoundland, from N. lat. 45° 25′ to George's Bank; taken mostly in 170 to 300 fath.

Most of the specimens are larger than the original type figured, and have a broader and more tumid disk, with wider and more swollen rays, which are usually nine. The dorsal pseudopaxillæ are rather large, stout, and stellate, giving the back a rather coarsely spinulose appearance. The adambulacral and actinal spines are long and tapered.

This is allied to *S. Dawsoni* Ver. (1879), from the N. W. coast of America, in 8 to 15 fath.

CROSSASTER PAPPOSUS Müll. and Troschel.
Asterias papposa Fabricius, Fauna Grönlandica, p. 369, 1780.
Solaster papposus Forbes, Mem. Wern. Soc., vol. viii, p. 121, 1839; Brit. Starfishes, p. 112, fig., 1841; Stimpson, Invert. Grand Manan, p. 15, 1853; Müll. and Trosch., Syst., p. 26, 1842; Perrier, Stellerides du Mus., p. 94; Danielssen and Koren, op. cit., p. 48, pl. 9, fig. 12, 1884.
Crossaster papposus Müll. and Trosch., Wieg. Arch., vol. iv, part 1, p. 183, 1840; Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 345, 1866; A. Agassiz. North Amer. Starfishes, pp. 99, 112, pl. 12, figs. 1–5, 1877; Duncan and Sladen, op. cit., p. 36, pl. 3, figs. 1–4, 1881; Sladen, Voy. Challenger, vol. xxx, p. 444.

B. range, 0 to 179 fath. Taken by the Gloucester fishermen at numerous localities on all the fishing Banks, from off Newfoundland, N. lat. 49° 20′ 30″ to George's, in 40 to 125 fathoms; and by the U. S. Fish. Comm., from N. lat. 46° 58′ to 40° 09′. It is common in the Bay of Fundy, from extreme low-water mark to 60 fathoms on hard bottoms; less common and smaller in Casco Bay and Massachusetts Bay, 10 to 50 fath. It is found in the Arctic Ocean and on the northern coasts of Europe.

A closely related species (*S. penicellatus* Sl.) occurs in the S. Atlantic, S. lat. 37° 25′ 30″ to 46° 43′, in 110 to 140 fath. Another allied form occurs on the N.W. coast of America.

CROSSASTER HELIANTHUS Verrill.
Proc. Nat. Mus., vol. xvii, p. 274, 1894.

B. range, 100 to 150 fath., near George's Bank.

LOPHASTER FURCIFER Verrill.
Solaster furcifer Duben and Koren, K. Vet. Akad. Förhandl., p. 243, pl. 6, figs. 7–10, 1844; Thomson, Depths of the Sea, pp. 119, 456, figs. 14, 75, 1873; Danielssen and Koren, op. cit., p. 47, pl. 8, fig. 12; pl. 9, figs. 9–11, 1884.
Lophaster furcifer Verrill, this Journal, vol. xvi, p. 214, 1878; Duncan and Sladen, op. cit., p. 43, pl. 3, figs. 9–12, 1881; Verrill, Expl. by the Albatross, p. 541, pl. 16, figs. 49, 49^a, 1885; Sladen, Voyage Challenger, vol. xxx, p. 459, 1889.

B. range, 111 to 640 fath. Taken at several stations from N. lat. 47° 40′ to 40° 01′; also in the Gulf of Maine in 150 fath., 1872. It is also European and Arctic (N. lat. 81° 41′).

An allied 5-rayed species (*L. radians* Perrier) occurs in the West Indies.

Another closely related species (*L. stellans* Sl.) occurs off the W. coast of S. America, in 40 to 1325 fath.

Family PTERASTERIDÆ.

PTERASTER PULVILLUS M. Sars.
Pteraster pulvillus Sars, Overs. Norges Echinod., p. 62, pl. 6, figs. 14–16, pls. 7, 8, 1861; Verrill, this Journal, vol. xvi, p. 371, 1878.

B. range, 20 to 111 fath. Rare. N. lat. 46° 50′ to Gulf of Maine, off Isles of Shoals, N. H. Bay of Fundy, 20 fath. Banks off Nova Scotia and Newfoundland. It occurs also off the northern coasts of Europe and in the Arctic Ocean.

PTERASTER MILITARIS Müll. and Trosch.

Asterias militaris Müller, Zool. Dan. Prod., p. 234, 1776; Rathke, Zool. Dan., vol. iv, p. 14, pl. 131, 1806.

Pteraster militaris Müller and Troschel, Syst., Aster., Supl., p. 128, pl. 6, fig. 1, 1842; Stimpson, Invert. Grand Manan, p. 15, 1853; M. Sars, Overs. Norges Echinod., p. 48, pl. 3, figs. 8, 9, pl. 4, figs. 4–6, 1861; Duncan and Sladen, op. cit., p. 46, pl. 3, figs. 13–16. Danielssen and Koren, op. cit., p. 70, pl. 13, figs. 18, 19, 1884; Verrill, Expl. by the Albatross, p. 541, pl. 13, fig. 35, 1885.

B. range, 10 to 200 fath. From 10 to 530 fath. (Sladen). Taken at many stations from N. lat. 47° 29′ to Massachusetts Bay. Common in the Bay of Fundy in 10 to 50 fath. Also European and Arctic.

TEMNASTER HEXACTIS Verrill.

Pteraster (*Temnaster*) *hexactis* Verrill, Proc. Nat. Mus., vol. xvii, p. 175, 1894.

B. range, 57 fath. Only one specimen taken, N. lat. 43° 05′. No allied species is known.

DIPLOPTERASTER MULTIPES Verrill.

Pteraster multipes M. Sars, Vidensk. Selskabs. Förhandl., 1865, p. 200; Fauna Litt. Norvegiæ, p. 65, pl. 8, figs. 1–17, 1877.

Diplopteraster multipes Verrill, this Journal, vol. xx, p. 400, 1880; Ann. Report U. S. Fish Comm., for 1882, vol. x, p. 659, 1884; op. cit., vol. xi, Expl. by the Albatross in 1883, p. 542, pl. 14, fig. 43, 1885.

Retaster? multipes Sl., op. cit., pp. 477, 478, 800, 1889.

B. range, 67 to 640 fath. Most commom between 100 and 300 fathoms. Taken at many stations between N. lat. 44° 26′ and 37° 07′ 50″. Occurs also off the Norwegian coast.

The two following species, described by Mr. Sladen from the southern hemisphere, appear to belong to this genus and to be closely allied to our species:

Diplopteraster verrucosus V. = *Retaster verrucosus* Sl., Magellan Str., 55 fath.

D. peregrinator V. = *Retaster peregrinator* Sl., off Kerguelen I., 127 fath.

These have the ambulacral feet in four rows and the broad, thick, fleshy actinal membrane characteristic of this genus.

LOPHOPTERASTER, gen. nov.

Form and general appearance as in *Pteraster*, from which it differs chiefly in having a very prominent, solid crest or keel-like prominence on the center of each jaw; it forms the inner angle of the jaw, separating the two groups of oral spines in the middle. The latter are otherwise webbed together. Two small, actinal jaw-spines on each side. Actinal radial spines well developed. Adambulacral spines webbed. Supradorsal membrane nearly as in *Pteraster*. Definite, dorsal interradial channels.

LOPHOPTERASTER ABYSSORUM, sp. nov.

Form stellate, with five short rays. Radii 42 and 22^{mm}. Disk large and swollen dorsally, covered with definite, angular areolations, due to the outer circle of paxillary spinules being longer than the others; many of the shorter ones project slightly above the cuticle within the areolæ; the central spinules is scarcely larger than the rest. Muscular fibers feeble, radiating. Papulæ small and rather numerous. In each interradial area there is a furrow, bordered by divergent, webbed groups of spinules; no definite openings are visible in them, except some pores rather larger than usual. The slender, glassy, actinal radial spines, covered with thin membrane, project as a fringe at the margin. Adambulacral spines slender, five to seven, webbed for about half their length, and bordered with web to the tips. Valve of the segmental pores semi-oval, attached by the entire adoral margin and supported by a short, central spinule.

B. range, 2021 fath. Two specimens (8141) from station 2226, in 2021 fathoms, N. lat. 37°, W. long, 71° 54′.

No allied species is known.

Dorsally this species resembles *Pteraster pulvillus*, for which it was mistaken at first.

HYMENASTER MODESTUS Verrill.

Hymenaster modestus Verrill, this Journal, vol. xxix, p. 151, 1885; Proc. Nat. Mus., vol xvii, p. 277, 1894.

B. range, 1098 to 1451 fath. Very rare. Taken at two stations, N. lat. 39° 40′ 05″ and 39° 22′ 20″.

HYMENASTER REGALIS, sp. nov.

Form stellate with five rays. Greater radii, 70^{mm}; lesser, 45^{mm}. Disk somewhat swollen, with the interradial areas sunken; rays broad, somewhat swollen, broadest a little beyond the base, regularly tapered. The entire dorsal surface is covered with long, prominent, sharp spines, which project far beyond the super-dorsal membrane, but are covered with cuticle to the tip; these spines form nine regular, longitudinal rows on each ray; those in the two rows on each side of the rays are united by a web extending about a third of their height. About ten clusters of similar spines surround the central area of the disk, which is covered by five, broad, concave, valve-like structures, which close the central pore. These valves are supported by numerous slender spines, which project along their inner margins, and several stouter spines on the distal margin, all of which are webbed together. Each dorsal spine is the central spinule arising from a large, elevated paxilla, the other spinules being rudimentary or absent.

Attached to each spine is a group of numerous strong radiating fibers which extend from spine to spine and support the intervening membrane, which rises in a tent-like form at the base of each spine. The spiracles are everywhere numerous and rather large. The actinal interradial areas are covered by a smooth, thick integument, which extends out as a web, between the bases of the arms, and as a border along their sides, to near the end. The radial spines are short and nearly concealed by the membrane. Those about opposite the middle of of the furrow are the longest and reach the margin of the web, but do not project beyond it; but those toward the tips of the rays, where the web is narrow, project beyond its margins; those toward the inner end of the furrow become quite short; but those next the jaws are again somewhat lengthened. The furrows are wide and shallow. The ambulacral feet are very large, arranged in two rows, conical, with a small sucker at the tip. Each adambulacral plate bears three long slender spines of which the two outer are much the longest, they stand in an oblique row, the two inner ones being more aborally placed than the other, and nearly side by side; the innermost is much smaller than either of the others; all are covered and bordered by soft cuticle, which also extends in a soft flap beyond the tip. The segmental pores are very large and conspicuous and covered by a soft membranous valve, irregularly ovate in form, bilobed at the tip, and attached by the end next the furrow, where it is supported by a short, thick, stump-like spine. Each jaw bears a median, solid, short, thick, elevated crest or keel, which projects inward slightly, between the oral spines; a large actinal spine arises on each of its sides, a little nearer the inner than the outer end; another pair of similar, but somewhat smaller, spines arises on each side of the inner end; three much smaller, slender spines arise from the lateral margin of each jaw; these spines are covered with cuticle which projects in long flaps beyond the tips, but does not form a web.

B. range, 1374 fath. A single specimen (No. 15,556) was taken at station 2725, N. lat. 36° 34′, W. long. 73° 48′.

Species of this genus are found in all the oceans at great depths. None of the numerous described species resemble this very much.

Family Echinasteridæ Verrill.

Cribrella pectinata Verrill.
Proc. Nat. Mus., vol. xvii, p. 278, 1894.

B. range, shallow water (about 20 fath.), Bay of Fundy.

CRIBRELLA SANGUINOLENTA Lütken.

Asterias sanguinolenta Müller, Zoöl. Dan. Prod., 2836, 1776.
Asterias oculata Pennant, Brit. Zoöl., vol. iv, p. 61, pl. 30, fig. 56, 1777.
Asterias spongiosa Fabricius, Fauna Grœnl., p. 368, 1780.
Linkia oculata Forbes, Wern. Mem., vol. viii, p. 120, 1839.
Cribella oculata Forbes, British Starfishes, p. 100 (figure), 1841.
Echinaster oculatus Müller and Troschel, Syst. Asterid., p. 24, 1842.
Linkia oculata Stimpson, Invert. of Grand Manan, p. 14, 1853.
Linkia pertusa Stimpson, op. cit , p. 14.
Echinaster sanguinolentus Sars, Fauna Litt. Norveg., i, p. 47, pl. 8, figs. 3–6; Oversigt af Norges Echinodermer, p. 84, 1861.
Cribrella sanguinolenta Lütken, Grœnl. Echinod., p 31, 1859; Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 345, 1866; Verrill, Invert. Vineyard Sd., pp. 407, 425, 1873; A. Agassiz, N. Amer. Starfishes, p. 113, pl. 18, 1877.
Cribrella oculata Perrier,* Stellerides, in Arch. Zoöl. Exper., vol. iv, p. 373, 1875; Duncan and Sladen, op. cit., p. 32, pl. 2, figs. 18–21, 1881; Danielssen and Kor., op. cit., p. 34, 1884; Sladen, op. cit., p. 542,1889.

B. range, 0 to 471 fathoms; off New Jersey in 1350 fathoms, Sladen. Rare below 200 fathoms on our coast. Very abundant north of Cape Cod in 1 to 50 fath., on hard bottoms. Common in the cold area south of Martha's Vineyard, in 10 to 60 fathoms. It is found off Cape Hatteras. Taken at more than 400 stations between N. lat. 47° 29′ and 35° 38′. It enters the eastern part of Long Island Sound. It ranges to Greenland and the Arctic Ocean generally, and to northern Europe.

Allied species are found in all the oceans; about 14 are recognized.

Family PEDICELLASTERIDÆ.

PEDICELLASTER TYPICUS M. Sars.

Oversigt over Norges Ecinod., p. 77, pl. 9, figs. 9–17, pl. 10, figs. 1–10, 1861; Verrill, this Journal, vol. xvi, p. 214, 1878; Danielssen and Koren, op. cit., p. 36, 1884; Sladen, Voy. Challenger, pp. 557, 814, 1889.
Pedicellaster palæocrystallus Duncan and Sladen, op. cit., p. 34, pl. 2, figs. 22–26, 1881; Sladen, Voy. Challenger, vol. xxx, pp. 557, 560 (note).

B. range, 79 to 122 fath. From 50 to 620 fath., Sladen. Taken a few times, sparingly, from N. lat. 43° 19′ to 42° 15′ 25″. Also found in the Gulf of St. Lawrence. It ranges to the Arctic Ocean and northern Europe.

Nine or ten species of this genus are recorded from the Atlantic and Antarctic regions, mostly in deep water.

Family ZOROASTERIDÆ Sladen.

ZOROASTER DIOMEDEÆ Verrill.

Zoroaster Diomedeæ Verrill, Brief Cont., No. 55; this Journal, vol. xxviii, p. 217, 1884; Expl. by the Albatross in 1883, p. 540 [38], 1889.
?*Zoroaster fulgens* (pars) Sladen, Voy. Challenger, vol. xxx, p. 418, plates 66 and 68, 1889.

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* I do not consider it justifiable to follow Perrier, Sladen, and others in the revival of the ancient name (*oculatus*) given to this species in 1733 by Linck, who was not a binomial writer. If it be necessary to do so in this case, the same argument would apply to all his other trivial names, and to all his generic terms also. The name of this species would, in that case, stand as *Pentadactylosaster oculatus* Linck.

B. range, 1098 to 1555 fath. Most abundant from 1300 to 1500 fath. In one doubtful case, recorded from 471 fath. (one specimen). Dredged at 16 stations from N. lat. 41° 09′ 40″ to 37° 27′.

Allied species are found at great depths in most seas. *Z. fulgens* Thomson, from the eastern Atlantic, 500 to 1350 fath., and *Z. Ackleyi* Per., from the West Indies, are nearly related to our species if not identical. Mr. Sladen refers specimens dredged by the Challenger off our coast in 1250 to 1350 fath. to *Z. fulgens*. These were probably identical with our species and indicate that the two described forms may be the same. He also records *Z. fulgens* from off Brazil, in 675 fath.

Family STICHASTERIDÆ Perrier.

NEOMORPHASTER FORCIPATUS Verrill.
Proc. Nat. Mus., vol. xvii, p. 269, 1894.

B. range, 852 to 990 fathoms. Three stations off George's Bank and S. of Martha's Vineyard.

The only species allied to this is *N. eustichus* Sladen, from 900 to 1000 fath., off the Azores.

STICHASTER ALBULUS Verrill.

Asteracanthion albulus Stimpson, Invert. Grand Manan, p. 14, pl. 1, fig. 5, 1853.
Stichaster albulus Verrill, Proc. Boston Soc. Nat. Hist, vol. x, p. 351, 1866; Perrier, Arch. Zool. Exper., vol. iv, p. 347, 1875; Duncan and Sladen, op. cit., p. 29, pl. 2, figs. 13–17, 1881; Danielssen and Koren, op. cit., p. 31, pl. 8, figs. 13–15, 1884; Sladen, Voy. Challenger, vol. xxx, p. 432, 1889.
Asteracanthion problema Steenstrup. Vidensk. Medd. nat. Foren., p. 240, 1854; Lütken, Grönl. Echinod., p. 30, 1857.
Stephanasterias albula Verrill, Bulletin Essex Inst., vol. i, p. 5, 1871; Expl. Casco Bay, p. 353, 1874; Check List, 1879; Expl. by the Albatross in 1883, p. 540, 1885.

B. range, 0 to 229 fath.; in one case recorded from 435 fath., off Delaware. Common from low-water mark to 100 fath. in the Bay of Fundy and off the coast of Nova Scotia. Dredged at more than 100 stations between N. lat. 46° 50′ and 35° 12′ 30″. Off Cape Hatteras it is common in 16 to 50 fath. Common S. of Martha's Vineyard in 50 to 150 fath. Its range extends to Greenland, Iceland and other parts of the Arctic Ocean, and the northern coasts of Europe.

Allied species are found in most seas.

This family seems hardly worthy of separation from the next.

Family ASTERIIDÆ.

ASTERIAS FORBESII Verrill.

Asteracanthion Forbesii Desor, Proc. Boston Soc. N. H., vol. iii, p. 67, 1848.
Asterias arenicola Stimpson, Proc. Boston Soc. Nat. Hist., vol. viii, p. 268, 1862; Verrill, ditto, vol. x, p. 339, 1866; Invert. Vineyard Sd., p. 424, 1873.

Asteracanthion berylinus Ag. MSS., A. Agassiz, Embryology of Echinod., in Proc. Amer. Acad., 1863; Embryology of the Starfish, in Agassiz Contributions, vol. v, p. 3; Sea-side Studies, p. 108, figs. 141–145, 1865; N. American Starfishes, p. 94, pl. 9, 1877.

Asterias Forbesii Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 345, 1866; Invert. Vineyard Sd., p. 424, 1873; this Journal, vol. xi, pp. 418, 419, 1876.

Asterias Forbesii and *A. arenicola* Perrier, Arch., Zool. Exper., vol. iv, p. 315, 1875.

B. range, 0 to 27 fath., chiefly in the warm areas. Its normal range extends from Massachusetts Bay to Northern Florida and the northern shores of the Gulf of Mexico, in shallow water; rare and local, in sheltered localities, north of Massachusetts, as at Quahog Bay, east of Portland, Maine, and near the mouth of the Kennebeck River.

Very abundant in Long Island Sound; Buzzard's Bay; Vineyard Sound; and along the shores of Long Island, from low-water to 15 fathoms, especially on oyster beds, where it is very destructive.

ASTERIAS VULGARIS Stimpson, MSS.

Packard, in Canadian Naturalist and Geologist, 1863 (no description); Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 347, 1866 (description).

Asterias Stimpsoni (*pars*) Verrill, Proc. Bost. Soc. Nat. Hist., vol. x, p. 349, 1866, Young.

Asteracanthion pallidus Ag. MSS.; A. Agassiz, Embryology, in Proc. Amer. Acad., 1863 (no description); Embryology of the Starfish, in Agassiz' Contributions, vol. v, p. 3.

Asterias vulgaris Verrill, Invert. Vineyard Sd., pp. 490, 424, 1873; this Journal, vol. xi, p. 419, 1876 (revision).

Asterias pallida, *A. vulgaris*, and *A. Fabricii* Perrier, Arch., Zool. Exper., vol. iv, pp. 317–320, 1875.

B. range, 0 to 358 fath; most abundant in 1 to 60 fath. Belongs to the cold areas. Eastern part of Long Island Sound to Labrador, in shallow water; in deep water it ranges southward as far as off Cape Hatteras. Very abundant in Massachusetts Bay, Casco Bay, Bay of Fundy, from above low-water mark to 60 fathoms; common in the deeper parts of Vineyard Sound and off Buzzard's Bay in 6 to 45 fathoms; common S. of Martha's Vineyard in 10 to 50 fathoms, and occasionally in 190 to 358 fath.; off Watch Hill, Rhode Island, 4 to 20 fathoms, common; Faulkner's Island, Connecticut, low-water, rare.

ASTERIAS STELLIONURA Perrier.

Asteracanthion stellionura Perrier, Ann. des Sci. Nat., vol. xii, p. 420, pl. 1, figs. 10*b*, 10*d*, 1869.

Asterias stellionura Perrier, Stellerides, in Arch. Zoöl. Exper., vol. iv, p. 310, 1875; Verrill, this Journal, vol. xvi, p. 214, 1878; Danielssen and Koren, op. cit., p. 14, pl. 4, figs. 1–9, 1884.

B. range, 40 to 300 fathoms; strictly northern. Taken at numerous localities on the Grand Banks, Banks off Nova Scotia, and on George's Bank by the Gloucester fishermen, 40 to 300 fath. Dredged at many stations from N. lat. 44° 56′ to 43° 32′, in 69 to 127 fath. Its range extends to the Arctic Ocean, Iceland, etc.

ASTERIAS ENOPLA, sp. nov.

Rays five, long, rather slender, rounded. Disk small. Radii 7^{mm} and 42^{mm}. Abactinal surface with three regular rows of rather long, tapered, acute spines, standing singly, those of the median row slightly larger than the others; similar spines cover the disk. A prominent double lateral row of similar spines on each side, two divergent spines standing one above the other on each plate. A regular, simple, infero-marginal row of still larger, rather strong, acute spines situated close to the adambulacral series; the latter are much smaller, slender, tapered, acute; they stand mostly two on a plate, but often only one. The infero-lateral spines bear a very large cluster of cruciform pedicellariæ on the outer side; the supero-lateral spines bear a much smaller group on the upper side; the dorsal spines are mostly without pedicellariæ. Very large, ovate, acuminate, rectiform pedicellariæ are scattered between the spines, both above and below; the larger ones are often as broad as the adjacent spines; smaller and more acute ones border the inner edges of the ambulacral furrows. The papulæ are large, and mostly stand singly. The dorsal skeleton-plates are short, thick, and stout.

B. range, 53 to 100 fath. Off Nova Scotia, two specimens.

Allied to *A. Gunneri* Kor. and Dan., of the Arctic Ocean, and to *A. stellionura*, but it has a much firmer dorsal skeleton and much longer and larger dorsal spines than either of those species.

ASTERIAS POLARIS Verrill.

Asteracanthion polaris Müll. and Trosch., Syst. Aster., p. 16, 1842; Lütken, Syst. Overs. Grönlands Echinod., p. 28, 1857; Duncan and Sladen, op. cit., p. 23, pl 2, figs. 4–8, 1881.

Asterias polaris Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 356, 1866; Lütken, Vidensk. Meddel. nat. Forening, p. 28, 1871; Verrill, this Journal, vol. xi, p. 420, 1876; K. J. Bush, Proc. U. S. Nat. Mus., vol. vi, p. 246, 1883.

Asterias polaris and *A. borealis* Perrier, Stell. du Mus., in Arch. Zool. Exper., vol. iv, pp. 322, 323, 1875.

B. range, 0 to 60 fath. George's Bank to Greenland. Common from low-water to 20 fath. at Anticosti I., Gulf of St. Lawrence, and on the Labrador coast. Taken by the Gloucester fishermen on all the Banks, in 20 to 50 fath. Dredged by the U. S. Fish Comm. at several stations, from N. lat. 45° 44′ to 45° 10′, in 36 to 50 fath.

This species almost invariably has six rays. It becomes very large and abundant on the Labrador coast and on the Grand Bank.

ASTERIAS TANNERI Verrill.

Brief Cont. to Zool., No. 47, this Journal, vol. xxx, p. 401, 1880; Explorations by the Albatross in 1883, in Ann. Rep. Com'r. Fish and Fisheries, vol. xi, p. 540, pl. 13, figs. 42, 42^a, 1885.

B. range, 48 to 194 fathoms; in one instance recorded as from 373 fath., off C. Hatteras, perhaps an error. Taken at 35 stations, between N. lat. 40° 08′ and 35° 10′ 40″.

ASTERIAS AUSTERA, sp. nov.

Rays five, rather short and stout, smaller, subacute. The skeleton plates are larger, firmer, and more rigid than in the allied species. Radii 10^{mm} and 35^{mm}. Dorsal surface rather sparsely covered with short, stout, blunt, isolated spines, which do not form regular rows; those along the median area of the rays are a little longer and often stand in an irregular double row; a distinct, regular supero-marginal row of slightly longer, but similar, spines; two infero-marginal rows of still longer and more acute spines, separated by a line of papulæ, placed singly to near the end of the rays, and sometimes with a short row of intervening spines distally. Adambulacral spines small, slender, not very long, scarcely tapered, arranged either one or two to a plate, sometimes alternately, but generally the solitary ones are most numerous. Papulæ stand singly or in small clusters. Cruciform pedicellariæ minute, forming a close wreath around all the dorsal and lateral spines, those of the ventral spines interrupted below. Rectiform pedicellariæ of rather large size, narrow ovate or acute lanceolate in form, are scattered between the dorsal spines; others of large size and less acute occur between the ventral and adambulacral spines; smaller ones lie within the furrows.

B. range, 33 to 35 fath. George's Bank and off Cape Cod.

This species should, perhaps, be referred to *Leptasterias*. The character of its ova is not known.

ASTERIAS BRIAREUS Verrill.

Verrill, Brief Cont. to Zool., No. 50, this Journal, vol. xxiii, p. 220, 1882; Notice of Rem. Maine Fauna, in Ann. Rep. Com'r. of Fish and Fisheries for 1882, p. 659, 1884.

B. range, 78 to 373 fath. Rare. Taken at three stations, from N. lat. 37° 18′ 11″ to 36° 41′ 05″. It is also found in the West Indies.

LEPTASTERIAS COMPTA Verrill.

Asterias compta Stimpson, Proc. Boston Soc. Nat. Hist., vol. viii, p. 270, 1862; Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 340, 1866; Sladen, op. cit., vol. xxx, p. 583, 1889.

Leptasterias compta Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 350, 1866; Mar. Invert. Vineyard Sd., p. 425, 1873; Expl. Casco Bay, in Proc. Amer. Assoc. for 1873, pp. 353, 356, 1874; Check List, p. 14, 1879; Expl. by the Albatross in 1883, p. 540, 1885.

B. range, 10 to 100 fath. Taken at many stations, from N. lat. 45° 29′ to 37° 19′. Large and abundant in the cold areas S. of Rhode Island and Martha's Vineyard, in 20 to 50 fath. Allied to *L. hyperborea* (D. and Kor.) of arctic Europe.

LEPTASTERIAS TENERA Verrill.

Asterias tenera Stimpson, Proc. Boston Soc. Nat. Hist., vol. viii, p. 269, 1862; Verrill, op. cit, vol. x, p. 349, 1866.

Asterias (*Leptasterias*) *tenera* Verrill, loc. cit., pp. 349, 350.

Leptasterias tenera Verrill, this Journal, vol. vii, p. 504, 1874; Expl. Casco Bay, in Proc. Amer. Assoc. Adv. Sci. for 1873, p. 353, 1874; Check List, p. 14, 1779.

B. range, 10 to 129 fath. Cape Cod to Newfoundland. Common in Massachusetts Bay and the Bay of Fundy, in 10 to 40 fath. This is very closely allied to *L. compta*, of which it may be only a poorly nourished, slender variety. It requires more careful study to determine this question. It is closely allied to the European *L. Mülleri*,—perhaps the same.

LEPTASTERIAS GRŒNLANDICA Verrill.

Asteracanthion Grœnlandicus Lütken, Videns. Meddel. naturh. Forening, 1857, p. 29; Duncan and Sladen, op. cit., p. 27, pl. 2, figs. 9–12, 1881 (*grœnlandicum*).

Asterias Grœnlandica Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 357, 1866.

Leptasterias Grœnlandica Verrill, Check List, p. 14, 1879.

B. range, 5 to 100 fath. Strictly northern. Taken in the Bay of Fundy and Gulf of St. Lawrence, and on the fishing Banks off Nova Scotia. It ranges to the Arctic Ocean (N. lat. 81° 41′).

LEPTASTERIAS HISPIDELLA, sp. nov.

Rays five, rather short and thick, well rounded, tapered. Radii 5^{mm} and 27^{mm}. Abactinal surface covered with very slender, rather long, very sharp spines, placed singly, and forming three pretty regular marginal rows on each side and a rather indistinct median row, with about two more or less distinct rows between the median and supero-lateral; the marginal spines are longest; the infero-marginal spines are close to the adambulacral, and sometimes stand two on a plate proximally; a few single papulæ usually alternate with them proximally. Adambulacral spines long and slender, divergent, mostly alternately one and two to a plate. Rectiform or major pedicellariæ of actinal surface few, rather large, long-ovate or lanceolate, rather acute, with sharp, curved denticles at the tip; smaller ones border the furrows, within; crossed pedicellariæ form small clusters on the dorsal spines and larger ones on the laterals. The dorsal plates are rather slender, with large interspaces, in which the papulæ stand singly, or two or three together. Madreporite small, with few coarse short gyri.

B. range, 50 fath. N. lat. 45° 14′ 30″, stat. 2494, two specimens.

Allied to *L. littoralis*, but has much longer and very acute spines, which are less numerous.

LEPTASTERIAS LITTORALIS Verrill.

Asteracanthion littoralis Stimpson, Invert. Grand Manan, p. 14, 1853.

Asterias littoralis Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 349, 1866; Perrier, Stellerides, in Arch. Zool. Exper., iv, p. 315, 1875; Verrill, Expl. Casco Bay, p. 364, 1874.

Leptasterias littoralis Verrill, Check List Marine Invert., p. 14, 1879; K. J. Bush, Moll. and Echinod. Labrador, in Proc. U. S. Nat. Mus., vol. vi, p. 246, 1883.

B. range, 0 to 23 fath. Casco Bay, Me., to Cumberland Gulf. Eastport, Me., at low-water mark among rocks, locally abundant. Also found on the coast of Nova Scotia and in the Gulf of St. Lawrence. This is very closely allied to *L. Grönlandica.*

This, like the other species of *Leptasterias*, carries its large ova and young attached in large clusters around the mouth. It breeds early in the season, April and May, at Eastport, Me.

In addition to the five species of *Leptasterias* here named, there are other forms on our northern coast that may be distinct, but need much study. Some of these have hitherto been referred to *L. Mülleri* and to *L. Stimpsoni* V., 1866. The latter originally included, in part, young of *Asterias vulgaris*, but the description was largely based on a *Leptasterias* that is near *L. hyperborea* (Dan. and Kor.) and probably distinct from those here recorded.

HYDRASTERIAS OPHIDION Sladen.

Asterias (*Hydrasterias*) *ophidion* Sladen, Voyage of the Challenger, vol. xxx, p. 581, pl. 99, figs. 3 and 4; pl. 103, figs. 3 and 4, 1889.

Hydrasterias ophidion Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 279, 1894.

B. range, 1250 to 1742 fath. One specimen was dredged in N. lat. 40° 34′ 18″, W. long. 66° 09′, 1742 fath. It was taken by the Challenger in N. lat. 42° 08′, off Halifax, in 1250 fath.

Family BRISINGIDÆ Sars.

ODINIA AMERICANA Verrill.

Brisinga Americana Verrill, this Journal, vol. xix, p. 139, 1880; Expl. by the Albatross in 1883, in Rep. Com'r. Fish and Fisheries, xi, p. 636, pl. 17, fig. 52, 1885.

Freyella Americana Sladen, Voyage of the Challenger, vol. xxx, pp. 616, 617, 834, 1889.

Odinia Americana Verrill, Proc. Nat. Mus., vol. xvii, p. 279, 1894.

B. range, 175 to 400 fath. Two specimens were taken by the Gloucester fishermen on Banquereau, off Nova Scotia, one at N. lat. 44° 12′, W. long. 58° 37′, clinging to *Paragorgia arborea.*

Both of our specimens had 20 (detached) arms. It grows to great size.

BRISINGA COSTATA Verrill.

Brisinga costata Verrill, this Journal, vol. xxviii, p. 382, 1884; Proc. U. S. Nat. Mus., vol. xvii, p. 280, 1894.

B. range, 828 to 2021 fath. Taken at several stations from N. lat. 41° 28′ to 35° 45′ 23″.

Species of *Brisinga* and *Freyella* are found at great depths in all the oceans.

BRISINGA MULTICOSTATA Verrill.

Brisinga multicostata Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 280, 1894.

B. range, 1137 to 1742 fath. Dredged by the U. S. Fish Comm. at three stations from N. lat. 40° 34′ 18″ to 39° 35′.

BRISINGA VERTICILLATA Sladen.

Brisinga verticillata Sladen, Voyage of the Challenger, vol. xxx. p. 604, pl. 109, figs. 9–11, 1889; Verrill, Proc. Nat. Mus., vol. xvii, p. 283, 1894.

B. range, 906 to 1423 fath. Dredged at 9 stations from N. lat. 41° 13′ to 36° 34′. Taken by the Challenger at N. lat. 40° 17′, off New Jersey, in 1350 fath.

FREYELLA ELEGANS Sladen.

Brisinga elegans Verrill, this Journal, vol. xxviii, p. 382, 1884.
Freyella bracteata Sladen, Voyage of the Challenger, vol. xxx, p. 629, pl. 114; figs. 1–4, 1889.
Freyella elegans Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 283, 1894.

B. range, 1060 to 2021 fath. Taken at 18 stations by the U. S. Fish Comm. from N. lat. 41° 43′ to 36° 34′. Dredged by the Challenger at three stations from N. lat. 42° 08′ to 40° 17′, in 1250 to 1350 fath., off the American coast.

FREYELLA MICROSPINA Verrill.

Proc. U. S. Nat. Mus., vol. xvii, p. 286, 1894.

B. range, 1054 to 1060 fath. Taken twice by the U. S. Fish Comm., at N. lat. 39° 46′ 30″ and 39° 43′ 30″.

FREYELLA ASPERA Verrill.

Freyella aspera Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 285, 1894.

B. range, 1917 fath. One specimen was dredged at N. lat. 37° 59′ 20″, off Chesapeake Bay.

Fragments of a fourth species of *Freyella* were dredged at Sta. 2077, N. lat. 41° 09, in 1255 fath.

Bathymetrical Distribution of the Families of Asterioidea, in this Region.

[The numerals refer to the number of species found in each zone of depth.*]

Fathoms.	0–50.	50–100.	100–500.	500–1000.	1000–2000.	2000–2600.	Total species.
Archasteridæ	0	2	4	6	6	2	8
Porcellanasteridæ	1	1	1	2	1	0	2
Astropectinidæ	5	4	4	3	2	0	8
Goniasteridæ	2	5	5	3	2	1	8
Gymnasteridæ	0	3	4	2	0	1	5
Asterinidæ	0	1	1	0	0	0	2
Solasteridæ	3	5	5	3	2	0	8
Pterasteridæ	2	4	2	1	2	1	7
Echinasteridæ	2	1	1	0	0	0	2
Pedicellasteridæ	0	1	1	1	0	0	1
Zoroasteridæ	0	0	0	1	1	0	1
Stichasteridæ	1	1	1	1	0	0	2
Asteriidæ	11	9	5	0	1	0	15
Brisingidæ	0	0	1	2	6	2	7
No. of species	27	37	35	25	23	7	76

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* The slight differences in the numbers here given, as compared with the list on page 128, is due to the discovery of a few additional species after the first part of this paper was printed.

ART. XX.—*Drift Bowlders between the Mohawk and Susquehanna Rivers;* by ALBERT P. BRIGHAM.

THE district traversed in my investigations extends from Utica on the Mohawk River, south-south-westward to the confluence of the Chenango and Susquehanna Rivers at Binghamton, a distance of 95 miles. It is approximately the line of the Oriskany and Chenango valleys; or of the New York, Ontario and Western Railway from Utica to Oxford and the Delaware, Lackawanna and Western Railway from Utica to Binghamton. The main valleys, valley slopes and summits of the hill ranges were seen continuously for the first 40 miles from the Mohawk, and over a breadth of from 10 to 20 miles. Farther south a series of points was selected, with observations at all altitudes.

Topography.—The district belongs to the plateau region of central and southern New York, dropping down to the level of the Mohawk valley on the north. The Mohawk-Susquehanna divide averages 20 miles distance from the Mohawk River. From this divide extend northward and southward the valleys and hill ranges which are characteristic of central and western New York. The northern slope is drained by the Sauquoit, Oriskany, and Oneida Creeks; the southern slope carries the Chenango, Unadilla and Susquehanna Rivers. The divides in the region considered are: Cassville, altitude 1215 feet; Waterville, 1238 feet; Bouckville, 1147 feet; Pratts, altitude not known, but somewhat greater than that of Bouckville. At Rome we have 445 feet and at Utica, 410 feet. South of the divide the record is: Hamilton, 1111 feet; Norwich, 1001 feet; Binghamton, D. and L. and W. R. R., 846 feet; Binghamton, Susquehanna River 814 feet. The hills rise from 500 to 700 feet above the adjacent valleys, culminating in Tassel Hill, Paris, Oneida County, 1948 feet. Comparing the railway levels at Utica, and Binghamton with the summit at Bouckville, it will be seen that we descend northward 737 feet in 24 miles, and southward 301 feet in 71 miles, making the average northern slope of the valley bottoms 30·71 feet per mile; average southern slope 4·24 feet per mile. The distances are taken from the railroads. Air line measurement would slightly change the figures. From a limited number of aneroid determinations it is thought that the altitude of the hill ranges is even more sustained going southward, than that of the valley bottoms. The writer hopes to discuss the meaning of these facts in a later paper on the topographic history of the Chenango Valley region. Four sections of the moraine described by Professor Chamberlin,* lie within the field of this

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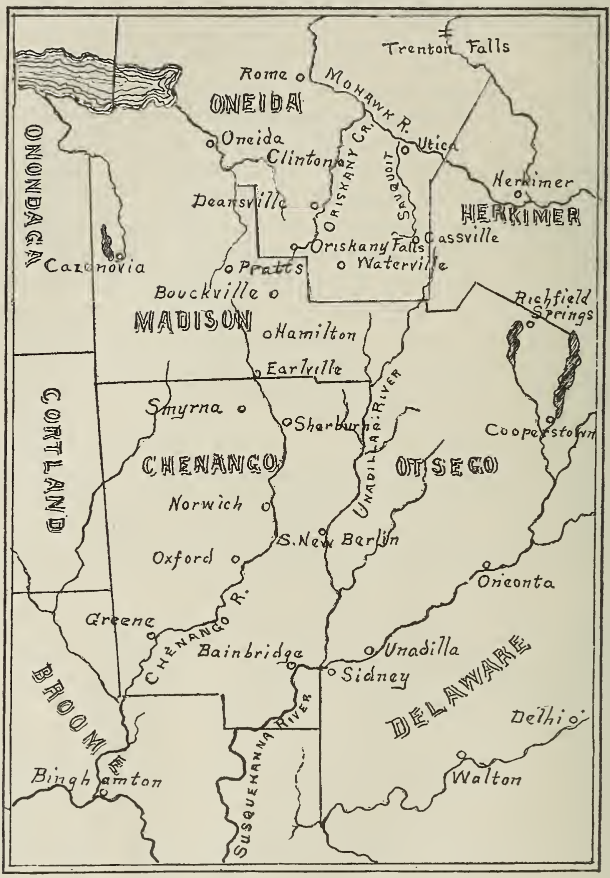
* Terminal Moraine, etc., 3d Ann. Rep. U. S. G. S., p. 360.

paper; viz: from Sauquoit to Cassville; about Waterville; from Deansville to Solsville, and from Munnsville to Pratts. These all stretch up the north flowing streams to about the position of the divides in the respective valleys. Extensive valley trains appear southward, with recurrent terraces and kames throughout the Chenango valley.



The Geological Formations.—The conditions are excellent for the determination of linear (southward) and vertical distribution of bowlders, from the manner in which narrow lines of outcrop cross the track of the ice. It is evident that we have here no such conditions for the study of lateral distribution as are afforded by Iron Hill in Rhode Island,[*] and the

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[*] N. S. Shaler, Bowlder Train from Iron Hill, Bull. Mus. Comp. Zool., vol. xvi, No. 11.

quartzite knobs of Wisconsin.* The pre-Paleozoic rocks referred to in this paper are for convenience classed as Archæan. The nearest outcrops, except by faulting at Little Falls, are at the southwestern base of the Adirondacks, 30 miles from Utica. The Cambrian is represented by the Potsdam sandstone of St. Lawrence, Jefferson and Lewis Counties. The Ordovician consists of Calciferous, Trenton, Utica and Hudson River, outcropping in a nearly N. W. by S. E. direction, only the Utica and Hudson River appearing as far south as the Mohawk valley, in this region. The Silurian beds, Oneida-Medina, Clinton, Niagara, Salina and Lower Helderberg, cross our field in nearly east and west bands, and as a whole extend south to Oriskany Falls. It is evident from the sharp descent from the divide to the Mohawk, that the outcrops must be narrow and that the bottom ice was pushed up across their bevelled edges. The Devonian column begins with the Oriskany sandstone, Corniferous and Marcellus about Oriskany Falls and Waterville and passes to a broad band of Hamilton extending southward to Smyrna, where it is succeeded by the Upper Devonian members, continuing to Binghamton.

Of the above masses, the Calciferous and Trenton have not been recognized within the field studied, though they doubtless exist in small fragments. The older and more distant Potsdam forms a quite constant element in our drift, being composed, both in its cement and constituent grains, of nearly pure quartz. But without microscopic examination it is in danger of being confused with certain Medina and Clinton fragments which resemble it in color.† The Utica, Salina and Marcellus are too soft for massive transportation beyond short distances. The sandstones of the Hudson River, and to a large extent of the Clinton, have not afforded ready identification, being largely without fossils and weathering to a non-committal brown.‡ The Niagara is very thin in Oneida County, though a certain peculiar structure is very characteristic,§ and four or five pebbles have been found from 20 to 50 miles from its outcrop. The main reliance has been upon the Archæan, Oneida, Lower Helderberg, Oriskany Sandstone and Corniferous. A separate discussion of these terranes and their bowlders will follow. Sandstones of the Hamilton and several of the higher

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* Ira M. Buell, Trans. Wis. Acad. Sci., ix, pp. 255–274; Cf. T. C. Chamberlin, Jour. Geol., i, pp. 255–267.

† Since writing the above, Professor C. H. Smyth, Jr. has kindly subjected to microscopic examination a representative fragment from my specimens, finding it to be a thoroughly indurated quartzite, not likely to be matched in any of our lower Paleozoic horizons save the Potsdam.

‡ On limitation of identification, see, The Drift—its Characteristics and Relationships, R. D. Salisbury, Jour. Geol., vol. ii, Oct.–Nov., 1894, p. 717.

§ Vanuxem, Geol. 3d. Dist. N. Y., pp. 92, 93.

members weather to monotonous browns and grays and would need careful attention to their fossil contents for trustworthy identification.

The dip of these beds, in connection with the dissection of the region into north and south trenches and ridges, is an essential fact in the study of vertical distribution, or of the plucking action of the ice. The several terranes first appear, as one goes southward, in northward loops on the hills, and disappear as southward loops in the valleys. Vanuxem cites a measurement for the Corniferous near Waterville, as 27 feet per mile S. W. The Oriskany sandstone at Oriskany Falls dips 47 feet per mile. 40 to 50 feet per mile, S. S. W. is probably a safe general statement for the region.

General Movement of the Ice.—Striæ observed at several localities indicate that the main movement of the glacial current was about S. 20° W. This conclusion is based upon comparison and averaging of movements at the higher altitudes, and where local topography would not be likely to modify direction. The trend may have been largely influenced by the Adirondacks as a local center of glaciation. If this be true, a S. S. W. flow along the Oriskany-Chenango axis is radial and would be expected. The Hudson River and Oneida bowlders of our field may thus have been plucked from the vicinity of Utica and Rome, although some were doubtless brought in by cross currents from more easterly and westerly points.

Archæan Bowlders.—These fragments of the drift are in the usual lithological variety. No consideration of them relative to their sources, can be had, until their Adirondack and more northerly localities shall have been studied in detail.* A profusion of large Archæan masses is found in northern Oneida County, over the Paleozoic terranes which lie within a few miles of the crystalline areas. For some miles south of the Mohawk, pieces having diameters of four feet are tolerably frequent. South of the divide such fragments are rare. A few comparisons from counts and estimates made in the field, will give the best notion of the facts. Approaching Oriskany Falls from Clinton, on the summit of the range to the westward, six Archæan pieces were observed having axes of four to six feet. These and many smaller ones were seen in increasing numbers on nearing the line of the moraine, which appears in its full strength in the valley at the above village. The valley moraine itself however, consists of kames, which are nearly free from large bowlders. Thirty feet of stone wall in the town of Madison, showing average complexion of bowlders of the adjacent field, give the following result.

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* For notes on such comparative study, see G. F. Wright on the Glacial Boundary, Bull. 58, U. S. G. S., pp. 50–52.

Archæan	12
Oriskany sandstone	17
Corniferous	2
Doubtful	1
Hamilton (subjacent)	28
	60

The altitude here is about 1200 feet, or 100 feet above the valley. In eastern Madison, altitude about 1600 feet, extensive heaps are composed wholly of pieces but few inches in size, and at least 99 per cent are from the local Hamilton. This freedom from outside material, with limited exceptions, is characteristic of the higher altitudes of the whole region. A similar estimate in Hamilton, choosing all fragments in a large heap, above one foot diameter, gave:

Archæan	50
Oriskany sandstone	17
Corniferous	2

Oneida and Medina were present but all smaller, likewise the Hamilton, while the larger Oriskanys from the same field, as was learned, had been buried. The cases cited represent more than the average prevalence of the Archæan in number, while in mass, the Oriskany would outrank the Archæan by many hundred per cent.

In the town of Eaton, near Hamilton, one northern piece, well-rounded, measured 9×7⅓×6¾ feet. This is the largest Archæan bowlder observed by the writer south of the Mohawk River. In 90 miles traversed in the towns of Madison, Hamilton, Eaton and Lebanon, less than a dozen Archæan masses were observed having average diameters of four feet or more. From Earlville to Smyrna no Archæan was seen above 2×2½ feet. At Smyrna, there is a morainic accumulation of considerable extent. A 60-foot section is exposed showing discordant beds of sand and coarse gravel, with 6 to 12 feet of till containing coarse, angular local material, at the top. 100 pieces from a heap rejected in procuring gravel, ranging from the size of one's fist to five or six inches, gave the following count:

Oneida	2
Clinton	3
Doubtful, perhaps Hudson River or Clinton	10
Doubtful, probably Potsdam and Medina	8
Helderberg limestones	26
Hamilton (subjacent)	51
	100

No Archæans appear in the count. They were rare in the section. Only one seen attained a diameter of one foot. About Norwich and South New Berlin Archæans even of one foot diameter are few. Two, measuring 1½ and 2 feet respectively, were the largest seen. A three foot piece, probably Archæan, was reported to me from near South New Berlin. This, however, had been broken up and removed. At Oxford the kames and terraces, rising 100 feet from the valley bottoms, contain the usual proportion of Archæan pebbles. Farther up, near the quarries of the F. G. Clarke Bluestone Company, heaps and walls containing many hundred cords of cobbles and bowlderets, do not show above one-thousandth part of material older than the Hamilton, that is, of fragments carried 40 miles or more.

The same dearth of distant material is evident on all the hill-slopes about Unadilla and Bainbridge on the Susquehanna, and Greene on the Chenango. At the last named place 1½ miles of fence wall above the 100 foot level, were observed without detecting a single Archæan fragment. At Binghamton, Archæan was found to the height of about 600 feet on the slopes south of the Susquehanna, but no pieces were above a few inches in diameter.

These facts regarding distribution in southern New York are fully in harmony with the facts reported from the adjacent part of Pennsylvania.*

Oneida Conglomerate.—This is a mass 30 to 40 feet thick in the hills two miles south of Utica, thickening somewhat to the westward.† Some layers are mainly composed of rounded quartz pebbles, while others consist of coarse sand. The altitude of the ledge is about 1000 feet near Utica, but drops with the S. W. dip to 620 feet one mile north of Clinton. The conglomerate is one of the most persistent members of the bowlder drift in central and southern New York, though the fragments are rarely numerous, or large. The exception to the latter statement is found within a few miles of the outcrop, as on the northern slope of Paris Hill, where slabs of 4 to 6 feet in length and breadth are not uncommon. In southern Oneida and Madison Counties, any large heap or wall is quite sure to yield small samples, usually not above eight inches in diameter. Only about a dozen were noted, after passing 10 miles from the outcrops, having cubic contents of more than one foot each. One 15-inch Oneida was found at Oxford. Pebbles and small cobbles occur at Binghamton. The falling off in size is much more gradual than in the case of

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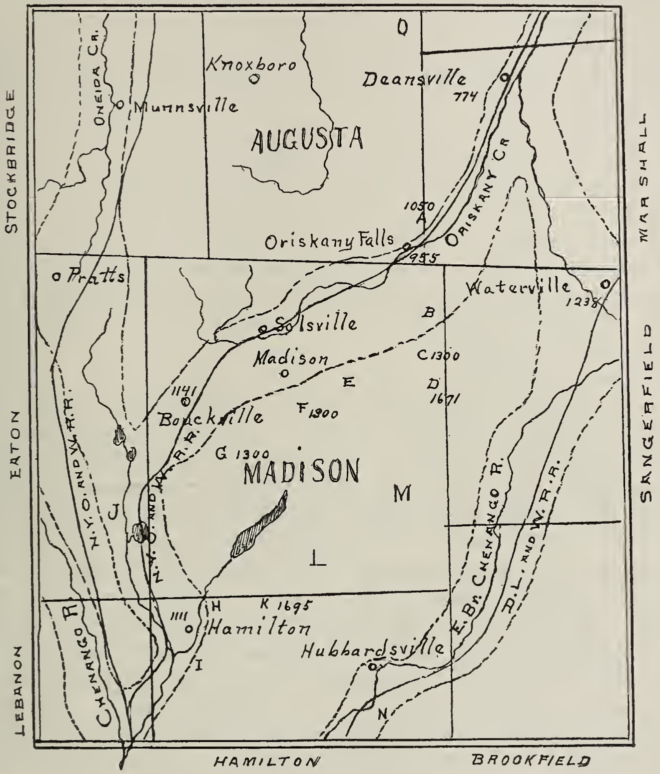
* See H. C. Lewis and G. F. Wright, 2d Geol. Surv. Pa., Rep. Z, p. 13.

† Reckoned 100 feet thick in generalized central N. Y. section, see C. S. Prosser, Bull. G. S. A., vol. iv, p. 110.

the Oriskany sandstones. These bowlders occur at all altitudes and some have been elevated considerably within moderate distances. The Oneida fragments, at their greatest height in northeastern Madison, have been lifted 600 feet in 14 miles, if we consider them to have come from the highest point in the outcrop. It is more probable that they came from a locality which would require an elevation of 800 feet in 10 miles.



Scale 4 miles to the inch. Dotted line gives the base of main valley walls. Divides at Waterville, Bouckville and Pratts. Oriskany and Helderberg ledges at A. Altitudes of L and M approximate those of D and K.

The bowlderets are commonly more rounded to the southward, though to this there are notable exceptions, perhaps due to splitting in transit.* It was hoped that Oneida fragments north and south of the moraine would afford interesting comparisons as to amount of discoloration and disintegration since the time of deposit. No such result was realized. It is thought

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* See N. S. Shaler, Bowlder Train from Iron Hill, Bull. Mus. Comp. Zool., vol. xvi, No. 11, p. 199.

that the variable amount of iron pyrites in the Oneida beds, occasioned the breaking up, or discoloration of some pieces, while others, shaped and deposited at an earlier date, show no signs of change.*

Lower Helderberg.—The limestones are deeply cut by the several valleys at about the position of the moraine belt in each, though not in all cases does the terrane outcrop above the glacial debris, except farther to the north on the hill sides and summits. At Oriskany Falls, 120 feet of these beds are exposed on the west side of the valley, in quarries and natural ledges. 40 feet are massive beds, the rest thin, two to six inches in thickness. The limestone is found not infrequently in slabs and rounded masses up to four feet in breadth or diameter. This is true for only six to eight miles from the outcrop; and it is only for this distance that the limestone occurs at high levels. From Hamilton southward, the fragments are small and almost confined to the gravel trains, terraces and kames of the valleys, rarely occurring above 100 feet from the valley bottoms. The possible causes of this distribution will receive further inquiry after an account of the Oriskany sandstone has been given.

Oriskany Sandstone.—The outcrop, from which the New York geologists named this terrane, is found one half mile north of Oriskany Falls, near the town line of Augusta and Marshall, Oneida County. It appears in a continuous ledge, three fourths of a mile long and 125 feet above the Oriskany Creek, the valley wall rising still 400 feet to the westward. Below it lie 120 feet of Lower Helderberg, and above are 50 feet or more of Corniferous. The hill range is capped with Marcellus and Hamilton. The general trend of the ledge is S. 23° W. The sandstone stands out to its full thickness, 12 feet at the north, thinning to 7 or 8 feet at the south, and dipping southward about 47 feet per mile. Below the sandstone on the valley side, is a broad shelf of Lower Helderberg. The sandstone forms a shelf about 5 rods wide, quite bare except where disintegration has taken place, making a slight cover of soil and vegetation. The rock is a coarse grained, grayish white sandstone, weathering to yellowish brown, with certain zones full of pockets from which the characteristic fossils have disappeared by solution. There are two sets of joints, S. 38°–48° E. and S. 33°–38° W. The joint blocks average 10 to 20 feet in breadth and length, and are often set off, from a few inches to several feet. There is no distinct bedding plane except at the top and bottom of the mass. The passage from the limestone below, and to the limestone above, is sharp, and the

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* Suggested to the writer by Professor C. H. Smyth, Jr.

abundant springs issuing on these planes suggest the setting off of the blocks by freezing. But some lie in positions in which only glacial plucking could have placed them.

The shelf of Lower Helderberg, varying from 40 to 80 rods in width and sloping gently to the eastward, has been swept clear of the overlying Oriskany. Evidently the power to pluck ceased more abruptly than the power to transport. But the outmost blocks of the ledge were considerably pared off by grinding action after their neighbors had been carried away. The general movement of the ice was slightly off the ledge to the eastward. The lower ice, which accomplished the plucking, may have swerved to the east locally on this rather steep valley wall, thus increasing the otherwise slight angle between the line of movement and the line of the ledge. Doubtless by weathering along the joint planes, and by solution of the upper surface of the subjacent limestone, as seen under the present ledge, the blocks had been loosened and plucking thus facilitated. Even with this assistance it is puzzling to understand how blocks of some scores of tons weight could be handled, with so little purchase as seems to have been possible.*

The Oriskany valley runs N. 60° E. from the divide to Oriskany Falls, and thence N. N. E. toward the Mohawk. We have here ideal conditions for seeing how ice behaves in crossing a valley diagonally. Our best data are afforded by the transport of large blocks from the above described ledge. The striæ so far as found, and certain glacial flutings on the hills, support the evidence furnished by the travelled blocks. These bowlders were noted by Vanuxem:†

"The Oriskany sandstone first appears out of place and at a higher level in Grout's quarry, amongst the drift, or alluvion on the top of the Onondaga limestone, the thickness of the Cauda-galli Grit and Onondaga Limestone being the difference of its original position and the top of the quarry. The sandstone showed characters of a local origin. The same sandstone is found in great abundance and immense blocks, scattered over the hills in the towns of Madison, Eaton, Hamilton and Lebanon, being more numerous toward the valley of the Chenango canal. They appear on the side-hills, but few having been noticed toward the middle of the valleys. All the blocks there seen were the counterpart of the mass at Oriskany Falls, being readily recognized from local differences in the rock, prevailing at all its points of outcrop." At page 127, Vanuxem speaks again of the frequency of the bowlders in the towns named and adds,—"In smaller masses it has been

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* See however T. C. Chamberlin, Rock Scorings of the great Ice Invasions, 7th Ann. Rep. U. S. G. S., p. 193.

† Geol. 3d Distr., N. Y., pp. 127, 222–223.

found from forty to fifty miles south of that line. The great facility with which this rock is recognized, its character so peculiar, contrasting so strongly with all the rocks of New York, its layers so thick at Oriskany Falls, make it a useful rock in investigating the history of the ancient flows of water in that section of the country."*

Going south from the ledge, diagonally across the valley, the southeast valley wall is reached at a distance of two miles. The summit of the range (D. map. p. 219) is three-fourths of a mile further and 600 feet above the ledge. The kame deposits of the moraine are here at least a mile wide, banked against the southeast side. They are transversely cut by a small valley heading near the southeast wall of the main valley. This depression in the moraine was doubtless kept open by a small ice tongue and near its head, but still on the moraine, is a profuse assemblage of large Oriskany bowlders (at B), probably the last of the train to come to rest. The hill-slopes rising directly above the moraine (C) are strewn with the same large fragments. The larger masses and by far the greater number lie on the lower 200 feet of the hillside, at an average altitude of 1300 feet, continuously for several miles to the southwest, (C E F G). In good numbers and up to a diameter of four feet, they rise to the top and are occasionally carried over the summit and through gaps in the range, to the further slopes of another valley which lies several miles to the southeast, about Hubbardsville (N).

At several points on the lower hill-slope referred to, 100 to 150 bowlders ranging from 2 to 7 feet in diameter can be counted upon a single acre. Three miles from the ledge (E) is found an Oriskany block measuring 19×12×8 feet. Its altitude is 1416 feet. On the slope 150 feet above Madison village (F) on a plot of three to four acres, 86 Oriskany masses were counted, whose dimensions range from 6 to 15 feet. Of these about 15 have lengths and breadths of 10 and 12 feet. All would probably average six foot cubes. Many smaller bowlders, not included in the count, range from five feet downward. Six four foot limestone slabs and one Archæan of like size, were found in this field; but the Oriskanys had been sorted and grouped to a surprising degree. The valley from Oriskany Falls to Pecksport has a bearing of S. 60° W., or at least 40° more westerly than the general ice movement. The hillsides on the northwest of this section of the valley are free from Oriskany bowlders. In the general southward movement

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* For other early discussions of New York bowlders see James Hall, Geol. 4th Distr., pp. 332–341. and W. W. Mather, Geol. 1st Distr., pp. 163–197. The latter adds a review of bowlders in New England, the Western States and foreign countries, with numerous references to the earlier literature.

the bowlders were swept diagonally across the valley, a moderate number were carried to, or over the summit of the range, but by far the greater number and almost all the larger fragments were swerved from 0° to 28° westward by the valley wall and caught on the lower slopes. It is a good illustration of the law stated for such cases by Professor Chamberlin.* In further harmony with the passage cited, it is to be noted that the Oriskany valley is neither so broad and shallow as to fail of diversion of the basal currents, nor so narrow and deep as to cause a decided cross current. There can be little doubt that the bowlders in question were moved while the ice was deep and its action vigorous, rather than by an ice tongue at a later and decadent stage.

Near Hamilton the valley bends toward the east and hence the Oriskany bowlders begin to appear on the western slopes. East of Hamilton near the base of the hill, an Oriskany block measures 21×12×10 feet. On the campus of Colgate University, eleven miles from the ledge, the bowlders are abundant, the largest measuring 15⅝×12×10 feet. From Hamilton to Earlville, masses with dimensions of 6 to 8 feet are not uncommon. From Earlville to Smyrna the number is much smaller and but three or four were seen having a diameter of four feet. Near Norwich the track of the ice was crossed for 10 miles. But two Oriskany pieces were seen, each about one foot in diameter, on the lower hill-slope, one mile southwest of Norwich. The last Oriskany fragment recognized, was an 8 inch piece in the valley 1½ miles north of Oxford, or 40 miles from the nearest outcrop.

Vertical distribution.—Oriskany material is infrequent in the kames and gravel trains of the valleys, which, being of somewhat later date, may have buried such of the Oriskany blocks as rested in the valleys. The greatest abundance is on the lower slopes facing the approach of the ice, with moderate carriage to the summits, dropping off to the lower levels, however, as we go southward. When we turn to the question of amount of glacial elevation, it must be noted that Oriskany bowlders occur on the hill range north of the ledge for five miles (to O). Portions of the Oriskany terrane were swept from the summit, whose floor is now of lower Helderberg limestone. Taking into account the dip and comparing the highest northern extension of the preglacial ledge with the greatest height attained by the bowlders in Madison, we find that 248 feet in 8 miles gives the largest rate of ascent which the facts compel us to accept. Several considerations make it probable that the most important assemblage of blocks (at C E F G) was derived from the ledge now seen at Oriskany

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* Rock Scorings of the Great Ice Invasions, 7th Ann. Rep. U. S. G. S., pp. 197–200.

Falls. This would give them an average elevation of 250 feet in an average distance of 4½ miles. The single mass before noted (E) would thus have been raised 366 feet in 3½ miles. Upham notes the uplifting of Niagara bowlders to a height of 100 to 200 feet within three or four miles.* C. H. Hitchcock reports the lifting of bowlders 4,000 feet in the White Mountains within moderate distances.†

As already suggested, the east and west extension of the central New York terranes vitiates conclusions as to lateral distribution, or "fanning out" such as has been described by Professor Shaler in Rhode Island and Massachusetts. The Oriskany sandstone is to a considerable extent exceptional, however. In the passage above cited, Vanuxem alludes to local differences and recognizes the Oriskany drift as from Oriskany Falls. For the only outcrop in the next valley to the eastward he notes the presence of a distinctive character. At Munnsville, 6 miles W. N. W. the Oriskany is not present, the two limestones being continuous, and the bowlders are nearly absent from Munnsville to Pecksport. If the Oriskany exists in the valley at all it is a thin wedge south of Pratts, carried by the dip beneath the valley filling. At Morrisville, 10 miles W. S. W., a deep boring apparently found no trace of Oriskany, except quartz grains in the limestone.‡ The ledge at Oriskany Falls thins 4 to 5 feet southward in three-quarters of a mile. The indications are that it thinned northward also. It is a shore formation, which we should expect to find variable within short distances. We probably have a thin lens of sediment, whose maximum thickness is at the present exposed ledge, and the southward bowlders are very surely to be connected with it. In the adjacent valleys, east and west, the Oriskany bowlders, with slight exception, do not occur, or are found so far southward that they can have come across from the Oriskany valley.

The fragments fan out to a width of six miles in a distance of eight miles.§ This cannot, however, be taken as a measure of normal dispersion on a plane surface, for the diagonally disposed valley has widened the train rapidly to the westward.

The Oriskany bowlders were observed with a view to ascertaining the comparative amount of disintegration at the ledge and southward. There has been appreciable loss from the sur-

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* Eskers, near Rochester, N. Y., Proc. Roch. Acad. Sci., vol. ii, p. 196, and Bull. G. S. A., vol. v, p. 76.

† Bull. G. S. A., vol. v, p. 37. See also this Journal, III, vol. xxviii, p. 233; Ibid., vol. v, pp. 218, 219. T. C. Chamberlin, Jour. Geol., vol. i, pp. 50–51.

‡ C. S. Prosser, "The Thickness of the Devonian and Silurian Rocks of Central N. Y.," Bull. G. S. A., vol. iv, p. 96.

§ Cf. "Bowlder Train from Iron Hill," Bull. Mus. Comp. Zool., vol. xvi, No. 11, pp. 196–202.

faces only upon relatively flat-topped masses, where water and frosts would act effectively, and along fossil zones, where a retreat of three to six inches from the general surface is not uncommon. On the whole it is thought that the surfaces at the ledge average slightly fresher than those to the southward. On the other hand the impression given is, that all the Oriskany masses belong to the same general movement, and that movement a late one. No buried specimens of large Oriskany bowlders have been found. They have the appearance of being left behind, upon the surface of the hills, in the course of a rapid retreat. They are not often associated with morainic accumulations, but lie upon thinly masked linear and often drumloidal elevations. The relations of the ledge, the bowlders associated with the valley kames at B, and the bowlder fields of the succeeding hills, strongly suggest that we are dealing with one piece of work so far as the Oriskany material is concerned.

But it does not seem probable that the carriage and letting down of the Oriskany bowlders can belong to the general advance to the southern limit of glaciation and the retreat therefrom; for on this supposition they should have reached to Binghamton and beyond. The texture, indeed, is not so firm as that of the Oneidas, but the comparatively abrupt manner in which they terminate renders their connection with a long continued and far southward movement questionable. It is suggested as a matter for farther inquiry, whether the termination of some such vigorous and rapid forward movement as seems indicated by these bowlders, may not be marked by the kames and other valley accumulations between Oxford and Greene, just southward from the last found pieces of the sandstone. This section belongs to a "Collateral belt of moraines" described by Chamberlin, in this region.*

Corniferous Limestones.—This formation overlies the Oriskany sandstone at Oriskany Falls, and has a thickness of at least 50 feet. For three or four miles it is quite freely mixed with other rocks in the hillside drift. Northwest of Hamilton, where the turn of the valley brings the Oriskany drift upon its western wall, Corniferous bowlders are found far exceeding those seen elsewhere. One slab near the valley bottom measures 19×11½×3 feet. Farther up, other and more rounded masses were seen, one of which measured 6×6×9 feet. Near Eaton village also is a tract where limestones exceed all other materials of the bowlder drift. This illustrates a quite general fact in the distribution of the more local drift, that the blocks of a given kind are often found in groups, dependent upon local conditions of exposure, plucking and transport. South

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* Term. Mor. Sec. Gl. Exp, 3d Ann. Rep. U. S. G. S., p. 372.

of Hamilton, limestones are rare above the kame and terrace limit, for which 100 feet is an average figure.

The writer has not found a fully satisfactory interpretation for the distribution of the limestones. The case may be stated as follows: from 8 to 12 feet of sandstone are intercalated in the midst of 200 or more feet of limestones at Oriskany Falls. The whole mass was attacked by the glacier. The amount of limestone left on the hills southward bears no comparison to the amount of sandstone. The limestone is practically absent from the hill summits beyond six miles. The Oriskany continues in good force for over 20 miles. That the Lower Helderberg continues far south in the valley train, might be expected, from prolonged erosion in the valley bottom at Oriskany Falls, during the presence of the ice front there, after work upon the higher sandstones had become ineffective. But how shall we get the limestone deposited in kames, with some striations still preserved, at Oxford, 40 miles south, without carrying the fragments of the same terrane to the hills above? We might suppose a valley tongue to account for the kames and the absence from the hills, but the distance is too great, with the slight descent, to admit of this view. Owing to the solubility of the limestones we may believe them less capable of distant carriage by glacial action, the pebbles of the valley being hastened forward by sub-glacial water currents. But we have records of limestone carriage for at least 60 miles.* Professor Shaler notes the disappearance of crystalline limestones within five or six miles.† But here again Emmons records the finding of many bowlders of "Primary" limestone south of Rome,‡ New York, and one two feet in diameter is reported from Clinton, New York. These latter fragments have with little doubt traveled as much as 60 miles.

We may perhaps find relief in the history of the gathering of the materials by the ice. The Corniferous overlaid by the perishable Marcellus shale and breaking up easily owing to its large quota of flints and the solubility of the lime, may have receded along the lines of its ancient outcrop, leaving considerable areas of sandstone exposed. A short and vigorous ice movement might pluck and carry off extensive masses of the sandstone, before action became highly effective upon the limestone ledges in retreat above, or those protected below. We may thus suppose the Oriskany to be well started on its journey before the migration of the limestones was fairly begun.

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* Chamberlin and Salisbury, Driftless Area of the Upper Mississippi Valley, 6th Ann. Rep. U. S. G. S., p. 267; also, A. P. Low, Glacial Geology of Labrador and Quebec, Bull. G. S. A., vol. iv, pp. 419–421.

† Bowlder Train from Iron Hill, Bull. Mus. Comp. Zool., vol. xvi, No. 11, p. 206.

‡ Agriculture of N. Y., vol. i, p. 260.

If to any extent the movement of the bowlders was by rotation* in the ice mass, the larger and more equidimensional sandstones would have the advantage in the race. The angularity of many of the sandstone blocks, however, renders rotation for this case doubtful.

To sum up briefly the facts of distribution: We find the Archæan and more northern Paleozoic fragments strewn over the whole district at all altitudes, but diminishing southward in size, and sparse in amount on the highest hills, especially to the southward, where the tops of the ranges are often surprisingly free from transported material.† The Oriskany sandstone drops off from the hilltops after about 25 miles and disappears, so far as observation goes, at 40 miles. The Lower Helderberg and Corniferous limestones appear only for six or eight miles at high levels, but continue far down in the valley drift. As a rule local material far exceeds the imported, at a given point.‡ Exceptions to this rule are due to special local conditions. We may note as factors on which the local distribution and southward extension depend: accessibility of the preglacial ledges for plucking; the bedding and joint planes and power of current, as controlling size and number of fragments plucked; surrounding topography as related to removal; southward extension and limit of the current doing the plucking; lithological character as controlling change of form and reduction of size during carriage; zone of carriage and mode of transport as affecting form, size and manner of deposition. This is doubtless a partial statement, and the several factors will be found in combinations of endless variety.

Whatever may be said of the more northern material, it seems plain that that from the Oriskany Falls region was carried in the basal portions of the ice. The position of the ledges and the combing out of the greater number of large blocks by the hill range, seem to assure this view. A valley tongue, whose top barely reached and caught away the blocks, does not satisfy the case. It could not have grappled the masses with sufficient power. It certainly could not have wrought the very considerable elevation which their present situation demonstrates. Had the bowlders risen to the upper zones of the ice while it was at its greatest thickness, the hilltops should show more of far travelled material. It is to be added that while some of the bowlders are rounded, others in the same groups are notably angular, joint blocks carried from 5 to 12 miles with almost no reduction of angles.

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* T. C. Chamberlin, Rock Scorings of the Great Ice Invasions, 7th Ann. Rep. U. S. G. S., pp. 232–233.

† See ref. to Rep. Z., Pa. Surv. already cited; also, J. C. Branner, this Journal, III, vol. xxxii, p. 365.

‡ Cf. R. D Salisbury, Ann. Rep. Geol. Surv. N. J., 1891, pp. 68–70.

The inquiry has afforded general suggestions as to the amount of glacial reduction of the surface of the district. The northern section seems to have suffered most. At and south of the moraine which runs so nearly coincident with the divide, the hills are often drumlin-like, or at least show much fluting, displaying the "linear" topography to perfection. On the slope which descends to the Mohawk, the ice acted with power. In the southern section, the country was less effectively scored and was planed during a shorter period. The bowlder drift in the best strewn fields is more impressive in its appearance, than its actual cubic contents would justify. The Lower Helderberg shelf at Oriskany Falls, so conspicuously stripped of the superjacent sandstones, would probably much more than receive all the Oriskany bowlders dispersed to the southward, if brought back and corded to the thickness of the ledge from which they were borne. If we say that four times as much sandstone has been crushed and carried down the valleys and to the sea, the amount would still be relatively insignificant. Erosion in certain situations, redistribution within moderate distances, and topographic changes, have been very great. Actual reduction of the general surface toward base level doubtless proceeded rapidly during glacial time, but even then, the process was rapid only in the geological sense, and the result a minute fraction of what has been accomplished since the region became a land surface.

Colgate University, December, 1894.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Determination of high Fusing Points.*—A new method of determining high fusing points has been devised by VICTOR MEYER in conjunction with RIDDLE and LAMB, based on the principle of measuring the temperature by means of a small air thermometer made of platinum. At the instant when the substance under examination fuses, the air in this thermometer is expelled by means of a soluble gas, into a graduated tube containing a liquid in which the expelling gas is dissolved. The substance to be examined is placed in a small platinum tube, which is attached to the bulb of the air thermometer, and the whole is immersed in a fused salt having a melting point considerably below that of the substance. The air thermometer consists of a spherical bulb of platinum, about 25^{cc} in its capacity, having two somewhat long capillary tubes of the same metal attached to it, one of which just enters the bulb while the other

reaches to the bottom. At top these tubes are bent at right angles, in opposite directions. In making a determination, the salt constituting the bath, contained in a large platinum crucible, is fused and the bulb of the air thermometer, with the attached substance-tube, is immersed therein; connection being made between one of the capillary tubes and a carbon dioxide apparatus and between the other and the gas measuring burette. To fix the point of fusion, a fine platinum wire is previously immersed in the fused substance, this wire being attached to a weight by means of a cord passing over a pulley. When now the substance is again fused by means of the bath, the wire is released and the weight falls and strikes a bell. The current of carbon dioxide is then started and by its means the air in the air-thermometer is driven into the measuring burette. Knowing the capacity of the thermometer, and the volume of air expelled, the temperature can be calculated. By the new method the author has determined the fusing points of KCl as 800·0°, of KBr as 722·0°, of KI as 684·7°; and of NaCl as 815·4°, of NaBr as 757·7° and of NaI as 661·4°; showing that a rise in the atomic mass of the halogen causes a fall in the melting point. Moreover, he observed for RbI the value 641·5° and for CsI, 621·0°; that for KI being 684·7°. For $CaCl_2$ the fusing point obtained was 806·4°, for $SrCl_2$ 832·0° and for $BaCl_2$, 921·8°. While therefore the melting point falls as the atomic mass rises, in the case of the alkali iodides, the reverse is the case with the chlorides of the alkali-earths. In either case however, the salt of intermediate molecular mass shows an intermediate fusing point. — *Ber. Berl. Chem. Ges.*, xxvii, 3129, November, 1894. G. F. B.

2. *On the Preparation of anhydrous Hydrogen peroxide.*—It has been shown by WOLFFENSTEIN that hydrogen peroxide, hitherto considered as very unstable, is capable of concentration and even of actual distillation under diminished pressure, with but little loss from decomposition. Ascertaining that the loss on concentration either in the air or in vacuo arose from vaporization, the author was led to attempt its distillation. A quantity of the commercial peroxide concentrated until it contained 50 per cent of H_2O_2, was purified by extraction with ether; whereby the quantity of H_2O_2 was raised to 73 per cent. On submitting this to distillation on the water bath at the pressure of 68^{mm} of mercury, two fractions were obtained, the one boiling at 71°–81° and the other at 81°–85°; the former containing 44 per cent H_2O_2 and the latter 90·5 per cent. On fractioning again the latter product, a distillate was obtained at 84°–85° which contained over 99 per cent of H_2O_2 and was practically pure peroxide. It is a colorless syrupy liquid, which scarcely wets the containing vessel and which evaporates in the air. It produces a prickly sensation upon the skin, causing a white spot. Even after distillation with soda it reacts strongly acid. Further experiments have shown that the treatment with ether is not essential; a 3 per cent solution being readily concentrated by repeated fractioning

to give the pure substance boiling at 84°–85°.—*Ber. Berl. Chem. Ges.*, xxvii, 3307, December, 1894. G. F. B.

3. *A supposed New Element in the Nitrogen group.*—A preliminary note has been published by Bayer upon a supposed new element which he has discovered in the residues from the older process for the preparation of alumina from the red bauxite of Var. After removing the vanadium as ammonium vanadate and the chromium as hydrate, the filtered liquid is saturated with hydrogen sulphide, again filtered and the sulphides precipitated by hydrogen chloride. This precipitate is deep brown in color, dries to an earthy mass and burns readily to a bright brown powder, evolving sulphur dioxide. It ignites on treatment with strong nitric acid, forming a dark brown solution, which deposits a small quantity of a yellow precipitate containing molybdic and arsenic acids. This brown liquid is free from tin, antimony and tellurium, but contains traces of vanadium, molybdenum and selenium. These are removed by calcining the recently precipitated sulphides, treating the residue with ammonia and ammonium nitrate and concentration of the solution. Two sets of crystals are obtained, one being ammonium molybdate, the other a less soluble substance in cubic crystals olive-brown in color. By dissolving these latter crystals in hydrogen chloride and treating the solution with hydrogen sulphide a trace of molybdenum is removed. Upon allowing the filtered liquid to evaporate in the air, it becomes at first bluish-violet and contains the new element in a lower state of oxidation; subsequently changing to lemon-yellow. In this condition, the oxide is markedly acid, corresponding probably to R_2O_6. The acid is soluble in water, and on evaporation is deposited in yellow crystals fusing at a red heat to a brownish mass. Ammonia converts it into a crystalline olive-green powder, which dissolves in water and crystallizes out in cubes on cooling. After reduction with hydrogen sulphide in presence of hydrogen chloride, the acid yields a voluminous dark violet-brown precipitate, rapidly becoming crystalline. When treated with ammonium sulphide the yellow solution of the acid becomes dark cherry-red from the formation of a sulphosalt. From this solution acids precipitate a sulphide of the color of iron rust. Silver nitrate gives a green precipitate soluble in nitric acid and in ammonia. Magnesia mixture gives a green precipitate in relatively large crystals. A nitric solution of ammonium molybdate gives a yellow precipitate as in the case of phosphoric acid. The chlorides of the new element appear to be volatile, and are readily soluble in water.—*Bull. Soc. Chim.*, III, xi–xii, 1155, December, 1894.

G. F. B.

4. *A Short History of Chemistry.*—By F. P. Venable, Ph.D., 12mo, pp. viii, 163. Boston, 1894 (D. C. Heath & Co.). This little book is based upon a course of lectures which the author has delivered for several years to his classes in the University of North Carolina, in the belief, as he tells us that, "one of the best aids to an intelligent comprehension of the science of chemistry

is the study of the long struggle, the failures and the triumphs of the men who have made this science for us." The first part describes the genesis of chemistry, the second treats of the alchemists, the third considers qualitative chemistry, the fourth has to do with quantitative chemistry, the fifth discusses structural chemistry, and the sixth is devoted to special branches of chemistry. Within so small a compass, it is evident that but a limited treatment of so broad a subject can be given. The book appears to be well written and seems adapted to be of service in those institutions where the history of chemistry forms a part of the prescribed course. G. F. B.

5. *Multiple Resonance.*—Various investigations have been made in the subject of the interference of electrical waves; and apparently the diffraction of these waves has been satisfactorily shown. V. Bjerknes points out, however, that an important difference exists between the phenomena of the interference of light waves and those of electrical waves. In the case of light we observe the phenomena by means of instruments which may be termed indifferent, that is, instruments which do not influence or are not influenced by the source emitting the waves. Whereas in electrical resonance, the resonator is especially sensitive to the various conditions of the electrical oscillation. In general the oscillator is more quickly damped than the resonator. Damped waves do not in general show sharp nodes. Various conditions may arise, which depend upon the circumstances of damping. If the resonator in comparison with the oscillator is strongly damped, the ventral segments and nodal points are relatively well defined. While the resonator is relatively insensitive to a stimulus of its own peculiar rate of oscillation. On the other hand, if the oscillator is strongly damped and the resonator relatively weakly damped, as is the condition in most of Hertz's apparatus, the ventral segments and nodes are not clearly defined, while the resonator is especially sensitive to the excitement of its own peculiar oscillations. In the experiments with a diffraction grating these peculiarities must be considered. What may seem to be spectral dispersion may be only the multiple resonance of the instrument.—*Ann. der Physik und Chemie*, No. I, 1895, pp. 58–63. J. T.

6. *Spectrum analyses of the color of the water in the Blue Grotto, of the Swiss ice holes and of the Yellowstone Springs.*—H. W. Vogel, twenty years ago, examined with a spectroscope the light in the blue grotto at Capri. The water inside and outside the grotto showed an absorption band between the Frauenhofer lines *b* and E together with a disappearance of the red end of the spectrum up to the line D. During the present year he has had an opportunity to examine the water and the light of the walls of the other grottos (green and red) of the island. He found no trace of the absorption band which he had noticed in the blue grotto in his examination of the walls and water in these colored grottos. The red end of the spectrum, however, was

absorbed. A streak of azure-blue water outside the green grotto showed the absorption bands previously observed. The red grotto showed no trace of red light. The spectroscope showed merely the absorption appearances of ordinary sea water. An examination of the Swiss ice holes by the spectroscope showed an absorption of the red end of the spectrum which gradually diminished toward the yellow. No especial or marked absorption bands were noticed. The Yellowstone Springs showed in a pronounced manner Schönn's aqueous bands in the red and red yellow.—*Ann. der Physik und Chemie,* No. I, 1895, p. 175–177.

J. T.

7. *The minimum temperature of visibility.*—A recent paper by P. L. Gray describes experiments made upon a strip of platinum with the object of determining the minimum temperature at which it becomes visible in the dark. The author refers to the paper by Draper* as giving the only exact results upon the subject. He shows that Draper's temperature of minimum visibility, corrected by recent determinations of the coefficient of expansion of platinum, becomes 490° C., instead of 525°, and is not very much above his own determination given below. Furthermore Draper's conclusion that *all solid bodies become visible at the same temperature* is fully confirmed by the author's observations with bright and lamp-blacked platinum.

In order to determine the temperature of the platinum strip Gray used a modified form of Joly's meldometer,† consisting essentially of a strip of very thin platinum, about 10^{cm} long, 1^{cm} broad and $\frac{1}{50}^{mm}$ thick, placed in a vertical plane. In regard to its use the author says:

"It can be heated by an electric current, and its linear expansion is indicated by an optical method, by which an alteration in temperature of 1° can easily be noticed. The method of calibration is described in Joly's paper, and in that already mentioned, so that it is unnecessary to do more than briefly refer to it here. Minute fragments of substances of known melting-points are placed on the strip and watched through a microscope, while the temperature is very slowly and cautiously raised until, in any case, melting is seen to take place, when the position of the spot of light which indicates the expansion of the strip is noted. In these experiments the substances used were K_2NO_3(339°), AgCl (451°), KBr (699°), and gold (1041°). From these observations a curve showing the relation between temperature and scale-readings is obtained." . . . .

"*Method of Making the Experiments.*—The first requisite was to get the strip in a perfectly dark enclosure, within which both eyes could be directed towards it without strain. To this end the apparatus was enclosed in a wooden box (blackened within), one end of which was replaced by a black velvet cloth, under which the observer placed his head, and which he could gather round

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* On the production of light by heat, Phil. Mag., xxx, 345, 1847.

† Proc. R. Irish Acad, III, ii, 38, 1891–92.

his neck and under his chin so that not a ray of light could penetrate the enclosure. The box was about 48^{cm} long, 30 broad, and 22 high, and ordinarily the eyes, in making an observation, would be about 30^{cm} from the strip. The other end of the box was provided with a hinged shutter, which was lifted immediately after an observation had been made, for the purpose of noting the temperature of the strip.

The strip itself was further protected from draughts, etc., by means of a piece of brass, bent twice at right angles, and resting on the slate block below the strip, as in the calibration experiments. The angular dimensions of the surface of platinum, as seen in any experiment, were therefore:

Apparent length = 3° 49′ approximately;
" width = 1 54 "

so that the apparent area subtended was about 36 times that of the full moon.

The current by which the strip was heated ran through a variable carbon resistance, the handle of which was within convenient reach of the observer as he sat with his head under the black cloth. He could thus alter the temperature of the platinum until it was on the very verge of invisibility, a very small fraction of a turn being then sufficient to produce utter darkness where before the area of faint light had been. A contact-breaker was also within convenient reach, so that the current could be broken or made at pleasure, and the objective reality of the faint luminosity at the limiting-point thus demonstrated. When he was satisfied that the limiting-point had been reached the hinged end of the box was opened, a beam of light sent to the mirror connected with the strip, and the deflection, giving the temperature, read on the scale. The possible error in the estimation of the absolute value of the temperature may be taken as certainly not more than 2°. . . .

The general conclusions reached are as follows:—

"(1) That the minimum temperature of visibility is the same for a bright polished metallic surface as for one covered with lampblack, although the intensity of the radiation in the two cases may be different.

This result may at first be, to some, unexpected, but a little consideration will show that it might have been, *à priori*, anticipated. For probably temperature governs the highest wave-length from a radiating body, and wave-length governs visibility, at least after an extremely small intensity of radiation has been passed.

(2) That the visible limit at the red end of the spectrum varies greatly for a normal eye, according to its state of preparation, i. e. according to the intensity of the light in which the observer has been before making the observation. . . .

Speaking generally, we may say that a bright light diminishes the sensitiveness of the eye to radiation of low frequency; that darkness increases it. Or that, as a rule, the eye is less sensitive in the morning than at night.

(3) That for the less sensitive condition, the minimum temperature of visibility for the surface of a solid is about 470° C., but that this may be much reduced by even a few minutes in a dark room.

(4) That at night, a surface at a temperature of 410° is visible, and that by resting the eyes in complete darkness, this may be reduced to as low as 370° nearly, below which apparently one cannot go, since 10 minutes' rest appears to be almost as efficacious as 3 hours'.

(5) That different people's eyes (of no special or known departure from normality) differ somewhat in their 'minimum temperature of visibility,' but probably not to any great extent, if tested under the same conditions as to preparation, etc. . . .

The loss of distinct *color* at the low temperatures is very striking; the appearance to the author, and to most of the observers, has absolutely nothing of red in it, but is like a white mist—the nearest comparison that can be made.

In the *morning* observations, however, when the strip disappeared at from 460° to 470°, the last appearance was distinctly reddish; and this agrees with one observation noted at night, when after getting the visibility critical-point at about 390° C., the temperature was raised until one could declare for certain that the light looked red: it was then found to be 449°.

Of course, in all the observations, the luminous area was most distinctly seen by somewhat averting the gaze from it; generally it was found best to look in the direction of either far upper corner of the enclosure.

As already mentioned, most of the observers pronounced the appearance at the critical-point to be that of a 'whitish mist;' one, however, thought he saw a slight 'lilac tinge' in it; and 'Case G' declared it to be decidedly yellow, which is interesting, because to him a red mark on white paper (such as a pip on a card belonging to one of the red suits of a pack) appears yellow, by artificial light at night.

In one experiment a plate of glass, $\frac{1}{8}$ inch thick, and in another a layer of water, $\frac{1}{2}$ inch thick, were inserted between the strip and the eye, without making the slightest difference in the phenomena; showing (1) that the point where these substances begin to be more or less opaque to infra-red radiation had not been reached; (2) that the small difference in intensity produced by their insertion had no appreciable effect. This last conclusion is far more strongly borne out by the equality of temperature in the case of the bare metallic and the black surfaces, and indicates that in all the cases it was *wave-length*, and not *intensity*, which was determinative of visibility, so disposing of the possible objection that the difference between 'morning' and 'evening' might be due merely to the state of enlargement of the pupil of the eye, which would naturally be more contracted at the one time than at the other, thus affecting the total amount of radiation falling on the retina. Also, if such an objection were valid, it would imply that fatigue of the muscles of the iris produced a relatively enormous 'time-lag' in following changes of luminous intensity, which we know does not exist.

There seems, in fact, to be little doubt that the difference is due to the retina itself becoming sensitive to long waves after rest, which were incapable of affecting it when it was in some way fatigued by exposure to the ordinary bright light of day.

The next and obvious step is to find the respective wave-lengths corresponding to the different temperatures. This point, however, and others, cannot be determined without some additions to the present apparatus, and will form the subject of a future paper." —*Proc. Phys. Soc.*, London, xiii, 122.

8. *On the liquefaction of air.* — A note communicated by Professor GEORGE DAVIDSON. The recent remarkable experiments of Professor Dewar in liquefying air, etc., recall the experiments of Perkins in 1822–1826 as detailed in a paper of the Royal Society read June 15, 1826 (p. 541).

Mr. Perkins describes the apparatus which he had devised and operated; and says, "this tube [of steel] I filled with water and subjected it to a pressure of 2,000 atmospheres. After repeating this experiment a great number of times, the average of the result showed that the column of water, 8 inches long, was compressed $\frac{2}{3}$ of an inch, or $\frac{1}{12}$ part of its length." . . . . .

"With the same apparatus I also made experiments on the compression of other fluids. The most remarkable result I obtained was with concentrated acetic acid; which, after compression with a force of 1100 atmospheres, was found to be beautifully crystallized, with the exception of about $\frac{1}{10}$ part of fluid, which, when poured out, was only slightly acid. . . . .

As it might be supposed that even glass was pervious to water by such a force, [500 atmospheres,] a small phial was made air-tight, by fitting into its neck a well-ground glass stopper. It sustained pressure of 500 atmospheres without change and was perfectly dry within, although it remained under that pressure 15 minutes. It was next subjected to a pressure of 800 atmospheres, and when taken out was found to be crushed to atoms.

"In the course of my experiments on the compression of atmospheric air, by the same apparatus that had been used for compressing water, I observed a curious fact, which induced me to extend the experiment; *viz.*, that of the air beginning to disappear at a pressure of 500 atmospheres, evidently by partial liquefaction, which is indicated by the quicksilver not settling down to a level with its surface. At an increased pressure of 600 atmospheres, the quicksilver was suspended about $\frac{1}{8}$ of the volume up the tube or gasometer; at 800 atmospheres, it remained about $\frac{1}{3}$ up the tube; at 1000 atmospheres, $\frac{2}{3}$ up the tube, and small globules of liquid began to form about the top of it; at 1200 atmospheres, the quicksilver remained $\frac{3}{4}$ up the tube, and a beautiful transparent liquid was seen on the surface of the quicksilver, in quantity about $\frac{1}{2000}$ part of the column of air. The gasometer was at another time charged with carburetted hydrogen, and placed in the receiving tube with its mouth immersed in the quicksilver; it was subjected to different pressures, and it began to liquefy at about 40 atmospheres, and at 1200 atmospheres the whole was liquefied.

"These instances of apparent condensation of gaseous fluids were first observed in January, 1822; but for want of chymical knowledge requisite to ascertain the exact nature of the liquids produced, I did not pursue the inquiry further," etc., etc.

9. *On the Value of μ for rapid Electrical Oscillations;* by Charles E. St. John (communicated).—In my paper "On Wave-Lengths of Electricity on Iron Wires," in a recent number of this Journal (vol. xlviii, 311). I gave as a by product of my investigation the value $\mu = 385$. Various estimates have been made for this quantity, but there has been a lack of experimental data. A late paper by Ignaz Klemencic in Wiedemann's Annalen, No. 12, 1894, contains the following values of the permeability in case of oscillations of 100,000 per second:

Soft iron $\mu = 118$
Steel $\mu = 106$ to 115

This value of μ led me to reëxamine my own results, and recalculation shows an arithmetical error, by which the values were multiplied by 4, so that the true approximate value yield by the data is 96, the separate values being $\mu = 107$, $\mu = 97{\cdot}5$, $\mu = 83{\cdot}5$ for the different specimens of iron. These are somewhat lower than the results found by Klemencic, but in my experiments the rate of oscillation was much higher.

In this connection a remark made by Mr. Oliver Heavyside in his Electrical Papers, vol. i, p. 361, is interesting. He says that μ is eminently variable but that $\mu = 100$ is a fair average value. Both Klemencic's results and my own confirm this assumption.

Berlin, Jan. 10, 1895.

10. *National Academy of Sciences on Electrical Measurement.*—In July, 1894, an act of Congress was passed to define and establish the units of electrical measure. By this law, Congress made it the duty of the National Academy of Sciences to prescribe and publish specifications necessary for the practical application of the definitions of certain units of electrical measure adopted in the act. This law (H. R. 6500), approved July 12, 1894, is as follows:—

An Act to Define and Establish the Units of Electrical Measure.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the passage of this Act the legal units of electrical measure in the United States shall be as follows:

First. The unit of resistance shall be what is known as the international ohm, which is substantially equal to one thousand million units of resistance of the centimeter-gram-second system of electro-magnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice fourteen and four thousand five hundred and twenty-one ten-thousandths grams in mass. of a constant cross-sectional area, and of the length of one hundred and six and three-tenths centimeters.

Second. The unit of current shall be what is known as the international ampere, which is one-tenth of the unit of current of the centimeter-gram-second system of electro-magnetic units, and is the practical equivalent of the unvarying current, which, when passed through a solution of nitrate of silver in water in accordance with standard specifications, deposits silver at the rate of one thousand one hundred and eighteen millionths of a gram per second.

Third. The unit of electro-motive force shall be what is known as the international volt, which is the electro-motive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of an international ampere, and is practically equivalent to one thousand fourteen hundred and thirty-fourths of the electro-motive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of fifteen degrees centigrade, and prepared in the manner described in the standard specifications.

Fourth. The unit of quantity shall be what is known as the international coulomb, which is the quantity of electricity transferred by a current of one international ampere in one second.

Fifth. The unit of capacity shall be what is known as the international farad, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.

Sixth. The unit of work shall be the Joule, which is equal to ten million units of work in the centimeter-gram-second system, and which is practically equivalent to the energy expended in one second by an international ampere in an international ohm.

Seventh. The unit of power shall be the Watt, which is equal to ten million units of power in the centimeter-gram-second system, and which is practically equivalent to the work done at the rate of one Joule per second.

Eighth. The unit of induction shall be the Henry, which is the induction in a circuit when the electro-motive force induced in this circuit is one international volt while the inducing current varies at the rate of one Ampere per second.

Sec. 2. That it shall be the duty of the National Academy of Sciences to prescribe and publish, as soon as possible after the passage of this Act, such specifications of details as shall be necessary for the practical application of the definitions of the amperc and volt hereinbefore given, and such specifications shall be the standard specifications herein mentioned.

To meet this requirement of Congress, it was necessary, in accordance with the constitution of the National Academy of Sciences, to appoint a special committee to consider the subject. This was done as soon as an official copy of the law was received from the State Department. The committee, selected from members of the National Academy, was as follows :—

Prof. H. A. Rowland, *Chairman*, Johns Hopkins University, Baltimore.
Gen. H. L. Abbot, United States Engineers, New York.
Prof. G. F. Barker, University of Pennsylvania, Philadelphia.
Prof. J. Trowbridge, Harvard University, Cambridge.
Prof. C. S. Hastings, Yale University, New Haven.
Dr. C. Barus, Smithsonian Institution, Washington.
Prof. A. A. Michelson, University of Chicago, Chicago.

The committee completed the work assigned to them, and the specifications they prepared meet the requirement of the law, and are also in accord with international agreement.

The report of this committee, approved by all its members, was submitted to the National Academy of Sciences at a special meeting held in New York, on the 9th of February, 1895, and was then unanimously adopted by the Academy.

At the same session, the National Academy of Sciences voted to prescribe and publish the specifications relating to the ampere and volt, as required by the above law.

To secure the necessary publication of these results, it was also voted, that the President of the Academy send a copy of the specifications to each house of Congress, and to the Secretary of State, with the request to the latter that they be issued by the State Department; and further that the Academy print a suitable number for public distribution. Certified copies have already been transmitted to Congress, and to the State Department, and the official copies to be distributed by the National Academy will soon be issued.

This action of the National Academy of Sciences completes the law of July 12, 1894, and makes the legislation of the United States on the standards for electrical measure in advance of that of any other nation.—O. C. M.

New Haven, Conn., Feb. 20, 1895.

11. *Physics for University Students;* by HENRY S. CARHART. Part I, Mechanics, Sound and Light. 344 pp. Boston, 1894 (Allyn & Bacon).—This brief and concise text-book has been prepared by the author to be used by his students in connection with the formal course of lectures by which they are introduced to the subject of general physics; other teachers similarly situated may well find that it also meets their needs. The subjects are for the most part presented clearly; a sufficient number of suitable illustrations accompany the text. The volume is about equally divided between mechanics, sound and light; the subject of light would seem to have deserved relatively a somewhat greater space than sound.

II. GEOLOGY AND MINERALOGY.

1. *The correlation of the Bohemian and Eifilian divisions of the Devonian.**—As the result of observations made in the neighborhood of Prague and the examination of the original collections of the Bohemian fossils the authors have made a comparison of the faunas of the Barrandian zones F. G. and H. with the faunas of the typical Eifelian Devonian.

They show that the Greifenstein limestone of the Rhine contains a fauna equivalent to the Bohemian fauna of the Mnenian limestone, which is above and distinct from that of the Konjeprus limestone. The latter limestone is shown to be the equivalent of the Hercynian limestone of the Hartz and thus they prove the Greifenstein limestone to belong above in the Middle Devonian as an equivalent of the Eifelian Cultrijugatus beds. They restrict the use of the term Hercynian to the calcareous beds of the lower

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* Ueber die stratigraphischen Beziehungen der böhmischen Stufen F. Gs. H. Barrandes zum rheinischen Devon. von E. Kayser in Marburg u. E. Holzapfel in Aachen, Jahrb. d. k. k. geol. Reichsanstalt, 1894, vol. xliv, Heft 3, pp. 479–514.

"*wieder Schiefern*" of the Hartz and formations in other regions bearing the same fauna. This limestone, according to their present opinion, is scarcely older than the *unter-Coblenz* or the highest of the *Siegener Schichten.* The equivalents of the Hercynian, so restricted, are the Konjaprus limestone of Bohemia, the Erbray limestone of France, the Ural limestone of Bjelaja river, Russia, and the Lower Helderberg of America.

The following scheme presents the correlations of the Bohemian zones, through the Hessen Nassau sections, with the standard Eifelian formations:

EIFEL.	HESSEN NASSAU.	BOHEMIA.
Upper Stringocephalus limestone.	Massen limestone.	H^2
Lower Stringocephalus limestone.	Oderhauser and Haina limestones.	H^1
Calceola beds.	Günterod-limestone.	G^3 G^2
Cultrijuatus beds.	Ballersbach-limestone. Greifenstein-limestone.	Mnenian limestone; G^1 (?)
Lower Devonian.		Konjeprus limestone and F^1

This determination, it will be noticed, restricts the Bohemian formations G and H to the Middle Devonian, and draws the line between the Greifenstein and Mnenian faunas, which are regarded as equivalent to the Cultrijugatus beds, and the typical Hercynian fauna of Lower Devonian age. The paper is an excellent illustration of the accurate correlation to be attained by a critical comparative study of local faunas. H. S. W.

2. *Daimonelix of the Lacustrine Miocene of Nebraska.*—Under the name of Daimonelix, Prof. E. H. BARBOUR has described in the "University Studies" of the University of Nebraska for 1892 and 1894, large open coils occurring in the Nebraska Miocene; the paper is accompanied by many excellent figures, some of them from photographs. The fossils had been called *Devil's corkscrews* and hence the name which he gives them. The coils stand vertically at different heights in a bed about 100 feet thick, and are ordinarily 6 to 8 feet high, though ranging up to over 12 feet, with the thickness of the stem of the coil 2½ to 8 inches. The basal portion is extended out laterally, with a rising curve, to a length sometimes of 13 feet, and has a varying diameter of 6 to 10 inches. The coils are both right handed and left handed; and sometimes they are double.

They were first thought by Prof. Barbour to be fossil freshwater sponges; but possibly burrows of Rodents which had become filled with sand,—the bones of a Rodent having been found in the base of one of the coils. In his later paper, of July, 1894, he states, on the ground of new observations, that the interior structure of the coils is coarse cellular; and that the surface is one tangle of ramifying, intertwining tubules, of a diameter from one sixty-fourth to one-eighth of an inch; some are full a fourth of an inch, but the average is about a thirty-second of an inch." "The tubules grow more densely clustered as we pass inward, and finally, as it were, thicken into a white solid compact wall" which in some cases is nearly an inch thick. The conclusion is thence reached that the coiled fossils were some kind of plant.

Prof. J. A. Allen, of the American Museum of Natural History, judging from the descriptions in the paper of 1892, expressed the opinion in the letter to the writer, that they were probably the burrows of a Rodent, one or more species of Rodent having been described from the Miocene beds.

Prof. W. G. Farlow of Cambridge, in view of the later as well as earlier described facts, writes rejecting the idea as to their being Algæ or of any other order of Cryptogams, and says, in conclusion that "on the whole, in spite of the failure of the microscopic sections to show the characteristic structure of roots, I cannot help believing that the coils were really hollows into which something like roots have grown and been fossilized. It would be of great interest to have a microscopic examination of the matrix in which the coils are imbedded; for it might afford a clew as to the possible nature of the filaments of which the coils are mainly composed."

This conclusion of Prof. Farlow is consistent with that of Prof. Allen, that they are probably the burrows of Rodents, and that the winding form of the burrow was adopted, as the latter suggested, to facilitate ascent and descent. J. D. D.

3. *Report of the geological survey of Ohio, Vol. VII., Economic Geology, Archæology, Botany, Paleontology*, pp. i–xvi, i–290, i–700, Plates I–LVI. A colored geological map of the state, 10 folio maps illustrating the coal fields, several woodcuts in the body of text and 11 charts and maps illustrating Archæology. 1893.—The volume is divided into two parts: Part I—Economic—contains chapters on the geological scale and geological structure of Ohio, the clays of Ohio, their origin, composition and varieties, and the coal fields of Ohio, by Prof. Edward Orton, and one on The clay working industries of Ohio, by Edward Orton, Jr. In the first chapter the state geologist calls attention to the importance of retaining the original boundaries of the Waverly group, the lowest member of which is the Bedford shale of Newberry of the northern part of the state, the name Waverly shale having been applied to the extension of the same formation in the southern part of the state. The Ohio shale, including the Huron, Erie and Cleveland shales of Newbury "fills the entire interval between the Hamilton proper and the Catskill group, and in the judgment of some geologists a wider interval even than that named above."

Part II contains the following chapters: Chapter I, The Archæology of Ohio, an abstract embodying the principal results of explorations and discoveries thus far made, designed for those to whom the hitherto published literature of the subject is not easily accessible, by GERARD FOWKE; Chapter II, Catalogue of Ohio Plants, by W. A. KELLERMAN and WM. C. WERNER. Besides the list itself (pp. 81–406) this article includes a valuable Bibliography of Ohio Botany from 1815–1893. Chapter III, on Paleontology, contains contributions to the Paleontology of Ohio, by R. P. WHITFIELD; 1. Descriptions of fossils from the Paleozoic rocks of Ohio (reprinted from Am. N. Y. Acad. Science, Vol. V, read Oct. 13, 1890). Plates I–XIII accompany this paper. Chapter IV, Observations upon the so-called Waverly group of Ohio, by C. L. HERRICK, pp. 495–515, Plates XIV–XXIV contain an introduction and brief summary of results already published in the Bulletins of Denison University, the Am. Geologist, and Bulletins of the Am. Geol. Society. The author still holds the view that the Berea grit is the real floor of the Carboniferous series—"not necessarily the base of the Carboniferous, but the most convenient base line for the Waverly," remarking that a study of localities "and collections on which Dr. Newberry's opinion [that the Bedford shale fossils are Carboniferous] was founded has convinced the writer that these species do not occur in the typical Bedford, but in thin flags associated or interbedded, while the typical Bedford, especially in central Ohio, where it reposes directly upon the 'Black shale,' carries a considerable series of fossils forming a decidedly Devonian assemblage."—(p. 507). In a critical case like this, it is unfortunate that so keen an observer as Professor Herrick should describe as "typical Bedford" a formation which confessedly does not contain the typical fossils of the Bedford shale. Chapter V, Fossils of the Clinton group in Ohio and Indiana, by AUG. F. FOERSTE, is apparently a republication of the author's paper on this subject which appeared in the Bulletins of Denison University. It is accompanied by plates XXV–XXXVII*a*. Chapter VI contains The Fossil Fishes of Ohio, by E. W. CLAYPOLE, with a supplement by A. A. WRIGHT, on the ventral armor of Dinichthys. Plates XXXVIII–XLIV accompany this chapter. The final chapter, VII, is entitled, New and little known Lamellebranchiata from the Lower Silurian rocks of Ohio and adjacent states, by E. O. ULRICH. This paper is illustrated by a fine series of plates, XLV–LVI, prepared by the author. H. S. W.

4. *Geological and natural history survey of Minnesota.* 22d Annual Report for the year 1893. pp. 210, 1894.—This Report gives account of the final field work of this survey. The state geologist, Winchell, makes the statement that there remains still to be published the third volume of the Final Report, which is in preparation and several Chapters of which have been already printed, and preliminary copies distributed. The following papers are included:—Summary statement; List of rock samples collected to illustrate the notes of N. H. WINCHELL, 1893; Preliminary report of field work during 1893 in northeastern Minnesota, chiefly relating to the glacial drift, by WARREN UPHAM; Pre-

liminary report of field work during 1893 in northeastern Minnesota, by U. S. GRANT; List of rock samples collected in 1893, by U. S. GRANT; List of rock samples collected in 1893, by A. D. MEEDS; Preliminary report of a reconnoissance in northwestern Minnesota during 1893, by J. E. TODD; Notes on the geology of Itasca county, Minnesota, by G. E. CULVER; Preliminary report of field work done in 1893, by J. E. SPURR; Preliminary report of levelling party, by C. P. BERKEY; Preliminary report of field work during 1893 in northeastern Minnesota, by A. H. ELFTMAN; List of rock samples collected in 1893, by A. H. ELFTMAN; Museum additions: Additions to the library since the report of 1892; The exhibit of the survey at the Columbian Exposition, by N. H. WINCHELL. H. S. W.

5. *Twelfth Report of the State Mineralogist of California* for the two years ending September 15, 1894. J. J. CRAWFORD, State Mineralogist, 541 pp. 8vo, Sacramento, 1894.—This, the second biennial report, contains a discussion of the mineral industries of the State arranged conveniently under subjects, as antimony, borax, gold, etc., with a list of localities by counties under each head. Much space (pp. 70–322) is devoted to gold, since the interest in gold mining has much increased during the past two years. The annual gold product, which for a number of years had remained between twelve and thirteen million dollars, is expected to be maintained now at fifteen to sixteen millions. The Report is thoroughly illustrated with views of mining works, maps, plans, etc.

III. BOTANY.

1. *The Ware Collection of Blaschka Glass Models of Plants and Flowers in the Botanical Museum of Harvard University.*—These specimens, which were referred to in the last number of this Journal, are now arranged with a degree of completeness which renders possible a general consideration of their origin and purpose.

In planning the arrangement of the Botanical Museum, the Director was so fortunate as to secure the advice and cordial coöperation of Mr. Alexander Agassiz. In the preparation of the plans much prominence was given to the subject of a synoptic room, where the types of vegetable structure could be comprehensively displayed somewhat after the fashion of the zoological synoptic room. But it was early seen that dried specimens of flowers would be too perishable and alcoholic specimens too obscure to render useful any attempts in this direction by ordinary means. Drawings and paintings of flowers seemed likewise unsatisfactory. Models alone remained. Examination of the available models in papier machè showed that they would occupy too much space, and be possibly misleading in the qualities of texture and color.

It occurred to the present writer that the Blaschkas, the artists who had constructed the exquisite glass models of marine invertebrata and had distributed them from their studio and laboratories in Dresden to museums throughout the world, might be induced to try their hand at the preparation of models of flowers and leaves. A visit expressly for this purpose was made to Germany in 1886. It was only after much solicitation that the Blaschkas, father and son, were led to undertake the construction of a few specimens. These proved entirely satisfactory. They were so thoroughly promising in every respect that arrangements were made at once for the preparation of about a hundred selected types. The Blaschkas reviewed their botanical studies, always with them a favorite pursuit, and engaged in the new work with interest and uninterrupted success. In the case of the elder Blaschka, the work was really the resumption of an undertaking begun at the instance of Professor Reichenbach in 1866. The models which were then made were sent to the Museum of Natural History at Liège, Belgium, and were consumed in the destructive fire of 1868. Since that date, no glass models of plants had been made by either the elder or the younger Blaschka: their time had been fully occupied with the preparation of models of marine invertebrata.

The new undertaking was of course very costly, but this consideration did not deter Mrs. Elizabeth C. Ware and her daughter Miss Mary L. Ware, of Boston, from authorizing extended contracts with the artists for their entire output of flower-models. The subjects for study were carefully selected with reference to a complete representation of the chief types of structure in the vegetable kingdom, and these subjects were confined, where practicable, to the species found in North, South, and Central America. Up to 1888, the generous patrons of the enterprise had not permitted their names to be known in connection with it, but it was now seen that the magnitude and beauty of the collection justified its designation as a memorial to the late Dr. Charles Eliot Ware.

The last contract with the artists bears date of 1890, and runs to 1900. The Phænogamia now on hand comprise 122 natural orders, 407 genera, and 507 species. These figures indicate sufficiently that the subjects have been chosen with reference to the widest possible range of illustration.

Each plant-model is accompanied by models of structural details, for the most part highly magnified. There are 2160 of these details, making with the large models, more than 2,600 pieces of glass-work. The present rate of production is about one hundred of the larger models and five hundred of the minor ones, each year. When it is remembered that all of this work is based on original botanical study of the species in hand, and is accomplished by two artists who carry on their modelling unaided by any assistants, the rapidity of execution must be acknowledged to be marvelous.

As Mr. Walter Deane has shown by his account of a minute examination of the Blaschka models of our Eastern plants, there is absolutely no flaw in the workmanship. Every detail is given with perfect accuracy and all are drawn to scale.

The subjects are supplied to the artists in the three following ways,—(1) Plants which can be raised out of doors in the garden near the laboratory and studio are cultivated from seeds and roots sent from this country. (2) Central and South American exotics are freely furnished from the Greenhouses of the Court of Saxony at Pilnitz, one mile from the studio, and (3) the economic plants of the tropics have been studied by Rudolph Blaschka during a recent journey made for that purpose. The sketches for these plants are among the most interesting features of the whole enterprise. They consist of accurate drawings of the whole plant, and of microscopic details throughout, together with full records of impressions as to color. These multifarious sketches are supplemented by alcoholic and dried material prepared for the specific object of supplying all possible information regarding structure.

With the exception of a few specimens where the use of very delicate wire is needed, all the models are constructed of glass or a transparent enamel. In some instances, the color is given to the glass before the model is made; in some cases mineral pigments are added after the completion of the form. In no case has there been observed the slightest change in color of the added pigments or in the character of the surface by exposure to light. It may be assumed, therefore, that these models possess a high degree of permanence under ordinary museum conditions. Since they are absolutely faithful copies of the specimens in hand, and since they undergo no change, they are valuable records of form, color and texture for future comparison.

In the case of American plants which are represented by identical species in the old world, the artists have been urged to employ, as far as practicable, the most typical specimens of the old-world form. This has led to the conviction that in no case yet studied are the old-world species *exactly* like ours. In a few instances, the differences are sufficiently marked to justify the separation into two distinct varieties, and in two cases the differences would be interpreted as specific.

From the foregoing, it will appear that the rapidly increasing collection at Harvard University Museum is of use not only to the public and to the students, but also to the systematist who is engaged in coördinating plant forms with a view to expressing affinities.

Further, it will plainly appear that these models are the best possible illustrations of the economic plants of the tropics, supplementing the alcoholic and dried specimens which are everywhere found.

The artists have already constructed some models to illustrate types of Cryptogamia. They have proceeded cautiously along this path, but their success is regarded by competent authorities to be assured. No specimen is allowed to leave their laboratory which has not been submitted to thorough examination as regards all possible points of doubt, and, hence, the illustrations of Cryptogamia will doubtless prove generally satisfactory. More than one hundred of these models are now in possession of the University, but they are not at present on exhibition, being withheld until the completion of the proposed series of types. With the exception of a few very large specimens, all of the models of flowering plants are now installed for exhibition. G. L. G.

2. *Monograph of the Mycetozoa;* by ARTHUR LESTER, F.Z.S. London, 1894, 8vo, pp. 224, Pl. 78 and 51 woodcuts.—The present monograph printed by order of the Trustees of the British Museum is the most important descriptive work on Mycetozoa which has appeared since the publication of Rostafinski's monograph on the order in 1875. That work, although written in Polish and therefore inaccessible to most botanists except in the partial translations and extracts given in the writings of Cooke, Schroeter and Berlese, served greatly to stimulate the interest of botanists in both Europe and America in the systematic study of these anomalous growths on the border-line between the animal and vegetable kingdoms. The result was the publication of numerous articles and monographs by the botanists of both continents but until now there has been no satisfactory critical general revision reducing to a solid basis the many scattered facts and descriptions. Mr. Lester's Monograph purports to be only "a descriptive catalogue of the species in the Herbarium of the British Museum" but it is much more than that. It is in fact a general monograph including descriptions of all known species, those of species not represented in the collections of the author and the British Museum being quoted from the original sources often with critical notes.

Mr. Lester's well known studies on the development and cytological peculiarities of Mycetozoa have contributed to give additional value to his more strictly systematic work and prevented his attaching undue weight to the trivial and accidental characters on which systematists are often inclined to depend. In the preparation of his work he has made extensive studies in the field, corresponded with specialists all over the world and examined the types in British and Continental collections. Probably no other botanist has ever had so much or so good material of the kind pass through his hands. In the presentation of his subject the author has shown great clearness and good judgment as well as extensive knowledge and where he differs from other writers he is courteous as well as candid.

The Introduction gives an admirable summary of the life history of the order including some original matter especially relating to the development of Ceratiomyxa. He includes Ceratiomyxa in the subclass Exosporeæ following Rostafinski and De Bary although admitting that the subclass is in some important respects unlike the rest of the order but he does not include the numerous monad-like forms classed by Zopt with Mycetozoa.

On the technical question whether Mycetozoa are plants or animals the author contents himself with the short remark that "the ingestion of bacteria by the swarm-cells appears to strengthen the view that the group is more nearly associated with the lower forms of animal than of vegetable life? The subdivisions of the Exosporeæ here given are essentially those adopted by Rostafinski. The Protodermaceæ disappear since the only supposed representative proves to be a Licea. The total number of genera of the order is given as 43 and the number of species of which descriptions are given is 275. Since a doubt exists as to the genuineness of some of the latter it will be seen that an unusually large proportion of the genera include only a single or, at most, two or three species. Although the number of species admitted by the writer is far short of the number that have been described by different botanists, it seems to us that in his reduction of many of them to synonyms, he is fully justified. One has only to read his excellent descriptions which comprise accounts of the plasmadia as well as the mature structures and his very full notes with regard to type-specimens examined and the variations assumed under different conditions to be convinced that his view with regard to specific limitations is as correct as it is far reaching. His treatment of Stemonitis and Trichia is refreshing after the confused account of those genera to be found in some treatises and even the perplexing genera Physarum and Cribraria lose much of their intrinsic difficulty at his hands.

For American botanists the present Monograph is especially valuable. Besides the specimens of older collectors in various herbaria Mr. Lester has examined abundant recent material from Rex, Macbride, Morgan and the writer, and he has given us at once the most connected and critical account of the species of the United States yet published. He remarks that the species of Mycetozoa have, as a rule, a wide distribution throughout the world and doubts whether unexplored districts are likely to furnish any large number of new species. The book is well printed and very copiously illustrated. The woodcuts of the genera are well adapted for their purpose. The plates of the species are collotype reproductions of water color drawings by Mr. Lester and his daughter and are as a rule very satisfactory. Like all photographs, however, they sometimes fail to give clearly the finer markings. We regret that the original drawings were not reproduced in colors, not that we think the colors themselves necessary in this case but because, the drawings being colored, photography could not be expected to bring out well all the finer points. One sees, in some cases, from the reproduction how much better the original drawing must have been. W. G. F.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Life of Richard Owen;* by his grandson the Rev. RICHARD OWEN, M.A. with the scientific portion revised by C. Davies Sherborn, also an essay on Owen's position in Anatomical Science by the Right Hon. T. H. Huxley, F.R.S. Portraits and illustrations. In two volumes, pp. 409 and 393. (London, John Murray; New York, D. Appleton & Co.). 1894—This is a remarkably interesting and vivid sketch of the life and experiences of one of the most eminent of English men of science told mainly through extracts of private letters to his mother and sisters and the journals of his wife. Owen's published writings--639 titles given in the bibliographic list at the end of the book—show the scientific side of the man and his immense industry, but these private records exhibit the social side of his life, tell of the men he met, the journeys he took, the modes of his work, the honors showered upon him, and, not least interesting, the many sources from which came the anatomical treasures he described; the Dinornis bones from New Zealand, the Mylodon from South America, Dicynodon skull from South Africa, sent by Prince Alfred, and everything rare and uncanny, as the "adder with two hind legs" from Charles Kingsley, from every part of the earth where Englishmen wandered. We see him dissecting the defunct criminals who perished in Lancaster Jaol, describing the Hunterian collections and lecturing at the College of Surgeons, reading papers at the British Association and in various learned societies, or at the Royal Institution, or to the young princes and princesses at Buckingham palace.

We find him chatting with Carlyle, Tennyson, or Dickens, or Ruskin, on art, music and Shakespeare, serving as an active member of the Commission of Inquiry into the health of towns, which leads him all over the kingdom examining slaughter houses and fish ponds, etc., or discussing with Gladstone or Lord Russell the plans for the British Museum, or dining at the club with Lord Macaulay, Duke of Argyle, Dean Milman, Whewell, or again with Sir R. Inglis, Chev. Bunsen, Mr. Brooke, the Rajah of Sarawah, and others, or traveling up the Nile with the Prince and Princess of Wales, Sir Samuel Baker, the Duke of Sutherland, the Bishop of Bombay, and his Excellency Nubar Pacha, or unbending and singing songs at the jovial meetings of the "Red Lions" of the British Association.

All the story is so directly told that we seem to see the genial, ever busy but always cheerful companion of his many friends. as he goes about accomplishing the great work of his life.

The book closes with an account of Owen's position in the history of Anatomical Science, written by Mr. Huxley, who, though often differing with him on scientific theories, speaks with knowledge and appreciation of his great contributions to their favorite science. H. S. W.

2. *The Life and Writings of Rafinesque;* by RICHARD E. CALL. Filson Club Publications, No. 10. Read at the Filson Club meet-

.ng, at Louisville, of April 2, 1894. 228 pp., 4to, with portraits and other illustrations. Louisville, Ky., 1895.—The name of Rafinesque, has, in this sumptuous volume and the kindly sketch of Dr. Call, all the generous treatment and honor that the eccentric naturalist could have reasonably desired. The many puzzling problems which Rafinesque left behind him in consequence of his eagerness and keenness of eye in noting distinctions, but hasty work in naming and describing genera and species, thereby duplicating names already accepted, and multiplying names with imperfect descriptions, or with no descriptions at all, have given much labor to those who would do him justice, and led some to question whether the study of any part of his scientific papers is not time lost. Dr. Call gives a lifelike picture of the enthusiastic naturalist and a judicious account of his work; and while admitting that part of the latter is peculiarly bad, rightly claims that what is good should be accepted. The volume closes with a carefully prepared bibliography. This Journal contains some of Rafinesque's earlier papers in its first volume, and an excellent biographic sketch and review of his botanical work by Dr. Gray, in volume xl, p. 221, 1841.

3. *The Mineral Collector.*—With the February number, this periodical has concluded its first volume. It is devoted to "the interests of the collector, student, dealer and miner of mineral specimens" and contains much both in articles and informal notes that is of interest and value to those mentioned and hence deserves their support. It has been through the past year under the editorship of Albert C. Bates and Arthur Chamberlain; and the ensuing year Mr. Chamberlain will take charge alone. The subscription price is one dollar per year (editorial address, 26 John St., New York City).

4. *Geological Society of London.*—The Bigsby medal has been presented by the Geological Society of London to Mr. Charles D. Walcott, Director of the U. S. Geological Survey.

5. *Geological Survey of Canada.*—Dr. George M. Dawson has been recently made Director of the Geological Survey of Canada, in place of Dr. A. R. C. Selwyn, who has retired at an advanced age.

OBITUARY.

PROFESSOR ARTHUR CAYLEY, F.R.S., the eminent mathematician of Cambridge, England, died January 26 in his seventy-fourth year.

DR. F. BUCHANAN WHITE, distinguished for his labors in entomology and botany, died at Perth, Scotland, December 3d.

DR. MURRAY THOMSON, Professor of Experimental Science at Roorkee, India, died January 13th in his sixty-first year.

DR. KARL VON HAUSHOFER, Professor of Mineralogy at Munich, died early in January.

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PELLUCID SELENITE GROUPS FROM MICHIGAN.

A large lot of groups of Selenite crystals were received during February. The best of them at 50c. to $5.00 are exceedingly choice, the crystals being remarkably sharp and as clear as glass. They form in geodic groups, commonly in a yellow, massive gypsum. With these fine specimens was a large number of specimens not well crystallized, but quite pretty and illustrating the properties of the mineral admirably. We will sell these at the rate of 10c. per pound—remarkably cheap, or 100 lbs. for $8.00.

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Chas. D. Walcott.

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXI.—*Niagara and the Great Lakes;* by FRANK BURSLEY TAYLOR.

Introduction.

IN the recent papers of Professor J. W. Spencer* and Mr. Warren Upham † the post-glacial history of the Great Lakes has been ably told according to two very different ideas of the cause of Pleistocene change. Prof. Spencer on the one hand levels all the higher abandoned beaches with the sea, and does not distinctly recognize a single ice-dammed lake. Mr. Upham, on the other hand, ascribes nearly all submergence to ice-dammed lakes, and admits none as marine except that which is proved by fossils. As often happens in such cases, the probability is that the truth lies between these wide extremes. Ice dams have played an important part, but not to the exclusion of marine submergence even at high levels. On the other hand, marine invasion is not available as an explanation for some of the most important areas of submergence.

The St. Lawrence river and the Great Lakes with their connecting channels are really all one stream. The lakes are great reservoirs which feed the rivers below them, and because they derive nearly all their supply from the lakes the rivers

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* "The Duration of Niagara Falls," by J. W. Spencer, this Journal, Dec., 1894; "A Review of the History of the Great Lakes," Am. Geol., vol. xiv, Nov., 1894.

† "Late Glacial or Champlain Subsidence and Reëlevation of the St. Lawrence River Basin," by Warren Upham, this Journal, Jan., 1895; Twenty-second Ann. Rep't Geol. and Nat. Hist. Survey of Minn., Part III, pp. 54–66; "Departure of the Ice-Sheet from the Laurentian Lakes," Bull. G. S. A., vol. vi, 1894.

themselves have almost no independent existence. If anything happens to the lakes to turn their discharge in some other direction the rivers go nearly or entirely dry. Niagara is one of these rivers, and its history is inseparable from that of the lakes above it. Prof. Spencer has described the salient features of the Niagara gorge, and has also given many important facts bearing on the lake history. But certain facts which he does not take into account indicate a somewhat different lake history, and in consequence a different Niagara history also. The lake history is recorded in the larger characters, and it seems best therefore to study it first. Reference will be made in the following pages to six papers in which the writer's observations on the abandoned shore lines of the upper lakes are recorded.* Another paper discussing the latest chapter in the history of the Great Lakes also belongs to this series. It is entitled, "The Second Lake Algonquin."† It precedes this paper in order, and relates to the lake stages following next after those discussed here. These two papers together cover, in a preliminary way, the whole period from the final disappearance of the great Laurentide glacier down to the present time. But they do not include, except by incidental reference, the period of the glacial recession with its lakes. The map which accompanies this paper is designed to show within its limits the probable distribution of land at the maximum of marine submergence, and also the extent of that part of the first Lake Algonquin of which shore lines still remain.

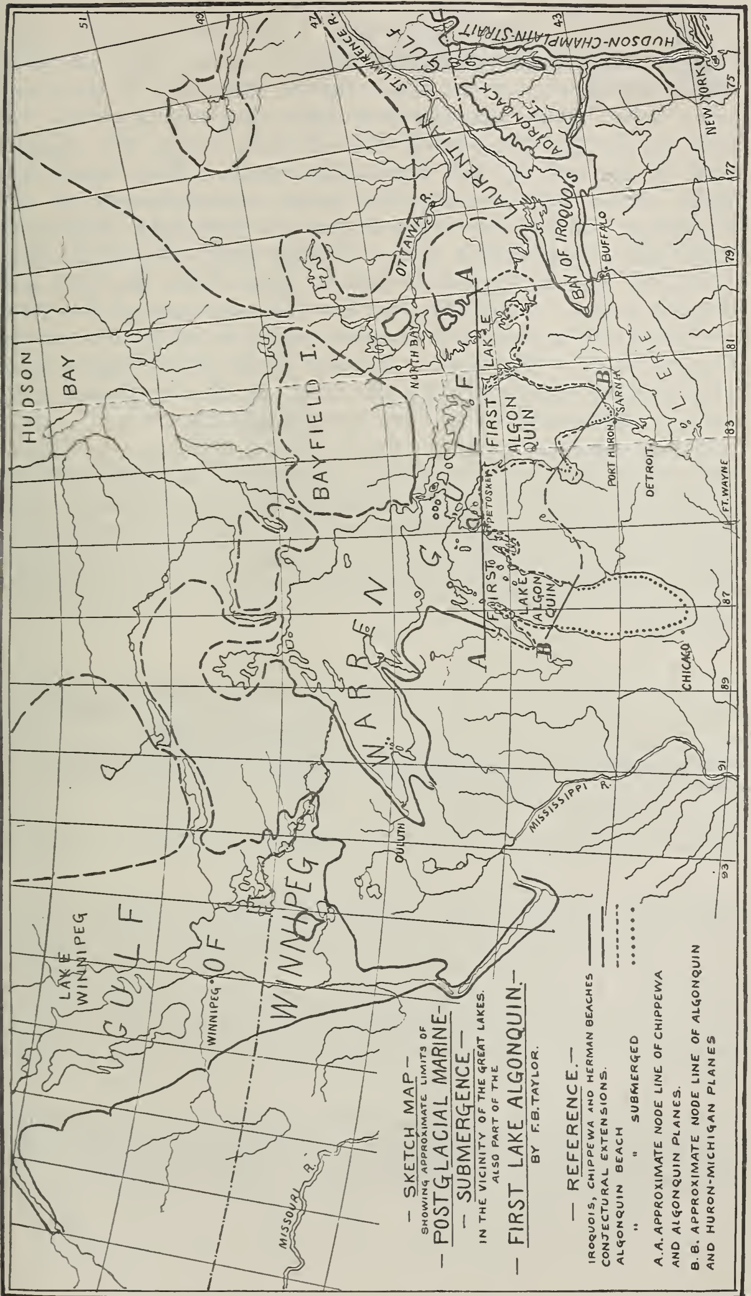
The Three Principal Beaches.

After the glacial recession the three principal critical stages in the recent history of the upper Great Lakes are marked by three great abandoned beaches. Two of these are lake beaches and one is marine. The lake beaches mark the highest stages of two independent epochs of Lake Algonquin, which had an outlet on each occasion eastward across the Nipissing pass at North Bay, Ontario. One epoch of this lake existed before the marine invasion and the other after. The latest one I have called the second Lake Algonquin, and its highest shore

---

* 1. "Highest Old Shore Line on Mackinac Island," this Jour., III, vol. xliii, March, 1892; 2. "The Ancient Strait at Nipissing," Bull. G. S. A., vol. v, 1893; 3. "A Reconnaissance of the Abandoned Shore Lines of Green Bay," Am. Geol., vol. xiii, May, 1894; 4. "A Reconnaissance of the Abandoned Shore Lines of the South Coast of Lake Superior," Am. Geol., vol. xiii, June, 1894; 5. "The Limit of Postglacial Submergence in the Highlands East of Georgian Bay," Am. Geol., vol. xiv, Nov., 1894; 6. "The Munuscong Islands," Am. Geol., vol. xv, Jan, 1895. These papers will be referred to hereafter by number.

† Am. Geol, vol. xv, Feb. and March, 1895.



— SKETCH MAP —
SHOWING APPROXIMATE LIMITS OF
— POSTGLACIAL MARINE —
— SUBMERGENCE —
IN THE VICINITY OF THE GREAT LAKES.
ALSO PART OF THE
— FIRST LAKE ALGONQUIN —
BY F. B. TAYLOR.

— REFERENCE. —

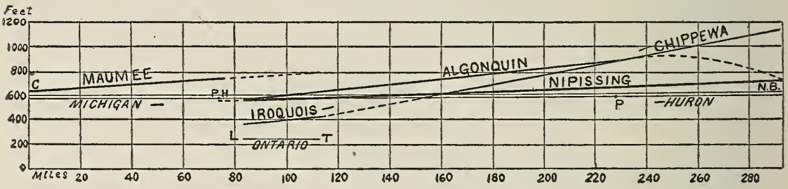
IROQUOIS, CHIPPEWA AND HERMAN BEACHES
CONJECTURAL EXTENSIONS.
ALGONQUIN BEACH
" " SUBMERGED

A. A. APPROXIMATE NODE LINE OF CHIPPEWA AND ALGONQUIN PLANES.
B. B. APPROXIMATE NODE LINE OF ALGONQUIN AND HURON-MICHIGAN PLANES.

line is the Nipissing beach. Next before its time there was a marine invasion which made what I shall call the Chippewa beach. This beach marks the highest level of Warren Gulf, which was an arm of the sea. Before the time of the Chippewa beach there was the first Lake Algonquin, which was very much like the second lake of that name. Its highest level is marked by the Algonquin beach. This beach was made under substantially the same circumstances as the Nipissing. Before the beginning of the first Lake Algonquin there was a considerable period during which the upper lakes outflowed just as they do to-day, by way of the St. Clair and Niagara rivers. I call this the first Niagara stage of the lakes to distinguish it from the present, which is called the second Niagara stage. The earlier beaches of the first Niagara lakes were made at comparatively low levels in the north and were entirely obliterated by the first Lake Algonquin.

The three great beaches named in their order are the Algonquin, Chippewa and Nipissing. Changes of land attitude occurred in the long interval between the two Algonquin lake epochs, and caused the difference between the present places of the Algonquin and Nipissing beaches. The following ideal section shows, in a general way, the relation of the principal beaches.

1.



C=Chicago, Fort Wayne, etc.; P. H.=Port Huron; P.=Petoskey; N. B.=North Bay; L.=Lewiston, and T.=Toronto. The Maumee beach may be taken to represent all the glacial lake beaches above the Algonquin plane. The latter plane rises from 20 feet below lake level at Port Huron and after passing under the Chippewa beach descends to North Bay. The later Nipissing beach connects the same points, but without having any marked unequal deformation. The Iroquois and Chippewa beaches are shown as one continuous plane, which they probably are, although the connection from Belleville to North Bay has not yet been traced.

These statements present a brief outline of the lake stages and the relations of the beaches, but it remains to discuss the facts which tend to establish them as valid conclusions.

The Chippewa Beach.

When the water stood at its highest level, whether it was a glacial lake, or an arm of the sea, it made a continuous strand in one form or another along the entire extent of its land margin. When that beach is determined at frequent intervals with care it is fair to assume that it is continuous. If the beach has characteristic features which suggest identity this inference is greatly strengthened, and is not to be given up without positive proof of discontinuity. As a matter of fact the highest beach in the north is generally strongly developed and shows by its structure that wave action, at and near its level, was powerful and of long duration. Its ridges could have been made only by the heavy surf of a large body of water. At many places the upper limit of submergence is marked by a compact series of strongly developed shingle or gravel ridges with lagoon hollows between, sometimes covering altogether a horizontal width of a quarter to a half mile and usually measuring 35 feet from the crest of the upper ridge down to that of the lowest of the series. This arrangement is a very persistent feature of this beach and appears at widely separated places. It is typical at Mackinac Island and Sault Ste. Marie and is only slightly less conspicuous at North Bay, Marquette, L'Anse, Burnt Bluff and other places. Its similarity in all these places points strongly to its unity as one continuous beach conditioned at all places alike by a very even and gradual recession of the waters for the first 35 feet. In other places where the ridge series is not so conspicuous or is absent there is sometimes equally impressive evidence of long duration of submergence near one level in great gravel and sand deltas like those near Marquette, Cartier, and Sault Ste. Marie, or in deep deltoid deposits of laminated silt like those at Bracebridge and Burk's Falls, Ontario. The character of the beach and its situation on the various coasts of the north seem to leave no reasonable doubt that it is all one beach and marks the margin of one water plane.

In the first of the six papers mentioned above, I called the highest old shore line on Mackinac Island the Algonquin beach, supposing it to be the same as Spencer's beach of that name on the east Huron and Georgian Bay shores. But I afterwards found reason to doubt this correlation, and so, pending a fuller knowledge of the facts which might enable me to make a better judgment, I henceforth adopted the common term "highest beach" and used that without attempting to establish identity with other beaches already named. But observations have been considerably extended in the last two or three years and enough facts are now at hand to form the basis of a much better correlation.

The highest beach of the north is not all of one age. A straight line drawn through Petoskey and Parry Sound, as shown on the map by AA, marks the approximate node line or place of division of the highest beach in two parts of different ages. South of this line the highest beach below the glacial lake beaches is all of one age, and is in fact Spencer's Algonquin beach. North of the line the highest beach is all of another age, and I propose to call it the Chippewa beach.* The reasons for the division on this line will be discussed farther on.

The Chippewa beach borders all the shores of the Great Lakes north of the Petoskey node line. In the following table its altitude is given at all places so far determined. The heights are in feet above sea level.

SUPERIOR BASIN.

Duluth, Minn.† (Lawson)	1134
Mt. Josephine, "	1207
Holyoke‡ (Upham)	1122
Maple Ridge, Wis.	1135
Kimball	1170
L'Anse, Mich.	1190
Marquette	1190
Sault Ste. Marie, Ont. (Lawson)	1014

MICHIGAN-HURON-GEORGIAN BAY BASIN.

Cook's Mill, Mich.	750
South Bay Hill	715
Burnt Bluff	705
Middle Munuscong Island	860
Mackinac	785
Petoskey	680
Cartier, Ont.	1200
Nelson's, near North Bay	1140
South River	1220
Sundridge	1205
Huntsville	1000

---

* I have long believed this beach to be one with the Iroquois beach of the Ontario basin. Reasons for this opinion will be set forth later. But inasmuch as this supposition has not yet been established by observations, it would seem premature to call it the Iroquois beach at the present time.

† "Sketch of the Coastal Topography of the North Side of Lake Superior with special reference to the Abandoned Strands of Lake Warren," by Andrew C. Lawson, Twentieth Annual Report, Geol. and Nat. Hist. Survey of Minnesota.

‡ Thirty miles southwest of Duluth. See Twenty-second Report Geol. and Nat. Hist. Survey of Minn., Part III, p. 59.

In the Superior Basin.—The Chippewa beach rises in 140 miles from 1134 feet above sea level at Duluth to 1207 feet at Mt. Josephine, near Grand Portage on the north shore, and in 172 miles to 1190 feet at L'Anse. Then from 1190 feet at Marquette in about 150 miles it drops to 1014 feet at Sault Ste. Marie. Cook's Mill is close to the north shore of Lake Michigan and is about 40 miles south from Old Munising. Along the comparatively low south shore east of Marquette we can only conjecture the probable height of the beach. Ground near Old Munising was washed over up to at least 250 feet. Scaffold Hill south of Munising station, rises a little higher, but has not been examined. If the beach rises northward from Cook's Mill at the same rate that it does from Mackinac to Sault Ste. Marie it would be about 340 feet above Lake Superior (940 feet above the sea) at Old Munising. Then from the Chippewa beach five miles west of Marquette to this point the descent would be about five feet per mile eastward.

On the north Superior shore, besides at Duluth and Sault Ste. Marie, the Chippewa beach has been reported probably at only one place, on Mt. Josephine at 1207 feet. The following are the principal high beaches observed by Lawson on the north Superior shore given in their order from west to east, Lake Superior being 602 feet above sea level. Those marked (*h*) are probably the Chippewa or highest post-glacial beach.

	Feet above Lake Superior.
Duluth, West, (*h*)	534
Duluth, 10th Ave., East, (*h*)	534.8
Hardy's School House	509.5
Two Harbors, D. & I. R. R.	475
Grand Portage*	458
Mt. Josephine, (*h*)	607.3
Kaministiquia (great delta)	455.1
Jackfish Bay "	418.3
Sault Ste. Marie, (*h*)	413.9

Jackfish Bay is the farthest north. But the observations of Lawson appear to show the Nipissing beach on the north shore at about 100 feet above the lake. It follows that the Champlain uplift raised this beach and necessarily all others lying above it relatively 125 feet from Duluth where the Nipissing beach is now submerged about 25 feet. The Nipissing beach rises northeastward a little over six inches per mile. The Chippewa beach rises from Duluth to Mt. Josephine about seven inches per mile. If the Chippewa beach continues in the same plane to Jackfish Bay its height would be about 1260 feet above sea level, or about 340 feet above Lawson's highest recorded beach at the latter place.

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* Prof. Lawson does not give this terrace in his table.

On the extreme north side there are two passes across the Height of Land to the basin of Hudson Bay. That at Kenogami Lake is said by Lawson to be 1102 feet above sea level, and the other, at Lake Missinaibi, 1040 feet. Unless it descends from Mt. Josephine 100 feet in 140 miles northeast, the Chippewa beach must be higher than the Kenogami pass, and a strait must have existed there to Hudson Bay; and unless it descends 60 feet more in 150 miles east to the Missinaibi pass, that too must have been a strait. From Mt. Josephine to Sault Ste. Marie around the north side we have no probable record of the Chippewa beach. The beach at the former locality is 183 feet higher than at the latter, and at both places it is inclined upward to the north. If the extensions from these two places unite in the north as one beach, it is obvious that the part extending northward from Sault Ste. Marie must rise more rapidly than the other. This supposition is supported by the facts in each locality. The northward rise from the Middle Munuscong Island to Sault Ste. Marie is over four feet per mile, while that northward from Duluth to Mt. Josephine is a little over one foot per mile. The pass at Lake Missinaibi is only 26 feet higher than the Chippewa beach at Sault Ste. Marie, and the distance is about 120 miles due north.

These considerations are not proof. But they are strong indications, and they are the best we can do in our present state of ignorance as to the place of the Chippewa beach on the north Superior shore. The strait of that time connecting Lake Superior with Lakes Michigan and Huron was about 110 miles wide.

In the Michigan-Huron-Georgian Bay Basin.—At the time of the Chippewa beach these three basins were all united together and with the waters of the Superior basin as one great gulf with only a few islands to break its entire stretch from Duluth and the west side of Green Bay to the highlands east of Georgian Bay. Southward the Chippewa beach intersects the Algonquin beach along the Petoskey node line, and the two appear to be physically continuous. The most critical extension of the Chippewa plane in these lower basins is toward the northeast from Lake Huron and Georgian Bay. In that direction it passes high over two divides, making straits to the Ottawa valley, with probably another beyond to the basin of Hudson Bay.

From 1014 feet at Sault Ste. Marie the beach rises to about 1200 feet at Cartier (130 miles east) and 1140 feet at Nelson's, five miles northeast of North Bay. From 1000 feet at Huntsville the beach rises to 1220 feet at South River (35 miles north), and probably a little higher at Trout Creek, 11 miles farther north and about 28 miles south of North Bay. This shows a descent of something over 80 feet from Trout Creek to the Chippewa beach at Nelson's—a rate of over two and a half feet per mile. This might suggest that the plane passes downward toward the north indefinitely so as to pass below the Abitibbi pass (957 feet). But at Cartier, which is about 25 miles farther north than North Bay and about 100 miles to the west, the height of the beach is about 1200 feet. Perhaps this leaves some uncertainty as to the existence of the Abitibbi strait to Hudson Bay, but it makes that over Lake Tamagaming to the upper Ottawa valley almost certain. The Nippissing strait was about 25 miles wide and nearly 500 feet deep, while the Tamagaming strait was probably between 300 and 400 feet deep and about 50 miles wide. The continuity and oneness of the whole Chippewa beach, stretching as the highest shore line from Duluth to North Bay and on all the shores north of the Petoskey node line, seems to be a certainty. It is believed that this great expanse of water was an arm of the ocean, and following previous usage as closely as possible, I call it Warren Gulf.*

From the Petoskey node line the Chippewa beach undoubtedly extends southward, but in all three basins it passes below the Algonquin plane, and unless it bends upward must strike far below the level of both the St. Clair and Chicago outlets. The Chippewa plane produced south from Burnt Bluff at its descent of two and one-third feet per mile from Cook's Mill passes under the lake on the Michigan shore close to Cave Point, about ten miles north of Sturgeon Bay and about at Peshtigo Point on the west side of Green Bay. The great littoral accumulations at a low level near the former place, and the great Menominee-Peshtigo delta at the latter, seem to give some support to this supposition. Continued to Chicago at the same rate the plane would strike over 350 feet below lake level.

The Chippewa beach marks the highest stage and greatest extent of Warren Gulf. For it is the highest post-glacial beach in the north. In one of his recent papers † Prof. Spencer describes several beaches at much higher levels. He supposes the extension of the deserted beaches of the Erie basin to the Adirondacks, and to other distant northern regions. It evidently seemed necessary to him to postulate these extensions because he takes all the beaches to be of marine origin.

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* Spencer at first called the expanded lakes "Lake Warren," although he recognized that it might be an arm of the sea. Later he adopted the less specific term "Warren Water." But he does not recognize its limits exactly as they are here defined.

† "High Level Shores in the Region of the Great Lakes, and their Deformation," this Journal, vol. xli, March 1891.

On that hypothesis such extensions seem inevitable. But this assumption is not borne out by observation. There are no beaches in the north corresponding to those of the Erie basin.* In exploring those regions I endeavored always to locate the *highest* beach. But I found no evidence of submergence above the Chippewa beach anywhere in the north. I did not find a single feature that could be attributed with certainty to wave action, and that is the crucial test for widespread submergence.

Prof. Spencer gives some prominence also to other supposed beaches at much higher levels.† The facts upon which their identity rests, however, are very scant and scattered. The basis for the broad conclusions which Prof. Spencer draws from them, following Dawson nearly to the utmost in his idea of widespread submergence at very high levels, seems to me to be altogether inadequate. For it is merely a promiscuous collection of random observations in which occasional features more or less resembling beaches, terraces or other littoral forms were observed by different persons at widely separated places. The characters which these observations record are not sufficiently clear to identify the shore line of a great expanse of water. Forms which show only general resemblance to beaches, terraces, etc., are not enough. Glacial and glacio-fluvial action make all these in abundance. The Erie and Michigan beaches and others above the Iroquois plane will probably all be finally correlated with moraines.

Warren Gulf, therefore, did not extend to the Erie basin, although it filled all the others above. Prof. Spencer has defined "Lake Warren," or "Warren Water," as the predecessor of "Lake Algonquin." On this account it has seemed best to apply the name to the water which made the Chippewa beach rather than to the glacial waters which made the Maumee beach of the Erie basin.

The Gulf of Winnipeg.

If there was a Warren Gulf there is the strongest reason to believe there was, contemporaneously with it, a Gulf of Winnipeg, covering the area commonly spoken of as the basin of

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* Mr. Upham, in the papers cited above, correlates the Nelson beach near North Bay with the Belmore beach of the Erie series in Ohio. Between Nelson's and South River there are probably recent faults, so that from Nelson's the Chippewa beach rises to South River and from there it descends and is almost certainly continuous to Huntsville where it intersects the Algonquin beach. The latter is better known and is continuous to Grand Bend 40 miles northeast of Sarnia, where it is 18 feet above the lake and descending westward about one foot per mile. Spencer's data for calculating its place at 20 feet below lake level off Sarnia are good. It seems to me therefore that Mr. Upham's correlation is impossible.

† Op. cit., pp. 209–211.

the glacial Lake Agassiz. The subject is a little apart from the present paper and I can discuss it no farther than to point out the probable continuity of the Chippewa beach and that known as the Herman beach of glacial Lake Agassiz. From Duluth to L'Anse the Chippewa beach rises about 56 feet in 172 miles, or about four inches per mile.* Mr. Upham shows the highest beach of "Glacial Lake Agassiz" reaching up to Lake Naquauquon at the west end of Hunter's Island on the international boundary.† This lake is 1186 feet above sea level and is about 140 miles west and 25 miles north from Mt. Josephine and 120 miles straight north of Duluth. On the best present data the Chippewa plane produced from these places strikes about 20 feet below its level. This lake is about 75 miles from the nearest point on the Superior shore.

From Mt. Josephine to the east side of Beltrami Island is about 250 miles a little north of west. The highest beach at Mt. Josephine is 1207 feet above sea level and that on Beltrami Island 1215 feet, and Lake Naquauquon lies almost directly between. The Chippewa plane carried westward strikes 50 to 100 feet below the Herman beach in the valley of the Red River of the North.

The Herman beach rises from 1045 feet at Lake Traverse to nearly 1170 feet at Maple Lake and 1215 feet on Beltrami Island, and to something more than 1186 feet at the west end of Hunter's Island; on the west side to 1226 feet at the international boundary in Dakota and to 1460 feet near the northwest corner of Manitoba. The altitude of Rainy Lake above sea level is 1117 feet and of the Lake of the Woods 1060 feet. About 200 miles northeast of the latter is the Height of Land and the divide between Lac Seul and Lake St. Joseph. The altitude of the former is 1232 feet and of the latter 1172 feet. Lake Nipigon is 915 feet above the sea. From this last lake it is only about 50 miles east to Kenogami Lake and the pass at 1102 feet. The Herman beach in Minnesota, Dakota and Manitoba rises steadily northward. The divide between Lac Seul and Lake St. Joseph is about 150 miles north and the same distance east from Beltrami Island where the beach is

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* Its plane produced passes about 60 feet over the pass at Upper St. Croix Lake, which is 468 feet above Lake Superior. This suggests that the waters that made the Chippewa beach were those of a lake with its outlet at this pass. No doubt there was an ice-dammed lake in the western part of the Superior basin during the glacial recession. But it does not follow that the highest beach found there to-day was made by that lake. It seems more probable that it was made by the waters of the later Warren Gulf. The apparent continuity of this beach with the rest of the highest beach eastward to North Bay makes marine origin more plausible. The marine invasion probably obliterated the remains of the glacial lake. The same thing probably occurred in the Ontario and Champlain basins and possibly also in the Winnipeg basin. In the last, however, there may have been only a great glacial river without any lake.

† Map with Mr. Upham's third paper referred to above.

1215 feet. Every probability suggested by a study of the abandoned shore lines of this region points to the inference that the beaches which pass north from Lake Superior and from Rainy Lake rise more or less toward the north. From Beltrami Island the beach need rise only 30 or 40 feet to clear the Seul-St. Joseph pass, and only 40 to 50 feet from Mt. Josephine.

It seems to me that the two planes in the Superior and Winnipeg basins come as near continuity and unity as could be expected where considerable unequal deformation is known to exist. Whatever the character of these waters they appear to be related to each other like different parts of the shore of one water body—as though their levels were both conditioned by the same cause, whether an outlet river or the plane of the sea.

The Hudson-Champlain Strait.

A glance eastward from Nipissing pass is still more suggestive of marine submergence at the time of the building of the Chippewa beach. Down the widening Ottawa valley to the St. Lawrence and thence to the sea and across by way of Lake Champlain and the Hudson valley the water must have stretched in one simple unbroken sheet unless there was not only an ice dam at the north, but a contemporaneous land elevation at the south.

For the maintenance of his glacial lake hypothesis Mr. Upham has found a pressing need to include the Hudson valley in his scheme. For if it were proved that the high post-glacial submergence in that valley was marine then the whole system of basins with which the Hudson valley connects toward the north, so far as relates to high post-glacial submergence, would have to be stricken from the category of ice-dammed lakes. Hence Mr. Upham had to suppose, besides an ice dam at the north, an extensive elevation of the submerged coastal plain 50 to 100 miles southeast of New York and also off the east end of Long Island. Merrill has found the marks of post-glacial submergence rising northward from 75 to 80 feet above sea level at New York to 210 feet at Fishkill and 340 feet at Schenectady.* Davis's Catskill deltas lie in the same plane and Mather's sand plains extend up to the Champlain basin, where Hitchcock, Baldwin and the writer have traced high-level submergence up to the Canada line. This plane produced southward strikes sea level 40 to 50 miles south of New York, where the old submerged Hudson river channel is now over 200 feet under water. The passage southeast-

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* "Post-glacial History of the Hudson River Valley," by F. J. H. Merrill, this Journal, III, vol. xli, June, 1891.

ward from Long Island Sound is about 100 feet deep, and the continental shelf all along slopes seaward. In order to make a land barrier for the water in the Hudson valley it is necessary to suppose a southward differential elevation of more than 200 feet 50 miles south of New York and of 100 feet off Montauk Point. But there is no evidence of such an amount of elevation, still less is there any evidence of differential rise to the south. The supposed post-Champlain elevation 100 feet higher than at present at New York and later re-submergence to the same amount, for which Merrill offers some evidence, can not serve Mr. Upham's purpose. For the glacial lake, if it ever existed, was long before the time of the Champlain submergence.*

The hypothesis of a southward land barrier of this ice-dammed lake seems to me to be in the face of the plain reading of the facts. The simplest interpretation is most likely to be true and in this case it is that the Hudson-Champlain trough was occupied at the highest stage of submergence by marine waters which connected with the Laurentian Gulf of that time. And this did not follow closely upon the retreat of the ice, but came at a time long after.

But if the sea filled the Hudson-Champlain trough, attaining a height of 700 feet† or more at the north end of Lake Champlain it is impossible to avoid the inference that this was the time of the formation of the Iroquois, Chippewa and Herman beaches. Considering the very recent occurrence of the Champlain uplift the absence of fossils in the much older, higher deposits can hardly be regarded as an important consideration in determining the character of those deposits.

The First Lake Algonquin.

The first Lake Algonquin was a post-glacial lake occupying the basins of the three upper lakes and having its outlet eastward over the Nipissing pass. Its area was a little larger than that of the second Lake Algonquin, for its shores are higher at all places save one at the head of the St. Clair river, where both planes come to one level.

The history of the second Lake Algonquin and the deformation of the Nipissing plane are fully discussed in the paper of that title referred to above. The facts at present in hand relating to that lake are much more numerous than those

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* The very recent date of the uplift that brought this submergence to a close is shown in the paper on the second Lake Algonquin; and the lateness of the submergence itself is readily inferred from the sequence of lake stages set forth below.

† I found well formed beach ridges at 660 feet near West Chazy, N. Y., with less certain marks of submergence up to about 800 feet.

which relate to the first Lake Algonquin. So far as they go, however, the latter are almost as good. Only the southern parts of the Algonquin beach are now left, those at the north having been washed over and obliterated by the later Warren Gulf. All the facts now known relating to the first Lake Algonquin are found south of the Petoskey node line.

In the Michigan Basin.—The history of Lake Algonquin in this basin was very simple in both epochs. More than half of the deformation which is found in the Algonquin beach was produced by the great Champlain uplift which so recently deformed the much younger Nipissing beach.

As nearly as I have been able to determine, the node line of the Chippewa and Algonquin planes passes east and west through Petoskey, as shown on the map by the line AA. North of this line the highest beach throughout is the marine beach of Warren Gulf and rises rapidly northward. South of the line is the true Algonquin beach. In the field the two so far as yet observed appear to be physically continuous as one beach. But taking the plane as a whole there is a decided break near the line AA, and this I take to be the node. This break in the plane is clear on both shores of Lake Michigan, but is less noticeable in the highlands east of Georgian Bay. Northward from Petoskey the Chippewa beach rises to Mackinac about three feet per mile, while southward from the same place the Algonquin beach declines about seven or eight inches per mile. The altitude of the Algonquin beach at Traverse City was not determined accurately. But terraces have been reported at Frankfort on the Michigan shore farther south, corresponding very closely to the extended Algonquin plane.

On the west side of the lake the Chippewa beach rises northward from Burnt Bluff to Cook's Mill at the rate of about two and one-third feet per mile. The Algonquin beach was found to pass under present lake level at Two Rivers, Wisconsin. Southward from that place it appears as submerged terraces off shore at Manitowoc and Sheboygan. Northward from Two Rivers it was found at Kewaunee, Green Bay, Sturgeon Bay, and Birch Creek north of Menominee. Its heights at all these places fall into an even plane which rises northward eight inches per mile. If this plane be produced northward to Cedar river on the west shore of Green Bay about 25 miles north of Menominee its altitude at that place would be about 60 feet above the lake. The Nipissing beach is calculated to pass under the lake at about the same place. Hence the Algonquin beach is there about 60 feet above the Nipissing. Cedar river is also near the node line AA, and is 120 miles straight west from Petoskey. At Petoskey the Nipissing beach is 25 feet above the lake, and the Algonquin 100 feet. From these data it appears that in 120 miles from west to east the Nipissing beach rises 25 feet and the Algonquin beach 40 feet, or at rates of two inches and three and one-half inches per mile respectively. On the east side the Algonquin plane projected southward, passes under the lake in the vicinity of Ludington or Pentwater. On the west side the plane carried from Two Rivers to Chicago 150 miles south strikes more than 100 feet below the lake.

Mr. Upham supposes his glacial Lake Warren to have had its outlet at Chicago, and he refers to my third paper to show that the highest beach of the Green Bay region continues southward about at present lake level. He may have been misled by a misprint in the table of altitudes in that paper.* But I state distinctly in the concluding paragraph of the article that the beach passes under the lake southward from Two Rivers. If he accepts the present facts without offering others to controvert the conclusions which they plainly indicate, Mr. Upham will have to grant that neither the waters which made the Algonquin beach nor those which made the Chippewa beach had an outlet at Chicago. There are beaches converging to the Chicago outlet, as is well proved by the observations of Andrews, Bannister and Leverett. But they do not extend far north, and all are in planes which lie above the Algonquin, Chippewa and Nipissing planes. These latter planes all pass down under the lake long before they reach Chicago. The Algonquin reaches farthest south above lake level, and its plane produced strikes higher at the south end of the lake than either of the others.

It is interesting to note the relation of this part of the Algonquin plane to the two outlets which served the second lake Algonquin. From Petoskey to Port Huron is about 175 miles south and 125 miles east, and the plane projected from Lake Michigan passes 40 feet above the calculated place of Algonquin beach off Sarnia. From Petoskey, North Bay is about 260 miles east and 60 miles north, and the plane produced passes 210 feet above Georgian Bay, or about 50 feet above the Nipissing beach at the old outlet at North Bay. Subtracting 40 feet for post-Nipissing local elevation from the altitude of the pass at North Bay, the Algonquin plane produced strikes 90 feet above the outlet. Considering the fact that the Algonquin beach is the oldest of the three it is not surprising that its plane produced from so great a distance comes no nearer to these outlets.

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* Third paper, second line in table on page 325, the altitude of the "Beach southward from Two Rivers, Wis.," was intended to read "—582" feet, not "582" feet.

The altitudes of the Algonquin beach at the different points of observation are given in the following table in feet above Lake Huron, which is 582 feet above sea level:

MICHIGAN BASIN.

Birch Creek	50
Sturgeon Bay	35
Green Bay	25
Kewaunee	15
Two Rivers	0
Manitowoc and Sheboygan	—0
Traverse City	70 or 80
Petoskey	100

HURON-GEORGIAN BAY BASIN.

Off Sarnia (Spencer) calculated	—20
Grand Bend “	18
Wilson's “	36
Eighteen Mile Creek (Spencer)	65
Southampton (Spencer)	132
Owen Sound “	167
Clarksburg “	191
Collingwood “	185
Colwell “	170
Elmsvale “	220
Wyebridge “	260
Midland (Taylor)	240
Orillia “	250
Barrie “	200
Lorneville “	235
Kirkfield (Spencer)	293
Gravenhurst (Taylor) approx.,	350
Bracebridge “	390
Huntsville “	418
Water level over the Nipissing pass	160

Prof. Spencer's heights were nearly all measured by leveling, those of the writer by aneroid barometer.

In the Huron-Georgian Bay Basin.—The eastern part of the Algonquin beach has been greatly deformed. But its relation to the St. Clair river points strongly to its origin as a lake beach. It has an eastward rise of about one foot per mile throughout. The northward rise is less at the south. At Grand Bend, which is about 40 miles northeast of Sarnia, the beach is 18 feet above the lake. The place of the beach (submerged 20 feet) off Sarnia was calculated on these data. It probably passes under the lake near Cape Ipperwash, which is about 25 miles northeast of Sarnia. On the opposite sides of Saginaw Bay there are two points, Sand point on the east side and Gravelly point on the west, which may also be, as Spencer makes them conjecturally, nodal points. But this has not yet been established as a fact by observation.

From 20 feet below lake level at Sarnia to the Nipissing pass is a rise of 140 feet (40 feet, as before, deducted from altitude of Nipissing pass for recent local uplift). The northward distance being about 235 miles, the rate of rise is about seven inches per mile. Southampton is 125 miles north of Sarnia and 50 miles east. Kirkfield is 140 miles east and six miles north of Southampton. The Algonquin beach rises northward from Lorneville to Kirkfield 60 feet in 15 miles, and it descends from Kirkfield to Southampton 161 feet. Taking off 24 feet for the greater distance of Kirkfield north makes 137 feet descent westward in 140 miles to Southampton. This descent continued 50 miles farther west to the meridian of Sarnia passes 82 feet above the lake, whereas the Sarnia-Nipissing plane is 19 feet lower—63 feet above the lake at the same point. As compared with this plane the Algonquin beach is 69 feet too high at Southampton, 130 feet at Lorneville, 190 feet at Kirkfield, and 334 feet at Huntsville. The same comparison shows that the beach at Petoskey is only five or six feet higher, and that at Cedar river on the west shore of Green Bay is about 34 feet lower. The Algonquin plane produced from Cedar river and Petoskey to Huntsville, 275 miles east, would be 90 feet above the Sarnia-Nipissing plane. It seems certain that the Algonquin beach was originally formed very nearly in the latter plane, and the present departure from it is the measure of the amount of subsequent unequal deformation.

These facts show how great is the eastward element of deformation east of Lake Huron and Georgian Bay. The northward uplift appears also to be irregular, especially farther north, as shown by the Chippewa beach. All this deformation, less that due to the later Champlain uplift, appears to have occurred after the Chippewa beach and before the Nipissing.

This is the present sum of the facts which bear directly upon the first Lake Algonquin, so far as relates to the evidence in the upper lake basins, and if this were all the existence of the lake as one with a two-outlet stage like the second Lake Algonquin would remain in some doubt. But there are facts connected with the Niagara gorge and Warren Gulf which define the conditions which existed just before and just after the supposed first Lake Algonquin so clearly that theoretical considerations show that this lake must have existed in the interval. These will be presented briefly later.

The Niagara Gorge.

In his admirable paper on the "Duration of Niagara Falls," Prof. Spencer presents five cross sections of the Niagara gorge. A close comparison of them is so instructive that I have reproduced them in a single cut. Some of the details of his drawings are omitted. The significance of the difference between C and D and E was sufficiently explained in the paper on the second Lake Algonquin. The conclusion then reached was, that considering the uniformity of the geological structure it must be admitted that if D and E were made by the great cataract, C could not have been, but must have been made by a stream of much less volume. That stream was the Erigan river, draining only Lake Erie, which did not then receive the discharge of the upper lakes. Prof. Spencer's explanation, that C was made while the great cataract had a sheer fall of 420 feet was shown to be inconsistent with the obvious fact that the Erigan section of the gorge is much shallower than the wider section above.

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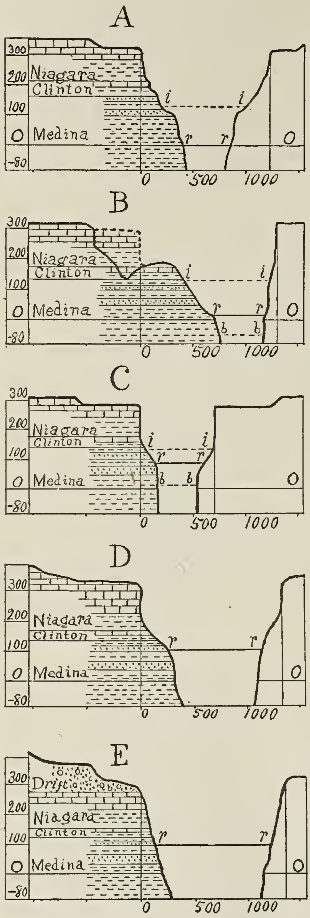

If this explanation of the origin of the Erigan gorge, which is represented by C, is valid, then the same argument applies to the lower section of the gorge which is represented by B and A. These sections must have been made by the great cataract and not by the Erigan Fall. For A and B are almost exactly the

Note to Fig. 2.—These cross-sections are situated as follows beginning at the north or lower end of the gorge. A, half a mile above lower end; B, at Foster's Flat; C, at Whirlpool rapids just below the railroad bridges; D, at Johnson's Ridge about one mile above the bridges; E, at the Horseshoe Fall. The top of the sections is hard Niagara limestone. Then comes softer, shaley layers with the harder Medina below. OO, level of Lake Ontario; *rr*, river level; *ii*, level of Iroquois marine water during middle of Erigan epoch; *bb*, probable bottom of gorge (about 75 feet below *rr*). Both scales in feet. The strata are substantially the same on both sides of the gorge. These sections are copied from Prof. J. W. Spencer's cuts in his paper in this Journal for December 1894, with some omissions and also with some additions. Note the shallowness of C (bottom about at *bb*) and narrowness at top as compared with A, B, D or E.

same as D and E, the differences being no greater than those which may arise from the action of a river of constant volume. The argument for difference of volume is as strong by the comparison of A and B with C as in the other two sections. It seems certain that the upper lakes did not drain through the St. Clair river during the making of the Erigan section. The great cataract has therefore had two independent periods of activity separated by the Erigan period. This much seems clear from an examination of the gorge alone.

The level of the water in the Ontario basin has undergone several changes during the making of the gorge. At the beginning of the first Niagara period the water probably stood higher than now at Lewiston, but not long above the Iroquois level. Then it gradually fell away to a level 80 to 100 feet lower than to-day. All this was during the first Niagara period. The great cataract stopped either at Foster's Flat or at the upper side of the Whirlpool. There is still some doubt on this point, with probability, it now seems to me, in favor of the latter place.

From the Whirlpool up to a point a few rods above the cantilever bridge the gorge is narrow and shallow, and the latter character continues also below the Whirlpool to the lower end of Foster's Flat. It was presumably about at the middle of the Erigan period that the Iroquois beach was made at Lewiston, 135 feet above present lake level. The water at that time stood in the gorge at a level slightly higher than the water level at the foot of the present falls. This, with the smallness of the Erigan Fall, explains why this part of the gorge is shallow. After that the water fell away again to 80 or 100 feet below its present level during the early part of the present period of the cataract and then more recently was raised again to its present level by the Champlain uplift which elevated the outlet of Lake Ontario. These changes, with the harder quality and higher level of the Medina rocks in the bottom of the gorge, explain its salient peculiarities below the Whirlpool, and the changes in the volume of the river find their correlatives in the history of the upper lakes.

The Succession of the Lake Stages.

In the paper on the second Lake Algonquin it was shown that the whole interval from the present day back to the time of Warren Gulf is completely filled by the series of events there described. The gorge of Niagara from the falls to the cantilever bridge suggests no change or variation in the volume of the river. But at and below the bridge th gorge grows narrow and shallow. Considering the uniformity of the geological structure, this feature is explicable only on the supposition that the great cataract was not then active, but was replaced by a much smaller one. That was the Erigan cataract.

In the lakes, the Nipissing beach, which is the latest abandoned shore line marking a critical stage, connects the St. Clair and Nipissing outlets, and was evidently made when both were flowing. But the Nipissing outlet is now 160 feet above Lake Huron, so that ever since that outlet was abandoned Niagara has had all the discharge of the upper lakes. The position of the Nipissing beach is such that the Chicago and Trent valley outlets are absolutely excluded. The Nipissing beach marks the activity of the St. Clair outlet and also that of the Nipissing outlet, but not of any other. In tracing back the order of changes we are therefore compelled to pass from the St. Clair to the Nipissing outlet, and so from the present lakes to the second Lake Algonquin. There is no escape from this step. This brings us to a time when Niagara did not receive the waters of the upper lakes,—the perfect correlative of the Erigan section of the Niagara gorge. But before the second Lake Algonquin there was Warren Gulf with its marine straits. The Erigan Fall replaced Niagara during that time also. The simplest possible supposition as to the cause of these changes, and it is the only cause which is indicated by the facts, is, that there has been going on throughout the whole period a very gradual differential elevation, greater always at the north than at the south. This elevation covers all the changes which have taken place since the Chippewa beach was at sea level, and tallies, we may say, with half the work done in the post-glacial Niagara gorge. That part of the gorge below the Whirlpool is similar to the part above the bridge, and suggests the existence of a pre-Erigan great cataract, substantially like the present one, which again suggests a pre-Warren lake stage, substantially like the present.

And for this we have only to suppose an immediately post-glacial condition of elevation at the north similar in a general way to the present land attitude and a progressive pre-Warren depression, to introduce in reverse order all the post-Warren changes. While that elevation existed the gorge was cut out from Lewiston to the whirlpool. The first marked change produced by the depression was the opening of the Nipissing outlet, at which the Niagara cataract began to weaken. Further progress of the depression closed the St. Clair outlet, and the erosion of the Erigan gorge began. The continuing depression next transformed the Nipissing outlet into a strait, and Warren Gulf was established. At the maximum of the depression the Chippewa marine beach was formed. The erosion of the Erigan gorge thus covers the duration of the first Lake Algonquin, Warren Gulf, and the second Lake Algonquin.*

If this is a true statement of the order and character of the changes, we should expect to find the strongest confirmation of it in the most recent beaches with confirmations less and less distinctly marked as we go backward in time. And so it is. In the article on the second Lake Algonquin are detailed the facts which seem to show the existence and boundaries of that lake, and that it filled the epoch of lake history immediately preceding the present. In the present paper have been stated facts in support of the view that the Chippewa beach marks the climax of a great marine invasion which formed Warren Gulf, and facts which show with less distinctness, but with some degree of force, the existence of the first Lake Algonquin. To this it may be added that if we accept the enlarged gorge below the Whirlpool as evidence of a pre-Erigan discharge of the whole lake system by the Niagara river, it will necessarily follow that between that stage and the Warren Gulf epoch there must have existed a first Lake Algonquin marking the transition from the first Niagara lakes to the Warren Gulf epoch, just as the second Lake Algonquin marked the transition from the Warren Gulf epoch back to the second Niagara system.

Chronological Conspectus.

At its maximum the great Laurentide glacier covered the whole area of the Great Lakes. By a correlation of the abandoned shore lines, moraines and outlets, and the gorges, recently submerged shores and rivers of this region the following order of events is made out for the post-glacial history of the Great

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* An idea of the probable slowness of the recession of the Erigan Fall and the time required to make its gorge may be gathered from the following words of Mr. G. K. Gilbert (Letter in Nature for May 17, 1894). After mentioning the several accurate surveys that have been made of the Falls, he says: "It has thus become known, first, that in the middle of the Horseshoe Fall, where the principal body of water descends, the brink retrogrades at the rate of four or five feet per annum; second, that the American Fall, carrying a much thinner sheet of water, retrogrades so slowly that its rate is concealed by errors of survey." Speaking of the post-glacial period when the upper lakes had their outlet in some other direction and Niagara was fed only by Lake Erie, he says: "During that epoch the volume of the river was so small that cañon-cutting was affected only by the feeble process now illustrated by the American Fall." This was the Erigan epoch. (See also Mr Gilbert's "History of Niagara River," Smithsonian Report, 1890) The brink of the American Fall is to-day almost exactly in line with the brink of the cañon wall above and below. While the Horseshoe Fall has receded from the center of the American Fall (about 3000 feet) the American Fall has receded at most not more than 100 feet and probably less than 50 feet, and it still strikes at its foot upon rock ledges and bowlders which it has not yet been able to remove. From the measured difference between the volume of the St. Clair and Niagara rivers it is found that the contribution of Lake Erie is about three-elevenths of the whole, and this, as Spencer states, is almost the same as the present volume of the American Fall. (See also L. Y. Schermerhorn, this Journal vol. xxxiii, April 1887.) The true Erigan section of the gorge is probably about three-fourths of a mile long.

Lakes. They are set down in seven principal stages with transitions or critical stages between.

I. Glacial, ice-dammed lakes. Outlets at Fort Wayne, Chicago and other places. Beaches correlated with moraines in Ohio. Glacial lakes fall by stages as outlets change on withdrawal of the glacier-dams. Land relatively high in the north but slowly subsiding.

First Transition: By withdrawal of glacier the Niagara river is opened and the upper lakes become united.

II. First Niagara lakes. First epoch of Niagara Falls begins at Lewiston. For a short time glacial Lake Iroquois receives the water from Niagara. Shore lines of lower levels of this glacial lake washed over and obliterated by later marine invasion. Gradual depression of land continues at north, finally opening Nipissing outlet.

Second Transition: First two-outlet climax. Marked by the ALGONQUIN BEACH. (Possible subdivision here for supposed Trent river outlet.) Gradual northward depression continues. First epoch of Niagara Falls closes at the Whirlpool. Epoch of Erigan Fall begins.

III. First Lake Algonquin. Outlet eastward over Nipissing pass.

Third Transition: Gradual northward depression continues. Nipissing outlet brought down to sea level. Lakes become marine.

IV. Warren Gulf (rising stage). Marine waters fill the three upper lakes, the Ontario, St. Lawrence and Winnipeg basins.

Fourth Transition: Marine climax. Marked by the CHIPPEWA BEACH. Northward depression ceases and gradual elevation begins. Iroquois and Herman marine beaches made at the same time as the Chippewa. This was probably the climax of the post-glacial warm epoch.

V. Warren Gulf (falling stage). Gradual northward elevation. Irregular uplifts in the north deforming Chippewa and Algonquin beaches.

Fifth Transition: Nipissing outlet raised to sea level. Upper lakes become fresh.

VI. Second Lake Algonquin. Outlet eastward over Nipissing pass. Probably a small amount of local uplift at outlet in early stage.

Sixth Transition: Second two-outlet climax. Marked by the NIPISSING BEACH. Epoch of Erigan Fall closes at a point between 40 and 80 rods above the cantilever bridge. Second (present) epoch of Niagara Falls begins.

VII. Second Niagara lakes (present stage). Lake Superior becomes independent. Great Champlain uplift at the northeast. Formation of St. Clair delta begins and continues to the present time.

Fort Wayne, Ind., Feb'y 18, 1895.

Art. XXII.—*Disturbances in the direction of the Plumb-line in the Hawaiian Islands*; by E. D. Preston.

Professor Alexander, Surveyor General of Hawaii has made a comparison of the astronomical and geodetic latitudes on the three principal islands of the group. In addition to this, since the observed latitudes at Kawaihae, Hilo, and Waiau (Mauna Kea) are consistent with one another the latter has been adopted as a standard and a comparison has been made between the observed latitudes and the Mauna Kea standard. This brings out some interesting deflections of the plumb-line. See Fig. 1.

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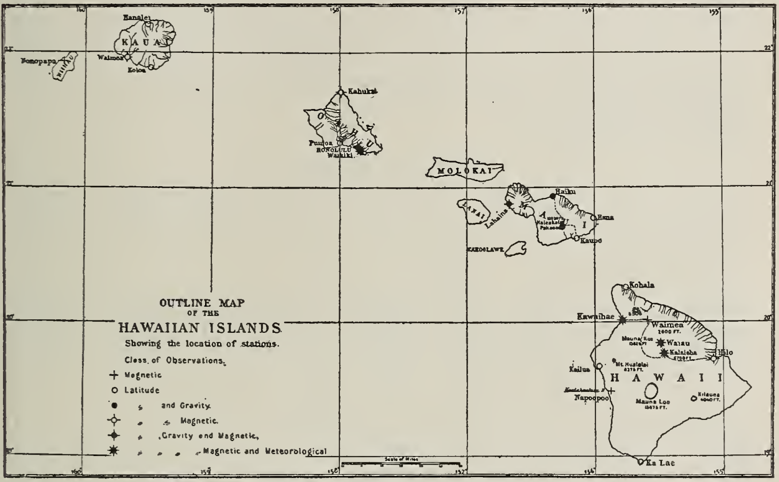

Scale 100 miles to one inch.

There appears to be a disturbance of more than a minute in the direction of gravity at the south point of Hawaii (Ka Lae). At Kohala the plumb-line is deflected half a minute towards the south and at Kalaieha nearly as much towards the north, the disturbance being in both cases towards the mountain. The enormous deflection at Ka Lae (67″) is also to the northward. This is evidently caused by the great mass of Mauna Loa,* which adds its effect to that of Mauna Kea and moreover is comparatively near to the astronomical station.

On Maui the same phenomenon appears. At Haiku there is a deflection towards the south and at Kaupo there is one to the north, and as before the astronomical latitude determined

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* Both Mauna Kea and Mauna Loa are nearly 14,000 feet high.

on the top of Haleakala (10,000 feet elevation) at Pakaoao appears to be a normal one for that island. Judging by analogy there seems to be no reasonable doubt that Oahu would have shown the same thing had a station been made on the summit between Kahuku and Puuloa.

The mean deflection for each of the islands (leaving out Ka Lae on the island of Hawaii) is:—

Hawaii	27″
Maui	29
Oahu	26

When we come to compare the mean latitudes for each island with one another we find that Maui is too small whether judged by the Hawaii or the Oahu standard. The amount is nearly the same in either case so that the most probable assumption is that there is a preponderance of matter deflecting the plumb-line to the northward at all the Maui stations. This supposition has been made by Professor Alexander and seems to be the most rational interpretation of the results. The following table has been furnished by him and is inserted here with his permission.

Hawaiian Latitudes.

STATIONS.	ASTRONOMICAL.	GEODETIC.	DIFF.	MAUNA KEA STANDARD.	DIFF.
Oahu					
Kahuku	21° 43′ 06″·1	21° 42′ 16″·1	+50″·0	21° 42′ 43″·2	+22″·9
Puuloa	21 19 15 ·6	21 19 11 ·8	+ 3 ·8	21 19 38 ·9	−23 ·3
Honolulu	21 18 02 ·5	21 18 02 ·3	+ 0 ·2	21 18 29 ·6	−27 ·1
Waikiki	21 16 24 ·5	21 16 26 ·8	− 2 ·3	21 16 53 ·9	−29 ·4
Maui					
Lahaina	20 52 22 ·8	20 52 53 ·2	−30 ·4	20 52 34 ·5	−11 ·7
Haiku	20 56 02 ·6	20 56 04 ·0	− 1 ·4	20 55 45 ·3	+17 ·3
Pakaoao	20 42 51 ·0	20 43 21 ·6	−30 ·6	20 43 02 ·9	−11 ·9
Kaupo	20 36 40 ·8	20 37 41 ·0	−60 ·2	20 37 22 ·3	−41 ·5
Hana	20 45 38 ·9	20 45 47 ·5	− 8 ·6	20 45 28 ·8	+10 ·1
Hawaii					
Kohala	20 15 29 ·3	20 15 17 ·7	+11 ·6	20 14 59 ·0	+30· 3
Kawaihae	20 02 05 ·9	20 02 25 ·1	−19 ·2	20 02 06 ·4	−00· 5
Mauna Kea	19 48 52 ·0	19 49 10 ·7	−18 ·7	19 48 52 ·0	±00· 0
Kalaieha	19 42 02 ·6	19 42 33 ·5	−30 ·9	19 42 14 ·8	−12· 2
Hilo	19 43 11 ·2	19 43 30 ·4	−19 ·2	19 43 11 7	−00· 5
Kailua	19 38 20 ·9	19 39 03 ·8	−42 ·9	19 38 45 ·1	−24· 2
Ka Lae	18 53 51 ·7	18 55 17 ·7	−86 ·0	18 54 59 ·0	−67· 3

The astronomical latitudes were determined by myself in 1883, 1887 and 1891–'92, using the method of equal zenith distances. The average probable error of a result for each station was ±0″·10. For the details of this work see Appendix, No. 14, U. S. Coast and Geodetic Survey Report for 1888. Determinations of Latitude and Gravity for the Hawaiian Government.

ART. XXIII.—*On the Glacial Lake St. Lawrence of Professor Warren Upham;* by ROBERT CHALMERS, of the Geological Survey of Canada.

IN an article in this Journal for January, 1895, entitled "Late Glacial or Champlain Subsidence and Re-elevation of the St. Lawrence River Basin," Mr. Warren Upham continues his discussions respecting hypothetical glacial lakes and glacial dams, and in endeavoring to account for the raised beaches in the region of the Great Lakes, etc., postulates still another glacial lake in the St. Lawrence valley between Lake Ontario and Quebec, held in by a glacial dam at or near the latter place. To this sheet of water he gives the name of the St. Lawrence Lake. Permit me to offer a few facts and inferences touching the question of this ice-dam and lake.

(1.) There is no evidence of a thick mass of ice having occupied the St. Lawrence valley at Quebec in the Pleistocene period. For the last ten years the writer has, at intervals, been investigating the glacial phenomena and the post-glacial shore lines, etc., of the south side of the St. Lawrence valley, especially between Mètis and the Chaudière river. During the past summer the work was revised and extended to the higher grounds of the Notre Dame Mountains in Quebec, and also to northern New Brunswick and northeastern Maine. The results do not afford any proofs of the movement of a great ice-sheet over this region at any time during the glacial period; on the contrary, the glacial phenomena on the slopes and higher grounds seem to be entirely due to local sheets of land-ice, of greater or less extent, moving in different directions, the course, on the slope facing the St. Lawrence, being mainly northward. In the bottom of the St. Lawrence valley, however, a northeast and southwest set of striæ occurs, which seems referable to the action of floating ice.

The theory that the later ice movements obliterated the earlier striæ does not find any support from the facts obtained on the south side of the St. Lawrence, so far as my examinations have extended. The glaciated surfaces everywhere exhibit criss-cross striæ, in fact these are the rule rather than the exception. The later sets, whether made by separate glaciers, or by succeeding portions of the same sheet conforming more closely to the minor topographical features as it decreased in thickness, show that the earlier striæ have not been effaced by later ice, except, perhaps to a very limited extent on exposed bosses.*

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* In Mr. Upham's review of the third edition of "The Great Ice Age" by Prof. James Geikie (Am. Geologist, Jan., 1895, p. 52), he states that "the northward

The glaciation of the southern flank of the Laurentide Range on the north side of the St. Lawrence river at Quebec seems to be of much the same character as that of the south side of the river. Mr. A. P. Low, of this survey, who has examined this district in some detail, gives a list of striæ in the Annual Report of the Geological Survey of Canada, vol. v, page 48L, from which it appears that the ice movements were quite divergent in that particular locality. The Laurentide ice-sheet does not seem to have descended into the St. Lawrence valley there, unless as broken, detached glaciers. The smaller river valleys and the slopes have also influenced the ice-flow on the north side of the St. Lawrence as well as on the south side. Some of the narrow valleys between the ridges which trend along the foot hills, and are parallel thereto, have caused local glaciers to move northeastwardly in certain places, in others southwestwardly. No single dominant course was observed.

(2.) In Mr. Upham's map (Plate I) he gives the direction of the striæ on the south side of the St. Lawrence below Quebec as northeastward. Has he examined this region himself? If not, on whose authority has he reversed the courses of the striæ there, these being shown on Sir Wm. Dawson's map (The Canadian Ice Age, page 150) as pointing southwestward, and are supposed to have been produced by floating ice moving up the valley? The author's information in regard to these striæ, from whatever source it may have been obtained, is incorrect. No general sheet of land ice flowed to the northeastward in that part of the St. Lawrence valley. All the striæ *in the bottom of the valley* trending northeast and southwest are regarded as due to floating ice, and were produced in the last stage of the glacial period when the land stood at a lower level. In a few instances the southwest sides of the bosses are stossed by this floating ice as it moved down stream but the principal movement was up stream. This system of striation is traceable along the St. Lawrence valley from Metis, or lower down, westward to Montreal.

(3.) No lacustrine deposits have been found anywhere in the St. Lawrence valley beneath the Leda clay, as far as investigations have been made.

glacial flow from northern New England towards the St. Lawrence, as suggested by Chalmers, appears to have belonged only to a very late stage when the melting of the ice in the St. Lawrence valley, proceeding faster than on the mountainous area at the south, left there a large isolated remnant of the departing ice-sheet." I have nowhere stated that I regard the northward ice-flow referred to as belonging to a very late stage of the glacial period; on the contrary, I hold that wherever the northward ice-movements occurred they belong to the maximum stage of the ice age as well as to the melting or later stage; but my own observations have not extended further west than Lake Megantic.

All the facts taken together, therefore, show that the hypothesis of an ice dam at Quebec holding in a lake in the St. Lawrence valley between that point and Lake Ontario, as set forth by Mr. Upham, is untenable.

The glaciation of the St. Lawrence valley is exceedingly complex, and cannot be explained by *à priori* theories. The problems it presents must be solved by actual field investigations. The region is a most interesting one, however, and I invite glacialists to come and see the facts for themselves before propounding any grand generalizations respecting its Pleistocene geology.

Ottawa, Jan. 16, 1895.

ART. XXIV.—*Argon, a New Constituent of the Atmosphere*; by LORD RAYLEIGH and Professor WILLIAM RAMSAY.

[Abstract of a paper read before the Royal Society; from advance sheets sent to this Journal by the authors.]

I. *Density of Nitrogen from Various Sources.*

In a former paper* it has been shown that nitrogen extracted from chemical compounds is about ½ per cent lighter than "atmospheric nitrogen."

The mean numbers for the weights of gas contained in the globe used were as follows:—

From nitric oxide	2·3001
From nitrous oxide	2·2990
From ammonium nitrite	2·2987

while for "atmospheric nitrogen" there was found—

By hot copper, 1892	2·3103
By hot iron, 1893	2·3100
By ferrous hydrate, 1894	2·3102

At the suggestion of Professer Thorpe experiments were subsequently tried with nitrogen liberated from *urea* by the action of sodium hypobromite. The hypobromite was prepared from commercial materials in the proportions recommended for the analysis of urea. The reaction was well under control, and the gas could be liberated as slowly as desired.

In the first experiment the gas was submitted to no other treatment than slow passage through potash and phosphoric anhydride, but it soon became apparent that the nitrogen was

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* Rayleigh, On an Anomaly encountered in Determinations of the Density of Nitrogen Gas, Proc. Roy. Soc., vol. lv, p. 340, 1894.

contaminated. The "inert and inodorous" gas attacked vigorously the mercury of the Töpler pump, and was described as smelling like a dead rat. As to the weight, it proved to be in excess even of the weight of atmospheric nitrogen.

The corrosion of the mercury and the evil smell were in great degree obviated by passing the gas over hot metals. For the fillings of June 6, 9 and 13 the gas passed through a short length of tube containing copper in the form of fine wire heated by a flat Bunsen burner, then through the furnace over red-hot iron, and back over copper oxide. On June 19 the furnace tubes were omitted, the gas being treated with the red-hot copper only. The mean result, reduced so as to correspond with those above quoted, is 2·2985.

Without using heat, it has not been found possible to prevent the corrosion of the mercury. Even when no urea is employed, and air simply bubbled through, the hypobromite solution is allowed to pass with constant shaking over mercury contained in a U-tube, the surface of the metal was soon fouled.

Although the results relating to urea nitrogen are interesting for comparison with that obtained from other nitrogen compounds, the original object was not attained on account of the necessity of retaining the treatment with hot metals. We have found, however, that nitrogen from ammonium nitrite may be prepared, without the employment of hot tubes, whose weight agrees with that above quoted. It is true that the gas smells slightly of ammonia, easily removable by sulphuric acid, and apparently also of oxides of nitrogen. The mean result from three fillings is 2·2987.

It will be seen that, in spite of the slight nitrous smell, there is no appreciable difference in the densities of gas prepared from ammonium nitrite with and without the treatment by hot metals. The result is interesting as showing that the agreement of numbers obtained for chemical nitrogen does not depend upon the use of a red heat in the process of purification.

The five results obtained in more or less distinct ways for chemical nitrogen stand thus:—

From nitric oxide	2·3001
From nitrous oxide	2·2990
From ammonium nitrite purified at a red heat	2·2987
From urea	2·2985
From ammonium nitrite purified in the cold	2·2987
Mean	2·2990

These numbers, as well as those above quoted for "atmospheric nitrogen," are subject to a deduction of 0·0006 for the shrinkage of the globe when exhausted.* If they are then multiplied in the ratio of 2·3108 : 1·2572, they will express the weights of the gas in grams per liter. Thus, as regards the mean numbers, we find as the weight per liter under standard conditions of chemical nitrogen 1·2505, that of atmospheric nitrogen being 1·2572.

It is of interest to compare the density of nitrogen obtained from chemical compounds with that of oxygen. We have $N_2 : O_2 = 2·2984 : 2·6276 = 0·87471$; so that if $O_2 = 16$, $N_2 = 13·9954$. Thus, when the comparison is with chemical nitrogen, the ratio is very nearly that of 16 : 14; but if "atmospheric nitrogen" be substituted, the ratio of small integers is widely departed from.

To the above list may be added nitrogen prepared in yet another manner, whose weight has been determined subsequently to the isolation of the new dense constituent of the atmosphere. In this case nitrogen was actually extracted from air by means of magnesium. The nitrogen thus separated was then converted into ammonia by action of water upon the magnesium nitride and afterwards liberated in the free state by means of calcium hypochlorite. The purification was conducted in the usual way, and included passage over red-hot copper and copper oxide. The following was the result:

Globe empty, Oct. 30, Nov. 5	2·82313
Globe full, Oct. 31	0·52395
Weight of gas	2·29918

It differs inappreciably from the mean of other results, viz: 2·2990, and is of special interest as relating to gas which at one stage of its history formed part of the atmosphere.

Another determination, with a different apparatus, of the density of "chemical" nitrogen from the same source, magnesium nitride, which had been prepared by passing "atmospheric" nitrogen over ignited magnesium, may here be recorded. The sample differed from that previously mentioned, inasmuch as it had not been subjected to treatment with red-hot copper. After treating the nitride with water, the resulting ammonia was distilled off and collected in hydrochloric acid; the solution was evaporated by degrees, the dry ammonium chloride was dissolved in water, and its concentrated solution added to a freshly-prepared solution of sodium hypobromite. The nitrogen was collected in a gas-holder over water which

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* Rayleigh, On the Densities of the Principal Gases, Proc. Roy. Soc., vol. liii, p. 134, 1893.

had previously been boiled, so as, at all events partially to expel air. The nitrogen passed into the vacuous globe through a solution of potassium hydroxide, and through two drying-tubes, one containing soda-lime, and the other phosphoric anhydride.

At 18·38° C. and $754{\cdot}4^{mm}$ pressure, $162{\cdot}843^{cc}$ of this nitrogen weighed 0·18963 gram. Hence,

Weight of 1 liter at 0° C. and 760^{mm} pressure = 1·2521 gram.

The mean result of the weight of 1 liter of "chemical" nitrogen has been found to equal 1·2505. It is therefore seen that "chemical" nitrogen, derived from "atmospheric" nitrogen, without any exposure to red-hot copper, possesses the usual density.

Experiments were also made, which had for their object to prove that the ammonia produced from the magnesium nitride is identical with ordinary ammonia, and contains no other compound of a basic character. For this purpose the ammonia was converted into ammonium chloride, and the percentage of chlorine determined by titration with a solution of silver nitrate which had been standardized by titrating a specimen of pure sublimed ammonium chloride. The silver solution was of such a strength that 1^{cc} precipitated the chlorine from 0·001701 gram of ammonium chloride.

1. Ammonium chloride from orange-colored sample of magnesium nitride contained 66·35 per cent of chlorine.
2. Ammonium chloride from blackish magnesium nitride contained 66·35 per cent of chlorine.
3. Ammonium chloride from nitride containing a large amount of unattacked magnesium contained 66·30 per cent of chlorine.

Taking for the atomic weights of hydrogen H = 1·0032, of nitrogen N = 14·04, and of chlorine Cl = 35·46, the theoretical amount of chlorine in ammonium chloride is 66·27 per cent.

From these results—that nitrogen prepared from magnesium nitride, obtained by passing "atmospheric" nitrogen over red-hot magnesium has the density of "chemical" nitrogen, and that ammonium chloride, prepared from magnesium nitride, contains practically the same percentage of chlorine as pure ammonium chloride—it may be concluded that red-hot magnesium withdraws from "atmospheric nitrogen" no substance other than nitrogen capable of forming a basic compound with hydrogen.

II. *Reasons for suspecting a hitherto Undiscovered Constituent in Air.*

When the discrepancy of weights was first encountered, attempts were naturally made to explain it by contamination with known impurities. Of these the most likely appeared to be hydrogen, present in the lighter gas in spite of the passage over red-hot cupric oxide. But inasmuch as the intentional introduction of hydrogen into the heavier gas, afterwards treated in the same way with cupric oxide, had no effect upon its weight, this explanation had to be abandoned, and finally it became clear that the difference could not be accounted for by the presence of any known impurity. At this stage it seemed not improbable that the lightness of the gas extracted from chemical compounds was to be explained by partial dissociation of nitrogen molecules N_2 into detached atoms. In order to test this suggestion both kinds of gas were submitted to the action of the silent electric discharge, with the result that both retained their weights unaltered. This was discouraging, and a further experiment pointed still more markedly in the negative direction. The chemical behavior of nitrogen is such as to suggest that dissociated atoms would possess a high degree of activity, and that even though they might be formed in the first instance their life would probably be short. On standing they might be expected to disappear, in partial analogy with the known behavior of ozone. With this idea in view, a sample of chemically prepared nitrogen was stored for eight months. But at the end of this time the density showed no sign of increase, remaining exactly as at first.*

Regarding it as established that one or other of the gases must be a mixture, containing, as the case might be, an ingredient much heavier or much lighter than ordinary nitrogen, we had to consider the relative probabilities of the various possible interpretations. Except upon the already discredited hypothesis of dissociation, it was difficult to see how the gas of chemical origin could be a mixture. To suppose this would be to admit two kinds of nitric acid, hardly reconcilable with the work of Stas and others upon the atomic weight of that substance. The simplest explanation in many respects was to admit the existence of a second ingredient in air from which oxygen, moisture, and carbonic anhydride had already been removed. The proportional amount required was not great. If the density of the supposed gas were double that of nitrogen ½ per cent only by volume would be needed; or if the density were but half as much again as that of nitrogen, then 1 per cent would still suffice. But in accepting this explana-

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* Proc. Roy. Soc., vol. lv, p. 344, 1894.

tion, even provisionally, we had to face the improbability that a gas surrounding us on all sides, and present in enormous quantities, could have remained so long unsuspected.

The method of most universal application by which to test whether a gas is pure or a mixture of components of different densities is that of diffusion. By this means Graham succeeded in effecting a partial separation of the nitrogen and oxygen of the air, in spite of the comparatively small difference of densities. If the atmosphere contain an unknown gas of anything like the density supposed, it should be possible to prove the fact by operations conducted upon air which had undergone atmolysis. This experiment, although in view from the first, was not executed until a later stage of the inquiry (§ 6), when results were obtained sufficient of themselves to prove that the atmosphere contains a previously unknown gas.

But although the method of diffusion was capable of deciding the main, or at any rate the first question, it held out no prospect of isolating the new constituent of the atmosphere, and we, therefore, turned our attention in the first instance to the consideration of methods more strictly chemical. And here the question forced itself upon us as to what really was the evidence in favor of the prevalent doctrine that the inert residue from air after withdrawal of oxygen, water, and carbonic anhydride, is all of one kind.

The identification of "phlogisticated air" with the constituent of nitric acid is due to Cavendish, whose method consisted in operating with electric sparks upon a short column of gas confined with potash over mercury at the upper end of an inverted U-tube.*

Attempts to repeat Cavendish's experiment in Cavendish's manner have only increased the admiration with which we regard this wonderful investigation. Working on almost microscopical quantities of material, and by operations extending over days and weeks, he thus established one of the most important facts in chemistry. And what is still more to the purpose, he raises as distinctly as we could do, and to a certain extent resolves, the question above suggested. The passage is so important that it will be desirable to quote it at full length.

"As far as the experiments hitherto published extend, we scarcely know more of the phlogisticated part of our atmosphere, than that it is not diminished by lime-water, caustic alkalies, or nitrous air; that it is unfit to support fire, or maintain life in animals; and that its specific gravity is not much less than that of common air: so that though the nitrous acid,

* Experiments on Air, Phil. Trans., vol. lxxv, p. 372, 1785.

by being united to phlogiston, is converted into air possessed of these properties, and consequently, though it was reasonable to suppose, that part at least of the phlogisticated air of the atmosphere consists of this acid united to phlogiston, yet it was fairly to be doubted whether the whole is of this kind, or whether there are not in reality many different substances compounded together by us under the name of phlogisticated air. I therefore made an experiment to determine whether the whole of a given portion of the phlogisticated air of the atmosphere could be reduced to nitrous acid, or whether there was not a part of a different nature to the rest, which would refuse to undergo that change. The foregoing experiments indeed in some measure decided this point, as much the greatest part of the air let up into the tube lost its elasticity; yet as some remained unabsorbed it did not appear for certain whether that was of the same nature as the rest or not. For this purpose I diminished a similar mixture of dephlogisticated and common air, in the same manner as before, till it was reduced to a small part of its original bulk. I then, in order to decompound as much as I could of the phlogisticated air which remained in the tube, added some dephlogisticated air to it, and continued the spark until no further diminution took place. Having by these means condensed as much as I could of the phlogisticated air, I let up some solution of liver of sulphur to absorb the dephlogisticated air; after which only a small bubble of air remained unabsorbed, which certainly was not more than $\frac{1}{120}$th of the bulk of the phlogisticated air let up into the tube; so that if there is any part of the phlogisticated air of our atmosphere which differs from the rest, and cannot be reduced to nitrous acid, we may safely conclude that it is not more than $\frac{1}{120}$th part of the whole."

Although Cavendish was satisfied with his result, and does not decide whether the small residue was genuine, our experiments about to be related render it not improbable that his residue was really of a different kind from the main bulk of the "phlogisticated air," and contained the gas now called argon.

Cavendish gives data* from which it is possible to determine the rate of absorption of the mixed gases in his experiment. This was about 1^{cc} per hour, of which two-fifths would be nitrogen.

III. *Methods of causing Free Nitrogen to combine.*

To eliminate nitrogen from air, in order to ascertain whether any other gas could be detected, involves the use of some

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* Phil. Trans., vol. lxxviii, p. 271, 1788.

absorbent. The elements which have been found to combine directly with nitrogen are: boron, silicon, titanium, lithium, strontium, barium, magnesium, aluminium, mercury, and, under the influence of an electric discharge, hydrogen in presence of acid, and oxygen in presence of alkali. Besides these, a mixture of barium carbonate and carbon at a high temperature is known to be effective. Of those tried, magnesium in the form of turnings was found to be the best. When nitrogen is passed over magnesium, heated in a tube of hard glass to bright redness, combustion with incandescence begins at the end of the tube through which the gas is introduced, and proceeds regularly until all the metal has been converted into nitride. Between 7 and 8 liters of nitrogen can be absorbed in a single tube; the nitride formed is a porous, dirty, orange-colored substance.

IV. *Early Experiments on sparking Nitrogen with Oxygen in presence of Alkali.*

In our earliest attempts to isolate the suspected gas by the method of Cavendish, we used a Ruhmkorff coil of medium size actuated by a battery of five Grove cells. The gases were contained in a test-tube standing over a large quantity of weak alkali, and the current was conveyed in wires insulated by U-shaped glass tubes passing through the liquid round the mouth of the test-tube. With the given battery and coil a somewhat short spark or arc of about 5^{mm} was found to be more favorable than a longer one. When the mixed gases were in the right proportion the rate of absorption was about 30^{cc} per hour, or thirty times as fast as Cavendish could work with the electrical machine of his day.

To take an example, one experiment of this kind started with 50^{cc} of air. To this oxygen was gradually added until, oxygen being in excess, there was no perceptible contraction during an hour's sparking. The remaining gas was then transferred at the pneumatic trough to a small measuring vessel, sealed by mercury, in which the volume was found to be $1{\cdot}0^{cc}$. On treatment with alkaline pyrogallate, the gas shrank to $0{\cdot}32^{cc}$. That this small residue could not be nitrogen was argued from the fact that it had withstood the prolonged action of the spark, although mixed with oxygen in nearly the most favorable proportion.

The residue was then transferred to the test-tube with an addition of another 50^{cc} of air, and the whole worked up with oxygen as before. The residue was now $2{\cdot}2^{cc}$, and, after removal of oxygen, $0{\cdot}76^{cc}$.

Although it seemed almost impossible that these residues could be either nitrogen or hydrogen, some anxiety was not unnatural, seeing that the final sparking took place under somewhat abnormal conditions. The space was very restricted, and the temperature (and with it the proportion of aqueous vapor) was unduly high. But any doubts that were felt upon this score were removed by comparison experiments in which the whole quantity of air operated on was very small. Thus, when a mixture of 5^{cc} of air with 7^{cc} of oxygen was sparked for 1¼ hours, the residue was 0·47^{cc}, and after removal of oxygen 0·06^{cc}. Several repetitions having given similar results, it became clear that the final residue did not depend upon anything that might happen when sparks passed through a greatly reduced volume, *but was in proportion to the amount of air operated upon.*

No satisfactory examination of the residue which refused to be oxidized could be made without the accumulation of a larger quantity. This, however, was difficult of attainment at the time in question. It was thought that the cause probably lay in the solubility of the gas in water, a suspicion since confirmed. At length, however, a sufficiency was collected to allow of sparking in a specially constructed tube, when a comparison with the air spectrum, taken under similar conditions, proved that, at any rate, the gas was not nitrogen. At first scarcely a trace of the principal nitrogen lines could be seen, but after standing over water for an hour or two these lines became apparent.

V. *Early experiments on withdrawal of Nitrogen from Air by means of red-hot Magnesium.*

A preliminary experiment carried out by Mr. Percy Williams on the absorption of atmospheric nitrogen, freed from oxygen by means of red-hot copper, in which the gas was not passed over, but simply allowed to remain in contact with the metal, gave a residue of density 14·88. This result, although not conclusive, was encouraging; and an attempt was made, on a larger scale, by passing atmospheric nitrogen backwards and forwards over red-hot magnesium from one large gas-holder to another to obtain a considerable quantity of the heavier gas. In the course of ten days, about 1500^{cc} were collected and transferred gradually to a mercury gas-holder, from which the gas was passed over soda-lime, phosphoric anhydride, magnesium at a red heat, copper oxide, soda-lime, and phosphoric anhydride into a second mercury gas-holder. After some days the gas was reduced in volume to about 200^{cc}, and its density was found to be 16·1. After further absorption, in which the volume was still further reduced, the density of the residue was increased to 19·09.

On passing sparks for several hours through a mixture of a small quantity of this gas with oxygen, its volume was still further reduced. Assuming that this reduction was due to the further elimination of nitrogen, the density of the remaining gas was calculated to be 20·0.

The spectrum of the gas of density 19·09, though showing nitrogen bands, showed many other lines which were not recognizable as belonging to any known element.

VI. *Proof of the presence of Argon in Air by means of Atmolysis.*

It has already (§ 2) been suggested that if "atmospheric nitrogen" contains two gases of different densities, it should be possible to obtain direct evidence of the fact by the method of atmolysis. The present section contains an account of carefully conducted experiments directed to this end.

The atmolyser was prepared (after Graham) by combining a number of "churchwarden" tobacco pipes. At first twelve pipes were used in three groups, each group including four pipes connected in series. The three groups were then connected in parallel, and placed in a large glass tube closed in such a way that a partial vacuum could be maintained in the space outside the pipes by a water pump. One end of the combination of pipes was open to the atmosphere; the other end was connected to a bottle aspirator, initially full of water, and so arranged as to draw about 2 per cent of the air which entered the other end of the pipes. The gas collected was thus a very small proportion of that which leaked through the pores of the pipes, and should be relatively rich in the heavier constituents of the atmosphere. The flow of water from the aspirator could not be maintained very constant, but the rate of 2 per cent was never much exceeded.

The air thus obtained was treated exactly as ordinary air had been treated in determinations of the density of atmospheric nitrogen. Oxygen was removed by red-hot copper, followed by cupric oxide, ammonia by sulphuric acid, moisture and carbonic acid by potash and phosphoric anhydride.

In a total weight of approximately 2·3 grams the excess of weight of the diffused nitrogen over ordinary atmospheric nitrogen was in four experiments, 0·0049, 0·0014, 0·0027, 0·0015.

The mean excess of the four determinations is 0·00262 gram, or, if we omit the first, which depended upon a vacuum weighing of two months old, 0·00187 gram.

The gas from prepared air was thus in every case denser than from unprepared air, and to an extent much beyond the possible errors of experiment. The excess was, however, less than had been expected, and it was thought that the arrangement of the pipes could be improved. The final delivery of gas from each of the groups in parallel being so small in comparison with the whole streams concerned, it seemed possible that each group was not contributing its proper share, and even that there might be a flow in the wrong direction at the delivery end of one or two of them. To meet this objection, the arrangement in parallel had to be abandoned, and for the remaining experiments eight pipes were connected in simple series. The porous surface in operation was thus reduced, but this was partly compensated for by an improved vacuum. Two experiments were made under the new conditions, in which the excess was I, 0·0037; II, 0·0033.

The excess being larger than before is doubtless due to the greater efficiency of the atmolysing apparatus. It should be mentioned that the above recorded experiments include all that have been tried, and the conclusion seems inevitable that "atmospheric nitrogen" is a mixture, and not a simple body.

It was hoped that the concentration of the heavier constituent would be sufficient to facilitate its preparation in a pure state by the use of prepared air in substitution for ordinary air in the oxygen apparatus. The advance of 3½ milligrams on the 11 milligrams, by which atmospheric nitrogen is heavier than chemical nitrogen, is indeed not to be despised, and the use of prepared air would be convenient if the diffusion apparatus could be set up on a large scale and be made thoroughly self-acting.

VII. *Negative Experiments to prove that Argon is not derived from Nitrogen from Chemical Sources.*

Although the evidence of the existence of argon in the atmosphere, derived from the comparison of densities of atmospheric and chemical nitrogen and from the diffusion experiments (§ VI), appeared overwhelming, we have thought it undesirable to shrink from any labor that would tend to complete the verification. With this object in view, an experiment was undertaken and carried to a conclusion on November 13, in which 3 liters of chemical nitrogen, prepared from ammonium nitrite, were treated with oxygen in precisely the manner in which atmospheric nitrogen had been found to yield a residue of argon. The gas remaining at the close of the large scale operations was worked up as usual with battery and coil until the spectrum showed only slight traces of the nitrogen lines. When cold, the residue measured 4^{cc}. This was transferred, and after treatment with alkaline pyrogallate to remove oxygen measured 3·3^{cc}. If atmospheric nitrogen had been employed, the final residue should have been about 30^{cc}. Of the 3·3^{cc} actually left, a part is accounted for by an accident, and the result of the experiment is to show that argon is not formed by sparking a mixture of oxygen and chemical nitrogen.

In a second experiment of the same kind 5660^{cc} of nitrogen from ammonium nitrite was treated with oxygen. The final residue was 3·5^{cc}, and was found to consist mainly of argon.

The source of the residual argon is to be sought in the water used for the manipulation of the large quantities of gas (6 liters of nitrogen and 11 liters of oxygen) employed. When carbonic acid was collected in a similar manner and subsequently absorbed by potash, it was found to have acquired a contamination consistent with this explanation.

Negative experiments were also carried out, absorbing nitrogen by means of magnesium. In one instance 3 liters of nitrogen prepared from ammonium chloride and bleaching-powder was reduced in volume to 4·5^{cc}, and on sparking with oxygen its volume was further reduced to about 3^{cc}. The residue appeared to consist of argon. Another experiment, in which 15 liters of nitrogen from ammonium nitrite was absorbed, gave a final residue of 3·5^{cc}. Atmospheric nitrogen, in the latter case, would have yielded 150^{cc}, hence less than $\frac{1}{40}$th of the normal quantity was obtained. It should be mentioned that leakage occurred at one stage, by which perhaps 200^{cc} of air entered the apparatus; and, besides, the nitrogen was collected over water from which it doubtless acquired some argon. Quantitative negative experiments of this nature are exceedingly difficult, and require a long time to carry them to a successful conclusion.

VIII. *Separation of Argon on a Large Scale.*

To prepare argon on a large scale, air is freed from oxygen by means of red-hot copper. The residue is then passed from a gas-holder through a combustion-tube, heated in a furnace, and containing copper, in order to remove all traces of oxygen; the issuing gas is then dried by passage over soda-lime and phosphorus pentoxide, after passage through a small U-tube containing sulphuric acid, to indicate the rate of flow. It then enters a combustion-tube packed tightly with magnesium turnings, and heated to redness in a second furnace. From this tube it passes through a second index-tube, and enters a small gas-holder capable of containing 3 or 4 liters. A single tube of magnesium will absorb from 7 to 8 liters of nitrogen.

The temperature must be nearly that of the fusion of the glass, and the current of gas must be carefully regulated, else the heat developed by the union of the magnesium with nitrogen will fuse the tube.

Having collected the residue from 100 or 150 liters of atmospheric nitrogen, which may amount to 4 or 5 liters, it is transferred to a small gas-holder connected with an apparatus, whereby, by means of a species of a self-acting Sprengel's pump, the gas is caused to circulate through a tube half filled with copper and half with copper oxide; it then traverses a tube half filled with soda-lime and half with phosphorus pentoxide; it then passes a reservoir of about 300^{cc} capacity from which, by raising a mercury reservoir, it can be expelled into a small gas-holder. Next it passes through a tube containing magnesium turnings heated to bright redness. The gas is thus freed from any possible contamination with oxygen, hydrogen, or hydrocarbons, and nitrogen is gradually absorbed. As the amount of gas in the tubes and reservoir diminishes in volume, it draws supplies from the gas-holder, and, finally, the circulating system is full of argon in a pure state. The circulating system of tubes is connected with a mercury pump, so that, in changing the magnesium tube, no gas may be lost. Before ceasing to heat the magnesium tube the system is pumped empty, and the collected gas is restored to the gas-holder; finally, all the argon is transferred from the mercury reservoir to the second small gas-holder, which should preferably be filled with water saturated with argon, so as to prevent contamination from oxygen or nitrogen; or, if preferred, a mercury gas-holder may be employed. The complete removal of nitrogen from argon is very slow towards the end, but circulation for a couple of days usually effects it.

The principal objection to the oxygen method of isolating argon, as hitherto described, is the extreme slowness of the operation. In extending the scale we had the great advantage of the advice of Mr. Crookes, who not long since called attention to the flame rising from platinum terminals, which convey a high tension alternating electric discharge, and pointed out its dependence upon combustion of the nitrogen and oxygen of the air.* The plant consists of a De Meritens alternator, actuated by a gas engine, and the currents are transformed to a high potential by means of a Ruhmkorff or other suitable induction coil. The highest rate of absorption of the mixed gases yet attained is 3 liters per hour, about 3000 times that of Cavendish. It is necessary to keep the apparatus cool, and from this and other causes a good many difficulties have been encountered.

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* Chemical News, vol. lxv, p. 301, 1892.

In one experiment of this kind, the total air led in after seven days' working, amounted to 7925^{cc}, and of oxygen (prepared from chlorate of potash), 9137^{cc}. On the eighth and ninth days oxygen alone was added, of which about 500^{cc} was consumed, while there remained about 700^{cc} in the flask. Hence the proportion in which the air and oxygen combined was as 79 : 96. The progress of the removal of the nitrogen was examined from time to time with the spectroscope, and became ultimately very slow. At last the yellow line disappeared, the contraction having apparently stopped for two hours. It is worthy of notice that with the removal of the nitrogen, the arc discharge changes greatly in appearance, becoming narrower and blue rather than greenish in color.

The final treatment of the residual 700^{cc} of gas was on the model of the small scale operations already described. Oxygen or hydrogen could be supplied at pleasure from an electrolytic apparatus, but in no way could the volume be reduced below 65^{cc}. This residue refused oxidation, and showed no trace of the yellow line of nitrogen, even under favorable conditions.

When the gas stood for some days over water, the nitrogen line reasserted itself in the spectrum, and many hours' sparking with a little oxygen was required again to get rid of it. Intentional additions of air to gas free from nitrogen showed that about 1½ per cent was clearly, and about 3 per cent was conspicuously, visible. About the same numbers apply to the visibility of nitrogen in oxygen when sparked under these conditions, that is, at atmospheric pressure, and with a jar connected to the secondary terminals.

IX. *Density of Argon prepared by means of Oxygen.*

A first estimate of the density of argon prepared by the oxygen method was founded upon the data already recorded respecting the volume present in air, on the assumption that the accurately known densities of atmospheric and of chemical nitrogen differ on account of the presence of argon in the former, and that during the treatment with oxygen nothing is oxidized except nitrogen. Thus if

D = density of chemical nitrogen,
D' = " atmospheric nitrogen,
d = " argon,
α = proportional volume of argon in atmospheric nitrogen,

the law of mixtures give

$$\alpha d + (1-\alpha)D = D',$$

or

$$d = D + (D'-D)/\alpha.$$

In this formula $D'-D$ and α are both small, but they are known with fair accuracy. From the data already given

$$\alpha = \frac{65}{0{\cdot}79 \times 7925},$$

whence if (on an arbitrary scale of reckoning) $D = 2{\cdot}2990$, $D' = 2{\cdot}3102$, we find $d = 3{\cdot}378$. Thus if N_2 be 14, or O_2 be 16, the density of argon is 20·6.

A direct determination by weighing is desirable, but hitherto it has not been feasible to collect by this means sufficient to fill the large globe employed for other gases. A *mixture* of about 400^{cc} of argon with pure oxygen, however, gave the weight 2·7315, 0·1045 in excess of the weight of oxygen, viz: 2·6270. Thus, if α be the ratio of the volume of argon to the whole volume, the number for argon will be

$$2{\cdot}6270 + 0{\cdot}1045 / \alpha$$

The value of α, being involved only in the excess of weight above that of oxygen, does not require to be known very accurately. Sufficiently concordant analyses by two methods gave $\alpha = 0{\cdot}1845$; whence for the weight of the gas we get 3·193, so that, if $O_2 = 16$, the density of the gas would be 19·45. An allowance for residual nitrogen, still visible in the gas before admixture of oxygen, raises this number to 19·7, which may be taken as the density of pure argon resulting from this determination.

X. *Density of Argon prepared by means of Magnesium.*

The density of the original sample of argon prepared has already been mentioned. It was 19·09; and, after sparking with oxygen, it was calculated to be 20·0. The most reliable results of a number of determinations give it as 19·90. The difficulty in accurately determining the density is to make sure that all nitrogen has been removed. The sample of density 19·90 showed no spectrum of nitrogen when examined in a vacuum tube. It is right, however, to remark that the highest density registered was 20·38. But there is some reason here to distrust the weighing of the vacuous globe.

XI. *Spectrum of Argon.*

The spectrum of argon, seen in a vacuum tube of about 3^{mm} pressure, consists of a great number of lines, distributed over almost the whole visible field. Two lines are specially characteristic; they are less refrangible than the red lines of hydrogen or lithium, and serve well to identify the gas, when examined in this way. Mr. Crookes, who will give a full account of the spectrum in a separate communication, has kindly furnished us with the accurate wave-lengths of these lines, as well as of some others next to be described; they are respectively 696·56 and 705·64, 10^{-6} mm.

Besides these red lines, a bright yellow line, more refrangible than the sodium line, occurs at 603·84. A group of five bright green lines occurs next, besides a number of less intensity. Of the group of five, the second, which is perhaps the most brilliant, has the wave-length 561·00. There is next a blue or blue-violet line of wave-length 470·2; and last, in the less easily visible part of the spectrum, there are five strong violet lines, of which the fourth, which is the most brilliant, has the wave-length 420·0.

Unfortunately, the red lines, which are not to be mistaken for those of any other substance, are not easily seen when a jar discharge is passed through argon at atmospheric pressure. The spectrum seen under these conditions has been examined by Professor Schuster. The most characteristic lines are perhaps those in the neighborhood of F, and are very easily seen if there be not too much nitrogen, in spite of the presence of some oxygen and water vapor. The approximate wave-lengths are—

487·91	Strong.
[486·07]	F.
484·71	Not quite so strong.
480·52	Strong.
476·50	Fairly strong characteristic triplet.
473·53	
472·56	

It is necessary to anticipate Mr. Crookes's communication, and to state that when the current is passed from the induction coil in one direction, that end of the capillary tube next the positive pole appears of a redder, and that next the negative pole of a bluer hue. There are, in effect, two spectra, which Mr. Crookes has succeeded in separating to a considerable extent. Mr. E. C. Baly,* who has noticed a similar phenomenon, attributes it to the presence of two gases. He says:—"When an electric current is passed through a mixture of two gases, one is separated from the other and appears in the negative glow." The conclusion would follow that what we have termed "argon" is in reality a mixture of two gases which have as yet not been separated. This conclusion, if true, is of great importance, and experiments are now in progress to test it by the use of other physical methods. The full bearing of this possibility will appear later.

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* Proc. Phys. Soc., 1893, p. 147.

The presence of a small quantity of nitrogen interferes greatly with the argon spectrum. But we have found that in a tube with platinum electrodes, after the discharge has been passed for four hours, the spectrum of nitrogen disappears, and the argon spectrum manifests itself in full purity. A specially constructed tube with magnesium electrodes, which we hoped would yield good results, removed all traces of nitrogen, it is true; but hydrogen was evolved from the magnesium, and showed its characteristic lines very strongly. However, these are easily identified. The gas evolved on heating magnesium *in vacuo*, as proved by a separate experiment, consists entirely of hydrogen.

Mr. Crookes has proved the identity of the chief lines of the spectrum of gas separated from air-nitrogen by aid of magnesium with that remaining after sparking the air-nitrogen with oxygen in presence of caustic soda solution.

Professor Schuster also has found the principal lines identical in the spectra of the two gases, as observed by the jar discharge at atmospheric pressure.

XII. *Solubility of Argon in Water.*

Determinations of the solubility in water of argon, prepared by sparking, gave 3·94 volumes per 100 of water at 12°. The solubility of gas prepared by means of magnesium was found to be 4·05 volumes per 100 at 13·9°. The gas is therefore about 2½ times as soluble as nitrogen, and possesses approximately the same solubility as oxygen.

The fact that argon is more soluble than nitrogen would lead us to expect it in increased proportion in the dissolved gases of rain water. Experiment has confirmed this anticipation. "Nitrogen" prepared from the dissolved gases of water supplied from a rain-water cistern was weighed upon two occasions. The weights, corresponding to those recorded in § I, were 2·3221 and 2·3227, showing an excess of 24 milligrams above the weight of true nitrogen. Since the corresponding excess for "atmospheric nitrogen" is 11 milligrams, we conclude that the water "nitrogen" is relatively more than twice as rich in argon.

On the other hand, gas evolved from the hot spring at Bath, and collected for us by Dr. A. Richardson, gave a residue after removal of oxygen and carbonic acid, whose weight was only about midway between that of true and atmospheric nitrogen.

XIII. *Behavior at Low Temperatures.*[*]

Preliminary experiments, carried out to liquefy argon at a pressure of about 100 atmospheres, and at a temperature of

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[*] The arrangements for the experiments upon this branch of the subject were left entirely in Professor Ramsay's hands.

—90°, failed. No appearance of liquefaction could be observed.

Professor Charles Olszewski, of Cracow, the well-known authority on the constants of liquefied gases at low temperatures, kindly offered to make experiments on the liquefaction of argon. His results are embodied in a separate communication, but it is allowable to state here that the gas has a lower critical temperature (—121°) and a lower boiling point (—187°) than oxygen, and that he has succeeded in solidifying argon to white crystals, melting at —189·6°. The density of the liquid is approximately 1·5, that of oxygen being 1·124, and of nitrogen 0·885. The sample of gas he experimented with was exceptionally pure, and had been prepared by help of magnesium. It showed no trace of nitrogen when examined in a vacuum tube.

XIV. *Ratio of Specific Heats.*

In order to decide regarding the elementary or compound nature of argon, experiments were made on the velocity of sound in it. It will be remembered that, from the velocity of sound in a gas, the ratio of specific heat at constant pressure to that at constant volume can be deduced by means of the equation

$$n\lambda = v = \sqrt{\left\{ \frac{e}{d}(1 + \alpha t)\frac{C_p}{C_v} \right\}},$$

when n is the frequency, λ the wave-length of sound, v its velocity, e the isothermal elasticity, d the density, $(1 + \alpha t)$ the temperature correction, C_p the specific heat at constant pressure, and C_v that at constant volume. In comparing two gases at the same temperature, each of which obeys Boyle's law with sufficient approximation, and in using the same sound, many of these terms disappear, and the ratio of specific heats of one gas may be deduced from that of the other, if known, by means of the proportion

$$\lambda^2 d : \lambda'^2 d' :: 1{\cdot}41 : x$$

where, for example, λ and d refer to air, of which the ratio is 1·41, according to observations by Röntgen, Wüllner, Kayser, and Jamin and Richard.

Two completely different series of observations, one in a tube of about 2mm. diameter, and one in one of 8mm., made with entirely different samples of gas, gave, the first, 1·65 as the ratio, and, the second, 1·61.

Experiments made with the first tube, to test the accuracy of its working, gave for carbon dioxide the ratio 1·276, instead of 1·288, the mean of all previous determinations; and the half wave-length of sound in hydrogen was found to be 73·6, instead of 74·5, the mean of those previously found. The ratio of the specific heats of hydrogen found was 1·39, instead of 1·402.

There can be no doubt, therefore, that argon gives practically the ratio of specific heats, viz: 1·66, proper to a gas in which all the energy is translational. The only other gas which has been found to behave similarly is mercury gas, at a high temperature.*

XV. *Attempts to induce Chemical Combination.*

Many attempts to induce argon to combine will be described in full in the complete paper. Suffice it to say here, that all such attempts have as yet proved abortive. Argon does not combine with oxygen in presence of alkali under the influence of the electric discharge, nor with hydrogen in presence of acid or alkali also when sparked; nor with chlorine, dry or moist, when sparked; nor with phosphorus at a bright-red heat, nor with sulphur at bright redness. Tellurium may be distilled in a current of the gas; so may sodium and potassium, their metallic luster remaining unchanged. It is unabsorbed by passing it over fused red-hot caustic soda, or soda-lime heated to bright redness; it passes unaffected over fused and bright red-hot potassium nitrate; and red-hot sodium peroxide does not combine with it. Persulphides of sodium and calcium are also without action at a red heat. Platinum black does not absorb it, nor does platinum sponge, and wet oxidizing and chlorinating agents, such as nitro-hydrochloric acid, bromine water, bromine and alkali, and hydrochloric acid and potassium permanganate, are entirely without action. Experiments with fluorine are in contemplation, but the difficulty is great; and an attempt will be made to produce a carbon arc in the gas. Mixtures of sodium and silica and of sodium and boracic anhydride are also without action, hence it appears to resist attack by nascent silicon and by nascent boron.

XVI. *General Conclusions.*

It remains, finally, to discuss the probable nature of the gas, or mixture of gases, which we have succeeded in separating from atmospheric air, and which we provisionally name *argon*.

The presence of argon in the atmosphere is proved by many lines of evidence. The high density of "atmospheric nitrogen," the lower density of nitrogen from chemical sources,

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* Kundt and Warburg, Pogg. Ann. vol. cxxxv, pp. 337 and 527.

and the uniformity in the density of samples of chemical nitrogen prepared from different compounds, lead to the conclusion that the cause of the anomaly is the presence of a heavy gas in air. If that gas possess the density 20 compared with hydrogen, "atmospheric" nitrogen should contain of it approximately 1 per cent. This is, in fact, found to be the case. Moreover, as nitrogen is removed from air by means of red-hot magnesium, the density of the remaining gas rises proportionately to the concentration of the heavier constituent.

Second. This gas has been concentrated in the atmosphere by diffusion. It is true that it has not been freed from oxygen and nitrogen by diffusion, but the process of diffusion increases, relatively to nitrogen, the amount of argon in that portion which does not pass through the porous walls. This has been proved by its increase in density.

Third. As the solubility of argon in water is relatively high, it is to be expected that the density of the mixture of argon and nitrogen, pumped out of water along with oxygen, should, after the removal of the oxygen, be higher than that of "atmospheric" nitrogen. Experiment has shown that the density is considerably increased.

Fourth. It is in the highest degree improbable that two processes, so different from each other, should manufacture the same product. The explanation is simple if it be granted that these processes merely eliminate nitrogen from an "atmospheric" mixture. Moreover, as argon is an element, or a mixture of elements, its manufacture would mean its separation from one of the substances employed. The gas which can be removed from red-hot magnesium in a vacuum has been found to be wholly hydrogen. Nitrogen from chemical sources has been practically all absorbed by magnesium, and also when sparked in presence of oxygen; hence argon cannot have resulted from the decomposition of nitrogen. That it is not produced from oxygen is sufficiently borne out by its preparation by means of magnesium.

Other arguments could be adduced, but the above are sufficient to justify the conclusion that argon is present in the atmosphere.

The identity of the leading lines in the spectrum, the similar solubility and the similar density, appear to prove the identity of the argon prepared by both processes.

Argon is an element, or a mixture of elements, for Clausius has shown that if K be the energy of translatory motion of the molecules of a gas, and H their whole kinetic energy, then

$$\frac{K}{H} = \frac{3(C_p - C_v)}{2C_v},$$

C_p and C_v denoting as usual the specific heat at constant pressure and at constant volume respectively.

Hence if, as for mercury vapor and for argon (§XIV), the ratio of specific heats $C_p : C_v$ be $1\frac{2}{3}$, it follows that $K = H$, or that the whole kinetic energy of the gas is accounted for by the translatory motion of its molecules. In the case of mercury the absence of interatomic energy is regarded as proof of the monatomic character of the vapor, and the conclusion holds equally good for argon.

The only alternative is to suppose that if argon molecules are di- or polyatomic, the atoms acquire no relative motion, even of rotation, a conclusion exceedingly improbable in itself and one postulating the sphericity of such complex groups of atoms.

Now a monatomic gas can be only an element, or a mixture of elements; and hence it follows that argon is not of a compound nature.

From Avogadro's law, the density of a gas is half its molecular weight; and as the density of argon is approximately 20, hence its molecular weight must be 40. But its molecule is identical with its atom; hence its atomic weight, or, if it be a mixture, the mean of the atomic weights of that mixture, taken for the proportion in which they are present, must be 40.

There is evidence both for and against the hypothesis that argon is a mixture: for, owing to Mr. Crookes's observations of the dual character of its spectrum; against, because of Professor Olszewski's statement that it has a definite melting point, a definite boiling point, and a definite critical temperature and pressure; and because on compressing the gas in presence of its liquid, pressure remains sensibly constant until all gas has condensed to liquid. The latter experiments are the well-known criteria of a pure substance; the former is not known with certainty to be characteristic of a mixture. The conclusions which follow are, however, so startling, that in our future experimental work we shall endeavor to decide the question by other means.

For the present, however, the balance of evidence seems to point to simplicity. We have therefore to discuss the relations to other elements of an element of atomic weight 40. We inclined for long to the view that argon was possibly one or more than one of the elements which might be expected to follow fluorine in the periodic classification of the elements—elements which should have an atomic weight between 19, that of fluorine, and 23, that of sodium. But this view is completely put out of court by the discovery of the monatomic nature of its molecules.

The series of elements possessing atomic weights near 40 are :—

Chlorine	35·5
Potassium	39·1
Calcium	40·0
Scandium	44·0

There can be no doubt that potassium, calcium, and scandium follow legitimately their predecessors in the vertical columns, lithium, beryllium, and boron, and that they are in almost certain relation with rubidium, strontium, and (but not so certainly) yttrium. If argon be a single element, then there is reason to doubt whether the periodic classification of the elements is complete; whether, in fact, elements may not exist which cannot be fitted among those of which it is composed. On the other hand, if argon be a mixture of two elements, they might find place in the eighth group, one after chlorine and one after bromine. Assuming 37 (the approximate mean between the atomic weights of chlorine and potassium) to be the atomic weight of the lighter element, and 40 the mean atomic weight found, and supposing that the second element has an atomic weight between those of bromine, 80, and rubidium, 85·5, viz: 82, the mixture should consist of 93·3 per cent. of the lighter, and 6·7 per cent. of the heavier element. But it appears improbable that such a high percentage as 6·7 of a heavier element should have escaped detection during liquefaction.

If it be supposed that argon belongs to the eighth group, then its properties would fit fairly well with what might be anticipated. For the series, which contains

$$\mathrm{Si}_n^{\mathrm{IV}},\quad \mathrm{P}_4^{\mathrm{III\ and\ V}},\quad \mathrm{S}_{8\ \mathrm{to}\ 2}^{\mathrm{II\ to\ VI}},\quad \text{and } \mathrm{Cl}_2^{\mathrm{I\ to\ VII}},$$

might be expected to end with an element of monatomic molecules, of no valency, *i. e.* incapable of forming a compound, or if forming one, being an octad; and it would form a possible transition to potassium, with its monovalence, on the other hand. Such conceptions are, however, of a speculative nature; yet they may be perhaps excused, if they in any way lead to experiments which tend to throw more light on the anomalies of this curious element.

In conclusion, it need excite no astonishment that argon is so indifferent to reagents. For mercury, although a monatomic element, forms compounds which are by no means stable at a high temperature in the gaseous state; and attempts to produce compounds of argon may be likened to attempts to cause combination between mercury gas at 800° and other elements. As for the physical condition of argon, that of a gas, we possess no knowledge why carbon, with its low atomic weight, should be a solid, while nitrogen is a gas, except in so far as we ascribe molecular complexity to the former and comparative molecular simplicity to the latter. Argon, with its comparatively low density and its molecular simplicity, might well be expected to rank among the gases. And its inertness, which has suggested its name, sufficiently explains why it has not previously been discovered as a constituent of compound bodies.

We would suggest for this element, assuming provisionally that it is not a mixture, the symbol A.

We have to record our thanks to Messrs. Gordon, Kellas, and Matthews, who have materially assisted us in the prosecution of this research.

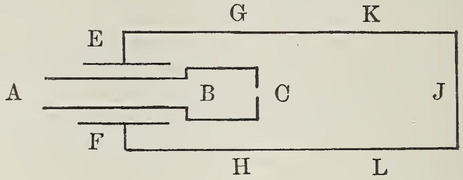
ART. XXV.—*The Velocity of Electric Waves;* JOHN TROWBRIDGE and WILLIAM DUANE.

SOMETIME since the following method of measuring the velocity of electric waves suggested itself to us; increase the size, and if necessary change the shape of an ordinary Hertz vibrator until the period of oscillation is sufficiently long to be determined by photographing the spark; measure the length of the waves induced in a secondary circuit tuned to resonance with the vibrator; and the quotient of the wave length by the time of a complete oscillation will be the required velocity.

The first apparatus experimented with was that used by Mr. St. John in investigating the peculiarities of waves along iron wires. For a detailed description of this apparatus see this Journal for October, 1894. It has been assumed by certain writers that the reaction between the circuits, arranged in the manner employed by Mr. St. John, is to a large extent, what would be called in the older theory of electricity, electro-magnetic rather than electrostatic. Certain phenomena, however, that appeared in the early part of our investigation seemed to point to the view that the greater portion of the action was electrostatic; and we therefore concluded to arrange the apparatus so that the reaction should be wholly electrostatic, thinking by this means to obtain a more powerful oscillation and a more regular wave than with the apparatus described and used so successfully by Blondlot. The first attempt arranged on the electrostatic principle proved a complete failure. A second trial about a fortnight later, however, proved so successful that we fully determined to adopt the electrostatic method.

The first point in the course of the investigation worthy of detailed notice is the production of electric waves along parallel wires in such a manner that they are actually visible to the eye. The arrangement of the apparatus to accomplish this was as follows:

1.



A primary condenser A B (Fig. 1) was held with its plates in vertical planes by means of suitable wooden supports (not represented in the figure), and was joined in a circuit B C consisting of two wires about 75^{cm} long placed 4^{cm} apart. In reality this circuit B C should be represented as perpendicular to the plane of the paper, (which is taken as the horizontal plane passing through the center of the apparatus). The plates of the condenser A B were of sheets of tin foil 101×40^{cm} glued to hard rubber sheets and the dielectric between them consisted of other similar sheets of hard rubber sufficient in number and thickness to make the distance between the condenser plates $4{\cdot}2^{cm}$. Outside the primary condenser plates and separated from them by hard rubber plates, (total thickness $\cdot 6^{cm}$) were two secondary plates E and F each 40^{cm} square. To these plates was attached the secondary circuit E G J H F, the form of which is represented in fig. 1. This latter circuit consisted of copper wire, diameter $\cdot 13^{cm}$ and its total length from E to F was 4200^{cm}. A spark gap with spherical terminals $2{\cdot}5^{cm}$ in diameter was placed at C in the primary circuit, and another spark gap with pointed terminals was sometimes inserted at J in the secondary circuit, although this latter spark gap had no effect upon the phenomena to be described. The primary condenser was charged by means of a large Ruhmkorf coil excited by five storage cells with a total voltage of ten volts. The current from these cells was made and broken by the automatic interrupter used by Mr. St. John and described by him in his paper above referred to. Every time the primary condenser was charged, a spark passed at C causing an oscillatory discharge. These oscillations induced charges on the plates E and F which were rapidly reversed in sign, and which traveled out along the wires E G and F H. The dimensions of the primary circuit were altered, until by trial it was found that a charge of, let us say, positive electricity starting from E would meet at the point G one of negative electricity that had previously started from F and traveled around F H J G, another at the point J, and still another at the point H. Stationary vibrations in the circuit E G J H F were thus set up with nodes at the points G, J and H, and ventral segments halfway between them at K and L. The method of discovering when the circuits were in tune, and of investigating the shape of the waves will be described later. The point to be noticed here is that the vibrations were sufficiently powerful to cause a luminous discharge on the surface of the wire at points where the accumulation of electricity was a maximum, i. e. at K and L, while at the nodal points G, J and H the wire was entirely dark. Still further the wave formation could be made apparent to the sense of hearing as well as that of sight; for placing the ear within a few centimeters of the wire and walking along it, a distinct crackling sound could be heard at the points K and L whereas no such sound could be heard at G, J and H. By placing bits of glass tubing on the wire the sound was much intensified at the points K and L, and the phenomena made more striking. It might be supposed that by decreasing the capacity of the primary condenser, and therefore the period of its oscillation, the secondary circuit could be broken up into a new set of shorter stationary waves, with nodes at J and at points somewhere near K, L, G and H, and ventral segments between them. This we tried with perfect success except that it was not possible to cause the light at K and L to actually disappear. There was decidedly less light at these points however than on either side of them. The light of course is simply that which always appears around wires carrying very high potential currents, the interesting point being that it appears in some places on the circuit and not in others. The experiment showing how the circuit breaks up in several different ways would form a most beautiful lecture experiment.

As a means of ascertaining when the circuits were in resonance, and of investigating the form of the wave in the secondary circuit a bolometer similar to that designed by Paalzow and Rubens* was used. The bolometer was used in this present investigation to detect electrical disturbances in a conductor and to measure their magnitudes; but it did not indicate either the direction or sign of the quantities measured. Its use for this purpose is described in the paper of Mr. St. John already referred to.

The conductors that were electrically connected to the arm of the bridge, and that were brought near the circuit consisted

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* Anwendung des bolometrischen Princips auf Electrische Messungen, Wied. Ann., xxxvii, 529.

of two pieces of wire insulated with rubber, bent into circles of about 2^{cm} radius, and fastened to a bit of pine wood by means of a heavy coating of paraffine. The two wires of the secondary circuit passed through holes in this bit of wood in such a manner as to pass through the centers of the two circles. In the early part of the investigation the bolometer and galvanoscope were placed at a sufficient distance from the oscillating circuits to prevent any direct action of one on the other, and the leads running from the circular conductors to the bolometer consisted of long fine wires. Later when longer circuits and longer waves were experimented with, great inconvenience was experienced from the long leads since their relative position had considerable effect upon the galvanoscope deflections. In order to obviate this difficulty short leads of heavily insulated wire were used and the bolometer was placed on wheels and moved along from place to place. A bolometric study of the circuit just described showed the character of the oscillation to be that mentioned, namely, nodes at the points G, J and H, and maximum accumulations at the points K and L. A careful run was made from one end of the circuit to the other, which furnished data from which a very regular curve was drawn.

Two points deserve notice here, before we pass on to the next arrangement of the apparatus. First the automatic current interrupter that worked so beautifully in connection with the Hertz vibrator would not function well, when the vibrator was replaced by the circuit and condenser just described. For a detailed description of this interrupter we must again refer to Mr. St. John's paper. The essential feature of the apparatus was this: the circuit was interrupted by the regular periodic lifting of a platinum plunger from a glass cup partially filled with mercury. Alcohol was poured over the surface of the mercury in order to keep it clean, and this effectually stopped the sparking when the Hertz vibrator was used. When, however, the induction coil was used to charge the large condensers, violent sparks occurred at the point where the plunger left the mercury, almost any one of which was sufficiently strong to blow the alcohol out of the cup. As the same current in the primary of the induction coil was used in the two cases, the most probable explanation of this is the following. The capacity of the condenser being considerably greater than that of the two plates in the Hertz vibrator, the current in the secondary of the induction coil in the first case must have been much greater than that in the second case. Hence the reaction of the secondary current on the primary of the induction coil, must have been much greater. This would cause a greater reaction of the secondary current on the primary of the induction coil, and would throw a greater stress on the point of rupture of the primary circuit; hence the sparking. To obviate the difficulty several methods of exciting the induction coil were tried, with more or less success. Finally, an ordinary reed interrupter with a comparatively large hammer and anvil arrangement was adopted, which gave little trouble.

The second point, and this is very important in the light of what is to follow, is the following: the insertion of a small spark gap (1^{mm}–3^{mm}) at the point in the secondary circuit marked—J (fig. 1) had no appreciable effect upon the position of the nodal points G and H, or of the points of maximum accumulation K and L. The form of the wave was slightly altered for a meter on each side of J, and the bolometer showed a slight accumulation in the immediate neighborhood of the spark gap. This was probably due to the charging of the spark terminals to a sufficiently high potential to break through the dielectric. The fact that the insertion of a spark gap, into a secondary circuit in the manner described has no effect upon the length of the waves set up in that circuit was tested for a number of different cases, (in none of which, however, the length of the waves was greater than in the present case) and found to be true in each one of them.

In order to determine the time of vibration we used a concave rotating mirror: and the images of the oscillating sparks were thrown on a sensitive plate. If the mirror rotated about a horizontal axis, the photographs showed bright horizontal lines perpendicular to which at their extremities extended two series of dots. The distance between the successive dots was evidently the distance on the plate through which the image of the spark gap moved during the time of a complete oscillation. Hence by determining the speed of the mirror and measuring the distances from the mirror to the plate the time of oscillation can be calculated.

The advantages of photographing the secondary spark rather than the primary are numerous. In the first place to properly photograph a spark it is necessary to use pointed terminals: but experiment has shown that the waves excited in a secondary circuit depend to a large extent upon the character of the primary spark, and that the most active sparks are those between metallic spheres with polished surfaces. It is true that waves can be produced by sparks between points, but the oscillations are not so powerful or well marked. In the second place, from the results obtained by Bjerknes one would expect the oscillations in the secondary circuit to be much less damped than those in the primary. This expectation has been fully realized. Photographs show from ten to twelve times as many oscillations in the secondary as in the primary. In the third and by no means the least important case, the question how close the resonance is does not affect the accuracy of the results. By photographing the sparks in the secondary the period of oscillation is determined, not of a circuit that is altered until by trial it is found to have as nearly as possible the same period of vibration as the circuit on which the length of the wave is measured, but that of the circuit along which the wave itself is actually traveling.

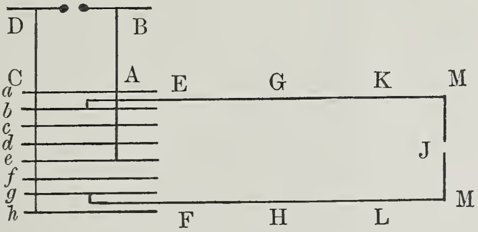
The great difficulty to be overcome is the production of secondary oscillations that will produce sparks of sufficient brightness to photograph. It is comparatively an easy task to photograph the primary spark, but in order to photograph the secondary the dimensions of the circuit must be chosen with great care.

With a view to increasing the light of the spark together with the length of the waves, it seemed desirable to lengthen the period of oscillation by enlarging the condensers rather than by increasing the self induction of the primary circuit. A castor oil condenser was therefore designed and constructed on the following plan. Eight plates ($25^{cm} \times 20^{cm}$) were cut out of sheet zinc, and were held in vertical planes side by side 2^{cm} apart by a suitable hard rubber frame. The plates were entirely immersed in castor oil contained in a glass jar. They were connected together in the manner shown in fig. 2.

The plates marked *a*, *c* and *e* were fastened to the conductor A B and formed one armature of the condenser. Those marked d, f and h were joined to C D and formed the other armature. The two ends of the secondary circuit E, G, J, H, F, were fastened to the plate *b* and *g*. The plane of the secondary circuit was 50^{cm}, and that of the primary 3^{cm} above the upper edge of the condenser plate. The total length of the secondary circuit from one condenser plate through E, G, J, H, F, to the other plate was 6338^{cm}. The circuit consisted of copper wire (diameter $\cdot 215^{cm}$) supported at each end by suitable wooden frames, and also once in the middle by hard rubber hooks fastened by long pieces of twine to a wooden crossbar above. The distances from F to E and from K to L were 30^{cm} and a spark gap with pointed tin terminals was inserted at J. The primary circuit consisted of copper wire (diameter $\cdot 34^{cm}$). The distances between the two parts A B and C D was 45^{cm}. The portion B D contained a spark gap with platinum-faced spherical terminals, and was made so as to slide back and forth, to and from the condenser. The motion of this movable piece varied the self induction and therefore the period of oscillation of the primary circuit. By this means the circuits were brought into resonance. With certain arrangements of the condensers, the resonance was very sharp, and the position of the movable portion could be determined to within ·25^{cm}. In the arrangement which was finally adopted the resonance was not so sharp. Even in this case the distance of the sliding part from the plate *a* could not have been in error by more than 2^{cm}. The length 65^{cm} was finally chosen for its value.

At first it was found impossible to produce anything but a complex vibration in the secondary circuit when the spark gap was open. Some slight evidence of resonance was obtained, but nothing of a decided character. When, however, the spark gap was closed, very good resonance ensued and a wave, the length of which could be measured to within ·4 per cent, was excited. Some photographs were taken of the spark in the secondary circuit, and they showed immediately the character of the complex wave formation. The secondary circuit could and did oscillate in three different ways, and the ratios of the periods were those of the notes in an open organ pipe, namely 1:2:3. Usually the lowest or fundamental oscillation together with one of the overtones was present; but several sparks were noticed that furnished unmistakable evidence of the simultaneous existence of all three. We have observed in a circuit 10000^{cm} long the same peculiarities of oscillation, excited by a primary circuit that, judging from its dimensions, could not have been in resonance with the secondary. It was evident that the oscillation having nodes at the points marked (fig. 2) E and F is that whose period is $\frac{1}{3}$ of the fundamental.

2.



A number of measurements of this period have been made, and from these several values the velocity of the waves has been calculated. The results appear in the following table. As an average of five measurements of the wave length, none of which differed from the mean by more than 20^{cm}, the value 5888^{cm} was chosen. The distance from the mirror to the photographic plate in each case except the last was 300·1^{cm}. Each of the first five values in the second column of the table is an average of 30 measurements of distances ranging in the neighborhood of 1^{cm}. The speed of the mirror was determined to one part in five hundred by means of an electric chronograph.

Number of revolutions of mirror per sec.	Distance between two successive points on plate. cm.	Velocity of Waves. cm.
71·2	·05608	$2·819 \times 10^{10}$
70·85	·05600	$2·810 \times 10^{10}$
70·7	·05532	$2·835 \times 10^{10}$
71·3	·05637	$2·808 \times 10^{10}$
70·8	·05611	$2·808 \times 10^{10}$
	Average.	$2·816 \times 10^{10}$
69·2	·05340	$2·988 \times 10^{10}$

The last line in the table contains the results of measurements on photographs of the primary spark instead of the secondary. In this case the distance from the mirror to the photographic plate was 311·5$^{\text{cm}}$. In spite of the fact that the last value of the velocity is much nearer that of the velocity of light, and of the ratio of the two systems of electrical units than the average of the first five, we do not think it can be relied upon, for two reasons. First because of the possible error introduced by the fact that the two circuits had not exactly the same period of oscillation; and second because the distances measured on the photographic plate were only about ·05$^{\text{cm}}$, instead of 1·00$^{\text{cm}}$.

The generally accepted value for the velocity of light is $2·998 \times 10^{10}$ centimeters. At present it does not seem to us likely, judging from the table as it stands, and from a consideration of the possible errors in the various measurements, that the total error in our determination can be as great as the difference between the average just given and $2·998 \times 10^{10}$.

Whether this discrepancy is due to the fact that the circuit may not have been long enough in comparison with the length of the waves to allow of their full development, or not, we do not undertake to say. If the bends in the circuit at M and M′ have a retarding effect upon the waves, this fact can be very easily discovered and allowed for. As yet we have not had time to investigate the question. We therefore publish the results above tabulated as a preliminary record, hoping to refine upon the measurements in several important particulars, and to extend the investigation to circuits of different sizes and shapes, one of which will probably be a long circuit of some 300 meters running out of doors, and at a considerable distance above the ground.

In the final paper, too, we hope to publish a great many details of the method, together with some interesting phenomena that have appeared in the photographs, of the primary and secondary sparks.

If it appears, as theory seems to indicate, that electric waves travel in air with the velocity of light, it may be that the latter can be determined more accurately by an electrical and photographic method than by the eye methods which have hitherto been used.

Jefferson Physical Laboratory.

Art. XXVI.—*Epochs and Stages of the Glacial Period*; by WARREN UPHAM.

RENEWED studies of the origin and order in age of our Minnesota drift deposits have led me to the results presented in the following table, which I think will contribute toward a reconciliation and harmony of the lately opposing doctrines (1) of unity and (2) of duality or greater complexity of the Ice age. Unity or continuity of our Pleistocene glaciation, with fluctuations of the ice margin, much greater in the interior of the continent than eastward, appears to me the most acceptable view and statement, when the whole period and the whole drift-bearing area are considered. The evidences of a recession of the ice-sheet in Minnesota about two hundred miles backward from the nearest portions of its former boundary, followed by growth again nearly to its previous limits, are to be found in *The Geology of Minnesota*, final report, volumes I (1884) and II (1888), by index references for "Interglacial formations, drainage and water-courses," etc.

The two stages of growth of the ice-sheet may have been due, aside from their principal dependence on the high elevation of the land, to the last two passages in the precession of the equinoxes, with accompanying nutation, bringing the winters of the northern hemisphere in aphelion about 30,000 years ago and again about 10,000 years ago. The intermediate time of the earth's northern winters in perihelion would be the stage of great retreat of the ice margin in the upper Mississippi region; but eastward, from Ohio to the Atlantic coast, there appears to have been little glacial oscillation.* This explanation accords with Prof. N. H. Winchell's computations from the rate of recession of the falls of St. Anthony for the Postglacial or Recent period,† and with his estimate of the duration

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* J. D. Dana, this Journal, III, vol. xlvi, pp. 327–330, Nov., 1893.

† Geol. and Nat. Hist. Survey of Minnesota, Fifth Ann. Rep. for 1876, pp. 175–189; Final Report, vol. ii, 1888, pp. 313–341, with fifteen plates (views showing recent changes of the falls of St. Anthony, and maps). Quart. Jour. Geol. Soc., London, vol. xxxiv, 1878, pp. 886–901.

of the interglacial stage from the now buried channel which appears to have been then eroded by the Mississippi river a few miles west of the present gorge below these falls.*

Adopting the helpful new nomenclature proposed by Chamberlin,† we may provisionally formulate the minor time divisions of the Glacial and Champlain epochs as follows. The order is stratigraphic, so that for the advancing sequence in time it should be read upward.

Champlain Epoch.—(Land depression; disappearance of the ice-sheet; partial reëlevation of the land.)

WISCONSIN STAGE.—(Progressing reëlevation.) Moderate reëlevation of the land, advancing as a permanent wave from south to north and northeast; continued retreat of the ice along most of its extent, but its maximum advance in southern New England, with fluctuations and the formation of prominent moraines; great glacial lakes on the northern borders of the United States; slight glacial oscillations, with temperate climate nearly as now, at Toronto and Scarboro', Ont.; the sea finally admitted to the St. Lawrence, Champlain, and Ottawa valleys; uplift to the present height completed soon after the departure of the ice. (The great Baltic glacier, and European marginal moraines.)

CHAMPLAIN SUBSIDENCE.—Depression of the ice-covered area from its high Glacial elevation; retreat of the ice from its former Iowan limits; abundant deposition of loess.

Glacial Epoch.—(Ice accumulation, due to the culmination of the Lafayette epeirogenic uplift.)

IOWAN STAGE.—Renewed ice accumulation covering the forest beds and extending south nearly to its early boundary. (Third European glacial stage.)

INTERGLACIAL STAGE.—Extensive glacial recession in the upper part of the Mississippi basin; cool temperate climate and coniferous forests up to the waning ice-border; much erosion of the early drift.

KANSAN STAGE.—Maximum extent of the ice-sheet in the interior of North America, and also eastward in northern New Jersey. (Maximum glaciation in Europe.)

UNDETERMINED STAGES of fluctuation in the general growth of the ice-sheet.—Including an early glacial recession and reädvance shown by layers of interglacial lignite on branches of the Moose and Albany rivers, southwest of James bay. (First glacial stage in the Alps.)

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* Am. Geologist, vol. x, pp. 69–80, with three plates (sections and map), Aug., 1892.

† In two chapters (pp. 724–775, with maps forming plates xiv and xv) of J. Geikie's "The Great Ice Age," third edition, 1894, Prof. T. C. Chamberlin proposes a chronologic classification of the North American drift under three formations, named in the order of their age, beginning with the earliest, the Kansan, East Iowan, and East Wisconsin formations.

ART. XXVII.—*Structure and Appendages of Trinucleus;*
by CHARLES E. BEECHER. (With Plate III.)

TRINUCLEUS departs so widely from the common type of trilobite form, that any contribution of new facts regarding its structure and appendages is a matter of interest. Moreover, this added information will be of assistance in interpreting some peculiar and striking features in the natural group of genera of which *Trinucleus* is evidently a member.

For the present, it is convenient to consider in this group such forms as *Trinucleus*, *Harpes*, *Harpides*, *Dionide*, and *Ampyx*. Most of these have the genal angles extending to or beyond the pygidium, with a broad, finely perforated or punctate margin around the head. They are further characterized by the absence or obsolescence of visual organs, while the facial sutures are either peripheral, as in *Harpes*, or in addition include the genal spines, as in *Trinucleus*, *Dionide*, and *Ampyx*. Several other genera have been recognized as having affinities with those mentioned, but they are imperfectly known, and will be merely noticed here. *Harpina*, Novák, based upon the features of the hypostoma, is probably of only subgeneric value under *Harpes*. *Arraphus*, Angelin, is apparently based upon a specimen of *Harpes* denuded of the punctate border. *Salteria* of W. Thompson, and *Endymionia* of Billings, both generally considered as closely related to *Dionide*, were founded upon too imperfect material to afford decisive data as to their affinities. Angelin's sub-genera of *Ampyx* (*Lonchodomus*, *Raphiophorus*, and *Ampyx*) are based upon the length of the glabellar spine, and the possession of five or six free thoracic segments. Similar characters in *Trinucleus* are not considered as worthy of such marked distinction.

In 1847, Salter* illustrated and described an eye-tubercle on each cheek of *Trinucleus*, from which there was a raised line extending obliquely upward to a punctum or spot on each side of the glabella. He considered this line as a discontinuous facial suture, but the true suture was afterwards correctly determined by Barrande,† and in well-preserved specimens, may easily be observed, extending around the entire frontal and lateral border of the head, and including the genal spines. The "eye-line" was further recognized by McCoy,‡

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* On the structure of Trinucleus, with Remarks on the Species, Quar. Jour. Geol. Soc., vol. iii. pp. 251–254.

† Syst. Sil. Bohême, I., 1852.

‡ Ann. Mag. Nat. Hist., 2d Series, vol. iv., 1849.

and made one of the bases for a division of the genus into two sections or genera—*Trinucleus* proper and *Tetraspis*. These divisions were accepted by Salter, but later were thoroughly discussed, and rejected by Barrande (*l. c.*, p. 617), upon valid grounds. Nicholson and Etheridge,* in 1879, reviewed these facts at some length, and gave original figures illustrating the ocular tubercle and eye-line. They also agree with Barrande in recognizing them as clearly adolescent characters.

The justice of these conclusions is substantiated, and additional results are reached, from the study of a series of *Trinucleus concentricus* Eaton, found associated with *Triarthrus Becki* Green, in the Utica slate, near Rome, New York. The remarkable preservation of the fossils at this locality, has already afforded a means of determining all the principal details of the ventral structure of the trilobite genus *Triarthrus*, and there is now distinct evidence as to the nature of the appendages in another type—*Trinucleus*, as well as to the probable significance of the so-called "eye-tubercle."

As compared with *Triarthrus*, specimens of *Trinucleus* are not very common at this locality, and, although more than fifty individuals of the latter have been obtained from the collections presented to the Yale Museum by Professor Marsh, not more than half a dozen of these are adult specimens, and but three show any appendages. Young specimens of all ages occur, from about 1^{mm} across the cephalon upwards, and in all the eye-line and eye tubercle are present until a width of nearly 5^{mm} is attained, when in the present species these features dwindle and disappear, leaving no discoverable traces in the adult.

Two cephala of young individuals, without the free cheeks, are shown enlarged in figures 1 and 2 of Plate III. Figure 2 represents a specimen before the appearance of the perforate border, and figure 1 gives a later stage, having two rows of perforations around the head. On both specimens the eye-line is clearly shown, extending somewhat obliquely backward from the anterior lobe of the glabella to the central area of the fixed cheeks, enlarging slightly, and terminating in a rounded node or tubercle (*a*, *a*, figure 2).

In seeking for homologous features in other trilobites, the genera *Harpes* and *Harpides* are immediately suggested, since they have similar ocular ridges extending from the sides of the glabella, and ending in a tubercle, which, in *Harpes*, contains from one to three eye-spots, as determined by Barrande. They further agree in having these visual organs on the

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* Monograph of the Silurian Fossils of the Girvan District in Ayrshire, Fasc. II., 1879.

fixed cheeks, while in all other trilobites with distinct eyes, the free cheeks carry the visual areas. This type of eye is thus quite different in its relations to the parts of the cephalon from that of *Phacops* or *Asaphus*, and more nearly resembles the eyes of some of the *Merostomata* (*Bellinurus*), as do also the triangular areas in the young *Trinucleus*, so distinctly marked off from the fixed cheeks on each side of the glabella behind the eye-line. Adult *Trinucleus* and *Harpes* have these areas much reduced, and often obsolescent. A spot or node in the median line on the glabella has been noticed by many observers, and although its nature has not been demonstrated, it has generally been called an ocellus. It is more clearly preserved in adult specimens, though it can be detected in young examples, as indicated in figures 1, 2, Plate III.

An eye-line occurs in many early trilobite genera, and is well marked in *Conocoryphe*, *Olenus*, *Ptychoparia*, and *Arethusina*. At least four-fifths of the Cambrian forms preserve this feature, which is almost entirely eliminated before Devonian time. It differs in extent, but not necessarily in nature, from the eye-line of *Trinucleus* and *Harpes* in running entirely across the fixed cheeks to the free cheeks, ending in the palpebral lobe in eyed forms. It is evidently a larval character in the trilobites, as shown from its geological history and the ontogeny of *Trinucleus*. From the direction of the optic nerve in *Limulus*, and its relations to the surface features of the cephalothorax, the eye-line probably represents the course of that nerve, and is of much less morphological importance than the different types and arrangement of visual organs.

The pygidium of young *T. concentricus* (Plate III, figure 3) is remarkable for the lack of definition between the axis and pleura. In later and adult stages the number of ridges on the pleura and axis do not correspond, and from figures 4, 5, and 6, it is evident that in this genus the number of pleura is no indication of the number of pygidial segments or pairs of appendages, which, however, may be shown, as in this case, by the annulations of the axis. In this respect, the pygidia in *Encrinurus*, *Cybele*, and *Dindymene*, are of the same nature. Figure 6 also shows a narrow, striated doublure, a character generally overlooked in descriptions of *Trinucleus*.

Appendages.

Three specimens have thus far been observed which show the nature of the appendages in *Trinucleus*. Two of these are illustrated in figures 4, 5, and 6, of Plate III. Figure 4 represents the thorax and pygidium viewed from the dorsal side. In this specimen the pyrite which replaced the chitinous remains of the animal has decomposed, and the dorsal crust weathered away, exposing below the stems of the exopodites, with their fringes extending over the entire pleural areas on both sides. A pygidium, with three attached thoracic segments, from another entire specimen (figures 5 and 6), preserves the details of the appendages in the most perfect and satisfactory manner. As both halves showed essentially the same extent and disposition of the fringes on the dorsal side, the specimen was cut in two along the center of the axis, and the left side was then imbedded in paraffine. By careful preparation the appendages were exposed from the ventral side.

The cephala of the three specimens described are considerably compressed, and from them a very imperfect knowledge of the mouth parts could be obtained, so that this information must be left to future discovery.

Endopodites.—The three posterior thoracic endopodites are very similar, and in a general way closely resemble those of *Triarthrus* from the same region of the thorax. They are, however, comparatively shorter and stouter, and could not be extended beyond the ends of the pleura. The two distal joints are cylindrical, with well-marked articular surfaces and ridges. The joints preceding these proximally become much wider, flattened, and produced into transverse extensions which carry large tufts of setæ at the end, as also does the end of the last joint of the limb (dactylopodite).

The endopodites on the pygidium offer no conspicuous differences from those just described, except that a gradual change in form is manifest as the terminal limbs are reached. The separate endites become more and more transversely cylindrical, until the whole limb appears to be made up of cylindrical segments transverse to its length. A similar condition was observed in the young of *Triarthrus.*[*]

Exopodites.—These seem to be composed of slender joints, the distal exites being long and slightly curved outwards. They carry very long, close set, overlapping, lamellose fringes, which evidently had a *branchial* function. Some of the lamellæ are spiniferous. The exopodites become shorter on the pygidium, and apparently are represented near the end of the series of limbs by the oval plates indicated at *c*, figure 6. If this interpretation is correct, the posterior exopodites are simple flabella attached to the limbs, as in *Apus.*

Both Professors A. E. Verrill and S. I. Smith agree that the characters of the appendages in *Trinucleus* indicate an animal of burrowing habit, which probably lived in the soft

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[*] This Journal, vol. xlvii, Pl. VII, fig. 3, April, 1894.

mud of the sea bottom, much after the fashion of the modern *Limulus.* In addition to its limuloid form, the absence of eyes seems to favor this assumption. So does the fact that many specimens have been found preserving the cast of the alimentary canal, showing that the animal gorged itself with mud like many other sea-bottom animals.

Yale Museum, New Haven, Conn., March 15th, 1895.

EXPLANATION OF PLATE III.

Trinucleus concentricus Eaton.

FIGURE 1.—Cephalon of young individual without genal spines; showing ocular ridges and two rows of perforations around anterior and lateral borders. × 40.

FIGURE 2.—Cephalon of younger individual before the growth of the perforate border; showing distinctly the clavate ocular ridges, *a*, *a*. × 40.

FIGURE 3.—Pygidium of young individual; showing the indistinct limitation of axis and the elevated transverse ridges of the pleura and axis. × 40.

FIGURE 4.—Thorax and pygidium of an entire specimen from which the dorsal test has been removed by weathering, exposing below the fringes of the exopodites, which entirely cover the pleural portions. The stronger lines ascending from the axis are the main stems of the exopodites. The black dots along the axis are the fulcra for the attachment of the limbs. × 4.

FIGURE 5.—One-half the pygidium with three attached thoracic segments, from an entire specimen, with a portion of the test removed; showing the highly developed, lamellose fringes of the exopodites. × 11.

FIGURE 6.—The same; lower side; showing the short, stout, phyllopodiform endopodites, *a*, and the long, slender, exopodites, *b*, bearing the lamellose branchial fringes. In the lower third of the figure the ends of the joints of the separate endopodites are shown by the oblique ascending rows of setiferous nodes. The small ovate organs (*c*) along the side are provisionally correlated with the exopodites. A narrow striated doublure margins the pygidium and the ends of the thoracic pleura. × 11.

Utica slate. Near Rome, N. Y.

SCIENTIFIC INTELLIGENCE.

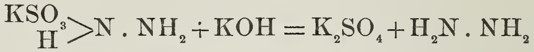
I. CHEMISTRY AND PHYSICS.

1. *On the Inorganic Preparation of Hydrazine.*—Hitherto the preparation of hydrazine has been possible only from complex organic compounds. DUDEN however has now succeeded in effecting its synthesis from inorganic materials. For this purpose he makes use of a compound originally discovered by Davy, produced by the action of sulphurous acid upon potassium nitrite, and which has the composition $K_2SO_3 . N_2O_2$. And he finds that this substance, upon careful reduction with sodium amalgam or with zinc dust and ammonia or soda, at a low temperature, gives a solution having very strong reducing properties and which yields

after acidification, the salt of hydrazine corresponding to the acid employed. In practice the recently prepared compound of nitrogen dioxide and potassium sulphite is suspended in water cooled by ice, the whole is placed in a freezing mixture and sodium amalgam is gradually added until the liquid is found to reduce Fehling's solution strongly and to yield, after being acidified and heated to expel the sulphur dioxide a precipitate of benzalazine on the addition of benzaldehyde. The benzalazine thus obtained is identical with that described by Curtius, fusing at 93° and having the formula $(C_6H_5CHN)_2$. This substance treated with sulphuric acid yields hydrazine sulphate $(N_2H_4)_2 . H_2SO_4$, of melting point 256°, and otherwise identical with the product obtained from organic sources. The reaction appears to take place in two stages. In the first

$$\begin{matrix}KSO_3\\KO\end{matrix}\!>\!N.NO+H_6=\begin{matrix}KSO_3\\H\end{matrix}\!>\!N.NH_2+H_2O+KOH$$

Then a subsequent reaction takes place between the alkali and the sulphite compound thus



$$\begin{matrix}KSO_3\\H\end{matrix}\!>\!N.NH_2+KOH=K_2SO_4+H_2N.NH_2$$

—*Ber. Berl. Chem. Ges.*, xxvii, 3498, January, 1895. G. F. B.

2. *On the Production of Carbon chlorides at ordinary Temperatures.*—The production of C_2Cl_4 and C_2Cl_6 by the dissociation of carbon tetrachloride at a red heat, with the setting free of chlorine is well known. Victor Meyer has now called attention to the fact that during the preparation of carbon tetrachloride by the chlorination of carbon disulphide at ordinary temperatures, these two chlorides are produced. At these works of Müller and Dubois, near Mannheim, this process is operated on the large scale, at temperatures between 20° and 40°. After some days, the liquid becomes deeply colored owing to the production of sulphur dichloride S_2Cl_2. The tetrachloride is then distilled off leaving the chloride of sulphur. On rectification of the tetrachloride an oily liquid having a higher boiling point, is obtained. Upon fractioning this the author finds that it separates into three constituents, CCl_4, C_2Cl_4 and C_2Cl_6, the last being a solid, and being thus obtained in crystals, practically pure. Since the carbon disulphide also was practically pure, the author considers that the chlorides C_2Cl_4 and C_2Cl_6 are produced by direct synthesis, as follows:

$$\begin{aligned}(CS_2)_2+Cl_{10} &= C_2Cl_6+(S_2Cl_2)_2\\(CS_2)_2+Cl_8 &= C_2Cl_4+(S_2Cl_2)_2\end{aligned}$$

—*Ber. Berl. Chem. Ges.*, xxvii, 3160, November, 1894. G. F. B.

3. *On the Atomic masses of Nickel and Cobalt.*—In the earlier determinations of the atomic masses of nickel and cobalt, made by Winkler, he obtained the values 58·90 for the former metal and 59·67 for the latter; the results being secured by analysis of the chlorides prepared from electrolytically deposited metals.

He now finds that a small error was introduced in the case of cobalt, due to the fact that the metal deposited on the platinum electrode contained a minute quantity of the hydrate $Co_2O_3 . (H_2O)_2$. No such result however occurs with nickel. Moreover he finds that a solution of iodine in potassium iodide of decinormal strength is capable of dissolving the deposited metal from the platinum terminal at once, without attacking the latter. In the case of nickel the platinum is left perfectly clean, while after the removal of the cobalt a stain remains due to about one half per cent of oxide. To remove this oxide, the electrodeposited cobalt was reduced by hydrogen before use; and then it proved to be pure on solution in iodine. The determination was made by titrating with sodium thiosulphate the excess of iodine left after the pure metals were dissolved. As a result of two complete and concordant series of analyses the final values obtained are 58·72 for nickel and 59·37 for cobalt, H being 1 and I 126·53; the atomic mass of cobalt being apparently about one-half a unit higher than that of nickel.—*Zeit. anorg. Chem.*, viii, i, December, 1894. G. F. B.

4. *On the Atomic Mass of Bismuth.*—More than forty years ago SCHNEIDER fixed the mass of the bismuth atom as 208, relative to that of hydrogen. A few years subsequently, i. e. in 1859, Dumas made atomic mass determinations of a number of elements, among which was bismuth; giving to this metal the value 210. This figure continued to be accepted down to 1883 when Marignac undertook his well known investigations upon atomic mass and by a series of determinations which were carried out with great thoroughness concluded upon 208·16 as the atomic mass of bismuth; thus corroborating the work of Schneider. In consequence of the slightly higher result 208·9, obtained by Classen by an electrolytic method, Schneider has now repeated and extended his work in this direction. The method adopted by him in this new series of determinations is based upon a comparison of the equivalent relation of metallic bismuth to the trioxide of bismuth; with a view of testing certain suggestions made by Classen concerning possible errors in his former estimations. The result finally obtained, for $O = 16$, is 208·05; the greatest divergence from this mean among the values obtained in all the experiments being only 0·21. This result not only confirms the value originally obtained by Schneider himself, and also that of Marignac, but it is specially important as tending to show that bismuth belongs to the increasing class of elements whose atomic masses are represented by whole numbers.—*J. prakt. Ch.*, II, l, 461, November, 1894. G. F. B.

5. *On the Use of Dihydroxytartaric acid as a Reagent for Sodium.*—By oxidizing tartaric acid in presence of iron, FENTON observed the production of a new crystallized acid, which by oxidation is converted into dihydroxytartaric acid. To effect this oxidation, the crystallized acid is covered with glacial acetic acid and a solution of bromine in this glacial acid is added drop by

drop with constant shaking, until a faint permanent yellow color appears. On neutralizing with sodium carbonate, a heavy white crystalline precipitate is produced, which after washing and drying, finally in vacuo over sulphuric acid, proved to be sodium dihydroxytartrate. From this salt, by covering it with anhydrous ether and passing dry hydrogen chloride into the mixture, dihydroxytartaric was obtained on evaporation. Owing to the ease with which this acid can now be procured, the author suggests the use of it as a reagent for the detection of sodium. For this purpose, a few crystals of the acid are dissolved in a drop of water on a watch-glass, the solution to be examined is added and if necessary the liquid is neutralized with a drop of ammonia. On stirring with a rod, a white crystalline precipitate of the sodium salt appears, generally in lines as in the detection of potassium by tartaric acid. The test is fairly delicate, a one per cent solution of sodium chloride giving the reaction almost immediately. Neither potassium nor ammonium interferes with the reaction.—*J. Chem. Soc.*, lxvii, 48, January, 1895. G. F. B.

6. *On the Commercial Synthesis of Acetylene.*—The production of the carbides of barium, strontium and calcium, by Moissan in his electric furnace,* seems likely to become of considerable commercial utility. In a paper by Lewes, read before the Society of Arts, he has called attention to the production of acetylene by the action of water upon these carbides as the starting point of important practical developments. Although Wöhler had made calcium carbide by fusing an alloy of zinc and calcium with carbon, and had obtained acetylene from it by the action of water; and although in 1892 Macquenne had made barium carbide by heating together barium carbonate, magnesium powder and charcoal, and still later Travers had made calcium carbide by the action of a high temperature upon a mixture of calcium chloride, carbon and sodium, yet no commercial importance was attached to these processes on account of their expense. But when working with the electric furnace, in the attempt to form alloys of calcium, Willson observed that a mixture of lime and pulverized anthracite, exposed to the high temperature of the arc, fused to a semi-metallic mass, which when thrown into water, effervesced strongly and evolved acetylene, the process became of practical value. The calcium carbide thus produced is a dark gray substance, having a density of 2·262. When pure a pound of it yields 5·5 cubic feet of gas, containing 98 per cent of acetylene. This gas is colorless, with a penetrating odor resembling garlic. It is poisonous, and is soluble in a little less than its own volume of water, and in one-sixth of its volume of alcohol. It has a density of 0·91. It burns with a highly luminous and smoky flame, and liquefies at 0° C. under a pressure of 21·5 atmospheres. When sprayed into the air the liquid evaporates rapidly, absorbing so much heat that a portion of it is converted into a snow-white solid. For illuminating purposes it can be burned only in

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* See this Journal, III, xlviii, 506, December, 1894.

small flat-flame burners, and then gives a light of 240 candles when consumed at the rate of five feet per hour. It is claimed that calcium carbide can be produced in this way for about $20 per ton. Since a ton will yield about 11,000 cubic feet of gas, the cost at this rate would be about $1·60 per thousand cubic feet, deducting the value of bye-products. In illuminating value, it would be equivalent to ordinary coal gas at about ten or twelve cents per thousand. Moreover, since acetylene is the starting point for a multitude of organic syntheses, this cheap production is of great importance in chemical industry.—*Nature*, li, 303, January, 1895. G. F. B.

7. *Theoretical Chemistry from the Standpoint of Avogadro's rule and Thermodynamics.* By Prof. WALTER NERNST, PH.D., of the University of Göttingen. Translated by Prof. CHARLES SKEELE PALMER, PH.D., of the University of Colorado, 8vo, pp. xxvi, 697. London and New York, 1895 (Macmillan & Co.), $5.—Dr. Nernst is well known as one of the leaders of the new School of Physical Chemists. His papers upon subjects within this domain have received marked attention and have made him an authority in this branch of chemistry. A book from his pen, like the one now before us, therefore, cannot fail to be of great service in advancing chemical science and will, no doubt, be warmly welcomed by his co-laborers in every land. It is divided into four principal divisions or books, preceded by an introduction upon matter and energy and their relations. The first book treats of the universal properties of matter, such as the gaseous, the liquid and the solid states of aggregation, the physical mixture and dilute solutions. The second book considers the atom and the molecule, taking up successively the atomic theory, the kinetic theory of the molecule, the determination of molecular weight, the constitution of the molecule, the relation between physical properties and molecular structure, the dissociation of gases and electrolytic dissociation, the physical properties of salt solutions, and the absolute size of molecules. Book third discusses the transformation of matter, being the first part of the doctrine of affinity; its chapters being upon the laws of chemical mass-action, the chemical statics of homogeneous and heterogeneous systems, chemical equilibrium in salt solutions and chemical kinetics. Book fourth is devoted to the transformation of energy, being the second part of the doctrine of affinity; its first five chapters treating of thermochemistry and its last two of electrochemistry and photochemistry respectively. Two valuable appendices complete the work. One, edited by Dr. Nernst himself, contains important matter which has appeared since the publication of the German edition. The other, edited by Dr. Kaiser, is a synchronistic comparison of the chief periodicals bearing on this department of chemistry. From this résumé will appear at once not only how wide is the range of subjects treated in this volume, but also how clear and logical is the order in which they are taken up. Dr. Nernst everywhere speaks with

the authority of a master of his subject. So that his book, notwithstanding the treatises of Ostwald and others on Physical Chemistry, seems to us, in the excellence of its arrangement, the clearness of its style and the thoroughness of its subject-matter, to be the best book of its kind which has yet appeared. Dr. Palmer deserves especial thanks for putting the book so admirably into its English dress. Typographically also, the book is a credit to its publishers. G. F. B.

8. *Qualitative Chemical Analysis of Inorganic Substances*, as practiced in Georgetown College, D. C. Short 4to, pp. 61. New York, 1894 (American Book Company).—This book consists of a series of tables for qualitative analysis, divided into four sets. The first is on Basic Analysis, the second on Acid Analysis, the third on Preliminary Examination, and the fourth on Solution and on Special treatment. Though in the main following well established authorities, yet there is some originality of arrangement and some satisfactory explanatory matter added to the tables. The book appears to have been prepared with considerable care. G. F. B.

9. *Double refraction of Electric waves.*—K. MACK by interposing pieces of wood between Hertz's well known parabolic reflectors, the axes of which are inclined to each other, has shown that electric waves can be doubly refracted. Most specimens of wood have a different structure along the direction of the fibres from that perpendicular to this direction, and accordingly resemble in this respect doubly refracting crystals possessing a structure parallel to their optic axis different from that at right angles to this axis. When pieces of wood about 20^{cm} thick were interposed on the line joining the foci of the mirrors, clear evidence of the doubly refracting properties of the wood could be shown by the appearance or disappearance of the spark in the micrometer connected with the receiving mirror.—*Ann. der Physik. und Chemie*, No. 2, 1895, pp. 342–351. J. T.

10. *National Academy of Sciences on Electrical Measurement.*—The standard specifications for the practical application of the definitions of the electrical units, ampere and volt, referred to in the act of Congress of July 12, 1894, quoted in the last number of this Journal (p. 236), are given below; they are taken from Miscellaneous Document, No. 115, of the Senate of the United States. These specifications were approved by all the members of the committee named, of which Prof. H. A. Rowland was the chairman, and were unanimously adopted by the Academy at a special meeting held in New York on the 9th of February, 1895.

Specifications for the practical application of the definitions of the Ampere and Volt.

SPECIFICATION A.—*The Ampere.*

In employing the silver voltameter to measure currents of about one ampere, the following arrangements shall be adopted:

The kathode on which the silver is to be deposited shall take the form of a platinum bowl not less than 10 centimeters in diameter, and from 4 to 5 centimeters in depth.

The anode shall be a disc or plate of pure silver some 30 square centimeters in area and 2 or 3 millimeters in thickness.

This shall be supported horizontally in the liquid near the top of the solution by a silver rod riveted through its center. To prevent the disintegrated silver which is formed on the anode from falling upon the kathode, the anode shall be wrapped around with pure filter paper, secured at the back by suitable folding.

The liquid shall consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms.

Method of Making a Measurement. The platinum bowl is to be washed consecutively with nitric acid, distilled water and absolute alcohol; it is then to be dried at 160° C., and left to cool in a desiccator. When thoroughly cool it is to be weighed carefully.

It is to be nearly filled with the solution and connected to the rest of the circuit by being placed on a clean insulated copper support to which a binding screw is attached.

The anode is then to be immersed in the solution so as to be well covered by it and supported in that position; the connections to the rest of the circuit are then to be made.

Contact is to be made at the key, noting the time. The current is to be allowed to pass for not less than half an hour, and the time of breaking contact observed.

The solution is now to be removed from the bowl and the deposit washed with distilled water and left to soak for at least six hours. It is then to be rinsed successively with distilled water and absolute alcohol and dried in a hot-air bath at a temperature of about 160° C. After cooling in a desiccator it is to be weighed again. The gain in mass gives the silver deposited.

To find the time average of the current in amperes, this mass, expressed in grams, must be divided by the number of seconds during which the current has passed and by 0·001118.

In determining the constant of an instrument by this method, the current should be kept as nearly uniform as possible and the readings of the instrument observed at frequent intervals of time. These observations give a curve from which the reading corresponding to the mean current (time-average of the current) can be found. The current, as calculated from the voltameter results, corresponds to this reading.

The current used in this experiment must be obtained from a battery and not from a dynamo, especially when the instrument to be calibrated is an electrodynamometer.

Specification B.—*The Volt.*

Definition and Properties of the Cell. The cell has for its positive electrode, mercury, and for its negative electrode, amalgamated zinc; the electrolyte consists of a saturated solution of zinc sulphate and mercurous sulphate. The electromotive force is 1·434 volts at 15° C., and between 10° C. and 25° C., by the increase of 1° C. in temperature, the electromotive force decreases by ·00115 of a volt.

1. *Preparation of the Mercury.* To secure purity it should be first treated with acid in the usual manner and subsequently distilled *in vacuo.*

2. *Preparation of the Zinc Amalgam.*—The zinc designated in commerce as "commercially pure" can be used without further preparation. For the preparation of the amalgam one part by weight of zinc is to be added to nine (9) parts by weight of mercury and both are to be heated in a porcelain dish at 100° C. with moderate stirring until the zinc has been fully dissolved in the mercury.

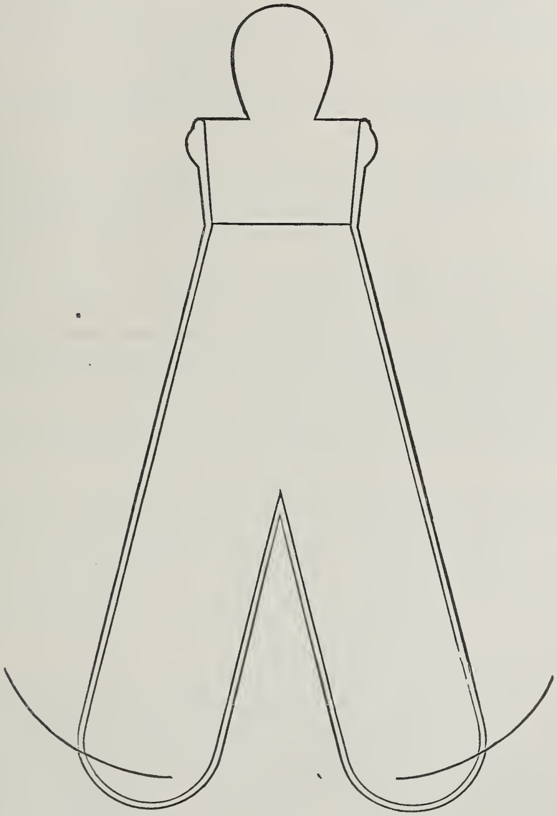
3. *Preparation of the Mercurous Sulphate.* Take mercurous sulphate, purchased as pure, mix with it a small quantity of pure mercury and wash the whole thoroughly with cold distilled water by agitation in a bottle; drain off the water and repeat the process at least twice. After the last washing, drain off as much of the water as possible. (For further details of purification, See Note A.)

4. *Preparation of the Zinc Sulphate Solution.* Prepare a neutral saturated solution of pure re-crystallized zinc sulphate, free from iron, by mixing distilled water with nearly twice its weight of crystals of pure zinc sulphate and adding zinc oxide in the proportion of about 2 per cent. by weight of the zinc sulphate crystals to neutralize any free acid. The crystals should be dissolved with the aid of gentle heat, but the temperature to which the solution is raised must not exceed 30° C. Mercurous sulphate, treated as described in 3, shall be added in the proportion of about 12 per cent by weight of the zinc sulphate crystals to neutralize the free zinc oxide remaining, and then the solution filtered, while still warm, into a stock bottle. Crystals should form as it cools.

5. *Preparation of the Mercurous Sulphate and Zinc Sulphate Paste.* For making the paste, two or three parts by weight of mercurous sulphate are to be added to one by weight of mercury. If the sulphate be dry, it is to be mixed with a paste consisting of zinc sulphate crystals and a concentrated zinc sulphate solution, so that the whole constitutes a stiff mass, which is permeated throughout by zinc sulphate crystals and globules

of mercury. If the sulphate, however, be moist, only zinc sulphate crystals are to be added; care must, however, be taken that these occur in excess and are not dissolved after continued standing. The mercury must, in this case also, permeate the paste in little globules. It is advantageous to crush the zinc sulphate crystals before using, since the paste can then be better manipulated.

To set up the Cell. The containing glass vessel, represented in the accompanying figure, shall consist of two limbs closed at bottom and joined above to a common neck fitted with a ground glass stopper. The diameter of the limbs should be at least 2^{cms} and their length at least 3^{cms}. The neck should be not less than $1{\cdot}5^{cms}$ in diameter. At the bottom of each limb a platinum wire of about $0{\cdot}4^{mm}$ diameter is sealed through the glass.



To set up the cell, place in one limb pure mercury and in the other hot liquid amalgam, containing 90 parts mercury and 10 parts zinc. The platinum wires at the bottom must be completely covered by the mercury and the amalgam respectively. On the mercury, place a layer one cm. thick of the zinc and mercurous sulphate paste described in 5. Both this paste and the zinc amalgam must then be covered with a layer of the neutral zinc sulphate crystals one cm. thick. The whole vessel must then be filled with the saturated zinc sulphate solution, and the stopper inserted so that it shall just touch it, leaving, however, a small bubble to guard against breakage when the temperature rises.

Before finally inserting the glass stopper, it is to be brushed round its upper edge with a strong alcoholic solution of shellac and pressed firmly in place. (For details of filling the cell, See Note B.)

NOTES TO THE SPECIFICATIONS.

(A.) *The Mercurous Sulphate.* The treatment of the mercurous sulphate has for its object the removal of any mercuric sulphate which is often present as an impurity.

Mercuric sulphate decomposes in the presence of water into an acid and a basic sulphate. The latter is a yellow substance—turpeth mineral—practically insoluble in water; its presence, at any rate in moderate quantities, has no effect on the cell. If, however, it be formed, the acid sulphate is also formed. This is soluble in water and the acid produced affects the electromotive force. The object of the washings is to dissolve and remove this acid sulphate and for this purpose the three washings described in the specification will suffice in nearly all cases. If, however, much of the turpeth mineral be formed, it shows that there is a great deal of the acid sulphate present and it will then be wiser to obtain a fresh sample of mercurous sulphate, rather than to try by repeated washings to get rid of all the acid.

The free mercury helps in the process of removing the acid, for the acid mercuric sulphate attacks it, forming mercurous sulphate.

Pure mercurous sulphate, when quite free from acid, shows on repeated washing a faint yellow tinge, which is due to the formation of a basic mercurous salt distinct from the turpeth mineral, or basic mercuric sulphate. The appearance of this primrose yellow tint may be taken as an indication that all the acid has been removed; the washing may with advantage be continued until this tint appears.

(B.) *Filling the Cell.* After thoroughly cleaning and drying the glass vessel place it in a hot water bath. Then pass through the neck of the vessel a thin glass tube reaching to the bottom to serve for the introduction of the amalgam. This tube should be as large as the glass vessel will admit. It serves to protect the upper part of the cell from being soiled with the amalgam. To fill in the amalgam, a clean dropping tube about 10^{cms} long, drawn out to a fine point, should be used. Its lower end is brought under the surface of the amalgam heated in a porcelain dish, and some of the amalgam is drawn into the tube by means of the rubber bulb. The point is then quickly cleaned of dross with filter paper and is passed through the wider tube to the bottom and emptied by pressing the bulb. The point of the tube must be so fine that the amalgam will come out only on squeezing the bulb. This process is repeated until the limb contains the desired quantity of the amalgam. The vessel is then removed from the water bath. After cooling, the amalgam must adhere to the glass and must show a clean surface with a metallic lustre.

For insertion of the mercury, a dropping tube with a long stem will be found convenient. The paste may be poured in through a wide tube reaching nearly down to the mercury and having a funnel-shaped top. If the paste does not move down freely it may be pushed down with a small glass rod. The paste and the amalgam are then both covered with the zinc sulphate crystals before the concentrated zinc sulphate solution is poured in. This should be added through a small funnel, so as to leave the neck of the vessel clean and dry.

For convenience and security in handling, the cell may be mounted in a suitable case so as to be at all times open to inspection.

In using the cell, sudden variations of temperature should, as far as possible, be avoided, since the changes in electromotive force lag behind those of temperature.

II. GEOLOGY AND MINERALOGY.

1. *Change of level in the West Indian Region.*—Mr. C. T. STIMPSON has a paper on the Distribution of the land and freshwater Mollusks of the West Indian Region, and the evidence they afford with regard to past changes of land and sea. He concludes that all the evidence of the terrestrial and fluviatile molluscan fauna of this region indicates that in the early Tertiary period, perhaps, there was a general land elevation of the Greater Antilles, and possibly of some of the adjacent area; that Wallace's theory of a land connection of the greater islands is correct; that during some part of this time a landway extended across to the continent; that the species and groups of this then connected territory migrated to some extent from one part of it to another, and that a probable connection existed over the Bahama plateau to what was at that time no doubt the island of Florida.

Jamaica, by the evidence of its land snails, stands the most isolated of any of the islands; Cuba is the next most so, while those of Haiti and Puerto Rico are much more nearly related to each other than to those of either of the first two. About 20 genera and minor groups are confined to or have their metropolis in Jamaica; a like number belong to Cuba, 7 to Haiti, and 1 to Puerto Rico.

It bears directly on this subject, that the strait between Haiti and Jamaica is deeper than that between any of the other islands, being nearly 1,000 fathoms in depth; that the strait between Cuba and Haiti, is slightly more shallow, being only about 875 fathoms, while the one between the latter islands and Puerto Rico carries but 260 fathoms. Supposing these islands to have been united at a former time, then, during a period of gradual subsidence, Jamaica would be separated sometime before the rest of the Antillian island would be broken up; then Cuba would be isolated, while Haiti and Puerto Rico would remain united for a longer time. The distribution and character of the land-snail faunas of these islands agree exactly with just what would be the result of such a subsidence and separation.

2. *Glacial phenomena Northwest and West of Hudson Bay.*—Mr. J. B. Tyrrell, of the Canada Geological Survey, concludes, after an examination of the region on the northwest and west of Hudson Bay, and especially from the direction of the glacial scratches, that within a comparatively short distance of the northern portion of the bay, there was "one of the great gathering grounds for the snow of the Glacial period;" and that from the ice-plateau thus made, the movement of the ice was eastward, into the Hudson Bay depression, northward toward the Arctic Ocean, and a long distance westward toward the Mackenzie River. There was also a southward movement "toward the great plains. At this time Hudson Bay was probably to a great extent open water."

After the recession of the ice from the lower country, the land was about 400 feet below its present level. There are terraces at different heights about the lakes. Those of Aberdeen Lake have the heights 290, 220, 180, 150, 105, 90 and 60 feet above it. Similar terraces are found in favorable localities all along the shores of Hudson Bay.

3. *Faults of post-Glacial origin.*—In Bulletin XII of the Natural History Society of New Brunswick (p. 34) Dr. G. F. Matthew describes small faults observed by him over a considerable area in the ledges of slate near St. John. The relations of the faults to the glacial striæ indicates that they are post-Glacial. Their courses vary; but at St. John the greatest throws and the most frequent have a northeast to southwest course, and the more the joints depart from this course the less is the displacement; rarely any occur at right angles to it. The displacements observed are mostly between half an inch and ten inches. Dr. Matthews regards it as probable that the faulting is due to lateral pressure from the southeast.

4. *Pre-Cambrian Radiolarians.*—The paper of L. Cayeux, on Radiolarians in the pre-Cambrian rocks of Brittany (Bull. Soc. Géol. de France, 1894, p. 197) is accompanied by a plate giving figures of 45 of the forms observed. The figures appear to sustain fully the author's conclusion as to the Radiolarian character of the organisms. He describes them as having generally a distinct outer shell, which is pierced by pores. The age of the rocks is pronounced pre-Cambrian by Barrois. They are quartzites,

and compact siliceous slates or phthanite. In a section near Pléboule, the beds are represented by Barrois, as standing nearly vertical and as conformable with beds of argillyte, granulitic gneiss, hornblendic schist, and other rocks. Pebbles of the Radiolarian rock are found in the Cambrian conglomera of Montfort and Erquy and in pre-Cambrian conglomerates at the base of the "Phyllades de Saint Lo;" and from this the conclusion is drawn that the Radiolarian beds are at least pre-Cambrian.

5. *Geological Survey of Alabama:* 1894, Report on the Geology of the Coastal Plain of Alabama by E. A. SMITH, L. C. JOHNSON and D. W. LANGDON, Jr., with contributions to its Paleontology, by T. H. ALDRICH and K. M. CUNNINGHAM, with illustrations, pp. i–xxiv, 1–759, 1894.—The nucleus of the present report was published in 1887 as Bulletin No. 43 of the U. S. Geological Survey, but the present work contains considerable new matter and a revision ot the Bulletin in the light of later discoveries.

In the Tertiary part, upon the work of Mr. Johnson, the horizon of the "Grand Gulf" formation has been shown to be of Miocene age, and a new formation at its top, has been described and its age determined to be also Miocene, by Dr. Dall.

The "Tuscaloosa" formation which was described in the Bulletin No. 43, but then only doubtfully referred to some place in the Cretaceous, and since then referred to the lower Cretaceous,* is shown by its fossil plants, discovered in 1892 and identified by Dr. Ward, to be nearly equivalent to the Amboy clays (= Raritan group, Dakota Epoch), the lower member of the Upper Cretaceous. The specimens identified are of species described from the Amboy clays, Dakato group, and Cretaceous of Greenland.

The species of fossils described by Mr. Aldrich are from the (Midway) Clayton Tertiary, of the lowest beds of the Eocene.

H. S. W.

6. *Paleozoic Corallines.*—The first of Paleozoic Algæ of the group of Corallines has been described and figured by R. P. WHITFIELD in the Bulletin of the American Museum of Natural History, vol. vi, p. 351, 1894. He names the single species thns far discovered *Primicorallina trentonensis.*

7. *Lehrbuch der Petrographie* von Dr. FERDINAND ZIRKEL. Zweite gänzlich neu verfasste Auflage. Dritter Band. 833 pp. large 8vo. Leipzig (Wm. Engelmann).—The third volume of this exhaustive work appeared near the close of the past year. The earlier volumes have been already noticed in this Journal and the minute and at the same time comprehensive character of the whole has been dwelt upon. The opening part of this third volume discusses the rocks containing a lime-soda feldspar with nephelite or leucite; those with nephelite, leucite, or melilite without feldspar, and those containing no constituent corresponding to feldspar. The crystalline schists are then taken up, also the crystalline rocks of simple mineralogical character; then

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* Dana's Manual of Geology, 4th edition, 1895, p. 816.

follows the discussion of the clastic rocks, that is, the conglomerates, breccias and tuffs of rocks of different types; then the sandstones and sedimentary deposits and finally kaolin, clay, marl, etc. The index for all the three volumes, which closes the work, contains rock-names only and is so brief as to seriously impair the usefulness of the whole. The author is to be heartily congratulated in the completion of his work; the many workers in this department of science will not fail to estimate aright the value of his arduous labors.

8. *Chemical Contributions to the Geology of Canada from the laboratory of the Survey;* by G. CHRISTIAN HOFFMANN (Annual Report, vol. vi, 1892–93, Part R).—Mr. Hoffmann's report contains, besides analyses of fuels, assays of ores and other matters of economic bearing, also a number of points of mineralogical interest. Among these we note the identification of the following minerals, of several of which analyses are given: löllingite from Galway, Peterborough County, Quebec, containing nearly 3 per cent of cobalt and 0·8 per cent of nickel; strontianite from Nepean, Carleton County, Ontario, where it occurs in veins of some extent; also the same mineral from near the Horsefly river, Cariboo district, British Columbia; native iron in minute spherules occurring with the perthite of Cameron, Nipissing, Ontario; pyrargyrite from the Dardanelles claim near Bear Lake, West Kootanie, British Columbia; anglesite from the Wellington mine in the same region; calamine from the Skyline claim, near Ainsworth, West Kootanie; altaite from Liddle Creek, West Kootanie; arsenolite with native arsenic from Watson Creek, British Columbia; cinnabar, perhaps in a large deposit, near the mouth of Copper Creek, Kamloops Lakes, British Columbia.

9. *Meteoritenkunde;* von E. COHEN. Heft 1. Untersuchungsmethoden und Charakteristik der Gemengtheile, 340 pp. 8vo. Stuttgart, 1894 (E. Schweizerbart'sche Verlagshandlung — E. Koch).—This volume forms the first part of a comprehensive work on meteorites, which will be warmly welcomed by all interested in this subject. Such a work is much needed at the present time. In recent years, especially during the past two decades, the literature of the subject has increased remarkably, many investigations after the improved modern methods of research have been made of recent, as of earlier, falls, and the collation and digestion of this vast amount of new material have become a matter of the highest importance. This work obviously involves great labor and calls for the knowledge and experience which are possessed in a high degree by the author.

The present part, which is chiefly devoted to a description of the mineral constituents of meteorites, will be followed by others discussing the structure, external and internal, of meteorites, their classification and finally the phenomena of fall and the hypotheses advanced to explain their nature. The work on this mineralogical side of the subject has been performed with care and thoroughness and the completion of the whole will be looked for with interest.

III. BOTANY.

1. *Field, Forest and Garden Botany.* By ASA GRAY. Revised by L. H. BAILEY. Am. Book Co., N. Y. 1895. By the publication of the first edition of a popular treatise on our more common, wild and cultivated plants, Professor Gray met a want which had long been felt. The work was received with pleasure and used with profit by a great number of teachers and pupils throughout the country, and it has ever since held its own. But for some years it has been apparent that the treatise could be made more useful by additions and modifications. It was Professor Gray's intention to undertake this revision himself, but a great increase of care connected with the Synoptical Flora of North America, led him to defer the task, and the wished-for leisure never came. After the death of Professor Gray the revision was taken in hand by one of our energetic systematists and carried by him through a good part of the Polypetalæ. But certain reasons led him to the relinquishment of the work, and so the whole matter remained without change until it was taken up by Professor L. H. Bailey, of Cornell University.

It is apparent that the revision of a treatise constructed on the broad lines of the *Field, Forest and Garden Botany*, presents peculiar difficulties. Not only is it very hard to know what to add and what to leave out, but, at this time, when nomenclature is undergoing so many changes of one kind and another, it is almost impossible to preserve consistency throughout.

Professor Bailey has been successful in a high degree in meeting all these difficulties. Although he is inclined personally to favor one of the new systems of nomenclature, he has preserved in a remarkable manner the system which was preferred by Professor Gray. Moreover, the additions and omissions have been determined with excellent judgment, and have resulted in keeping the treatise on nearly the lines laid down by its author. A careful examination of these changes has convinced the present writer that the proportions have been well maintained throughout. Some species, which it would have been a pleasure to see in the revision, are lacking, and there are some species given which might perhaps have been well spared, but, as a whole, the selection is good, and the book is sure to be of great use to the mass of pupils and amateurs employing it. Professor Bailey is to be sincerely congratulated on his work. G. L. G.

2. *A Popular Treatise on the Physiology of Plants*, for the use of Gardeners or for Students of Horticulture and Agriculture, By Dr. PAUL SORAUER, Director of the Experimental Station at the Royal Pomological Institute, in Proskau (Silesia). Translated by F. E. WEISS, B.Sc. F.L.S., Professor of Botany at the Owens College, Manchester. London, Longmans, Green & Co., 1895. Some of our older readers will doubtless remember the valuable Theory of Horticulture, by Professor Lindley, which was introduced to American students in an edition revised and

annotated by Professor Asa Gray. In that work, which was then well up to date, the practice of the gardener was explained as far as might be, and a great amount of thoroughly digested material was placed at the disposal of all interested in cultivating plants. In comparing that work with the present, one is struck by the very slight change in practice which has been demanded by the vast advance in theoretical knowledge. The old rules, many of which were very plainly empirical, still hold, although their *raison d'être*, may be put in a different manner nowadays.

Professor Weiss has given us a clear, idiomatic translation, and with his work no fault can be found. But the original is of very uneven quality. In some places, as for instance, the treatment of manures, the whole might serve as an exercise for correction, but in others, for example, the subject of shoots and their management, all the statements are correct and telling. In the hands of a teacher, this volume can be made of great use in systematizing and coördinating the cardinal facts relative to the vegetative processes, and in applying them to the practical needs of the gardener. G. L. G.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Prize-Question pertaining to Physical Science proposed by the Schnyder von Wartensee Foundation for Arts and Sciences at Zurich.**—The Schnyder von Wartensee Foundation proposes, for the year 1897, the following prize-question concerning problems in the domain of physics.

As the numbers which express the atomic heats of the elements still show very considerable divergences, the researches conducted by Professor H. F. Weber on boron, silicon and carbon, regarding the increase of the specific heat with the temperature, are to be extended to several other elements prepared as pure as possible and also to combinations or alloys of them. Further the densities and the coefficients of thermal dilatation of the substances investigated are to be ascertained as carefully as possible.

The conditions are as follows:

(1.) The treatises handed in by competitors for the prize-question may be either in German, French or English and must be sent in by September 30th, 1897, at the latest to the address given in paragraph 6.

(2.) The examination of the treatises will be entrusted to a jury composed of the following gentlemen: Professors Pernet, Zurich, A. Hantzsch, Wurzburg, E. Dorn, Halle-on-the-Saale, T. Wislicenus, Leipzig; also G. Lunge, Zurich, as member of the committee proposing the prize-question.

(3.) The prize committee has at its disposition a sum of four thousand five hundred francs, of which a first prize, of no less

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* For an earlier announcement, for the year 1894, see this Journal, vol. xliii, 240.

than three thousand francs will be awarded and minor prizes for the remaining sum.

(4.) The work to which the first prize is awarded remains the property of the Schnyder von Wartensee Foundation, which has to arrange with the author regarding its publication.

(5.) Every treatise sent in must bear a motto on the title page and be accompanied by a sealed envelope, containing the author's name and bearing the same motto outside.

(6.) The treatises are to be sent into the following address, within the time named in paragraph 1. An das Pràsidium des Conventes der Stadtbibliothek in Zurich (concerning prize-question of the Schnyder von Wartensee Foundation, for the year 1897).

Zurich, 31st December, 1894.

By order of the City Library of Zurich. The Committee for the Schnyder von Wartensee Foundation.

2. *American Association for the Advancement of Science.*—A circular from F. W. Putnam, Permanent Secretary, dated Jan. 30, announces that at a special meeting of the Council, held on January 26th, it was decided to postpone the proposed meeting in San Francisco. An invitation from Springfield, Mass., to hold the meeting of 1895 in that city, was accepted. The date of the meeting was fixed as follows: Council meeting, Wednesday, August 28th, at noon; General Sessions, Thursday, August 29th, at 10 A. M. Special efforts will be made by the officers of the sections to prepare program for the sections in advance of the meeting and for this purpose members are requested to send abstracts of their papers, as early as possible, to the Permanent Secretary, or to the Secretaries of the Sections.

3. *International Zoological Congress.*—It is announced that the third meeting of the International Zoological Congress will be held at Leyden in September, 1895. The first meeting took place at Paris in 1889, and the second at Moscow in 1892. The arrangements for the reception and accommodation of the Congress at Leyden will be made by the Netherlands Zoological Society. The answers to invitations to be present and to coöperate are to be sent to Dr. P. P. C. Hoek, Secretary of the Society.

4. *A Manual of the Study of Documents* to establish the individual character of handwriting and to detect fraud and forgery including several new methods of research by PERSIFOR FRAZER. 218 pp. 8vo. Philadelphia, 1894 (J. B. Lippincott Company).—The subject of this volume does not strictly fall within the range of pure science, but Dr. Frazer has treated it with great thoroughness and it is interesting to note some of the methods of examination he has employed, as the application of composite photography to the study of signatures; the use of colored prisms to distinguish inks of different colors, and others.

5. *Smithsonian Geographical Tables* prepared by R. S. WOODWARD. Washington, 1894 (Smithsonian Miscellaneous Contributions, No. 854).—This volume is the second of the series planned

by Prof. S. P. Langley to take the place of the earlier Meteorological Tables of Dr. Arnold Guyot, the fourth and last edition of which was issued in 1884. The appearance in 1893 of the first volume of this new series, which is devoted to Meteorological Tables, was then announced in this Journal (vol. xlvi, 160); the third volume, still to come, is to include Physical Tables. The volume now issued contains 105 pages of introductory matter, giving useful formulas, discussion of mensuration, units, geodesy, astronomy, etc. Then follow forty-two tables, chiefly geographical in object, and finally the work closes with the Appendix giving the relations of units, prepared by the late Mr. G. E. Curtis for the earlier meteorological volume.

6. *French Academy of Sciences.*—The French Academy has recently conferred the Janssen prize upon Professor George E. Hale of the University of Chicago in recognition of his important discoveries in astrophysics.

Bulletin of the American Museum of Natural History, vol. vi, 384 pp. 8vo, with 10 plates, 1894.—This new volume of the American Museum Bulletin contains a paper by H. F. OSBORN and J. L. WORTMAN, On the Fossil Mammals of the Lower Miocene White River beds; two by J. L. WORTMAN, On the Affinities of *Leptaretus primus* of Leidy, and On *Patriofelis*, a Middle Eocene Creodont; several papers by J. A. ALLEN, On Mammals from New Brunswick, On Mammals of Arunsas Co., Texas, On Cranial variations in *Neotoma micropus*, On Chilonycteris rubiginosus of W. Mexico, and On fifteen new North American Mammals; two papers by F. M. CHAPMAN, On Birds of Trinidad, and On Mammals from Florida; three papers by W. BEUTENMÜLLER, On some N. A. Ægeriidæ, On some N. A. Orthopters, On N. A. Moths, and a Catalogue of Orthopters found within 50 m. of New York; and a paper by R. P. WHITFIELD on new forms of Algæ from the Trenton limestone.

OBITUARY.

DR. GEORGE A. REX.—Dr. Rex, of Philadelphia died suddenly on the fourth of February last. The following paragraphs are from the Proceedings of the Academy of Natural Sciences of Philadelphia, of which he was a member.

Dr. Rex was the highest authority on the Myxomycetes in the United States. It was his enthusiastic study of this group that first brought him to the Section, and his communications on this subject formed an interesting part of nearly every meeting. He was the author of numerous species, which, owing to his extreme conservatism, will doubtless continue to bear his name. Many forms, new to him, remained in his collection unnamed for years, and were only published when he had thoroughly convinced himself that they were really new to science.

Although he was interested principally in the Myxomycetes, he was an earnest student of the lower orders of Fungi and an ardent admirer of everything beautiful in microscopic nature.

Recent deaths abroad are the following: MARQUIS DE SAPORTA, the eminent botanist, at Aix; Professor HEINRICH WILD, of St. Petersburg, well known for his researches in magnetism and optics; Dr. ALFRED W. STELZNER, Professor of Geology at Freiberg, on February 25th.

WONDERFUL QUARTZ CRYSTALS FROM NORTH CAROLINA.

Mr. English has just visited a new locality in North Carolina and has obtained a startlingly fine collection of rare forms of Quartz crystals, including several showing the BASAL PLANE beyond question. The crystals are colorless to smoky and amethystine, and frequently exhibit the most beautiful etching we have ever seen. Good, movable water drops are also present in some of the crystals, while many of them are modified by the rarest of planes. Altogether this accession to our stock is the most interesting we have announced for a long time. Orders must be sent in immediately to secure an early pick.

SAMARSKITE.

We have just secured two shipments of choice specimens of this rare mineral, containing probably more and rarer earths than any other known mineral. Good-sized cabinet pieces 50 cts. to $2.00; small specimens, 10 cts. to 25 cts. Pure material for blowpipe analysis, $1.00 per lb. A few crystallized specimens $1.00 to $2.00.

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Heulandite, a few groups of mammoth crystals, two to four inches long and marvellously beautiful, $1.50 to $12.50. **Stilbite,** elegant clusters of well-defined sheaf-like crystals, $1.00 to $3.50. **Epistilbite,** extra good, $1.50 to $5.00. **Analcite,** attractive groups, $1.00 to $3.50.

RUSSIAN AND SIBERIAN MINERALS.

A shipment received about March 1st contained a splendid lot of little crystals of **Alexandrite,** which we can sell as low as $1.00 to $2.50; a few large crystals at $6.00, $12.50 and $25.00; a choice collection of highly modified **Golden Beryls** and *Aquamarines* at 50 cts. to $5.00, four good **Topaz** crystals at $7.50, $15.00 and $25.00. We still have several very fine specimens of **Dioptase** at $10.00, $17.50, $30.00 and $35.00 purchased by Mr. English during his recent European tour.

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The French Creek Mines are now closed, probably permanently, and we have, therefore, been buying up all the good specimens we could obtain. Several shipments have been received of the curious and interesting distorted cubes, cubes with rare modifications, etc. Notwithstanding their impending rarity we are selling them at lower prices than ever, 10c. to $1.50. No *Pyrites* of this character have been found elsewhere.

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Chas. D. Walcott,
U. S. Geol. Survey.

VOL. XLIX. MAY, 1895.

Established by **BENJAMIN SILLIMAN** in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

THIRD SERIES.

VOL. XLIX—[WHOLE NUMBER, CXLIX.]

No. 293.—MAY, 1895.

WITH TWO PLATES.

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1895.

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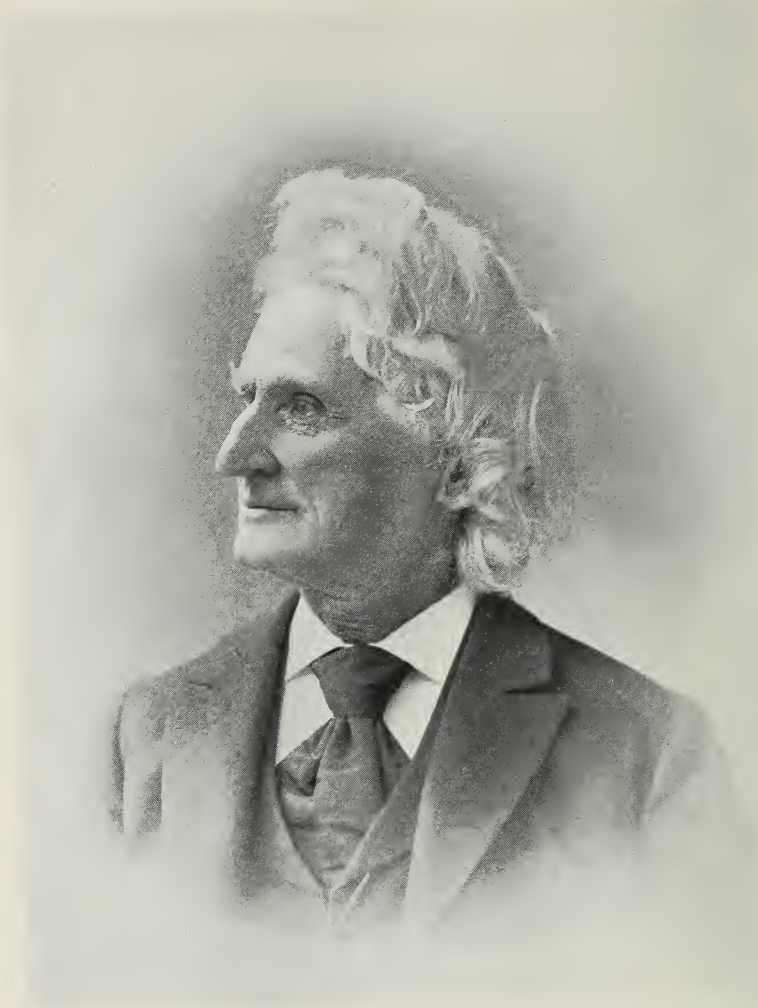

James W. Dana

Charles D. Walcott

JAMES DWIGHT DANA.

James Dwight Dana, Professor of Geology and Mineralogy in Yale College and for fifty years one of the editors of this Journal, died suddenly at his residence in New Haven, Connecticut, on the fourteenth of April, 1895, at the age of eighty-two years and two months.

He was born in Utica, New York, on the twelfth of February, 1813. His father, James Dana, was of New England birth, having moved to Utica from his parents' home in Massachusetts. He was a successful business man and died in 1860 at the age of eighty. His mother was Harriet Dwight, daughter of Seth Dwight of Williamsburgh, Massachusetts.

The strong inborn taste for science was shown in early years, and he was fond of relating his pleasant experiences at the Bartlett Academy in Utica, when, as a boy of twelve, he studied chemistry with his associates, sharing with them the responsibility of preparing the experiments and delivering to the others the formal lectures. At the same time, frequent excursions after minerals with his companions served to give a special direction to his scientific interests and thus helped to determine the department in which his first work was to be done when maturity had developed his powers. These excursions were led by Mr. Fay Edgerton, the excellent instructor in Natural Science, and extended to distant parts of the State and also to neighboring States; one excursion into Vermont was remembered with much delight.

To the opportunities afforded by the early training in science, that have been alluded to, and to the interest it excited, Professor Dana ascribed much of the success that he afterwards attained. One of his schoolmates, closely associated with him in the Bartlett Academy, was S. Wells Williams, for many years missionary in China and in his later life again a colleague among the corps of instructors at New Haven. A number of others, who subsequently rose to prominence, were among those who shared the inspiration of Mr. Edgerton's instruction. It is also of interest that Dr. Asa Gray, a close friend from early days, took Mr. Edgerton's place in the school in 1831.

In 1830, attracted by the name and reputation of Professor Silliman, he came to New Haven and entered the class of 1833 of Yale College, then in its Sophomore year. He was a faithful student, but those were days of a rigid course of study, chiefly in the classics, affording little to appeal to a mind with a strong bent for the methods and facts of science. It is not surprising, therefore, that though obtaining a good place on the honor list he did not make a brilliant record for general scholarship. He was, moreover, at a disadvantage because of insufficient training in the ancient languages, felt especially by one entering after the close of the first year of the course. It should be stated, however, that during his undergraduate life, he attained distinction in mathematics, a subject for which he always had decided aptitude. During this time he made much progress in science, especially in his favorite study of Mineralogy. In Botany also he took great interest; during his College life he made a large collection of the plants of the New Haven region, and a printed list of the local flora, carefully checked and annotated by him, is still preserved.

For music he had throughout his life a strong love, and when in College he devoted much attention to it, being on one occasion president of the Beethoven singing society, and for a time the leader of the college choir. He also made some attempts at musical composition. One of these was the music for an ode to the Ship "Peacock" of the Exploring Expedition (see p. 332), written by the Surgeon, Dr. J. C. Palmer; both gentlemen found a source of recreation and pleasure in their joint musical and poetical work during the voyage. It is interesting to note that many years later when upwards of seventy and unable because of ill health to write, he came back to his music and derived much comfort from working at it.

The influence of the elder Silliman, then at the height of his powers and reputation, did much to decide him to devote himself permanently to science, as will be seen in the events that followed. It is a point of interest also, as proving how deep his natural love of science was, that from home he obtained no encouragement whatever in turning his studies in this direction; indeed, from the time of graduation he assumed the entire burden of his own support. To his father's practical mind scientific pursuits did not commend themselves, but it should be stated that he lived to take a cordial interest and pride in his son's success.

Mr. Dana left New Haven in August, 1833, somewhat in advance of graduation, to avail himself of the opportunity offered of a cruise in the Mediterranean, as instructor in mathematics to the midshipmen of the United States Navy. In this capacity he visited a number of the seaports of France, Italy, Greece and Turkey, while on the "Delaware" and the "United States." This trip, lasting about fifteen months, brought much pleasure and profit. He was cut off for a time from his favorite minerals, but he occupied his leisure hours on shipboard with working out, by methods of his own, many of the more intricate problems of mathematical crystallography. Some notes of the voyage also mention the fact that he was interested in the study of the geology of the island of Minorca and that he made some collections in Natural History while there. It will be observed that the first paper recorded in the Bibliography, which follows this notice, is an account of the condition of Vesuvius in July, 1834, at the time of his visit; this was published in this Journal in 1835.

In 1836, Mr. Dana returned to New Haven and for two years remained there, occupied for more than a year as assistant in Chemistry to Professor Silliman. It was during this period that he published his first important contribution to Science,—the System of Mineralogy, a volume of 580 pages. This was in May, 1837, hardly four years after his graduation from College and when a young man of twenty-four; notwithstanding his youth, the work is that of a thoroughly mature and well informed scholar. A little earlier (1835) his notes mention the fact that he had constructed a set of crystallographic models in glass, probably the first time this had been attempted.

While at New Haven, another opportunity came to him for travel and observation, this time as Mineralogist and Geologist to the Exploring Expedition then about to be sent by the government of the United States to the Southern and Pacific oceans under the command of Commodore Charles Wilkes. The invitation, when first received in 1836, was refused, but on the urgent solicitation of Dr. Asa Gray, then expecting to go as Botanist, the decision was reconsidered and finally the position accepted. He was disappointed in failing to have the companionship promised, but subsequent events brought the two men closely together and Dr. Gray remained an intimate personal friend and highly valued scientific associate until his death in 1888.

The expedition, consisting of five ships, sailed in August, 1838, and Mr. Dana was connected with it until June, 1842. The route was briefly as follows. First to Madeira, then to Rio Janeiro, down the coast and through the Straits of Magellan, after passing which, while on board the "Relief" he nearly suffered shipwreck off Noir island, the ship remaining three days and nights in extreme peril; in the same storm one of the smaller accompanying vessels was lost. Then to Chili, Peru and across to the Paumotus, to Tahiti and the Navigator islands; then to New South Wales, where the naturalists remained while Commodore Wilkes went into the Antarctic; then to New Zealand, the Fiji islands, where two of the officers were murdered by the natives; to the Sandwich islands, the Kingsmill Group, the Caroline islands and thence north to the coast of Oregon. Here, near the mouth of the Columbia river, the "Peacock," the ship to which he had been assigned, was wrecked; entailing the loss of all his personal effects as well as many of his collections. He was, then, one of the party that crossed the mountains near Mt. Shasta and made their way down the Sacramento river to San Francisco. In his report of the expedition he states that the geological features indicated the probable presence of gold. This was six years before the discovery of gold in California, and rich mines have since been discovered in the region the party went over. At San Francisco the party were taken aboard the "Vincennes" and the homeward journey was made by way of the Sandwich islands, Singapore, the Cape of Good Hope and St. Helena. The arrival in New York was on June 10, 1842.

The opportunities of this long journey to many of the most interesting points in the world were such as have been offered to few young men of his years and could never come again. The stimulus of the multitude of new facts to observe and of new forms of life to collect and study was extraordinary, and the effect of these four years upon the attainments of his subsequent life was profound. Of the beauties of the life in the sea about the coral islands and of that of the tropics in general he never tired of speaking; his lecture on "Coral Islands" delivered in later years to many generations of college students, contained a vivid description of the scenes he enjoyed so much.*

It is interesting to note here, that a few years before the American expedition was in the Pacific, the British ship "Beagle," having the naturalist Darwin on board, had sailed through much of the same region. The theory explaining the formation of the coral atoll by gradual subsidence, first advanced by Darwin (1842), was also independently worked out to a large extent by the American naturalist.† The latter showed, moreover, that the reef-building corals lived only in water of at least 68 degrees Fahrenheit, which proved that the distribution of corals depended on the temperature of the water.

As already stated, Mr. Dana was first appointed in the field of Geology, and his observations and deductions are given in a large quarto volume of 756 pages with a folio atlas of 21 plates (1849). Later, however, in part because of the return of one of his colleagues to the United States, he assumed charge also of the Crustacea and Zoöphytes. These combined departments gave full scope to his zeal and industry. The results of his work in this department of Zoölogy include a *Report on Zoöphytes*, a quarto volume of 741 pages, with a folio atlas of 61 plates (1846); also a *Report on Crustacea*, in two quarto volumes aggregating 1620 pages (1853) and accompanied by a folio atlas of 96 plates (1854). These three reports will be more particularly spoken of later, but it may be mentioned here that a large part of the drawings of the plates in both works were made by his own hand.

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* This subject is presented in somewhat popular form in the work entitled "Corals and Coral Islands," first published in 1872.

† A brief discussion of this theory is given on a later page of this number (p. 426); it was one of the last subjects on which he wrote.

In June, 1842, Mr. Dana returned to the United States and for the next thirteen years devoted his chief energies to the study of the material collected on the expedition and to the preparation of the reports mentioned. His labors, however, were not limited to this field, for during the same period, he prepared and issued three editions of the System of Mineralogy (1844, 1850, 1854) and two editions of the Manual of Mineralogy (1848, 1857), besides writing numerous papers for this and other scientific periodicals.

From 1842 to 1844, he resided in Washington, and later in New Haven. On June 5, 1844, he married Miss Henrietta Frances, third daughter of Professor Benjamin Silliman, whose assistant he had been in 1836–37, and with whom he was from this time closely associated in scientific work.

The labor on the material from the Exploring Expedition was carried forward with the enthusiastic zeal of an earnest student with a new world open before him, and who was but little restrained by the thought that injury to health was possible. How severe and intense the labor of this period was will be evident from the fact that a few years after the last Report was published, Mr. Dana's health broke down, and so completely that though he lived thirty-five years after this and accomplished a wonderful amount of scientific work, life was from this time ever a struggle and, not always with success, against physical disability.

In 1846, Mr. Dana was made an editor of this Journal, associated with Professor Benjamin Silliman, who had founded it twenty-eight years before, and with his son, Professor Benjamin Silliman, Jr. His labors in connection with the Journal continued until the close of his life.

In 1850, Mr. Dana was appointed Professor of Natural History in Yale College, and in 1864 the title was changed to that of Professor of Geology and Mineralogy. His duties as instructor, however, he did not take up until 1855, but, after this date, with some interruptions due to ill health, as more particularly noted later, his active connection with the college continued until 1890. It is perhaps interesting to add that just before his appointment to Yale in 1850, he had been invited to a similar position at Cambridge, Massachusetts, in connection with Harvard College, but by the prompt action of a generous friend in the Yale Faculty in providing the necessary funds, he was induced to remain in New Haven on the "Silliman Professorship." This gentleman, who is still living, remained throughout the life of Mr. Dana one of his closest friends.

In 1859, as already noted, long continued over-work brought a break-down of a serious character and from which he never fully recovered. The nervous prostration was very complete at first, and even a period of nearly a year abroad, from Oct. 1859 to August 1860, seemed to have little result in the way of restoration. Although later some degree of health gradually came back, he was always subject to the severest limitations until the end of his life. Only those immediately associated with him could appreciate the inexorable character of these limitations and the self-denial that was involved not only in restricting work and mental effort, but also in avoiding intercourse with other men of science and friends in general, in which he always found the greatest pleasure.

Little by little the power for work was restored and by husbanding his strength so much was accomplished that, besides other writing, he was able to bring out in 1862 the first edition of his Manual of Geology, and in 1864 the Text Book of Geology, and four years later his last and most important contribution to Mineralogy, the fifth edition of the System.

This last great labor, extending over four years, was followed by a turn of ill health of an alarming character and from which restoration was again very slow. The years that immediately followed were filled with the same quiet labor, on geological investigations in the field, the writing of original papers and books, the editorial work of this Journal, and his duties as a college instructor. They were remarkably productive years, notwithstanding the difficulties contended against, notably renewed illness in 1874 and 1880, as will be seen by reference to the Bibliography. A large number of important papers were published, chiefly in this Journal: new editions of the Manual of Geology were issued in 1874 and 1880; of the Text Book in 1874 and 1883; while a new geological volume called "The Geological Story briefly told," was issued in 1875 and one on "Corals and Coral Islands" in 1872.

The years from 1887 to 1890 include the time when he most nearly threw off the limitations of ill health. In the summer of 1887, accompanied by his wife and youngest daughter, he revisited the Sandwich Islands, the acquaintance of which he first made in 1840, when on the Exploring Expedition. This was, indeed, the first long journey made except that to Europe in search of health in the years of 1859–60, since the expedition returned in 1842. He was led to make this journey* because of the interest aroused in discussing the phenomena connected with the eruption of the volcano of Kilauea on the island of Hawaii. The journey brought the keenest pleasure, not only that due to revisiting the Sandwich Islands themselves but also that of making the acquaintance of a number of interesting places in the western United States. Although travel had ordinarily been too severe a tax since his health gave out, this journey of ten weeks extending over ten thousand miles, proved of profit, and every incident was entered into with the enthusiasm of a mind which years could not make old. A number of papers upon the Hawaiian volcanoes were the result of this summer's outing, and in the winter of 1889–90, he prepared a volume on Volcanoes, a companion to that on Corals and Coral Islands, a new edition of which was issued at the same time. The prefaces of both works were dated on his seventy-eighth birthday, February 12, 1890.

In the summer of 1889, he attended the meeting of the American Association at Toronto, the first time he had been present at such a meeting since he delivered the presidential address more than thirty years before.

With the autumn of 1890 came a more serious illness than any since 1859, and the indications seemed very alarming. For a number of months absolutely no work was done, and later only a little light labor by means of dictation. It was at this time that the small volume on the New Haven region entitled "The Four Rocks," was given to the public. This disability was again partially thrown off—although he never again resumed active College duty—and the work on the fourth edition of the Manual of Geology, then far advanced, was resumed slowly at first and then with more vigor with returning

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* See this Journal, vol. xxxiv, 349, Nov. 1887.

strength. From this time, however, till the end he seldom exceeded a limit of three hours labor each day.

In February, 1893, the printers began their work on the volume mentioned and it was just two years before the last proof had been read and the volume was complete. To himself and still more to those about him it seemed many times as if the completion of this great work would have to be left to others, but with the self-control born of a strong will and long experience, and with the never failing watchful care of his life-long companion—without which his labors could never have been so productive nor have been continued so long—he worked on slowly, doing each day only what he had strength for, and, finally, the labor was accomplished. The completion of this work, which was rewritten and rearranged from beginning to end, involving a critical consideration of the many new facts and theories of the science, will be granted to have been a remarkable performance for a man of eighty-two. He finished it in February, 1895, and a month later he had completed the manuscript of a new edition of his Geological Story and then commenced work on that of the Text Book.

On Saturday, April 13th, he took his usual excursion to the Post Office, and through the day was as bright and vigorous of mind as ever. That evening there was a recurrence of a slight trouble in the action of the heart, of which there had been some manifestations in the few months immediately preceding; the following day he did not rise, although feeling relieved; in the evening the trouble returned and after a very brief period of unconsciousness, he passed quietly away.

The concluding years were marked by an ever increasing serenity, and happiness in his work and in the friends about him. Up to the last day there was no evidence of diminished mental force, though his physical strength was somewhat impaired. It was for him a most happy ending of a life, full of fruitful activity and honor.

The chief scientific results of this long life of continued and, except for its limitations, ever happy labor for science have been already indicated. To estimate properly their value and originality belongs to another place and time and demands the services of specialists in each of the three departments of Mineralogy, Geology and Zoölogy. Some further general words in regard to them seem, however, to be required.

The subject, to which he was earliest attracted, from the time of his first excursions, as a boy, after minerals, and that with which his name is, perhaps, most frequently connected is Mineralogy. The first edition of the System of Mineralogy was issued, as has been stated, in 1837, when he was only twenty-four years old. This large volume shows a close study of the great works of Häuy, Mohs and Naumann and of others who had preceded. It is, however, more than an industrious compilation from earlier authors, particularly as regards the chapters on crystallogeny and mathematical crystallography. The classification adopted is the so-called Natural System, the serious shortcomings of which were later fully appreciated. The nomenclature attempted, devised by him to suit this classification, was on the dual Latin plan "so advantageously pursued in Botany and Zoölogy." The second edition of the System (1844) preserved these features, but in a supplement, a classification based on chemical principles is proposed and this, further developed, is adopted in the third edition (1850) while the Latin nomenclature is abandoned.

In connection with this fundamental change, it seems worth while to quote from the preface of this edition, since what is said here was so characteristic of the author's attitude of mind to scientific truth in general.

> . . . To change is always seeming fickleness. But not to change with the advance of science, is worse; it is persistence in error; and, therefore, notwithstanding the former adoption of what has been called the Natural History system and the pledge to its support given by the author, in supplying it with a Latin nomenclature, the whole system, its classes, orders, genera and Latin names have been rejected. . . .

It was in the fourth edition of the Mineralogy, in 1854, that the chemical classification, essentially as now understood, takes its full place. In this edition, moreover, the other parts of the work were put in new and better form, containing the result of much thought on crystallogeny and homœomorphism. The fifth edition (1868), which includes only the description of species, is a monumental work—the most complete treatise, indeed, that had ever been attempted. In it the classification was still further developed, the nomenclature simplified and systematized, and in connection with the latter subject an exhaustive review of the entire mineralogical literature from the beginning was made in order to unravel the vexed questions of the history and priority of mineral names. This last feature of the volume was a labor involving great patience and skill. It was in recognition of this work that he received the degree of Doctor of Philosophy from the University of Munich in 1870. In the sixth edition of the System (1892), by his son, he took a lively interest, but was unable to coöperate in the labor actively, in consequence of the condition of his health; even the reading of the final proofs, though attempted, had to be soon given up.

Besides the System, he also issued a small work, called the Manual of Mineralogy, which has passed through four editions (1848, 1857, 1878, 1887). The pages of this Journal also contain, particularly down to 1868, many papers on mineralogical topics; his last paper in this field was published in 1874. The subjects that interested him were, for the most part, those of a general and philosophical nature, such as questions of classification, theories of crystallogeny, and the morphological relations of species. In the points connected with the descriptions of individual species he took less interest, though his observations here were numerous and important.

Mineralogy, however, did not afford scope enough for a mind so active, indeed he often spoke of it as a department of limited ideas and principles. To the broader field of Geology and geological investigation, he had been early turned by his labors for the Exploring Expedition, the results of which have been already mentioned.

The several editions of the Manual of Geology (1862, 1874, 1880, 1895) have been briefly alluded to. To the many geologists familiar with this work, it is unnecessary to remark that, like the System of Mineralogy, it is not simply a compilation of the facts of the science but a development of the whole subject with a breadth, philosophy and originality of treatment that has seldom been attempted. One of his colleagues remarks:

"The treatment of strata and fossils from a chronological point of view as Historical Geology is a characteristic feature of his Manual. The growth and development of the earth, its continents and seas and the progress in the organic life on its surface, were thus unified into a special department of Geology, the history of the earth and of its inhabitants, which was by other authors dealt with as formational, stratigraphic or paleontologic geology."

Each edition of the Geology was carefully worked over and the last was completely rewritten from beginning to end. It was a great pleasure to him in connection with this work to have the constant and ready coöperation of a number of the able young geologists in the country, without whose aid the volume could not have been so satisfactorily completed. Similar coöperation and pleasant relations he had enjoyed while at work upon his earlier volumes both in Geology and Mineralogy, but this is hardly the place to speak of that in detail. Allusion has also been made to the smaller works, the Text Book (first edition, 1864,) and the Geological Story (1875); of the last the manuscript of a new edition is now in the printers' hands.

In the general department of Geology his contributions again were largely to subjects of a broad and philosophical character: the origin of continents and of the grand features of the earth was discussed in early papers as well as later; the problems of mountain-making and the phenomena of volcanic action, to which he devoted much thought, are some of the other topics treated at length.

But, as a geologist, he was not only a thinker and writer in his study but also an active observer in the field. This remark applies obviously to the four years with the Exploring Expedition but further particularly to the period from 1872 to 1887, when he was carrying on the study of the crystalline rocks of the so-called Taconic system chiefly in western New England; also of the glacial phenomena of southern New England (1870 *et seq.*) The region included in western Connecticut and Massachusetts, and extending westward into New York and north to Vermont, was tramped and driven over many times, until one might almost say that there was hardly an outcrop accessible to any of the roads in this difficult region that had not been visited, its rocks examined and observations recorded on the dip and strike. These results and the conclusions derived from them fill many pages of this Journal. Against the dictum that all crystalline rocks, not volcanic, must be of pre-Paleozoic age, he rebelled strongly as against all similar dogmatic treatment of scientific facts and principles. His strength of feeling on this point was what largely prompted him to spend so much time and strength in this investigation.

He was no less interested in the country immediately about New Haven, especially as regards its glacial phenomena. In 1870, he published a large memoir on the Geology of the New Haven region. The observations, recorded in this paper, were made at a time when work at his table was impossible and the open-air exercise brought profit to health as well as scientific results. Twenty years later, when again incapacitated from writing and close thinking, he issued a small volume entitled "The Four Rocks of the New Haven region" describing some of the chief features of the region in popular form.

Thus far only his labors in Mineralogy and Geology have been spoken of in particular, and probably most of the younger generation of workers in science know him only in these fields. But his most extensive original contributions to science were in the department of Zoölogy, to which he made early contributions although chiefly attracted to it by the chance opening when on the Wilkes Expedition. The large volume devoted to the Zoöphytes, and the two volumes of the Crustacea, each work with an atlas of beautiful plates most of them drawn by himself, are classical works containing the descriptions of hundreds* of new species and with a philosophical development of the classification and the relations of species that is truly

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* The number of new species of zoophytes described was over two hundred; in the Report on Crustacea six hundred and eighty species were described, of which upwards of five hundred were new. A large part of the collections in Crustacea were lost by the wreck of the Peacock on the shores of Oregon. It may, perhaps, be worth recalling that many of the type specimens were later de-

profound. It is in this matter of the classification that the most important contribution to Zoölogy was made. This is true in general of both the works, and though the last half century that has elapsed has brought some slight changes to the classification of the Crustacea here developed, that of the Corals stands to-day nearly as it was given in the Expedition Report.

The volume upon the Zoöphytes is what would be called to-day a report on the Anthozoa, including the description of the corals and coral-making animals and of allied forms, of sea-anemones and including also a few hydroids. The value of the work is much increased by the fact that it was the first time that any considerable number of the coral animals had been described and figured from life; the original colored drawings were made by Mr. Dana from the living animals, as described in the quotation below, taken from the preface. The beautiful drawings of the sea-anemones, it should be stated, were made by the artist of the Expedition, Mr. Drayton. The volume thus marked a new era in the subject, since collections had hitherto been limited for the most part to the corals themselves.

> . . . . . The field for geological investigation there offered [the Fiji islands], was limited, as we were shut out from the interior of the islands by the character of the natives: at the same time coral reefs spread out an inviting field for observation, hundreds of square miles in extent. The three months, therefore, of our stay in that group were principally devoted to exploring the groves of the ocean, where flowers bloomed no less beautiful than those of the forbidden lands, and rocks of coral growth afforded instruction of deep interest. The specimens were obtained by wading over the reefs at low tide, with one or more buckets at hand to receive the gathered clumps, or where too deep for this, by floating slowly along in a canoe with two or three natives, and through the clear waters, pointing out any desired coral to one of them, who would glide to the bottom, and soon return with his hands loaded, lay down his treasures, and prepare for another descent. When taken

stroyed by fire in Chicago, while the copies of the published work suffered three times most seriously in the same way. The first time was during its publication at Philadelphia and resulted in the loss of many of the original colored drawings, to the permanent injury of the work, since they could not be replaced. The two other fires were at New Haven, the last one (1894) largely destroyed the residue of the plates when being collated by the binder preparatory to their being presented to some friends of the author.

> out of its element, the coral often appears as if lifeless: but placing it in a basin of sea-water, the polyps after a while expand, and cover the branches like flowers. Four-fifths of the observations in this department were made at the Feejee Group. . . . . .

The work accomplished on the expedition is the more remarkable, because there was from the first but little sympathy between the prominent naval officers and the active members of the scientific corps. This lack of coöperation resulted in the throwing of many obstacles—sometimes petty and provoking, again very serious—in the way of the young and ardent observer, and it is only fair to him to allude to this subject here, though it was one of which he was by no means fond of speaking. There is a painful contrast between the course of events in these particulars with the Wilkes expedition and the cordial aid given to science in some of the later ones.

Many papers upon zoölogical subjects were published in this and other Journals, especially during the time he was working up the collections of the Exploring Expedition, and these present many of the results and conclusions arrived at. The principle of Cephalization, or the domination of the brain in determining the development of an animal organism, was first brought out in 1852.* In regard to this subject, particularly in its relation to evolution, he says in the Manual of Geology (1895, p. 439):

> This subject has much interest in connection with the successional lines in the animal life of the globe which geology has brought to light. But the preceding remarks are not to be understood as intimating anything with regard to the origin of species. There was no such reference in the author's first presentation of the views in 1852. At that time the idea of evolution by natural causes had scarcely an advocate; for Darwin's work did not appear until 1859. Neither are the facts now to be regarded as adding to the causes of derivation. This much, however, may be learned from them:—
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> 1. Whatever the natural causes or methods concerned in evolution, organic conditions have determined lines, limits, and parallel relations, in accordance with the principle of cephalization.

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* In the Report on Crustacea; in 1863 the subject was discussed in this Journal.

2. In the evolution of the animal kingdom a "tendency upward" is a necessary consequence of the presence of a cephalic nervous ganglion or brain.

The theory of evolution, or the development of species, was one, as indicated above, that his mind approached slowly. He started, like most others, with the belief in the special creation of species; at the same time, his mind even at this period was opening out to a broader idea of the relation of species to each other. This is hinted at in the closing sentences of the following paragraphs quoted from a chapter on the geographical distribution of Crustacea.*

> . . . . . Although we cannot admit that circumstances and physical forces have ever created a species (as like can only beget like and physical force must result simply in physical force) and while we see in all nature the free act of the Divine Being, we may still believe the connexion between the calling into existence of a species and the physical circumstances surrounding it to be as intimate nearly as cause and effect."

In 1857 again, in a paper upon Species, published in this Journal (vol. xxiv), he says, (p. 307, the italics are his):

> A species among living beings, then, as well as inorganic, is based on *a specific amount or condition of concentered force defined in the act or law of creation.*

On a later page, he again speaks of a species as "essentially permanent or indestructible."

He always maintained, however, that the true scientific spirit was to keep the mind open to the reception of new truth, even if this was at first opposed to preconceived notions. This principle he had exemplified in regard to a subject of limited bearings by the change of view on mineralogical classification, as is well shown by the quotation from the preface to his Mineralogy given on a preceding page. And now in relation to this, perhaps the broadest generalization in science, he was true to this principle again. For gradually, by steps that it would be interesting to trace, he came to accept very fully the principle of evolution as a fundamental law,

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* Report on Crustacea; also this Journal, vol. xx, 358, 1854.

although it should be said that Darwinism in the narrow sense never seemed to him a sufficient explanation of the origin of species. To attempt to explain his views in full would be inappropriate in this place, but by quoting a few sentences from the closing chapter of the last edition of his Manual (1895), the main points in the position finally reached may be shown.

> . . . . The principles above stated are all in accord with a theory of evolution and through the added facts of later years, they favor the view of *evolution by natural variation.*
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> . . . . It is perceived that the law of nature here exemplified is *not* "like produces like," but like *with an increment* or some addition to the variation. Consequently, the law of nature, as regards kingdoms of life, is not permanence but change, evolution. . . . . The survival of the fittest is a fact; and the fact accounts in part for the *geographical distribution* of the races of men now existing and still in progress; but not for the *existence* of the fittest, or for the power that has determined survival. . . . . But the origin of the variation is without explanation. And so it is for the most part throughout the kingdoms of life. Enough is known to encourage study.

And finally, the closing paragraph of the work is as follows:

> Whatever the results of further search, we may feel assured, in accord with Wallace, who shares with Darwin in the authorship of the theory of Natural Selection, that, the intervention of a Power above Nature was at the basis of man's development. Believing that nature exists through the will and ever-acting power of the Divine Being, and that all its great truths, its beauties, its harmonies, are manifestations of His wisdom and power, or, in the words nearly of Wallace, that the whole Universe is not merely dependent on, but actually is, the Will of one Supreme Intelligence, Nature, with man as its culminant species, is no longer a mystery.

These are the words of the Christian Philosopher, with a rarely comprehensive grasp, and with whom the faith of his youth only grew stronger as his insight became deeper into Nature's laws.

As an editor of this Journal, Professor Dana was associated first with the two Sillimans (1846 to 1863), later with Benjamin Silliman, Jr. alone (1863 to 1875) and finally with his son Edward Salisbury, from 1875. The elder Silliman died in 1864 and the younger Silliman in 1885. The editorial labors were carried on almost continuously from 1850 to the end of his life. Ill health interrupted this work less than that involving severer and more consecutive thought. The closing pages of the present number contain several notices prepared by him within the past few weeks.

In connection with this labor, he did a vast amount of writing, including, besides original papers, hundreds of abstracts, critical reviews, obituary notices, and notes on many topics. These are far too numerous to find place in the Bibliography here given. He threw into this editorial work much of his best energy and always felt that he was serving science well in this way. No degree of pains was too great to ensure completeness and accuracy, and if an outsider might have thought that he insisted too strongly upon some rule of punctuation or spelling, it would have been from the failure to understand a mind which could be satisfied only with the highest degree of accuracy and excellence attainable. A piece of manuscript written for the Journal, like that of his books, was corrected and amended again and again, and the process of erasure and insertion of new words and paragraphs went on up to the moment of its passing into the printers' hands; the result was often trying to the compositor notwithstanding the clearness of the hand-writing.

As a College Instructor his labors commenced in 1855 and, except as interrupted by ill health, as has been explained, continued until 1890; in 1892 he formally retired and, in 1894, was made *Professor Emeritus.* He gave instruction at first in Mineralogy and Geology, but afterward in Geology alone, with occasional courses of lectures, as on Evolution and Cosmogony. The subject of Geology did not occupy a large place in the curriculum and consequently the number of exercises per week was not large. This, as he appreciated fully, was a great gain to him personally, so far as original writing was concerned, for it not only gave him much of his time for his own work but during seasons of ill health made the strain as light as possible. It had the accompanying disadvantage, however, that it did not bring him so near to the successive classes of young men as would otherwise have been the case. His personality, however, was so strong, his interest in the subject he was teaching so profound, his patience in explanation so untiring, that few of his many pupils could have failed to carry away a lasting impression of him, if not always of his subject. His relations with the students, always friendly, were made more close by the excursions to the various points of interest about New Haven and its vicinity, which he enjoyed himself quite as much as the boys and in much the same youthful spirit. These excursions were generally largely attended, and by many whose tastes did not lead to science; not a few of them will remember the earnest manner of the genial Professor in his out-door lectures and the quick step with which he led them up and down the hills, faster perhaps, in some cases, then they would have chosen to go.

In the deliberations of the College Faculty, he was always in favor of progress and especially interested in any step leading to the development of science. He was active in the building up of the University collections in Mineralogy and Geology, not only in the early years but also later as a Trustee of the fund given to the University by Mr. George Peabody in 1866 for a Museum of Natural History. The construction of the building erected in 1876, as regards internal arrangements, was largely determined by plans made by him. He also coöperated cordially in the establishment of the Scientific department of Yale University, known as the Sheffield Scientific School, and always took a sincere pleasure in its progress. The profound results of his influence, particularly in encouraging his younger scientific colleagues, can hardly be overestimated.

Of his habits of work, the constant activity of his mind, and of many personal characteristics, aside from those already hinted at, much might be said; but of these points it is more appropriate that others than the writer should speak, as also of the wonderful powers of generalization of one, who was a master of three sciences and at the same time had a profoundly comprehensive view of nature as a whole. Of his unquestioning religious faith, too, this is not the place to speak

Of the honors which fall to the successful worker in science, Professor Dana received a large number, but his mind was too free from pride or ostentation to dwell upon them. It would be most in accordance with his habit to omit any detailed statement here, but this account would then lack completeness.

In 1872 the Geological Society of London conferred on him the Wollaston medal, "in acknowledgement of his services to Mineralogy and Geology." In 1877 he received the Copley gold medal from the Royal Society of London, "for his Biological, Geological and Mineralogical investigations, carried on through half a century, and for the valuable works in which his conclusions and discoveries have been published." In 1892 the Boston Society of Natural History conferred upon him their "Grand Walker prize of $1000 for distinguished services in Natural History."

Professor Dana was elected president of the American Association for the Advancement of Science in 1854 and in August of the following year delivered his retiring address at the Providence meeting. In 1872 on the celebration of the fourth centennial of the University of Munich, he received the degree of Ph.D. and in 1886 at the Harvard celebration the degree of LL.D., was conferred upon him. The latter degree had been earlier given by Amherst College in 1853 and was also received from the University of Edinburgh in 1886. He was one of the original members of the National Academy of Sciences in the United States, and since the time when he was made correspondent of the Academy of Natural Sciences in Philadelphia in 1836, such honors were frequently conferred upon him, until he became thus connected with a large number of the scientific societies in the United States and abroad, including the Royal Society of London, the Institute of France, the Royal Academies of Berlin, Vienna and St. Petersburg and many others.

Professor Dana leaves a widow, four children, and four grandchildren.

The photograph from which the accompanying plate was made was taken about six weeks before his death.

E. S. D.

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Art. XXVIII.—*On the Color Relations of Atoms, Ions and Molecules;* by M. Carey Lea. Part I. (With Plate IV.)

The atoms of which elements are composed differ remarkably in color from the elements themselves; their colors are more important and more characteristic than those of the elements, and if we divide the entire series of elements into two classes, those whose atoms are always colorless whatever may be their valency, and those whose atoms are either sometimes or always colored, we shall find that this division harmonizes in a striking way with their chemical properties. The colors of the elements have no such significance or importance.

This present paper accepts the Arrhenius theory of dissociation, the author believing that the evidence in its favor is too strong to be resisted. But the facts to be stated, and the conclusions to be drawn therefrom are independent of any theory.

It is somewhat remarkable that it is never possible to deduce the color of an atom from that of the element which it forms by combining with another similar atom. Between the two, the atom and the element, there seems to be no color relation whatever. It is from the combinations of an atom with one or more dissimilar atoms, kathions with anions, that we can with facility and certainty deduce the color of the atoms themselves.

So far I have spoken of atoms only, but the matter in hand is simplified by considering dissociated ions also. And as a first step it becomes necessary to establish the following proposition: namely, that in any colored inorganic compound in solution, the color belongs essentially to the metallic atom, whether it exists in a free state as an ion or combined with a dissimilar atom or atoms to form a molecule. That is to say it does not belong to the ion with exclusion of the molecule as some have held, nor to the molecule with exclusion of the ion as has been held by others. Color when it appears, is the essential property of the atom, possessed by it in the free state and carried by it into any electrolyte which it forms.

This fact can be conclusively proved from the researches of Glan and of Ewan. Each of these chemists studied the action of copper salts and more particularly of the sulphate. Both observers used virtually the same method. A ray of light was passed through a small stratum of strong solution and then through a larger quantity of distilled water and the amount of absorption was noted. In another parallel tube the two were mixed and the amount of absorption was compared, in each case for particular wave lengths. Ewan used an eight-fold dilution. Glan usually a seven-fold but sometimes a three or five. In all cases the difference found was extremely small, scarcely if at all exceeding the magnitude of experimental error.* Had the color been a property of the ion only, or of the molecule only, the differences found would have been very great, in opposite directions.

Ewan calculates from the numbers found by Kohlrausch that in a solution of cupric sulphate containing 2·38 gram equivalents to the liter, the dissociation amounts to 15·3 per cent. A dilution reducing the proportion to 0·2856 equivalents to the liter increases the dissociation to 31·7 per cent. Therefore, if the color depended upon the ions only, the total absorption would be more than doubled. On the other hand if the color depended upon the molecules only, the absorption would be materially diminished. Now the work of Ewan, of Glan, and of previous observers shows that neither of these large changes takes place but that the absorption varies between narrow limits. Therefore it is certain that the color belongs to the atom, whether it exists as an ion or whether by union with a dissimilar ion, it forms part of an electrolyte.

These proofs would seem to be sufficient but others can be had in abundance. In dilute solutions of cobaltous salts the ions exhibit the color characteristic of cobalt. But cobalt cyanide also exhibits that color; it is quite anhydrous, no ions can be present and therefore the color must be due to the atoms. Cobalt carbonate exists in two forms, one freely hydrated, the other anhydrous, both show the characteristic color. In the hydrated salt the ions may possibly be dissociated, in the other they cannot be. Nickel cyanide is also anhydrous and yet shows the characteristic nickel color.

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* Both Ewan's and Glan's results will be found tabulated in Dr. Ewan's paper in the Philosophical Magazine, vol. xxxiii at p. 336. (1892.)

Chromic chloride after sublimation still shows the characteristic pale violet color of chromic salts.

These instances might be multiplied but they will sufficiently show that characteristic color belongs to the atom as well as to the ion.

When the atom enters into a molecule such as is produced by the union of an elementary kathion with an elementary anion, of course that molecule will not give exactly the same absorbtion spectrum as the free ion : the vibration of the ion is free whereas that of the atom in the molecule is constrained. What is contended for is that in the great majority of cases the color of the ion and that of the atom are substantially the same. Exceptional cases will occur, difficult to explain under any theory. Chromous chloride gives a blue solution in water, chromous acetate a red one: can therefore the chromous ion be both red and blue?

This case is quite the reverse of the results obtained by Ostwald in his well-known work done on the permanganates.

The green solution when concentrated of copper chloride is a case often cited to show that green molecules may yield blue ions. But this may be explained in quite a different way. It is known that many salts exist in strong solutions, as complex molecules. Hittorf has shown that cadmium iodide in strong solution in water exists as $(Cd\,I_2)_3$. Lenz* gives as a formula for the solution of potassium iodide in alcohol

$$a(KI),\ b(KI)_2,\ c(KI)_3, \text{ etc.}$$

the coefficients a, b, c diminishing rapidly.

It is quite probable that the green color of some copper compounds may be due to complex molecules and among them, copper chloride.

Criteria of Color.

In making determinations of the colors of ions, and therefore of atoms, I have used the following criteria.

1. When an electrolyte gives a solution in water which is colorless when dilute, both the kathion and the anion are colorless. Thus for example as lithium bromide gives a colorless solution in water it follows that the ions of lithium and bromine are colorless. It has been already said that no relation whatever exists between the color of an atom and that of its molecule. So two colorless bromine atoms form the intensely colored element bromine. If further proof be required of the colorless nature of the bromine atom it is easily obtained by considering that the compounds formed by that atom with

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* Mem. de l'Ac. Imp. de St. Petersburg, 30.

all the alkaline and earthy metals are colorless even when not dissociated. As potassium iodide forms a colorless solution in water it follows that the atoms of both potassium and iodine are colorless. Sodium monosulphide gives a colorless solution in water, therefore the atoms of sodium and of sulphur are colorless. But the polysulphides are yellow in solution : it follows therefore that in them a certain portion of the sulphur may exist in a molecular condition.

2. If an electrolyte gives a colored dilute solution in water it is necessary first to consider the constitution of the anion. If this is a single atom, then the color of the solution belongs entirely to the kathion. For it is a very remarkable fact that all elementary anions are colorless. This is all the more curious that the endless number or organic coloring matters are built up chiefly of these colorless anions and of colorless hydrogen.

This criterion enables us to judge as to a large number of atoms. As oxides, fluorides, chlorides bromides, etc, all have colorless anions, whatever color is shown by their *dilute solutions* must be due to the kathions.

3. Even if the anion is composite, information can often be gained. Many composite anions are colorless, for example So_4. So that when sulphates give solutions that are colored when dilute the color must be due to the kathion.

The same is the case with nitrates, phosphates, carbonates, etc. In these cases and in many others, knowing the anion to be colorless we are certain that the kathion must contribute any color that is present.

These criteria will afford the means of deciding upon the color of the entire series of elementary atoms.

CLASSIFICATION.

In the preceding sections proof has been offered that the colors of the atoms are substantially the same as those of the corresponding ions. Especially the fact that a solution of copper sulphate by a dilution which doubles the number of its dissociated ions scarcely shows the slightest change of total absorption is strong, one might say, final.

But as respects classification which will form the chief subject of the present paper it is absolutely unimportant whether these views be accepted or not. We may classify the elements according to the color and want of color of their ions or quite indifferently, by that of their atoms: the result will be identical.

The color of the atom is always easily ascertained and could be even if the dissociation theory had never been suggested.

The color of the atom has nothing to do with the element, for it we must go to the salts.

Finding that the chlorides, bromides and iodides of the alkaline metals and of calcium strontium, etc., are all colorless even in the solid form, we conclude that all the atoms in question are colorless since colored constituents do not form colorless compounds. When a metal combining with a colorless acid forms a colored compound we know that the atom of the metal is colored. We do not need to inquire for present purposes what that color is, all that we need to determine is whether color is present or not. In fact this matter is so simple that the color or absence of color of the atoms and the conclusions to be drawn therefrom might have been deduced generations ago from facts already then familiar.

From this we can obtain the results sought which are, first, a new classification of the elements based on more correct principles than those previously made, and second, a proof that *the color or non-color of an element is a function of its atomic weight.*

Elementary Ions.

Considering the elements in numerical series, we find:

1. Elements with atomic weights not exceeding 47 have colorless ions only.
2. With titanium (48) colored ions suddenly commence and we at once have a series of eight unbroken, viz: Ti (48), V (51·2), Cr (52·4), Mn (54·8), Fe (56), Co (58·6), Ni (58·6), Cu (63·4).
3. Next follows a series of nine metals with colorless ions only: Zn (64·9), Ga (69·9), Ge (72), As (74·9), Se (78·9), Br (79·8), Rb (85·2), Sr (87·2), Yttrium 92·5.
4. Then six metals with colored ions: Nb (94), Mo (95·8), Ru (103·5), Rh (104·1), Pd (probably,) (106·2), Ag (107·7).
5. Then nine more metals with colorless ions: Cd (111·6), In (113·4), Sn (117·8), Sb (122), Te (125), I (126·5), Cs (132), Ba (136·8), La (139).
6. Then ten more with colored ions: Ce (142), Di (145?), Sm (150), Er (169), perhaps Ta (182), W (184), Os (192?), Ir (192·5), Pt (194), Au (196·2).
7. Up to gold, the colored and colorless ions present themselves in large blocks of each kind. But the six remaining metals are of each sort alternately, thus Hg (199·8) colorless; Tl (203·6) colored; Pb (206·4) colorless; Bi (210) colored; Th (234?) colorless and finally U (240) colored.

Eleven metals have both one or more colored and one or more colorless ions.* For the moment these have been classed together with those that have colored ions only, in order to divide the entire series into two great classes.

The distinction however between so-called elements having none but colored ions and those having both colored and colorless is of very great importance and will be fully considered further on.

Placing the foregoing in tabular form we have :—

Ions colorless, 18	H	1
	Li	7
	Be	9·3
	B	11
	C	12
	N	14
	O	16
	F	19·1
	Na	23
	Mg	24·3
	Al	27·3
	Si	28
	P	31
	S	32
	Cl	35·5
	K	39
	Ca	40
	Sc	45
Ions colored, 8	Ti	48
	V	51·2
	Cr	52·4
	Mn	54·8
	Fe	56
	Co	58·6
	Ni	58·6
	Cu	63·3
Ions colorless, 9	Zn	64·9
	Ga	69·9
	Ge	72
	As	74·9
	Se	78·9
	Br	79·8
	Rb	85·2
	Sr	87·2
	Y	92·4
Ions colored, 6	Nb	94
	Mo	95·8
	Ru	103·5
	Rh	104·1
	Pd	106·2
	Ag	107·7
Ions colorless, 9	Cd	111·6
	In	113·4
	Sn	117·8
	Sb	122
	Te	125
	I	126·5
	Cs	132
	Ba	136·8
	La	139
Ions colored, 10	Ce	142
	Di	145
	Sm	150
	Er	169
	Ta ?	182
	W	184
	Os	192
	Ir	192·5
	Pt	174
	Au	196·2

Alternate.

Colorless	Hg	199·8
Colored	Tl	203·6
Colorless	Pb	206·4
Colored	Bi	210
Colorless	Th	233·9 ?
Colored	U	240

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* This expression is used for brevity and with the intention of expressing the fact that an elementary ion may assume different colors with different valencies.

THE LAW OF COLOR.

In the first part of this paper has been developed the conception that the color of the atom is all-important whilst that of the element has little significance. That there exists no relation whatever between the two, so that the color of the atom can never be deduced from that of the element. But the color of the ion can always be found by certain criteria which have been given and it has been shown that the color of the atom is the same as that of the ion. Both may or may not change with changes of valency.

Several interesting results follow from this conception. It appears that we must reject the well-known Periodic Law as being based on erroneous principles.

Another result is the establishment of the Law of Color, which may be formulated as follows:

No element having ions colored at all valencies can belong to the same natural group with elements having colorless ions only.

This law is rigorous and fundamental: rigorous because it admits of no exception; fundamental because it divides elements into two chief divisions with strongly marked differences.

They even differ in the method of classification which they require. The colorless elements fall into groups with atomic weights widely differing, the elements with colored ions tend to fall into series with atomic weights immediately following each other.

The periodic Law which we owe to Newlands, Mendeléef and Lothair Meyer, beautiful and fruitful as it has proved, contains nevertheless defects of a serious character; some already recognized, and condoned only in view of its great merits and services.

For the three metals copper, silver and gold the periodic law affords absolutely no place. The numbers of their atomic weights made it necessary to insert them amongst the metals of the alkalies, where they are thoroughly out of place. The fact that there was no choice but to put them there is in itself a proof that the law of octaves rests on a false basis.

A very grave fault is the complete exclusion of hydrogen. A system must be defective which finds a place for one element of water and none for the other, and which totally excludes the most important of all the kathions. This exclusion is so complete that in the published tables of the periodic law the symbol for hydrogen does not generally appear.*

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* Cf. Modernen Theorien, pp. 140, 143. Ostwald, Lehrbuch 2d German edition pp. 134, 135. Ramsay's Chem. pp. 628, 629.

This exclusion cannot be explained or accounted for in any way. Hydrogen simply will not fit in to a proper place, but has to be excluded to obtain symmetry.

Then there are the three metals, iron, cobalt and nickel and the six platinum metals. For all of these there is no place, and one has to be forcibly made. Whether this is accomplished by making them a fragmentary and disjointed eighth column as done by Lothair Meyer or whether they are inserted, three of them into each of a second, third and fifth vertical column, as done by Mendeléef, the effect is in either case forced and unnatural. These elements cannot like hydrogen be simply excluded, they must be placed somewhere, but one feels the symmetry is destroyed. Another most serious objection is to the exclusion of sodium from the series of the alkaline metals.

In both tables chromium and molybdenum are placed in the oxygen group and in Mendeléef's, fluorine and manganese constitute a group. All the metals having ions colored at all valencies are out of place. Other faults might be cited but the above are sufficient to show that the periodic law is a singular mixture of truth and error.

Periodic Systems.

The body of the elements separates itself as we have seen into two great divisions those with ions always colorless and those with ions always colored.

These two classes are always distinct and the elements forming each have no relation with the other ; that is to say, we shall never find in natural groups elements belonging to more than one of these two great divisions. The remarkable manner in which they meet at particular points or nodes and melt into each other will be described farther on. At present we have only to do with the consideration of classes taken separately.

First Division. Ions all Colorless.

And first as to the colorless class. If we arrange all its members in numerical order so as to form vertical columns of nine each, then if we read the horizontal lines we shall find that *the entire class of elements with colorless ions is divided*

TABLE I.—FIRST DIVISION OF ELEMENTS.

Elements with all Colorless Ions in numerical order, forming nine Natural Groups.

Valency.						
I	H 1	F 19	Cl 35·5	Br 80	I 127	------
	Li 7	Na 23	K 39	Rb 85	Cs 132	------
II	------	------	Ca 40	Sr 87	Ba 137	------
III	------	------	Sc 45	Y 90	La 139	------
II	Be 9	Mg 24	Zn 65	Cd 112	Hg 200	------
III	B 11	Al 27	Ga 69	In 113	------	------
IV	C 12	Si 28	Ge 72	Sn 118	Pb 206	Th 234
V	N 14	P 31	As 75	Sb 122	------	------
VI	O 16	S 32	Se 79	Te 125	------	------

into nine great groups, all absolutely natural, each element in its proper place accurately fitted.

An examination of Table I will show,

1. Hydrogen stands at the head of the halogen group, with the members of which it makes countless substitutions. Hydrogen has always been an element difficult to class, but this is its proper place.*
2. Next follows the group of the metals of the alkalies, with sodium in its right place. With these, hydrogen is intimately connected.
3. The calcium group begins with that metal, either because earlier members with lower atomic weights exist, but have not been discovered, or because the group naturally commences at a later stage than the preceding. The same thing is true with the scandium group next following.
4. The remaining groups need no particular description. They are eminently natural and very familiar.
5. In these groups following the horizontal lines, all members of each group have the same valency. To this there is no exception.

The foregoing applies to this table considered as groups corresponding to the horizontal lines. When it is intended to consider the serial relations according to columns they should be taken as one long serial without breaks.

Much importance has naturally been attached by Mendeléef to the progressive stages of oxidation in his groups, as for example, the series

$$Na_2O,\ Mg_2O_2,\ Al_2O_3,\ Si_2O_4,\ P_2O_5,\ S_2O_6,\ Cl_2O_7.$$

And the corresponding hydroxides, hydrides, methides, etc. Of these it may be said that Cl_2O_7 is purely hypothetical. The rest of this series will be found in precisely the same order in the second column in Table I and all the corresponding elements in each horizontal line have the same valencies and tend to form similar compounds.

This table representing the first great division of elements includes all those whose ions function as anions with part of the kathions.

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* By Roscoe & Schorlemmer and in the Graham Otto treatise it is placed immediately before the halogens. By Ramsay at the head of the lithium sodium group.

Transitional Elements.

Intermediate between the two divisions is a small class of eleven transitionals. These elements have ions which at some valencies are colored and others colorless.

TRANSITIONAL ELEMENTS.						
Ti 48	*Cu 63·3*	*Nb 94*	*Ag 108*	*Ce 142?*	*Ta 182*	*Tl 204*
V 51		*Mo 96*			*W 184*	*Bi 210*

(As to tantalum and niobium, satisfactory information is deficient and they are placed here provisionally.)

An inspection of the table will show that the metals composing it have little relation with one another.

Most of them on the contrary are noticeable as having each some marked peculiarity. Titanium when heated combines with atmospheric nitrogen. Vanadium forms a compound radical simulating a metal so completely that all chemists were deceived until Roscoe detected the fact. Copper forms a solution which has the property of dissolving cellulose. Silver can assume a condition in which it is freely soluble in water; it is also remarkable for the high sensitiveness to light of some of its compounds. Tungsten is remarkable amongst inorganic substances for the unexampled complexity of its compounds, as first observed by Gibbs. Thallium is noted for uniting in a singular way the properties of an alkaline and those of a heavy metal.

The relations of this peculiar group are chiefly with the elements having colorless atoms only, as shown in Table II. Into this, they enter as it were in a block, at the center, increasing the number of groups to thirteen, or twelve if we take the first two as constituting a double group of univalent elements. In this way as we follow the groups downwards the valency increases successively from one to six, then begins at one again and increases regularly from one to six again. This will be better seen by referring to Table II. In every group each member has the same valency.

Whether it is probable that all the blanks represent so many elements remaining to be discovèred seems doubtful. But it is certainly the opinion of many chemists that the number of existing elements as yet unknown, is large.*

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* Cf. Ramsay, Inorganic Chemistry, p. 87.

TABLE II.—*Elements with all Ions Colorless, and Transitional Elements (in italics) in numerical order, forming thirteen Natural Groups.*

Valency.						
I	H 1 Li 7	F 19 Na 23	Cl 35·5 K 39	Br 80 Rb 85	I 127 Cs 132	------ ------
II	------	------	Ca 40	Sr 87	Ba 137	------
III	------	------	Sc 45	Y 90	La 139	------
IV	------	------	*Ti 48*	------	*Ce 142*	------
V	------	------	*V 51*	*Nb 94*	*Ta 189*	------
VI	------	------	------	*Mo 96*	*W 184*	------
I	------	------	*Cu 63*	*Ag 108*	------	------
II	Be 9	Mg 24	Zn 65	Cd 112	Hg 200	------
III	B 11	Al 27	Ga 69	In 113	*Tl 204*	------
IV	C 12	Si 28	Ge 72	Sn 118	Pb 206	Th 234
V	N 14	P 31	As 75	Sb 122	*Bi 208*	------
VI	O 16	S 32	Se 79	Te 125	------	------

With elements having atoms always colored the relations of the transitionals are so slight that I hesitated about giving them a place in Table III and have done so chiefly to give emphasis to this fact, that in the entire series of elements *there is not a single case in which an element having atoms always colorless appears in the regular numerical series between a transitional element and one with atoms always colored. Also that there is not a single case in which an element with atoms always colored appears in the numerical series between a transitional element and one having colorless atoms only.*

This will be seen better by examining the diagram embracing the entire series. This perfect regularity seems to justify this new method of classification.

This group contains elements whose atoms function as kathions only.

Second Division. Ions all colored.

In Table III will be found the series of elements with all colored ions and to these have been added the transitionals, distinguished by being printed in italics. The transitionals fit equally well into either of the two great divisions, that of the colorless and that of the all colored ions, with this difference that in the first division they fit into the center, in the second division they act as outliers to the respective series, connecting the colored with the colorless. This last function is however better shown by the diagram at the end. Their chemical relations are with the first division.

The colorless elements when arranged in vertical columns form groups according to the horizontal lines. Members of each group though closely connected in properties, differ widely in atomic weights.

With the elements having all colored ions the case is very different. They fall into four series, members of which have their atomic weights immediately following each other in unbroken succession.

The first of these series consists of the metals chromium 52, manganese 55, iron 58, cobalt 59, and nickel 59. This is a very well marked group, the chromates, manganeses and ferrates being isomorphous. Also the sesquisulphates of the three metals replacing each other in the alums.

Chromium and manganese were formerly always placed in the iron group until the exigencies of the Periodic Law required the transfer of chromium to the oxygen group and of manganese to the univalent halogen group, a translocation for which there seems no sufficient justification.

TABLE III.—SECOND DIVISION.

Elements with Ions always colored. Also Transitional Elements (in italics) in Numerical Order.

Trans.	Ions always colored.	Transitional.		Ions always colored.	Transitional.		Ions always colored.	Trans.	Ions always colored.	Trans.	Ions always colored.
Ti 48	Cr 52	*Cu 63*	*Nb 94*	Ru 103	*Ag 108*	*Ce 142*	Di 145	*Ta 182?*	Os 192	*Ti 204*	U 240
V 51	Mn 55	----	*Mo 96*	Rh 104	------	------	Sm 150	*W 184*	Ir 192·5	*Bi 208*	-----
------	Fe 56	----	----	Pd 106	------	------	Er 169	------	Pt 194	------	------
------	Co 59	----	----	------	------	------	------	------	Au 196	------	------
------	Ni 59	----	----	------	------	------	------	------	------	------	------

The transitional elements titanium and vanadium on the one side of this series and copper on the other, are the outliers.

The second colored series contains the well known group rhodium, ruthenium and palladium. The third colored group contains the metals of the rare earths followed by the transitionals tantalum and tungsten. Finally the colored group of the platinum metals and gold. These and the remaining colored metals will be described in the next section.

One metal, zirconium, has proved rebellious to this classification.

The others have taken their places so easily and exactly that it seems as if there must be something inexact or incomplete in our data respecting this metal. The most probable supposition seems to be the following. Zirconium has but one degree of oxidation while the very closely allied metal titanium, has ions that are colored and colorless at different valencies.

Should zirconium prove to have a second degree of oxidation corresponding to colored ions, it would be brought into complete analogy with its congener and would find a place open for it in the tables.

In Table II it would take the vacant place immediately following titanium and between that metal and cerium. As a transitional metal it would take its place in Table III immediately before niobium in the second series. It is hardly necessary to remark that these are exactly the places for which its properties fit it.

All the elements contained in Table III have ions that function as kathions only.

A PERIODIC LAW OF COLOR.

It was necessary first to consider the elements in the great divisions into which they fall by reason of the color of their ions.

It now remains to consider the whole range of elements in one continued series from hydrogen to uranium.

Commencing with hydrogen (see Plate No. IV*) we have a double series of 18 elements with colorless ions only. Approaching one of the great colored groups which may be called the iron group we find two intermediate elements, titanium and vanadium which have both colored and colorless ions.

By their colorless ions they are united to the series which immediately precedes them in the order of numbers and by their colored ions they are united with the iron group which immediately follows. This iron group commences with the element chromium which in the numerical series immediately follows vanadium, so that after the transitionals titanium and vanadium each of which has at least one colorless ion, comes the group consisting of chromium, manganese, iron, cobalt and nickel; metals which have colored ions only.

Approaching the next colorless series we find interposed the transitional element copper, a metal having the colorless cuprous and the blue cupric ions.

From this we pass to a colorless series commencing with zinc and continuing with gallium, germanium, arsenic, selenium bromine, rubidium, strontium and concluding with yttrium. The ions of none of these elements show any tendency to color.

Continuing in numerical order the next colored group will consist of the metals ruthenium, rhodium and palladium. But in approaching these we find precisely as in the previous case two transitionals, molybdenum and niobium.

These are connected with the previous colorless group by their colorless ions and with the colored group next following by their colored ions. This colored group (Ru, Rh, Pd,) has colored ions only.

Continuing in numerical order we approach the next colorless group. But as we pass from the colored to the colorless we find as before, a transitional, in this case, silver, which is connected with the previous colored group by its colored ions corresponding with Ag_4O and Ag_2O_2† and to the following colorless group by its ion corresponding to Ag_2O.

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* In the plate the third and fourth colored groups should have been on the same horizontal line as the first and second.

† The first of these colored ions is seen in the deeply colored hemi-salts of silver. Another may exist in the peroxide which dissolves in sulphuric acid with a dark green color.

From this we pass to the next colorless group of nine elements commencing with cadmium and ending with lanthanum. Approaching the next colored group we as before find a transitional element, in this case but one. At least but one is now known, but as we have now come to the region of little known metals of the rare earths it is possible that some one of those not yet thoroughly known may take its place alongside of cerium and thus bring this approach into complete symmetry with all the others.

Cerium connects itself with the colorless group immediately preceding by having colorless ions and with the colored group immediately following by its colored ions.

The colored group thus reached, composed of metals having colored ions only, consists of didymium, samarium and erbium. Then follow the transitionals tantalum (?) and tungsten.

Next, a series having ions colored at all valencies, namely osmium, iridium, platinum and gold. With gold the regular series terminates.

There follows what may be called the most curious part of the entire range of elements. This is found in the little group of six at the extreme end. In the principal series the colored groups are always immediately preceded and introduced by transitional elements, that is elements having both colorless and colored ions. The usual number of these transitionals is two. In the small final group the first two colored elements act as transitionals to the third. The first of the colored metals is thallium, this metal is allied to the alkalies by its thallious salts which are colorless; it is also closely related to the heavy metals, lead and mercury which are on each side of it. Even thallic sulphate and nitrate are colorless salts decomposed by water. But the thallic haloids form colored crystals and colored solutions and thus correspond perfectly to colored ions. Therefore thallium whilst chiefly related to the colorless elements on each side of it has nevertheless made a well-marked step towards color by its single pair of colored ions.

The next colored metal, bismuth, has advanced much further towards color, for of its four valencies all but one have colored ions. It still retains its relation however with the colorless elements on each side of it, lead and thorium, by its one pair of colorless ions corresponding to bismuth trioxide.

Finally we have the last of all the metals, uranium, with colored ions at all valencies. Standing alone it occupies as it were the position of a group to which its transitionals, thallium and bismuth, lead up, and with it the series of the elements closes.

Amongst the conclusions to be drawn from the facts that have been mentioned is this, that the color of the elementary atoms is to a large extent a *function of their atomic weights.* We find that with atomic weights,

From 1 to 47 the atoms are always colorless
From 52 to 59 they are always colored
From 65 to 90 they are always colorless
From 103 to 106 they are always colored
From 112 to 139 they are always colorless
From 145 to 169 they are always colored
From 192 to 196 they are always colored.

Elements whose place in the numerical series falls between these periods, have both colored and colorless atoms.

The six metals that remain are as we have seen, alternately colored and colorless.

Ostwald remarks in his great *Lehrbuch* that when the properties of the elements shall show themselves to be functions of their atomic weights, we have next to seek in the latter the cause of the former, and then we shall hardly be able to avoid the conception of a single primordial form of matter as suggested by Crookes, a form whose varied modes of agglomeration condition the various kinds of matter (Vol. I, p. 138).

Perhaps the facts in this paper described may be found to make a step towards this great end.

With the aid of the Arrhenius theory it has been possible to establish the principle that the colors of the atoms are those which they show in dilute solutions of electrolytes, and that the colors of elements are comparatively of little importance. In the second part of this paper there will be given incidentally a proof of the correctness of the dissociation theory from a new direction. In that part will be considered the combinations of atoms and two laws controlling in certain cases the interaction of ions.

Art. XXIX.—*Further Notes on the Gold Ores of California;*

by H. W. Turner.

Some brief notes were published in this Journal on the gold ores of California in June, 1894, and the following may be considered as an appendix to that article.

Gold in barite.—During the past summer, the writer examined some gold veins on Big Bend Mountain in Butte County, California, and found that one of them was of an unusual character. The vein is known as the Pinkstown ledge. It is located about a half mile due south of the highest point of Big Bend Mountain (Bidwell Bar atlas sheet). The ledge strikes N. 13° W. and dips at a high angle (about 80°). It is from two to three feet wide where best exposed at the north end, and is composed of a soft heavy mineral, some of which is coarsely crystalline, with a granular structure, but most of it is finer grained with a schistose arrangement of the granules. No single crystals of the mineral were noted having a greater maximum diameter than five-eighths of an inch. Some of them show plainly a characteristic cleavage. Dr. Hillebrand made a chemical examination of this soft mineral and reported it to be barite. Three sections of the barite were examined microscopically, and these show that when fresh there is scarcely any impurity in the mineral, and in fact no other substance was noted except scattered minute reddish opaque grains which as seen under the microscope are reddish-yellow by reflected light, without metallic luster. They may be limonite. Many of the barite grains show distinct cleavages which appear in the thin sections to intersect at nearly right angles. A tendency to a radial structure like that of epidote was noted at several points. The relief of the barite is rather high. A sample was examined for gold by Dr. Stokes, who reported that "the barite contains gold but too small in amount to be determined in the wet way." There is said, however, to be enough gold in the deposit to pay to work, and the writer understood that the owner of the ledge obtained gold from it by grinding up the ore in a hand mortar, and panning it.

A considerable part of Big Bend Mountain, as exposed along the road from the bridge over the west branch of the north fork of the Feather river to the abandoned village of Big Bend, is made up of clay slates probably Paleozoic in age, with layers of greenstone schists, representing original augitic tuffs. The rocks along the east and south base of the mountain as seen along the river (the north fork of the Feather) are almost entirely greenstones, with one or two layers of sedimentary mica-schists. These greenstones are largely amphibolitic rocks representing original surface lavas and tuffs, probably augitic porphyrites, but now containing little or no augite. The exact nature of the schist enclosing the barite vein was not determined. The south extension of the Pinkstown ledge owned by Clarke was examined but no barite was found, the rock on the dump being a white, fine grained schist, with a greasy feel. This as seen in this section is composed chiefly of minute, brightly polarizing fibers, perhaps talc, with numerous minute cubes of pyrite, arranged in rows.

Gold associated with talc-schists.—The magnesian rocks of the Sierra Nevada consist chiefly of serpentine and talc and chlorite schists. All of these rocks together with some others of similar origin are frequently found in the same area, the different varieties alternating rapidly in a perplexing manner. There are, however, especially in the area of the Bidwell Bar atlas sheet (Butte and Plumas counties) very considerable streaks of talc and chlorite-schists with little or no serpentine. It has been noted by the writer that while quartz veins are very common in the talc-schist belts, they are very rare in the serpentine. Veins containing gold and forming pocket mines do exist in the serpentine areas, but in the two examples which the writer has himself seen, there is talc-schist directly associated with the vein, forming one or both walls.

One of the veins here referred to occurs on the Downieville sheet in Sierra County, on the spur north of Rock Creek and one and a half miles east of Goodyear's Bar. Here is a small quartz vein in serpentine with talc-schist forming one wall. This vein had evidently been worked for gold, and the writer was informed that a gold pocket was found in it.

The other mine is in Mariposa County on the Mariposa Estate, and is in charge of Mr. Ludwig, who kindly showed me the deposit. There is here a streak of talc-schist in serpentine near the west border of the large belt of that rock that extends from near Princeton to Mariposa forming the high ridge just west of the latter town. The exact locality is one and three-fourths miles a little south of east from Princeton. The deposit consists besides the talc, of white dolomite looking precisely like that associated with mariposite at the Josephine Mine near Bear Valley, pyrite, and a black mineral, the latter occurring in plates with metallic surfaces in the dolomite. This black mineral was determined by Dr. W. F. Hillebrand to be titanic iron ore (ilmenite). The gold occurs native in the talc-schist, and the pyrite and ilmenite are also saved for reduction. The writer's notes make no mention of quartz in this vein.

As stated above, the talc, chlorite, and other associated schists form considerable belts in the area of the Bidwell Bar atlas sheet, and contain frequent quartz veins, as may well be seen at Quartz Hill north of Lumpkin. The writer knows of no case, however, where one of these veins has proved to be large enough and to contain enough gold to warrant the erection of a quartz-mill.

The rare occurrence of quartz veins in serpentine, a very basic magnesian rock, and their comparative abundance in talc rocks, which are much more acid, would seem to indicate a connection between quartz veins and the rock in which they form.

But as both these rocks are altered forms of deep-seated igneous rocks, it does not follow that the silica of any particular quartz vein was leached out of the wall rock and re-deposited nearly in place. These igneous masses may extend to a great depth and the ascending hot waters and gases may have been in contact with rock like the wall-rock for a long distance and for a considerable time.

As a matter of fact, quartz-veins are more common in California in sedimentary rocks which are not presumed to extend deep into the earth's crust, than in igneous masses. The cause of this is more probably a physical than a chemical one, for fissures form more readily in sedimentary than in massive igneous rocks. It is extremely likely that the sedimentary series of the Gold Belt of California is underlain throughout by granite, and that this rock is the chief source of the silica of the quartz veins in the clay slates, and other associated rocks.

Serpentine being a rock in which fissures may be supposed to form with difficulty, it is by no means improbable that there is a physical as well as a chemical reason for the lack of quartz veins in that rock.

Mariposite.—The green micaceous mineral called mariposite by Silliman occurs abundantly at the Josephine Mine near Bear Valley. Several specimens of this were obtained in 1893, and submitted to Prof. F. W. Clarke for analysis. Thin sections of the material were made and these show that the mineral is micaceous, nearly colorless or slightly greenish with brilliant polarizing colors, resembling talc. There appears to be no perceptible pleochroism. The mineral is in the form of fibers and minute irregular foils with ragged edges, and extinguishes nearly or quite parallel to the longer axis of the fibers. Macroscopically it is not all green, some of it being nearly white. Two analyses are appended by Dr. Hillebrand, one of the green, and the other of the white mineral.

Analyses of Mariposite. (438 Sierra Nevada Coll.)

	Green.	White.
SiO_2	55·35	56·79
TiO_2	·18	25·29
Al_2O_3	25·62	
Cr_2O_3	·18	none.
Fe_2O_3	·63	1·59
FeO	·92	
CaO	·07	·07
MgO	3·25	3·29
K_2O	9·29	8·92
$(Li\ Na)_2O$*	·12	·17‡
H_2O†	4·52	4·72
	100·13	100·84

* Very strong lithium reaction. † No water given off below 300 C.

‡ Containing some K_2O.

The thin sections show that there is carbonate, probably chiefly dolomite mixed with the mariposite. This with some carbonate of iron was extracted with acetic acid followed by warm dilute HCl, the mariposite substance remaining unattacked. Dr. Hillebrand calls attention to the resemblance of the mineral in composition to pinite, and states that no definite formula is deducible. He determined the specific gravity of the green mineral to be 2·817 at 29·5° C. and that of the white mineral to be 2·787 at 28·5° C. The occurrence of chromium in the green variety and not in the white suggest that to be the cause of the green color. While resembling talc optically it will be noted that the chemical composition is very different.

Gold quartz veins in Tertiary Rocks.—Precious metal deposits in rocks of the Tertiary period are not uncommon in the western United States. As notable examples of this may be mentioned the Comstock lode in Nevada in part at least in Tertiary lavas, and the gold and silver veins of the Bodie district in hornblende-andesite.* Silver deposits also occur in rhyolite in Southern California.† But in the Sierra Nevada gold quartz veins in any but the Paleozoic or Jura-Trias rocks are rare. The occurrence of quartz with native gold in a rhyolite dike of Tertiary age in Plumas County has already been described.‡ The gold in the Silver Mountain district in Alpine County (Markleeville atlas sheet) is in chalcedonic quartz in Tertiary andesitic tuffs and the deposits of the Monitor district are likewise in Tertiary volcanic rocks. One of the ore specimens given the writer by Judge Arnot as coming from the last district is chalcedonic quartz containing gold. In both these districts the rocks containing the deposits are much decomposed by solfataric action, and both are on the east slope of the range in the Great Basin drainage.

About one and a half miles south of La Grange in Stanislaus County (Sonora atlas sheet) in a flat-topped hill there are abundant veins of white quartz in clay which appears at first glance to be the basal portion of the Tertiary clastic series that caps the hill. Overlying the clay is a sandstone containing pebbles of white quartz and pearly scales of a hydrous silicate of alumina, which is very abundant in the Ione sandstone.§ The age of the sandstone is thought to be Miocene. Portions of the underlying clay are white in color, other portions stained pinkish in streaks and patches. When first visited, some years ago, the clay appeared to the writer to represent the

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* This was first noted by Mr. W. Lindgren.

† W. Lindgren, Trans. Am. Inst. Mng. Eng., February, 1887.

‡ This Journal, vol. xlvii, p. 472.

§ American Geologist, vol. xiii, p. 240.

lower clay of the Ione formation, which is well exposed at Ione and elsewhere, and as the quartz veins are unquestionably in the clay it was then thought that the quartz veins were of Tertiary age. The quartz is the white, compact kind that occurs in the majority of the gold quartz veins, and not the chalcedonic quartz known to exist in veins in Tertiary rocks.

On a second visit to the locality in 1894, good evidence was found that the clay is but the decomposed bed rock, which is here a quartz-porphyrite. Pebbles of the hardened clay were found in the lower part of the sandstone and along some sharp contacts of the clay and overlying sandstone it was noted that the quartz veins stopped short at this contact. No quartz veins were found with certainty in the sandstone itself. Moreover some cracks in the clay extending down from its upper surface were filled with the material of the sandstone, showing that these cracks were in existence when the sandstone was being deposited and were filled in from above. At the head of a little gulch on the west side of the hill is a good exposure of the clay with numerous quartz veins. The latter have a varying course dipping mostly north at angles from 10° upward, some veins curving very noticeably in a vertical direction. In some of this much stained and discolored clay, porphyritic quartzes are to be seen, and as lower down in the gulch there is little altered quartz-porphyrite in place, there seems little question that the clay is a decomposed form of the same rock. At other points, notably on the east side of the hill the white clay shows no evidence of its derivation from the bed rock, being of even texture throughout and without discoloration. Slickensided surfaces were noted in the clay at several points, along seams that intersect at varying angles.

Tetrahedrite.—This sulphide of copper and antimony has not often been noted by the writer in the gold ores of the Sierra Nevada. What appears to be this mineral, however, occurs very abundantly in the quartz veins of Mono Pass, east of the Yosemite Valley. The specimens (No. 455 S. N. collection) collected there by the writer from the Golden Crown ledge were examined by Prof. R. L. Packard, who reported that the sulphide is tetrahedrite or an allied mineral giving blowpipe reactions for sulphur, antimony, copper, lead and iron. The ore is presumed to contain silver and perhaps gold, but neither of these were determined.

Mr. W. Lindgren informs me that he has detected tetrahedrite at the following mines: The Boulder, Hathaway, Golden Stag, and Pine Tree mines in the Ophir district in Places County; the Osborne Hill mine at Grass Valley, Nevada County; and the Miller & Holmes, Knox & Boyle, and Whiskey Hill in Tuolumne County, azurite being associated with the tetrahedrite in the last three mines.

Tioga mining district.—This is situated to the northwest of Mono Pass in the same body of schists that occurs in the pass. Some specimens obtained here in 1886 by the writer from the Isbell claim on Lee Vining Creek. These were assayed by Dr. W. H. Melville with the following results:

No. 876 Sierra Nevada Collection—

a: chiefly made up of zinc blende; contains 5 oz. gold and 7 oz. silver to the ton.
b: largely iron and copper pyrites; contains a trace of gold, and nearly 16 oz. silver to the ton.
c: contains a large amount of arsenical pyrite, 51 oz. gold and 32 oz. silver to the ton.

The above samples probably do not represent an average of the ore and are merely given to show the association of minerals in the vein.

Washington, D. C.

ART. XXX.—*On Some Relations between Temperature, Pressure, and Latent Heat of Vaporization*; by C. E. LINEBARGER.

THE well-known equation

$$\frac{dp}{dT} = A\frac{\rho}{T(v-v')}, \text{ or } \frac{dp}{dT} = A\frac{\rho}{Tdv}, \qquad (1)$$

in which p is the pressure; T, the temperature; ρ, the latent heat of vaporization; v, the volume of the saturated vapor; and v', that of the liquid, may be considered to resume most of the relations between temperature, pressure, and latent heat of vaporization; it expresses fundamental relationships between heat,—and volume-energy, as is at once seen, when it is thrown into the form:

$$dp\ dv = A\rho\frac{dT}{T}, \qquad (2)$$

an equation of which the left-hand member contains only the factors of volume-energy, and the right-hand member only those of heat-energy. But certain relationships between these factors of energy were found out quite independently of the fundamental equation; guided by no theoretical considerations, their discoverers, by scrutinizing experimental data, saw some regularities which, when generalized, became laws, although approximate and containing inexplicable anomalies. Also, the differential forms of equations (1) and (2) do not readily permit of direct comparison with empirical facts; they must first by suitable hypotheses and integrations be thrown into other forms. The comparison of the deductions and discovered relationships with the experimental data generally shows a close correspondence. Sometimes, however, variations and exceptions occur which cannot be referred to experimental errors.

The object of this paper is to give an account of the efforts that have been made and the results that have been obtained in regard to the relations between pressure, temperature, and latent heat of vaporization; to subject to a critical revision all experimental data bearing upon the question; to discuss the differences seemingly present between theory and experiment; and to apply the results to certain practical problems. The division of the matter is the following: first, a historical account of such papers as have dealt with the theoretical side of the question; second, a review in tabular form of experimental data together with a discussion of their comparative value; third, a comparison of the results of theory and experiment; fourth, an application of results to a practical problem.

I.

The first paper in which an endeavor was made to find out relations between latent heats of vaporization and other energy-factors is due to Ure;[*] this pioneer in this field of research determined the heats of vaporization of a number of common liquids, and concluded from his results that under the same pressure the latent heat of vaporization is inversely proportional to the vapor density.

Desprets,[†] in a paper read before the French Academy towards the end of the year 1818, but of which merely an abstract seems ever to have been published, communicated the results of some determinations of the latent heats of vaporization of water, alcohol, ether, and essence of terebinthine. An inspection of his data led him to state that a liquid at its point of ebullition requires for volatilization so much the less heat, the denser its vapor; latent heats of vaporization are approximately proportional to densities at the boiling points.

Person[‡] after determining the latent heats of vaporization of ten additional liquids, notwithstanding that his results were not as accurate as those of Desprets, as he himself admits, and without giving any data, formulated a law, which is "for the heat of vaporization what the law of Dulong and Petit is for the specific heat," and "even more general, since it applies to

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[*] Phil. Mag. liii, 191, 1819.

[†] Ann. Chim. et Phys., xxiv, 323, 1823.

[‡] Comptes Rend., xvii, 498, 1843.

simple and to compound bodies without distinction." This law is: "The heats of vaporization of different substances range themselves exactly in the order of their temperatures of ebullition, when, instead of equal weights, atomic weights are taken. In a "Note" three years later Person* reverts to his law, and drawing up a table of latent heats of vaporization from the data due to Favre and Silbermann shows how well his previous statements are corroborated by these determinations. The exceptions presented by the acids are explained away by making allowance for their abnormal vapor densities. In this paper, he puts his law in a somewhat different form: "The amount of heat needed to vaporize substances under the same pressure is identical, when the volume produced is the same, and it is smaller or greater according as the volume produced is smaller or greater."

Trouton† "on comparing the quantities of heat necessary to evaporate at constant pressure quantities of different liquids taken in the ratio of the molecular weights,"—found that the amount of heat required by any body is approximately proportional to its absolute temperature at the point of ebullition." He then propounded the following law:" The molecules of chemically related bodies, in changing from the gaseous to the liquid state at the same pressure, disengage quantities of heat, which may be called the molecular latent heat, directly proportional to the absolute temperature of the point of ebullition."

The above laws are purely empirical; they were found through observation of rows of figures; they have no theoretical grounding; being subject to exceptions and irregularities, they can never as deduced rise to the rank of great generalizations; they have been drawn up by the inspection of experimental data, which is an inversion of the usual order of discovery, experimental data as a rule being a means of corroboration rather than of deduction of laws of nature.

We now pass to the consideration of the work that has been done along theoretical lines in the finding out of relations between heat of vaporization, temperature, and pressure.

The first effort made in this direction is due to Raoul Pictet, in a paper truly remarkable for its time, although it seems to have attracted but little attention. Pictet considers a cycle in which a liquid is evaporated from one chamber, condensed in another, and finally returned to the first. Admitting the validity for the case in hand of the laws of Boyle and Gay-Lussac, he then finds mathematical expressions for the work done and the heat absorbed. In order to equate these essen-

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* Comptes Rend., xxiii, 524, 1846.

† Phil. Mag., V., xviii, 54, 1884.

tially independent expressions he makes two hypotheses: 1, the cohesion of liquids is the same for all: 2, Carnot's cycle is applicable to volatile liquids, and to their changes of volume: and there exists a relation between heat taken in and work performed. The expressions finally arrived at show a satisfactory correspondence for the most part with the determinations of latent heats of vaporization made by Regnault. The conclusions which have a bearing upon our subject are: I—The product of the latent heats of liquids at the same pressure by their atomic weights, divided by the absolute temperature at which the vaporization takes place, is the same for all: II—The difference between the internal heats of vaporization at any two temperatures, multiplied by the atomic weights, is a constant number for all liquids.

We will not enter into any discussion of these results, contenting ourselves with remarking that the first conclusion is a plain enunciation of "Trouton's law" mentioned above. If priority of publication has any moment in the choice of the name of a discovery, the law in question ought to be called Pictet's law since the date of Pictet's paper is 1876 and that of Trouton's 1884.

Equation (1) seems first to have been made use of by van der Waals* for the establishing of relationships between temperature, pressure, and latent heat of evaporation. If for p, T, and v, εp, $m\,T_1$, and $\varphi(m)\frac{b}{v}$ (p_1 being the critical pressure, T_1, the critical temperature, b, the covolume, and ε, m, $\varphi(m)$, coefficients) be substituted in equation (1), and it be kept in mind that

$$\frac{v\mu}{b} = f(m),$$

(μ being the molecular mass), the equation

$$\frac{d\varepsilon}{dm} = \frac{8{\cdot}273}{A} \cdot \frac{\rho\mu}{T_1} \cdot \frac{1}{\varphi m} \tag{3}$$

or

$$\frac{d\varepsilon}{dm} = C \cdot \frac{\rho\mu}{T_1} \cdot \frac{1}{\varphi} \tag{4}$$

results. Now when m is the same, that is, at the same reduced temperature, $\frac{d\varepsilon}{dm}$ must have the same value, and as a necessary consequence it follows that

$$\frac{\rho\mu}{T_1} = F(m) \tag{5}$$

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* Continuität des gasförmigen und flüssigen Zustandes, p. 137.

where F is a constant number for all bodies. But equation (5) is nothing else than the mathematical expression for "Trouton's law," and again the rightfulness of this name may be justly questioned, for the German translation of van der Waal's book appeared three years before Trouton's paper. Van der Waals called to mind the similarity of the expression as developed just above to the law proposed by Desprets (loc. cit.), and drew up a little table of data to see if experiment corroborated theory, which in a certain measure he found to be the case.

Bouty* sought to transform the fundamental equation (1) so as to get the quotient of the molecular heat of vaporization by the square of the absolute temperature equal to a constant. His course of reasoning is as follows. If, in the formula

$$\rho = \mathrm{T}(v-v')\frac{dp}{d\mathrm{T}} \qquad (6)$$

the specific volume of the liquid be neglected in comparison with that of the vapor, and if the density of the latter be normal, it ensues that

$$v = \frac{1}{\mathrm{D}\mu}\frac{p_0}{p}\cdot\frac{\mathrm{T}}{273}, \qquad (7)$$

where D is the absolute specific gravity of hydrogen at the temperature zero and under the pressure of 760^{mm} of mercury. By the combination of (6) and (7) the equation

$$\rho\mu = \frac{p_0}{273\mathrm{D}_0}\frac{\mathrm{T}^2}{p}\frac{dp}{d\mathrm{T}} \qquad (8)$$

is obtained; and if T_0 be the boiling point under the pressure p_0,

$$\rho\mu = \frac{\mathrm{T}_0^{\,2}}{273\mathrm{D}}\left(\frac{dp}{d\mathrm{T}}\right)_0. \qquad (9)$$

If it be admitted with Dalton that all vapors have the same tensions at temperatures equidistant from the boiling points of the liquids which give them off, the expression

$$\left(\frac{dp}{d\mathrm{T}}\right)_0$$

must be the same for all liquids, and the expression

$$\frac{\rho\mu}{\mathrm{T}_0^{\,2}} \qquad (10)$$

becomes equal to a constant.

Although Bouty is inclined to admit that Dalton's "law" is incorrect, and hence (10) cannot be constant, he gives a table of "constants" for a number of liquids, of which, as de Heen

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* Journ. de Phys., II, iv, 26.

remarks* "it is needless to say that the variations to be found in the values of $\frac{\rho\mu}{\mathrm{T}_0^2}$ are enormous." If, however, it be assumed that $\mathrm{T}\frac{dp}{d\mathrm{T}}$ be constant,† it at once follows that $\frac{\mu\rho}{\mathrm{T}} =$ constant, which is Trouton's or better Pictet's law.

Le Chatelier‡ also has transformed equation (1) into another directly comparable with the results of experiment. After putting it in the form

$$\frac{\rho}{\mathrm{T}}d\mathrm{T} + \mathrm{A}(v - v')dp = 0, \tag{11}$$

(ρ in Le Chatelier's calculations is always taken to be the *molecular* heat of vaporization) by multiplying and dividing the second term by p, he obtained this expression

$$\frac{\rho}{\mathrm{T}}d\mathrm{T} + \mathrm{A}p(v - v')\frac{dp}{p} = 0 \tag{12}$$

If the volume of the liquid be neglected in comparison with that of the vapor, and the gas equation

$$pv = \mathrm{RT}$$

be introduced, after division by T, the expression

$$\rho\frac{d\mathrm{T}}{\mathrm{T}^2} + \mathrm{AR}\frac{dp}{p} = 0 \tag{13}$$

or

$$\rho\frac{d\mathrm{T}}{\mathrm{T}^2} + 2\log p = 0 \tag{14}$$

is obtained. If this equation be integrated between the limits T and T_0, it being admitted that the heat of vaporization is constant, the equation

$$2\int_{\mathrm{T}_0}^{\mathrm{T}}\frac{dp}{p} + \int_{\mathrm{T}_0}^{\mathrm{T}}\rho\frac{d\mathrm{T}}{\mathrm{T}_2} = 0 \tag{15}$$

results, and, all calculations being made on the assumption that ρ is independent of T,

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[*] Bulletin de l'Académie royale de Belgique, III, ix, p. 281, 1885.

[†] The results of Ramsay's and Young's experiments show that $\mathrm{T}\frac{dp}{d\mathrm{T}}$ is constant for considerable differences of pressure. If it be true that $\mathrm{T}\frac{dp}{d\mathrm{T}}$ is constant then $\frac{\rho}{dv}$ must be constant also, for

$$\frac{dp}{d\mathrm{T}} \cdot \frac{\mathrm{T}}{\mathrm{A}} = \frac{\rho}{dv}.$$

Ramsay and Young have also experimentally proven the truth of this relation. See Phil. Mag., V, xx, p. 515, 1885; ibid., xxi, pp. 33 and 135; and ibid., xxii, p. 33. 1886.

[‡] Recherches expérimentales et théoriques sur les equilibres chimiques, Ann. des Mines, Mars–Avril, 1888, p. 337.

$$2 \log \frac{p}{p_0} + \rho\left(\frac{1}{T} - \frac{1}{T}\right) = 0. \qquad (16)$$

This equation contains no constant, but if the terms T_0 and p_0, which together form a constant, be transferred to the second member, the equation

$$2 \log p + \frac{\rho}{T} = \text{constant} \qquad (17)$$

is obtained, and if the pressure be kept constant.

$$\frac{\rho}{T} = \text{constant}, \qquad (18)$$

or, if ρ be taken as the heat of vaporization of the unit of mass of liquid,

$$\frac{\mu\rho}{T} = \text{constant}. \qquad (18 \text{ bis})$$

It is seen from the foregoing that the constancy of the quotient of the molecular heat of vaporization by the absolute temperature at which the vaporization takes place has been arrived at by various scientists in different ways. This in itself is strong warrant for the truth of the relation. Still there exist certain discrepancies between the theory and the experimental determinations, which must be accounted for. Before taking up their consideration, however, it is necessary to pass in review what experimental work has been done.

II.

In Table I are given the latent heats of vaporization of a number of liquids, which have been determined by direct experiment at or near the ordinary atmospheric pressure. Only such liquids as are chemical units are admitted, solutions of acids and the like being excluded; also the determinations made with very volatile liquids, such as ammonia, sulphur dioxide, etc., are omitted. With these exceptions it is believed that no omissions of importance have been made.

The first column refers to the "References;" the second column (*a*) gives the name of the liquids; the third (*b*) their formula, and the fourth (*c*) their molecular masses; in the fifth (*d*) and sixth (*e*) columns are contained the temperatures at which vaporization took place and the latent heats for one gram of the liquid in heat units of which one warms one gram of water from 0° to 1° C., while the seventh (*f*) column shows the quotient obtained by dividing the molecular heat of vaporization by the absolute temperature. The eighth column (*g*) gives the pressure in rounded millimeters of mercury; when the pressure has not been indicated by the investigator, the space has been left vacant; however, from the nature of the methods, the pressure cannot vary greatly from normal atmospheric pressure.

TABLE I.

	Name.	Formula.	Molecular Mass.	Temp.	Latent Heat.	$\frac{\mu\rho}{T_{abs}}$	Pressure.
	a	*b*	*c*	*d*	*e*	*f*	*g*
I	Bromine	Br_2	160	58	45·6	22·04	752
XIV	“	“	160	61·6	43·7	20·95	----
XX	Sulphur	S_x	32_x	316	362·0	19·66	760
XX	Mercury	Hg	200	350	62·0	19·90	760
I	Phosphorus chloride	PCl_3	137·3	78·5	51·4	20·07	750
I	Tin tetrachloride	$SnCl_4$	259·5	112·5	30·5	20·49	753
XVIII	*Sulphur chloride	S_2Cl_2	135	136	49·4	16·30	----
I	Carbon bisulphide	CS_2	76	46·2	86·7	20·64	758
XXVIII	“ “	“	76	46·1	83·8	19·96	----
XXIV	“ “	“	76	46·6	85·7	20·37	759
XVIIa	Diethylamine	$C_4H_{11}N$	73	58	61·0	20·07	----
IV	*Amylene	C_5H_{10}	70	12·5	75·0	18·49	----
XXVI	Benzene	C_6H_6	78	80·35	93·4	20·63	765
XXVIII	“	“	78	80·1	92·9	20·50	----
XXVI	Toluene	C_7H_8	82	110·8	83·6	20·02	765
XXVI	Ethylbenzene	C_8H_{10}	106	134·7	76·4	19·86	757
XXVI	Propyl benzene	C_9H_{12}	120	157·0	71·8	20·00	754
XXVI	Metaxylene	C_8H_{10}	106	139·9	78·3	20·09	766
XXVI	Pseudocumol	C_9H_{12}	120	168·0	72·8	19·58	764
XXVI	Cymol	$C_{10}H_4$	134	175·0	66·3	19·83	755
XI	Methylene chloride	CH_2Cl_2	84·7	41·6	75·3	20·25	----
XXVIII	Chloroform	$CHCl_3$	119·1	60·9	58·5	20·84	----
XXVIII	Carbon tetrachloride	CCl_4	153·6	76·4	46·4	20·35	----
XXIII	“ “	“	153·6	76·4	46·6	20·49	758
I	Methyl iodide	CH_3I	141·5	42·2	46·2	20·66	751
XI	Ethylidene chloride	$C_2H_4Cl_2$	98·7	60	67·0	19·88	----
XXIV	Ethyl chloride	C_2H_5Cl	64·4	21·17	89·3	19·59	----
XXVIII	“ bromide	C_2H_5Br	109	38·2	60·4	21·15	----
VIII	“ “	“	109	38·4	61·6	22·25	----
I	“ iodide	C_2H_5I	155·5	71·3	46·9	21·16	742
VIII	Ethylene bromide	$C_2H_4Br_2$	188	131	43·8	20·38	----
VIII	*Amyl chloride	$C_5H_{11}Cl$	106·5	107	56·3	15·78	----
VIII	*Amyl bromide	$C_5H_{11}Br$	151	129	48·3	18·14	----
VIII	*Amyl iodide	$C_5H_{11}I$	197·5	156	47·5	21·87	----
I	*Methyl formiate	$C_2H_4O_2$	60	32·9	117·1	22·96	752
X	* “ “	“	60	33(?)	115·2	22·58	----
I	*Ethyl “	$C_3H_6O_2$	74	54·3	105·3	26·86	752
X	* “ “	“	74	53·5(?)	100·4	22·75	----
XXVI	“ “	“	74	53·5	92·2	20·88	753
XXVI	Propyl “	$C_4H_8O_2$	88	81·2	85·3	21.18	760
XXVI	Isobutyl “	$C_5H_{10}O_2$	102	98·0	77·0	21·17	759
XXVI	Isoamyl “	$C_6H_{12}O_2$	116	124·0	71·7	20·93	759
XXVI	Methyl acetate	$C_3H_6O_2$	74	57·3	94·0	21·04	757
I	* “ “	“	74	55·0	110·2	24·86	----
I	*Ethyl “	$C_4H_8O_2$	88	74·6	92·7	23·46	----
XXVI	“ “	“	88	77·0	83·1	20·88	760
XXVIII	“ “	“	88	73·1	84·3	21·43	----
XXVI	Propyl “	$C_5H_{10}O_2$	102	102·3	77·3	21·00	760
XXVI	Isobutyl “	$C_6H_{12}O_2$	116	116·8	69·9	20·83	761
XXVI	Isoamyl “	$C_7H_{14}O_2$	130	142·0	66·4	20·78	757
XXVI	Methyl propionate	$C_4H_8O_2$	88	80·0	84·2	20·97	760
XXVI	Ethyl “	$C_5H_{10}O_2$	102	98·7	77·1	21·15	759

TABLE I—*Continued.*

	Name.	Formula.	Molecular Mass.	Temp.	Latent Heat.	$\frac{\mu\rho}{T_{abs}}$	Pressure.
	a	*b*	*c*	*d*	*e*	*f*	*g*
XXVI	Propyl propionate	$C_6H_2O_2$	116	122·6	71·5	20·96	759
XXVI	Isobutyl “	$C_7H_{14}O_2$	130	136·8	66·0	20·96	760
XXVI	Isoamyl “	$C_8H_{16}O_2$	144	160·5	63·1	20·94	755
XXVI	Methyl butyrate	$C_5H_{10}O_2$	102	102·3	77·3	20·70	760
XXVI	Ethyl “	$C_6H_{12}O_2$	116	119	71·5	21·15	751
XXVI	Propyl “	$C_7H_{14}O_2$	130	143·6	66·2	20·65	761
XXVI	Isobutyl “	$C_8H_{16}O_2$	144	156·7	61·9	20·74	756
XXVI	Isoamyl “	$C_9H_{18}O_2$	158	178·0	59·4	20·80	761
XXVI	Methyl isobutyrate	$C_5H_{10}O_2$	102	92·5	75·5	21·06	757
XXVI	Ethyl “	$C_6H_{12}O_2$	116	110·0	69·2	20·96	758
XXVI	Propyl “	$C_7H_{14}O_2$	130	134·0	63·9	20·36	759
XXVI	Isobutyl “	$C_8H_{16}O_2$	144	148·6	59·9	20·47	760
XXVI	Isoamyl “	$C_9H_{18}O_2$	158	168·0	57·7	20·65	758
XXVI	Methyl valerate	$C_6H_{12}O_2$	116	116·3	69·9	20·83	758
XXVI	Ethyl “	$C_7H_{14}O_2$	130	134·0	64·7	20·67	758
XXVI	Propyl “	$C_8H_{16}O_2$	144	155·5	61·2	20·56	758
XXVI	Isobutyl “	$C_9H_{18}O_2$	158	169·0	57·9	20·69	760
XXVI	Isoamyl “	$C_{10}H_{20}O_2$	172	187·5	56·2	20·99	763
I	*Ethyl oxalate	$C_6H_{10}O_4$	146	184·4	72·7	23·22	756
XI	Ethylene oxide	C_2H_4O	44	13·5	138·6	21·28	----
XV	Ethyl oxide	$C_4H_{10}O$	74	34·9	89·9	21·63	----
I	“ “	“	74	34·9	90·5	21·75	----
XXVIII	“ “	“	74	34·5	88·4	21·27	----
XXII	“ “	“	74	34·8	84·5	20·31	----
	Methylal	$C_3H_8O_2$	76	42·0	89·9	21·54	----
XVII	Water	$(H_2O)x$	$18x$	99 8	535·8	25·87	----
I	“	“	$18x$	100	535·9	25·85	760
XXV	“	“	$18x$	100	532·0	25·67	----
XXVIII	Methyl alcohol	$(CH_4O)x$	$32x$	64·5	267·5	25·36	----
XVII	“ “	“	$32x$	66·5	263·9	24 87	----
XVII	Ethyl “	$(C_2H_6O)x$	$46x$	78·4	208·9	27·34	----
I	“ “	“	$46x$	77·9	202·4	26·53	759
XXV	“ “	“	$46x$	78·0	206·4	27·04	----
XXVIII	“ “	“	$46x$	78·1	205·0	26·85	----
XIXa	“ “	“	$46x$	78·3	201·4	26·37	----
XIXa	Propyl “	$(C_3H_8O)x$	$60x$	96·9	164·1	26·61	----
XIXa	Isopropyl “	$(C_3H_8O)x$	$60x$	82·2	159·7	26·98	----
XIXa	Butyl “ (nor)	$(C_4H_{10}O)x$	$74x$	116·5	138·2	26·25	----
XIXa	Isobutyl “	$(C_4H_{10}O)x$	$74x$	107·7	136·2	26·47	----
XVII	Amyl “	$(C_5H_{12}O)x$	$88x$	131(?)	121·4	26·44	----
XXV	“ “	“	$88x$	131	120·0	26·13	----
XIXa	“ “	“	$88x$	130·1	118·2	25·79	----
	Dimethylethyl carbinal	$(C_5H_{12}O)x$	$88x$	102·1	110·4	25·90	----
XVII	Cetyl alcohol	$(C_{16}H_{34}O)x$	$242x$	360(?)	58·5	22·36	----
XXVIII	Acetone	$(C_3H_6O)x$	$58x$	56·6	125·3	22·05	----
XVII	Formic acid	$(CH_2O_2)x$	$46x$	100	120·7	14·88	----
X	“ “	“	$46x$	100	103·7	12·78	----
XIII	Acetic “	$(C_2H_4O_2)x$	$60x$	118	84·9	13·03	----
XVII	Butyric “	$(C_4H_8O_2)x$	$88x$	164	114·7	23·09	----
XVII	Valeric “	$(C_5H_{10}O_2)x$	$102x$	175	103·5	23 57	----
XIa	Nitromethane	$C_1H_3NO_2$	60	101	116·7	18·71	----
XIa	Nitroethane	$C_2H_5NO_2$	75	113	92·0	17·72	----

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It is not easy to make an estimate of the accuracy of some of the data recorded in the foregoing table; the determinations have been made by scientists employing different methods and different preparations, and hence the same degree of exactitude cannot be attributed to the work of each. Two principal sources of error are encountered in the determinations of latent heats of vaporization: the method may not be accurate: the liquid may not be pure. As a rule, in the same investigation both these sources of error are met with; that is, those investigators who have worked by faulty methods have also not always taken liquids of requisite purity. Nearly all the earlier determinations are subject to this criticism, as those by Person, Brix, and, to some extent, especially as regards the purity of the products, those by Favre and Silbermann. Andrews' work which, as far as the method is concerned, is remarkably accurate for the time when it was done, has been performed in some cases with impure liquids; this is especially true of the ethers investigated by him. Schiff states how difficult it is to obtain in a state of great purity the more volatile ethers. Thus, for ethyl formiate, a liquid very hard to purify, Schiff found the heat of vaporization to be 92·15 cal., while Andrews found 105·3 cal. With the exception of the ethers, however, Andrews' determinations may be regarded as very precious data. Of the purity of the liquids used by Berthelot and by Ogier, it is especially hard to form an opinion, inasmuch as these scientists have not indicated with but few exceptions their methods of purification. If it be permitted to judge from a single example taken at random, we cannot admit that their products were always as pure as necessary; thus, they found for the latent heat of vaporization of ethyl formiate, which, as stated just above, Schiff determined to be 92·15 cal., equal to 100·4 cal. The impurity within compounds of the ether class is for the most part water. Since water requires much more heat for vaporization than most liquids, its presence, even in minimal amount, exercises considerable influence upon the value of a determination. In those cases, therefore, where water may be present as impurity, the heat of vaporization will be too high. And, as a matter of fact, the determinations on the ethers made by Andrews, as well as by Berthelot and by Ogier, all give values higher than those found by Schiff, who took the greatest pains to fully rid his preparations of water. The method employed by them is, however, quite beyond any but the sharpest criticism, so that their determinations may be admitted as sufficiently accurate with the exception of the amyl halogen compounds, amylene, ethyl formiate, and sulphur chloride. The work of the other investigators may be admitted without question, especially that due to Schiff, which is a marvel of accuracy. Such determinations as are not trustworthy are marked in the table with a star.

III.

An inspection of Table I shows that the numbers in column *f* are quite constant, with the exception of the alcohols, the acids, and the nitro-compounds, as well as water and acetone. Leaving these liquids aside for a moment,—their seemingly irregular behavior will be explained away later on—we will consider the various family of compounds of which Table I is made up. Taking all the reliable determinations into consideration, we find that the average value of the "constant" is for about seventy liquids equal to *20·70*, the greatest value being 22·04 for bromine (Andrews I).* For the elements and inorganic compounds, the "constant" is equal to *20·41* with 22·04 and 19·66 as extreme values; for the hydrocarbons, to *20·19*, 20·63 and 19·58 being the extreme values; for the halogen compounds, to *20·63*, with extreme values equal to 21·16 and 19·59; for the esters, to *20·87*, the extremes being 21·43 and 20·36. With the exception of the esters, the determinations have been made by different men in different ways, so that a great degree of "constancy" is hardly to be expected; yet the

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* The determination by Berthelot and Ogier (xiv), however, gives 20·95 as the value of the "constant," so that it is perhaps better to reject Andrews' determination. If that be done the greatest value is 21·54 for methylal (Berthelot) and the smallest value being 19·58 for pseudocumene (Schiff).

"constant" is remarkably constant. Schiff's work was most carefully done by the same method and hence his results are at once reliable and comparable in an eminent degree; and, as a matter of fact, the extreme values of the constant calculated from his data differ from the average value by hardly three per cent.

Such a regularity as the above implies that the liquids at their boiling points are in corresponding states (the term "corresponding states" being used in the sense given it by van der Waals (loc. cit.) As far as the pressure is concerned, it may be stated that atmospheric pressure can be reckoned as "corresponding" in questions of this sort. That boiling points for certain properties of liquids are "corresponding temperatures" in a not inconsiderable measure has been shown by C. M. Guldberg* who in comparing the quotient of the absolute boiling points by the absolute critical temperature found it to remain close to an average value of about $\frac{2}{3}$, and concluded that quantities which vary slowly with the temperature (among which latent heats of vaporization are to be counted) may be reckoned as being approximately in corresponding states at their points of ebullition. This conclusion follows directly from equation (4) which indicates that the relation

$$\frac{\rho\mu}{T_1} = \psi\frac{T}{T_1} \tag{19}$$

must obtain (ψ being an unknown function). Guldberg then states that through comparison of various liquids the equation

$$\psi(\tfrac{2}{3}) = 14 \tag{20}$$

is found by means of graphic interpolation, and accordingly at the boiling points the relation

$$\frac{\rho\mu}{T_1} = 14 \tag{21}$$

obtains with a certain approximation. Inasmuch as

$$\frac{T}{T_1} = \tfrac{2}{3},$$

it follows that

$$\frac{\rho\mu}{T} = 21. \tag{22}$$

Guldberg thus obtains about the same "constant" as has been shown in the foregoing to be the average of reliable determinations.

As stated above, the values of $\frac{\mu\rho}{T}$ given in the table differ

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* Zeitschr. für phys. Chemie, v, p. 374, 1890.

considerably from the normal average value in the case of the acids, nitro-methane and nitro-ethane, the alcohols, acetone and water. For the acids and nitro-compounds they are too small; for the alcohols, water, and acetone, they are too large. The cause of this abnormal behavior is to be found in the "association" of the molecules of these liquids, and in the changes which the molecular aggregations undergo during the process of vaporization. We will consider the case of the alcohols, water, and acetone first.

The brilliant experiments of Ramsay and his associates on the surface tensions of liquids, and his theoretical deductions have taught us that the liquids in question are made up of molecules in a state of association. No facts are known, however, which indicate that an appreciable amount of molecular association is persistent in the vaporous state; on the contrary, the normality of the vapor density, and other properties of the vapors, show that they consist exclusively, it may be said, of simple molecules. Accordingly, when the alcohols, etc., are evaporated, there occurs a decomposition of the complex molecules into simple ones. This requires the expenditure of a certain amount of energy, which is manifest as heat energy. The heat necessary to convert a molecularly polymerized liquid into its normal vapor consist then of two terms,* the heat expended in actually turning the liquid into a gas, and the heat used up in decomposing the molecular aggregations or "tagmas." The value of ρ, then, in the expression $\frac{\rho\mu}{T} =$ const. is greater for associated than for normal liquids; hence the value of the "constant" becomes greater, and, indeed, so much the greater, the more complex the liquid molecule. It seems at present impossible to make a reliable correction for the heat employed in decomposing the complex molecules.

In the case of the acids, the state of affairs is somewhat different. It has long been known that the organic acids, as formic, and acetic acid, have abnormal vapor densities due to the association of the molecules in the vaporous state; as the temperature rises, the degree of association becomes less and less until the normal molecule is reached. At the boiling points under ordinary atmospheric pressure, the vapor density of formic acid may by extrapolation from the data due to Petersen and Ekstrand† be put at 2·5 at 100°; this multiplied by 28·87 gives a molecular mass of 72; and this value of μ when introduced into the relation $\frac{\mu\rho}{T_{abs}} =$ const., gives for the

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* See Guye's paper: Sur la polymirisation moléculaire des liquides: Archives des Sciences physiques et naturelles, III, xxxi, 160, 1894.

† Ber. der deutschen chem. Gesell., xiii, 1194.

"constant," *19·89*. Likewise from extrapolation of Cahours* determinations of the vapor density of acetic acid, its vapor density at 118° may be set at 3·3, which by multiplication by 28·87 gives as molecular mass 95; and this in turn shows the value of the "constant" to be *20·34*. Now we have every reason to believe that the gaseous associated molecule does not dissociate on passing into the liquid state; on the contrary, there can scarcely be any doubt but that it increases more or less in complexity. Accordingly, the molecular masses calculated for the gaseous molecules may be set as very near those of the liquid molecules of the two acids in question, and, indeed, the experiments of Schall† indicate that for acetic acid, at least, such is the state of affairs. The values of the "constant" found for these corrected molecular masses are seen to be practically identical with that found for normal liquids, and the exception presented by the acids is seen to be but seeming. For butyric and valeric acids, however, the "constants" cannot be corrected as for the two preceding acids, since they are found to be too large even when calculated on the assumption that their molecular masses are normal. If their determinations of latent heat of volatilization are sufficiently accurate—which is somewhat doubtful—it is probable that the complex liquid molecules in their case undergo decomposition on passing into the vaporous state, similar to the alcohols, etc. In the absence of experiments on their vapor densities it is not possible to judge what is the true state of the case.

Nitromethane and nitroethane also give values of the constant less than the normal. Ramsay and Shields‡ have measured the superficial tension of nitroethane, finding it such as to legitimatize the assumption that the molecules of this liquid are in a state of association; by analogy it may be admitted that nitromethane is also an associated liquid, although no experimental data are at hand. If what has been said in explanation of the seeming abnormality in the behavior of the acids as regards the "constant" be in accordance with fact, it is necessary to suppose that the two nitro-compounds also pass from the liquid into the gaseous condition without the complex molecule suffering much dissociation.

The immediately preceding considerations indicate a method of getting an approximation of the degree of association of a liquid. If any liquid, whose latent heat of volatilization be known, gives a value for the "constant" close to 20·7, it is pretty certain that it is normal. 'If it gives a less value, it is associated in the liquid as well as in the gaseous state; if it

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* Comp. Rend., xix, 771.

† Ber. der deutschen chem. Gesell., xvii, 2199, 1884.

‡ Zeitschr. für phys. Chem., xii, 433, 1893.

gives a greater value, it must be associated in the liquid state alone. The greater the variation from the normal value of the "constant," the greater the amount of the association.

Thus far, we have considered the application of the formula $\frac{\mu\rho}{T_{abs}} = \text{const.}$ only to determinations made under the pressure of about one atmosphere. But how will it be at other pressures and hence other temperatures ? All of the deductions of the formula have been made on the assumption that the pressure was that of one atmosphere, with the exception of the one developed by Le Chatelier, which contains a term referring to pressure (Equation 17). This equation, however, was derived on the supposition that the latent heat of vaporization is independent of temperature and pressure; such an assumption, however, does not accord with the experimental results obtained by Regnault, Ramsay and Young, Jahn, and others. The heat of vaporization of a liquid decreases with rise of temperature and concomitant increase of pressure until at the critical point it becomes equal to zero. Yet for all temperatures and concurrent pressures below the critical, the relation (17) obtains, and the lower the temperature, the larger the "constant." The number of reliable data at hand for the comparison of the theory with experiment at other pressures than the atmospheric is relatively small. Most of them have been made at the freezing point of water under the pressure of the saturated vapor at that temperature. In Table II are given such data as are reliable, and only for normal liquids. In the first column is given a reference number to the investigator's names and places of publication,—directly below the table. Columns *a*, *b*, *c*, and *d* give the name, formula, molecular mass, and the latent heat of vaporization, respectively of the liquids in question. The sixth (*e*) column contains the value of the expression $\frac{\mu\rho}{T_{abs}}$, and the seventh (*f*) the value of twice the natural logarithm of the pressure. (The pressure in the case of such liquids as have had their vapor tension determined is generally set as equal to that of the saturated vapor at 0° ; for the others, the pressure has been put at 60^{mm} of mercury, as Jahn, in his experiments, reduced the pressure to this point before allowing evaporation to take place, and the others examined by him have not been investigated thoroughly as regards their vapor tensions. The pressure is reduced to absolute measure by multiplication by 13·6.) The last column gives the value of Le Chatelier's relation (17), obtained by adding the values found in columns *e* and *f* for each liquid.

TABLE II.

Ref. No.	Name.	Formula.	Molecular Mass.	Latent Heat.	$\frac{\mu\rho}{T_{abs}}$	2 log *p*.	
	a	*b*	*c*	*d*	*e*	*f*	*f* and *e*
I	Benzene	C_6H_6	78	107·6	30·75	9·8	40·55
II	"	"	78	109·0	31·14	9·8	40·94
II	Chloroform	$CHCl_3$	119·4	67·0	29·20	12·85	42·05
II	Carbon tetrachloride	CCl_4	156	52·0	29·25	12·21	41·46
II	Carbon disulphide	CS_2	76	90·0	25·00	14·92	39·92
III	" "	"	76	89·5	25·09	14·92	40·07
III	Ethyl ether	$(C_2H_5)_2O$	74	93·5	25·21	15·67	40·87
II	" "	"	74	94·0	25·49	15·67	41·16
I	Ethyl formiate	$C_3H_6O_2$	74	113·25	30·69	9·8	40·49
I	Propyl formiate	$C_4H_8O_2$	88	105·37	33·96	9·8	43·76
I	Methyl acetate	$C_3H_6O_2$	74	113·86	30·86	9·8	40·09
I	Ethyl acetate	$C_4H_8O_2$	88	102·14	32·92	9·8	42·72

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II, Regnault, Memoires de l'Académie, xxvi, 761, 1862.
III, Winkelmann, Wiedemann's Annalen, ix, 208 and 358, 1880.

Table II shows that, while it is impossible to speak of a constancy for the values contained in the sixth column, through the introduction of the pressure correction in equation (17) a value is found equal in mean to about 40·5; it is remarkable that such a constancy is to be found in the values, since no great amount of accuracy can be attributed to the determinations of the latent heat or of the pressure. If the pressure correction be applied to the determinations of the latent heats of vaporization carried out under or nearly under atmospheric pressure, the "constant" is found to become equal to *39·18*, since 2 log 760 equals 18·48; this value, as is to be expected, is very near to that found for the liquids under the circumstances given in table II; undoubtedly, approximately the same value for the expression would be found under other pressures and concurrent temperatures, although the data at hand are too meager to make it worth while to perform the necessary calculations. As a conclusion to all that precedes and as a prediction of all future experimental work on latent heats of vaporization, it may be stated that the relation deduced by Le Chatelier may be put equal to about 40·00, thus

$$2 \log p + \frac{\mu\rho}{T_{abs}} = 40{\cdot}00 \qquad (17 \text{ bis})$$

IV.

In accurate determinations of temperatures of ebullition, it is often necessary to make a correction for the variation of the pressure from the normal pressure of 760^{mm} of mercury. In case the latent heat of vaporization of the liquid under examination is known, this correction is easily made by the application of equation (1), which gives in terms of latent heat, temperature, and volume, the change of the boiling point with the concomitant variation of pressure. But the latent heats of volatilization are known for only a comparatively small number of liquids. In this case, the "law" treated of in the foregoing sections is specially applicable. We know from what precedes that near atmospheric pressure

$$\frac{\mu\rho}{T_{abs}} = \text{const.}, \qquad \text{(A)}$$

The "constant" varying slightly for different classes of liquids from an average value of 20·7, at least, for normal liquids. If we set for the "constant," the letter C, neglect the volume of the liquid in comparison with that of the vapor —which will introduce no appreciable error,—and substitute for T its equal $\frac{\mu\rho}{C}$, equation (1) becomes transformed into

$$\frac{dT}{dp} = \frac{v\mu}{C}. \qquad \text{(B)}$$

If now, from the gas equation

$$v = \frac{2T}{p} \qquad \text{(C)}$$

we take the value of $\mu\rho$ ($\mu\rho = V =$ a gram-molecule of saturated vapor), and set it in equation (B), we obtain the equality

$$\frac{dT}{dp} = \frac{2T}{pC}; \qquad \text{(D)}$$

and if p be the normal pressure of 760^{mm}, we get finally

$$\frac{dT}{dp} = \frac{2T}{760\ C} = \frac{T}{380\ C}, \qquad \text{(E)}$$

or

$$dT = \frac{T}{380\ C} \,.\, dp. \qquad \text{(F)}$$

By putting for C, that value of the constant found for the class of liquids to which the liquid under examination belongs (see page 359), and for T, the absolute temperature of ebullition, we may obtain with a very considerable degree of accuracy the desired correction, with the restriction, however, that the variation of pressure is but slight, that is, not over 50 millimeters of mercury.

Chicago, January 22d, 1895.

Art. XXXI.—*On the Double Halides of Cæsium, Rubidium, Sodium and Lithium with Thallium*; by J. H. Pratt.

In previous investigations upon the double halides of trivalent thallium with the alkali metals, the salts of only potassium and ammonium seem to have been carefully studied. The only cæsium and rubidium salts that have been made are $Cs_3TlCl_6 . 2H_2O$ and $Rb_3TlCl_6 . 2H_2O$ described by Godfrey,* but in the present investigation the compounds of this type were found to have one instead of two molecules of water of crystallization.

The present research has been carried out very carefully and systematically in order to obtain as complete a series of double salts in each case as possible. The salts that have been made belong to four types, corresponding to those previously made with potassium and ammonium, and are as follows,

3:1	2:1	3:2	1:1
$Cs_3TlCl_6 . H_2O$	Cs_2TlCl_5	$Cs_3Tl_2Cl_9$	----------
	$Cs_2TlCl_5 . H_2O$	--------	----------
-------------	-------------	$Cs_3Tl_2Br_9$	$CsTlBr_4$
-------------	-------------	--------	$CsTlI_4$
$Rb_3TlCl_6 . H_2O$	$Rb_2TlCl_5 . H_2O$	--------	----------
$Rb_3TlBr_6 . H_2O$	-------------	--------	$RbTlBr_4 . H_2O$
-------------	-------------	--------	$RbTlI_4 . 2H_2O$
$Na_3TlCl_6 . 12H_2O$			
$Li_3TlCl_6 . 8H_2O$			

For comparison, a list of the previously described double salts with potassium and ammonium is also given.

3:1	2:1	3:2	1:1
$K_3TlCl_6 . 2H_2O$	$K_2TlCl_5 . 3H_2O$	$K_3Tl_2Cl_9 . 1\frac{1}{2}H_2O$	$KTlBr_4$
$(NH_4)_3TlCl_6 . 2H_2O$		$K_3Tl_2Br_9 . 1\frac{1}{2}H_2O$	$KTlI_4 . H_2O$
$(NH_4)_3TlCl_6$			$(NH_4)TlBr_4 . 5H_2O$
			$(NH_4)TlBr_4 . 2H_2O$
			$(NH_4)TlBr_4$
			$(NH_4)TlI_4$

Several points of interest, already noticed in connection with double salts prepared in this laboratory, are well illustrated by the series of new compounds to be described. With cæsium, a more complete series of salts was prepared than with the other alkali metals; and there is also an increase in ease of formation and in number of salts, from the iodides to the chlorides. The salts, formed from the alkali metal with

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* Landenberg's Handwörterbuch.

the lower atomic weight are generally more soluble in water, form in larger crystals and with more water of crystallization than those with higher atomic weight.

Preparation.—The double salts were prepared in each case by mixing solutions of the thallic halide with the alkali halide in widely varying proportions, evaporating and cooling to crystallization. With the bromides and iodides the conditions for obtaining the double salts were improved by the presence of a little free bromine and iodine.

The crystals, soon after forming, were removed from the solutions, quickly pressed between filter papers to remove the mother-liquor, and, with the exception of the sodium and lithium salts, allowed to stand exposed to the air for some time. The latter on account of their instability, were placed in tightly stoppered weighing-tubes as soon as they were free from the mother-liquor.

Method of analysis.—In determining thallium, the salt was dissolved in warm water and a slight excess of ammonium sulphide added to precipitate the thallium as thallous sulphide. This was filtered and washed with water containing a little ammonium sulphide. The precipitate was then dissolved in hot dilute nitric acid, the solution evaporated with sulphuric acid in a platinum crucible, and then heated to constant weight within a porcelain crucible over a small flame. The filtrate from the thallous sulphide precipitation, was evaporated with sulphuric acid, the ammonium salts driven off, and the residual alkali sulphate ignited in a stream of air containing ammonia. The halogens were determined as silver salts in separate portions, with the precaution of adding sulphurous acid in the case of the iodides to prevent loss of iodine in dissolving, and it was found to be necessary in all cases to use a large excess of nitric acid in order to obtain the silver halide in a pure condition. Water was determined by igniting in a combustion tube, behind a layer of dry sodium carbonate, in a stream of dry air and collecting it in a weighed calcium chloride tube.

3 : 1 Cæsium and Rubidium Thallic Chlorides, $Cs_3TlCl_6 . H_2O$ *and* $Rb_3TlCl_6 . H_2O$.—The cæsium salt is obtained, as a white precipitate, when 0·25 g. of thallic chloride is added to a solution of 50 g. of cæsium chloride. The precipitate dissolves somewhat slowly upon heating the solution and crystallizes out on cooling. The range of conditions is very narrow as 3 g. of thallic chloride to 50 g. of cæsium chloride give the salt, Cs_2TlCl_5. The salt is soluble in hot water, but $Cs_3Tl_2Cl_9$ crystallizes from the solution.

The rubidium salt has a much wider range of formation. It is obtained when 1·5 to 25 g. of thallic chloride are added to a solution of 40 g. of rubidium chloride. It is very soluble in cold water but gives another salt, $Rb_2TlCl_5 . H_2O$ upon crystallization. Both salts are white as are all the chlorides with one exception. Two separate crops of each were analyzed with the following results :

		B.		Calculated for
	A.	I.	II.	$Cs_3TlCl_6H_2O$.
Cæsium	48·44	48·05	48·33	47·84
Thallium	24·21	24·45	24·37	24·46
Chlorine	25·37	25·53		25.54
Water	2·74	1·97		2·16

	A.	B.	Calculated for $Rb_3TlCl_6H_2O$.
Rubidium		36·54	37·09
Thallium	29·02	29·65	29·50
Chlorine	30·99	31·17	30·81
Water	2·51	1·72	2·60

The cæsium salt was obtained in hair-like crystals, too small for measurement. The rubidium salt crystallized in thin plates having a rhombic outline. Under the microscope these showed an extinction parallel to the diagonals and in convergent light a bisectrix at one side of the field, with the plane of the optic axes at right angles to the longer diagonal, indicating monoclinic symmetry.

2 : 1 Cæsium and Rubidium Thallic Chlorides, Cs_2TlCl_5, $Cs_2TlCl_5 . H_2O$ *and* $Rb_2TlCl_5 . H_2O$.—The anhydrous cæsium salt is formed when 5 to 8 g. of thallic chloride are added to a somewhat concentrated solution of 100 g. of cæsium chloride, and the hydrous salt, when 8 to 15 g. of thallic chloride are added to a more dilute solution of 100 g. of cæsium chloride. The rubidium salt was observed when 1·25 to 18 g. of rubidium chloride were added to a rather concentrated solution of 30 g. of thallic chloride. The two hydrous salts are white and the anhydrous compound is pale green. The cæsium salts are readily soluble in hot water but the salt $Cs_3Tl_2Cl_9$ crystallizes from the solution. The rubidium salt recrystallizes unchanged from water. The following analyses were made upon separate crops.

		B.		Calculated for
	A.	I.	II.	Cs_2TlCl_5.
Cæsium		40·46	40·17	41·07
Thallium	31·11	31·82	31·62	31·52
Chlorine	27·19	27·30	27·20	27·41
Water	·81		·81	

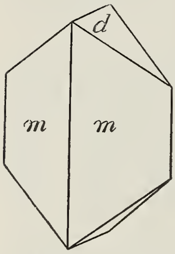
The small amount of water found in the above analyses, equivalent to about one-fourth of a molecule, was probably held mechanically by the crystals.

	A. I.	A. II.	B.	C.	Calculated for $Cs_2TlCl_5 . H_2O$.
Cæsium	40·03	39·84	40·30	39·85	39·97
Thallium	30·75	30·71	31·11	30·98	30·65
Chlorine	26·85		26·56	26·93	26·67
Water			2·88	2·37	2·71

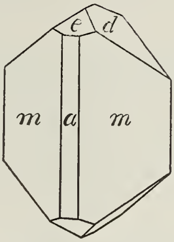
	A.	B.	Calculated for $Rb_2TlCl_5 . H_2O$.
Rubidium	29·09	28·97	29·97
Thallium	35·94	35·74	35·76
Chlorine	30·74	30·97	31·11
Water	3·34		3·16

The crystals of Cs_2TlCl_5 were in needles too small for measurement.

1.



2.



The crystallization of $Cs_2TlCl_5 . H_2O$ and $Rb_2TlCl_5 . H_2O$ is orthorhombic. The salts are similar in habit and are developed as in figs. 1 and 2. The forms observed are as follows:

a,	100	*d*,	011
m,	110	*e*,	102

The crystals of the cæsium salt were only about ·4 to ·6^{mm} in length, but the faces were smooth and gave good reflections on the goniometer. The axial ratio is,

$$\breve{a} : \bar{b} : \acute{c} = 0{\cdot}6762 : 1 : 0{\cdot}6954.$$

		Measured.	Calculated.
$d \wedge d$,	$011 \wedge 0\bar{1}1$	*70°	
$m \wedge m$,	$110 \wedge 1\bar{1}0$	*68 22′	
$m \wedge a$,	$110 \wedge 100$	34 3 30″	34° 11′
$a \wedge e$,	$100 \wedge 102$	62 51	62 44
$m \wedge d$,	$110 \wedge 011$	71° 14′; 71° 16′	71 12
$d \wedge e$,	$011 \wedge 102$	43° 9′	43 16
$e \wedge e$,	$102 \wedge \bar{1}02$	54 6	54 32

Crystals of the rubidium salt were obtained from about 1·5 to 4^{mm} in length. The axial ratio is,

$$\breve{a} : b : \acute{c} = 0{\cdot}6792 : 1 : 0{\cdot}7002.$$

		Measured.	Calculated.
$d \wedge d$,	$011 \wedge 0\bar{1}1$	*69° 36′	
$m \wedge m$,	$110 \wedge 1\bar{1}0$	*68 7½	
$m \wedge a$,	$110 \wedge 100$	34° 4′; 34° 9′; 34° 5′	34° 4′
$a \wedge e$,	$100 \wedge 102$	62° 52½′	62 49
$m \wedge d$,	$110 \wedge 011$	71° 26′; 71° 23′	71 21
$d \wedge e$,	$011 \wedge 102$	43° 19′	43 4½
$e \wedge e$,	$102 \wedge \bar{1}02$	54 15	54 22

3 : 2 Cæsium Thallic Chloride, $Cs_3Tl_2Cl_9$.—The conditions under which this salt can be made are very wide, ·5 to 29 g. of cæsium chloride form a heavy white precipitate when added to a solution of 40 g. of thallic chloride. This dissolves readily in the solution upon heating and crystallizes in slender hexagonal prisms terminated by the pyramid. When the ratio of the cæsium chloride to the thallic chloride is 30 g. to 50 g. a salt is obtained which crystallizes in hexagonal plates. Analyses of the plates do not agree very closely with theory, but it is evident that they are the same as the prismstic salt with another crystalline habit. The high percentage of cæsium and the corresponding low percentage of thallium is probably due to the slight inclusions held by the crystals, which could be seen with the microscope. This salt is white, permanent in the air and recrystallizes unchanged from water. The analyses given below are of separate crops made under very different conditions.

	Cæsium.	Thallium.	Chlorine.	Water.
A	34·93			·65
B	35·09	35·64–35·51	28·09–27·99	
C			28·06	·95
D		35·63		
E	35·03	35·69	28·06	
F (Plates)	36·64	33·85	28·15	
G (Plates)	36·18	34·46	28·18	·61
Calculated for $Cs_3Tl_2Cl_9$	35·42	36·22	28·36	

The water found in these analyses was probably held mechanically by the crystals.

The prismatic variety of this salt showed only the forms of the prism, $10\bar{1}0$, and pyramid, $10\bar{1}1$.

Axis $c = 0{\cdot}82566$ $0001 \wedge 10\bar{1}1 = 43° \ 37' \ 50''$

	Measured.	Calculated.
$p \wedge p$, $10\bar{1}1 \wedge 01\bar{1}1$	*40° 21′	
$m \wedge p$, $10\bar{1}0 \wedge 10\bar{1}1$	46 21½; 46° 22′	46° 22′

Sections parallel to the basal plane show in convergent polarized light the normal uniaxial interference figure, with weak negative double refraction. The crystals served very well as 60° prisms for the determination of the indices of refraction with the following results:

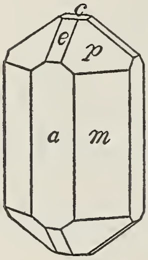
	Red, Li.	Yellow, Na.	Green, Tl.
$\omega =$	1·772	1·784	1·792
$\varepsilon =$	1·762	1·774	1·786

3 : 1 Rubidium Thallic Bromide, $Rb_3TlBr_6 . H_2O$.—This salt was formed, when 1·5 to 24 g. of thallic bromide were added to a very concentrated solution of 50 g. of rubidium bromide. It crystallizes in beautiful golden yellow crystals, which are very soluble in water, giving the 1 : 1 salt on recrystallizing. Careful efforts were made to obtain a 2 : 1 and 3 : 2 rubidium thallic bromide, but without success. Several separate products, made under very different conditions, were analyzed with the results which follow :

	Rubidium.	Thallium.	Bromine.	Water.
A	28·57		49·29	2·49
B		20·39	49·66	
C	28·18	20·59		
D	28·03	20·16	49·42	
E	27·70	20·33	50·28	
F		20·64		
G	26·56	21·17	50·49	
Calculated for $Rb_3TlBr_6 . H_2O$	26·76	21·28	50·08	1·88

The somewhat high percentage of rubidium and the low percentage of thallium found in the first four analyses is probably due to the large excess of rubidium bromide in the concentrated solutions from which the crystals were obtained. As more thallic bromide was added, better crystals were obtained in more dilute solutions, which give percentages agreeing very well with the calculated.

3.



The crystallization of this salt is tetragonal. Doubly terminated crystals were obtained up to a length of 6^{mm}.

The forms observed are:

a, 100	*m*, 110	*p*, 111
c, 001	*e*, 101	

The habit is shown in fig. 3.

Axis $\dot{c} = 0·80728$; $001 \wedge 101 = 38° \, 54' \, 45''$

		Measured.	Calculated.
$e \wedge e$,	$\bar{1}01 \wedge 101$	*77° 49½′	
$a \wedge e$,	$100 \wedge 101$	51° 6′; 51° 2′; 51° 3½′	51° 5½′
$a \wedge p$,	$100 \wedge 111$	57 52; 57 54; 57 53	57 52
$e \wedge p$,	$101 \wedge 111$	32° 5′; 32° 12′	32 8
$c \wedge p$,	$001 \wedge 111$	48 51; 48 55	48 46
$m \wedge p$,	$110 \wedge 111$	41 7; 41 4	41 13

The crystals show a weak negative double refraction.

3 : 2 Cæsium Thallic Bromide, $Cs_3Tl_2Br_9$.—This salt was observed, as yellowish red crystals, when 1 to 15 g. of thallic bromide were added to a solution of 50 g. of cæsium bromide. It was always obtained in small striated crystals, which were not adapted for measurement. It is permanent in the air and recrystallizes unchanged from water. Analyses of separate products gave the following results,

	A.	B.	C.	D.	Calculated for $Cs_3Tl_2Br_9$.
Cæsium ----		26·52	26·14		26·13
Thallium ---	27·36	27·21	27·28		26·72
Bromine ---	47·24	47·14	47·08	47·27	47·15

1:1 Cæsium and Rubidium Thallic Bromides, $CsTlBr_4$ *and* $RbTlBr_4 . H_2O$.—These two salts are of nearly the same color, pale yellow. The rubidium compound which retains its luster and color much better than the other, recrystallizes unchanged from water, while the cæsium salt gives $Cs_3Tl_2Br_9$, when its solution is evaporated to crystallization. The cæsium salt was observed when 2 to 10 g. of cæsium bromide were added to 40 g. thallic bromide, and the rubidium salt when 3 to 24 g. of rubidium bromide were added to 40 g. thallic bromide. Analyses of several different crops gave the following results:

	A.	B.	C.	D.	Calculated for $CsTlBr_4$.
Cæsium ----	19·14			20·44	20·25
Thallium ---	32·36	31·79	32·04		31·05
Bromine ---	47·76		48·39	48·88	48·70

	A.	B.	C.	Calculated for $RbTlBr_4 . H_2O$.
Rubidium ----	13·77	13·41	13·91	13·63
Thallium ----	32·18			32·51
Bromine -----	50·06		50·30	50·99
Water ------	3·80			2·87

The crystallization of these two salts is isometric, the cube being the only form observed.

1:1 Cæsium and Rubidium Thallic Iodides, $CsTlI_4$ *and* $RbTlI_4 . 2H_2O$.—Both of these salts were prepared from solutions containing a large excess of thallic iodide and also from solutions containing a large excess of the alkali iodide, so that no other type of double iodides with these two metals could be obtained. As the thallic iodide was very difficultly soluble in water, alcoholic solutions were used where the thallic iodide was in excess. The salts are ruby red, with a brilliant luster, which is slowly lost in the air. Both are decomposed by water. The analytical results obtained from several different crops are given below.

	A.	B.	C.	Calculated for $CsTlI_4$.
Cæsium -----	16·57	16·38		15·74
Thallium ----	24·09	24·04		24·14
Iodine -------		59·48	59·67	60·12

	A.	B.	Calculated for $RbTlI_4 . 2H_2O$
Rubidium	10·34	9·78	10·26
Thallium	24·98	25·23	24·47
Iodine	60·38–60·32	60·79	60·94
Water	4·50		4·32

These salts crystallize in the isometric system, the habit being usually the cube truncated by the octahedron.

3 : 1 Sodium and Lithium Thallic Chlorides, $Na_3TlCl_6 . 12H_2O$ *and* $Li_3TlCl_6 . 8H_2O$.—Only one type of double salts could be obtained with these metals and it does not seem possible that others exist, for the ground was covered very carefully and systematically. On account of the extreme solubility of these salts, especially that of the lithium compound, the solutions had to be kept very concentrated, in a more or less syrupy condition, which accounts for the high alkali metal and low thallium found. These salts are transparent and colorless when first taken from the mother-liquor, but, upon exposure to the air, the sodium salt becomes opaque and the lithium compound deliquesces. Analyses of different products gave the following results:

	A.	B.	Calculated for $Na_3TlCl_6 . 12H_2O$.
Sodium	11·13	10·48	9·83
Thallium	27·79	28·39	29·06
Chlorine	31·23	30·45	30·34
Water		29·75	30·77

	A.	B.	C.	D.	Calculated for $Li_3TlCl_6 . 8H_2O$.
Lithium	3·71	3·79	3·73	3·78	3·61
Thallium	34·51				35·06
Chlorine	36·09	36·01	36·40	36·31	36·59
Water	25·14*				24·74

On account of the instability of the sodium and lithium salts no crystallographic determinations were made.

Repeated attempts to prepare lithium and sodium thallic bromides were entirely without success, hence no attempt was made to prepare the iodides.

The author wishes to express his indebtedness to Prof. H. L. Wells for valuable advice in connection with the chemical part of this work, and to Prof. S. L. Penfield for suggestions concerning the crystallography.

Sheffield Scientific School, December, 1894.

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* By difference.

ART. XXXII.—*Argon, Prout's Hypothesis, and the Periodic Law;* by EDWIN A. HILL.

IF Argon be an element, its properties indicate that its place in the periodic classification is between F and Na, with an atomic weight of 20. Its non-metallic acidic electro-negative character, and low melting and boiling points, link it to Series 2 ending with F rather than Series 3 beginning with Na; just as Fe is more closely allied to Mn than Cu. Its resemblance to the members of transitional Group VIII, into which it would therefore fall, is shown in many ways. All the members of this group have high specific gravities, small atomic volumes, very weak chemical affinities, are inert, and with basic or acidic properties very weakly developed if at all. Argon is as truly transitional from Na to F as Group VIII in general is transitional between the two halves of Mendeléef's long periods, and belonging in a short period, is cut off from the other long period members of Group VIII by the same differences in boiling points, melting points, atomic volumes, specific gravities, and other properties, which separate the Series F, O, N, from Mn, Cr, V. To assign it an atomic weight of 40, thus usurping the place of calcium, and placing it among elements to which it bears no analogies whatever, would violate all the principles of the periodic law as now understood; and the great mass of accumulated evidence, upon which that generalization rests, requires us to accept any reasonable explanation of the supposed inconsistency, between the specific heat ratio of 1·66 and the diatomicity of the molecule, rather than the conclusion that it is monatomic.

That is to say the burden of proof is on those who oppose the conclusions drawn from the periodic law.

The argument for monatomicity, briefly stated, is this: The Argon molecule, if diatomic, being eccentric, would by molecular contacts acquire rotational energy, which it does not possess, as proved by the specific heat ratio; hence its molecule must be monatomic, and its atomic weight 40. The whole argument is based on the assumption that a molecular encounter involves an actual contact of atoms, or is of the nature of a collision between two elastic balls. This, however, is not a necessary assumption, nor was it Maxwell's view.* As pointed

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* "I have concluded (he says) from some experiments of my own that the collision between two hard spherical balls is not an accurate representation of what takes place, . . . a better representation of such an encounter will be obtained by supposing the molecules to act on one another in a more gradual manner, so that the action between them goes on for a finite time during which the centers of the molecules first approach each other and then separate." And again: "We have evidence that the molecules of gases attract each other at certain small distances, but when they are brought still nearer they repel each other."

out by Thomson, Maxwell, and others, we need only postulate particles in motion, and a mutual action between them, tending to reverse that motion when they approach within certain small distances of each other, in order to arrive at all the ordinary conclusions of the kinetic theory of gases; which in its simplest form does not depend on any assumptions whatever as to the exact nature of the process by which the motion is reversed. It is only when Boyle's law no longer holds, that is when because of reduced volume the molecules are within the sphere of their mutual actions for an appreciable time, that the theory has to deal with the nature of the encounter, as in the case of viscosity, and for those conditions where we make use of Van der Waals' equation instead of the more simple form, PV=RT. But this ratio of the two specific heats in Argon, was determined under ordinary conditions of pressure and temperature, for which the gas obeys Boyle's law, hence in explaining this ratio we can without going counter to the ordinary kinetic theory of gases, make any assumptions we please as to the nature of the encounter and the constitution of the molecule, not at variance with known facts and the fundamental postulate of moving particles and reversed motion at small distances. Whenever we reach problems in any way conditioned by the nature of the encounter, the ordinary kinetic theory fails. Evidently the nature of the encounter is by it not properly taken into account. Maxwell, in order to test the theory as to viscosity found that, assuming the molecules to be hard elastic balls only acting on each other when in actual contact, viscosity should be proportional to the square root of absolute temperature, but assuming them to be systems repelling each other with a force varying inversely as the 5th power of distance, it should be proportional to the absolute temperature. As shown, however, by Barus and others, viscosity varies more rapidly than required by the first hypothesis, and more slowly than required by the second. Hence the encounter is not a mere collision involving an actual contact. Sutherland, says Thomson, concludes that the molecules *act without contact by a repulsive force* varying inversely with the fourth power of distance, and Pickering in his theory of solutions, represents chemical attraction to be due to charges on the surfaces of the attracting matter, but inalienable from the matter, *owing to a repulsive force* between the atoms similar to that which produces elasticity, preventing the atoms ever coming close enough together to allow of the charges combining by actual contacts. Now if we suppose the atom endowed with such a force of repulsion, varying inversely say as the fourth power of distance (following Sutherland) and combine this with the force of gravitation, then as the atom is approached the repulsive force will first become equal to, and then greatly exceed the attractive force. Now conceive the atom, as enveloped by an imaginary spherical surface or shell, whose radius is the half distance at which these forces become equal, two such atoms would evidently act upon each other like perfectly elastic spheres of that radius; that is, they would strongly repel each other when separated by less than their imaginary diameter, and yet the atoms themselves if they have magnitude and are not mere Boscovitch points may be small as compared to their imaginary diameters, and so the approach of two such atoms might be checked and reversed without any actual contact between them.

Now the force which binds atom to atom within the molecule must do so in opposition to this force of repulsion, and if resembling (it is probably closely connected with) electrical attraction it would vary as the inverse square of distance, and two similar atoms drawn together by it to form a molecule would approach each other, until this force plus gravitation became equal to the force of repulsion. The stronger this attractive force the less the distance between the atoms of a diatomic molecule compared to the distance nearer than which two such molecules could not approach, which latter distance, as between two diatomic molecules, will be that at which the various attractions and repulsions are equally balanced (disregarding kinetic energy of translation which will tend to reduce this distance). Now when the force drawing the atoms together is large compared to that of gravity, the distance between the atoms within the molecule will be small compared with their least distance of approach, and the greater the difference between these quantities the less the action of atom upon atom, which is the action tending to produce internal rotations, and the closer will the action between two molecules during an encounter approximate to that of two repulsive forces concentrated at their respective centers of gravity.

Here we can apply the principle made use of in astronomy to simplify the problem of the three bodies in the case of perturbations, viz: That when the distance between two systems of bodies is large compared to the distance between their components, each system practically affects the other as if all its matter were concentrated at its own center of gravity. Evidently the nearer the approach to this condition (i. e. the stronger the force which aggregates the atoms within the molecule against the force of repulsion) the less the tendency to produce internal rotation.*

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* The assumption here made is that the force of aggregation differs from gravitation and other forces, in what chemists refer to when they speak of an affinity being saturated or satisfied, thereby recalling the mutual saturation of the two

Says Professor Fitzgerald (discussing Lord Rayleigh's paper): "That the atoms in Argon may be very closely connected seems likely from its very great chemical inertness. Hence the conclusion from the ratio of its specific heats may be not that it is monatomic but that its atoms are so bound together in its molecule that it behaves as a whole as if it were monatomic."

And again (Dr. Armstrong): "It is quite likely that the two atoms exist so firmly locked in each other's embrace . . . that they are perfectly content to roll on together without taking up any energy that is put into the molecule."

A rigid mathematical analysis would unduly lengthen this paper but the principles involved are obvious. Some preliminary calculations which I have made show that if $G =$ the force of gravitation, $R =$ the force of repulsion, and $d =$ any distance from the atom then

For $d =$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2	4	8
$G-R =$	-4032	-240	-12	0	0·188	0·058	0·0154

Showing how rapidly the repulsive force would increase at less than the imaginary atomic diameter ($d = 1$). At close distances theory requires that the repulsive should greatly exceed the attractive force, in order to produce rebound after impact, but at distances greater than the molecular diameter the attractive should be the greater force. This repulsive force evidently corresponds to that resisting compression in liquids and solids, and which at small distances from the surface is nil, but at the surface quickly becomes enormous in amount. Says Maxwell "It seems probable from the great resistance of liquids to compression that the molecules are at about the same distance from each other as that at which two molecules of the same substance in the gaseous form act on each other during an encounter."

A molecule composed of atoms of this kind, having no real surfaces in contact with those of other molecules during the encounter (friction eliminated) would act in a way tending to avoid internal rotation where solid elliptical or eccentric atoms would when in contact give rise to it. Thus A^1 A^2, B^1 B^2 being the atoms of molecules A and B during an approach, the distance A^1 B^1 between one pair of atoms would usually be less than between the other pair. When this distance was reduced to d, their approach would be very quickly checked, the distance A^2 B^2 almost as quickly reduced to d, the same value, and their

electrical fluids, Thus when two atoms are aggregated into a molecule by this force, it is thereby cancelled or saturated within the molecule, its energy becomes potential so to speak, and the force unlike gravitation, ceases to act on bodies without the molecule.

motion likewise checked, and the four repulsions would as to their tendency to produce rotation, be more or less balanced, with the tendency nil or very small in the case of one molecule, while in the case of the other, the tendency would depend partly on the circumstances of the encounter, but could not exceed a certain maximum value, depending on the ratio of the distance between the component atoms to d, the imaginary molecular diameter or least distance of approach. The greater this ratio the less the tendency for internal rotation. Now in a gaseous system as we would have all possible variations in the circumstances of the individual encounters, so also would we have all possible values of the internal rotations from the maximum value thus imposed, down to zero; but the average value of this rotation would be constant, and bear a fixed relation to the maximum value, and it would be this fixed average value which would determine the ratio of the translatory to the rotatory energy, so that a near approach of the ratio of the two specific heats to the value 1·66 would merely indicate that the distance between the atoms in the molecule was so small compared to their least distance of approach, that their mutual action on each other was the same as if all of their matter was concentrated close to their respective centers of gravity.

Now have we not here the explanation of that hitherto unexplained fact the varying values of this ratio which we find in diatomic gases? Thus the molecular gram of O^2, N^2, H^2, NO and CO has about 1·92 cals. of internal energy while that of Cl^2 and Br^2 has about 3·84 cals or twice as much. Ostwald's values are

H^2 and $N^2 = 1·82$ $CO = 1·86$ $NO = 1·95$ $O^2 = 1·96$
Cl^2 and $Br^2 = 3·84$*

In Halogen Group VII strong chemical affinity for other elements would imply corresponding weakness in the force aggregating the atoms in the molecule, hence a greater distance between those atoms compared with their molecular diameter, therefore large atomic volume which we find to be the case, the volumes of the Group (VII) being comparable in size only with those of Group I where the same conditions apply with equal force; and Ostwald has said "The two conceptions of chemical affinity, stability on the one hand and activity on the other have been confused . . . Thus it is the chemically inactive bodies that are held together by the most powerful affinity, compounds which react with ease and rapidity can only hold their components loosely bound if at all."

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* Ostwald gives a lower value for Br, but Regnault's specific heat determination leads to practically the same value (3.84) as for Cl.

If the views outlined are correct then the following relations ought to hold at least in Mendeléeff's short periods.*

Properties, etc.	Groups I and VII.	Groups III, IV, VIII.
Atomic volume	large	small
Tendency toward internal energy of rotation	"	"
Tendency to combine directly with other elements	"	"
Heat absorbed in separating atom from atom (dissociation)	small	large
Heat of formation in solution	"	"
Distance between the atoms in the molecule	large	small
Force of attraction for the atoms of other molecules	"	"
Distance between the atoms of different molecules	small	large
Force of attraction between atoms in the same molecule	"	"

How far does this scheme of properties conform to nature? In the two short periods Li—F and Na—Cl the atomic volume (distance between the atoms) decreases from alkali Group I to Carbon Group IV, and then increases from Nitrogen Group V to Group VII the Halogens. We are ignorant of the amount of internal energy of rotation in Groups I, II, III and IV but we have in Groups V, $N^2=1\cdot82$, in VI, $O^2=1\cdot96$, and in VII, $Cl^2=3\cdot84$. These values show the constant increase which the theory requires.

That the tendency for direct combination with other elements is a maximum in Group I decreases to Group IV and then increases again to Group VII is too well known to require illustration.

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* Just as this article is going to press I note the following remarks made by Mendeléeff, March 14th, before the Russian Chemical Society:

"In favor of this supposition (monatomicity) we have the specific heat ratio at constant volumes and pressures, K, found by Rayleigh and Ramsay, to be near to 1·66, i.e. to the value which is considered as characteristic for monatomic gases. It must however be borne in mind that K varies for compound molecules, even when these last contain the same number of atoms; thus for most bivalent gases (nitrogen, oxygen, etc.) K is near to 1·4, while for chlorine it is 1·3. This last figure makes one think that K depends not only upon the number of atoms in the molecule, but also upon chemical energy, that is upon the stock of internal motion which determines the chemical activity of a body and the quantity of which must be relatively great with chlorine. If, with the chemically active chlorine, K is notably less than 1·4, we may admit that for the inactive argon it is much more than 1·4, even though the molecule of argon may contain two or more atoms."

Mendeléeff seems to lean toward the view that Argon is N^3 though prefers an atomic weight of 20 to one of 40 if it be a new element.

The data on dissociation are meagre. Iodine in Group VII as is known is easily melted and dissociated by heat, and probably also the alkali metals of Group I, while such bodies as C and Si of Group IV are but little affected, so that so far as known theory is again complied with; but more satisfactory conclusions can be drawn from the heats of formation in solution, for on the very probable theory, that in aqueous solutions of binary salts the elements are almost entirely dissociated, we can compare these thermal reactions of members of Series 3.

Na^2	Group I	$2(Na, Cl, Aq) = 193020$	Diff. $= -180840$
Mg^2	Group II	$2(Mg, Cl^2, Aq) = 373860$	Diff. $= -101790$
Al^2	Group III	$2(Al, Cl^3, Aq) = 475650$	
Si^2—P^2			
S^2	Group VI	$2(Na^2, S, Aq) = 208000$	Diff. $= + 14980$
Cl^2	Group VII	$2(Na, Cl, Aq) = 193020$	

As the chlorides of Groups IV and V decompose instead of dissolve in water the series is broken. Now in the reaction 2(Na, Cl, Aq) we have the dissociation of Na^2 and Cl^2 and in $2(Mg, Cl^2, Aq)$ the dissociation of Mg^2 and Cl^4 that is to say the difference is the difference between the heat of dissociation of Na^2 and Mg^2 plus the dissociation heat of Cl^2. This term Cl^2 is a constant addition to the first two series differences. We are evidently justified in concluding that in Groups I and VII the heat of dissociation is small but large in Groups III and IV. We may however consider this series of heats of formation

Group I $2(Na, Cl) = 195380$,
Group II $2(Mg, Cl^2) = 302020$,
Group III $2(Al, Cl^3) = 321060$,
Group IV $2(Si, Cl^4) = 315280$,
Group V $2(P, Cl^5) = 209980$.

Here as before the result is masked by a constant addition depending on the constant increment Cl^2, but still the maximum values plainly are attained in families III and IV and the minimum in family I as the theory requires. "Substances," says Muir, "which are formed with the disappearance of heat are generally more readily decomposed by the application of outside forces than substances which are formed with the production of heat;" and Mendeléeff has noted the fact that elements of large atomic volume combine easily with others, and explains it by assuming a comparatively large distance between the single atoms in the molecule.

Our theory requires that the force holding the atoms together be large compared with both gravitation and the (elastic) force of repulsion. And there is evidence that this is so. For instance, at 18° Centigrade 2 grams of H and 16 grams of O, combined by the electric spark into 18 grams of water, give off 68360 calories of heat or more than 6 times the quantity necessary to raise the water thus produced from 18° to 100° and vaporize it. Now the heat of combination is closely related to the difference between the forces binding H^2 to O and H to H and O to O, and if the heat of combination is large, the difference between these forces must be large, as also the forces themselves, compared with both gravitation and the force of elasticity or repulsion, for the latter will be of about the same order (at the least distance of molecular approach) as kinetic energy of translation. The fact that the energy of the motion of translation of the O and H molecules before combination is, as shown by Thomson, only about $\frac{1}{70}$th part of their total store, the great bulk of which must be potential, shows how great must be the forces binding the atoms together (upon whose differences the magnitude of the heat of formation depends), not only compared to gravitation but also to all other forces acting within the molecule.* The modern theory of electrolysis and salt solution postulates enormous electrical charges on the dissociated ions, which fully accords with the view herein expressed that the force of atomic aggregation is large compared to other forces. The intimate connection existing between valency, electrical character, chemical affinity and the electrons or charges on the ions has long been noted. The magnitude of these charges appears to be of the same order as the potential energy of chemical affinity, and as indicated by Ostwald, when valency is understood, so also will probably be all these other and closely related subjects.

Nature, in the edition of Feb. 7th, makes an apparently strong point for monatomicity when it states "that no diatomic gas has a specific heat ratio greater than about 1·42, and to place among them a substance for which the ratio is 1·66 would be entirely opposed to all other indications of a theory, which though admittedly only approximate, nevertheless in all other cases accords fairly well with the conceptions of the chemist."

It is notwithstanding a reasonable view, that when internal, vibrations are small (disregarding the higher order of vibrations which produce the lines in the spectrum) the tendency to split up into free ions will also be small. Chemical inertness goes naturally with the minimum of internal energy and atomic volume; and with practically no internal energy in Argon we ought to find it, just as we do, chemically very inert, so there are two horns to the dilemma. True if diatomic, Argon is the only diatomic gas known having so high a ratio for the two specific heats, but on the other hand if monatomic then its

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* Mendeléeff remarks that 1 gram of H cooled to the absolute zero of temperature would evolve about 1000 units of heat and 8 grams of O half this amount, while in combining together they evolve more than thirty times that quantity, and hence the store of chemical energy must be much greater than the physical store proper to the molecule.

molecules are free ions, and what other instance have we of a chemically inert free ion? Which of the two horns shall we choose? The nascent state is par excellence the state of maximum tendency towards chemical combination, and finds its best explanation in the idea that the free and unincumbered ion is exceptionally prone to combination with the first partner it finds, but what have we about Argon, if monatomic, which in the slightest degree reminds us of the nascent state? Is not its great inertness just what we would not expect a free ion to possess? Which is the more unique, a diatomic gas without rotational energy or a free ion devoid of chemical affinity?

On the whole, therefore, it seems a fair conclusion as to Groups III, IV and VIII that the force binding the atoms together in the molecule is great, therefore their atomic volume is small, likewise the distance between the atoms in the molecule, their tendency to combine directly with other elements, and their tendency as diatomic gases to acquire internal rotation; hence the large quantities of heat required for their dissociation, and evolved when they are dissociated by solution in water or combine with other elements.

The theory on which these conclusions rest (which conclusions accord with the facts found) accords also with fact in that the resultant force causing the elements to combine in the free state to form a binary compound is not identical with that holding the atoms together after combination, which thing has proved a stumbling block to more than one theory of affinity, for certain forces may come into play to facilitate or restrain combination, as for instance the force required to dissociate the two component atoms, which are no longer factors in the problem after combination has occurred. The stability of the elementary molecule, the tendency to combine with other elements, and the stability of the compound, will in each case depend not on single forces, but will be determined by the magnitude of the resultant of many forces, changing in various ways and with varying conditions just as we find actually occurs in nature, as for instance in cases of reversed chemical action and many others which will occur to the mind at once.

We may then briefly sum up the matter as follows: The Periodic law places Argon if an element between F and Na with an atomic weight of 20; which law has been confirmed by such a mass of evidence that any reasonable hypothesis should be adopted rather than a theory inconsistent therewith.

While Argon may yet prove to be an allotropic form of nitrogen, yet the specific heat ratio of 1·66 is apparently even less consistent with a triatomic than a diatomic molecule, so that in either case it is in order to show that such a ratio does not necessarily involve monatomicity.* The weak point in the assumption that it does, lies in the view taken that the molecular encounter involves actual contacts, which is not a necessary assumption in the kinetic theory of gases. That such contacts do not occur is shown by Maxwell's computations coupled with the experiments on viscosity. Moreover, Maxwell did not believe in this theory of the encounter, and both Sutherland and Pickering assume the existence of a repulsive force. The greater the force of aggregation, and the smaller the distance between the atoms compared to the imaginary molecular diameter or least distance of approach, the less the tendency for internal rotation as shown by the application of the astronomical methods used in the problem of the three bodies. In Groups I and VII we have the maximum of atomic volume, internal rotation, and chemical activity, combined with small heats of dissociation both in solution and otherwise, indicating a weak force of aggregation within the molecule. In Groups III, IV and VIII we have these properties reversed, small volume, little if any internal rotation, chemical inertness, and large heats of dissociation indicating a strong force of aggregation within the molecule; and the fact that the translatory energy of the H and O molecules before combination is only $\frac{1}{70}$th of their total store of energy, which is not rotational and

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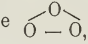
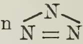
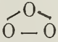
* The evidence grows stronger that Argon may be Nitrogen with the molecular formula N^3, the theoretical density of which (21), would closely agree with that (19·9) found for Argon. There would then be more or less analogy between Oxygen $O=O$, Ozone  Nitrogen $N\equiv N$, and Argon  Thomson and Threlfall in 1886, observing a contraction in volume when the electric spark was passed through pure nitrogen, concluded that an allotropic form resulted; but Threlfall's later repetition of the experiment led to negative results. Johnson, from observations on the action of a hot tube upon Nitrogen. also concluded that the gas can exist in two forms; one active, the other inactive. It has been recently remarked that as in Ozone, O^3, the characteristic properties (chemical activity) of Oxygen O^2 are enhanced; so in Argon, if it be N^3, the characteristic property of Nitrogen N^2 (its chemical inactivity) should also be enchanced; hence its very inert character. The boiling points seem to contradict this view. Oxygen—182·2°, Ozone—106·0°, Nitrogen—194·0°, Argon—187·0°. The two latter are almost the same, the two former widely separated; but Brauner (Chem. News, Feb. 15, 1895) has endeavored to explain this apparent inconsistency.

Quite recently Berthelot has succeeded in causing combination between Argon and the vapor of benzene, by means of the electric spark; thereby producing resinous compounds very similar to those produced, under like circumstances, by the action of benzene vapor on nitrogen.

In the formula  (Ozone) the molecule is apparently less eccentric than in $O=O$ (Oxygen) and application of the principles already discussed will show, that its tendency for internal rotation should be less than in the case of oxygen. I know of no data as to the specific heat ratio for Ozone, but it would be interesting to know whether or not it is greater than in Oxygen. Evidently if Argon be N^3 we have here another principle tending toward small value of the internal energy, and a correspondingly large value in the ratio of the two specific heats.

hence must be potential, is only one of many similar facts proving that this force is very large as theory requires it to be, compared with the other molecular forces. Moreover, to call Argon monatomic, requires us to explain how a free ion, which should possess all the activities of the nascent state, can be as chemically inert as Argon has been shown to be.

In view therefore of the fact that the burden of proof is upon those attempting to prove monatomicity, it would seem safer at present to adopt some such way as this of explaining the supposed inconsistency between the specific heat ratio found and the diatomicity of the molecule, and follow the almost peremptory indications of the periodic law by accepting an atomic weight of 20.*

A very interesting question connected with the discovery of Argon, is what will be the effect of these researches upon Prout's hypothesis? Is it possible that Argon has been an unsuspected cause of error, which when properly allowed for will show the ratio of H to O to be almost exactly 1 to 16? This would make so many atomic weights even or half multiples of H as to render probable, what has been often surmised, the generation of the elements from a common form of matter (Protyle) by the continued addition of some one or more constant increments of mass. As pointed out by Mendeléeff the periodic law does not indicate continuous but abrupt variations of weight and properties, from family to family, corresponding to the changes in valency. Some years since I noticed the prevalence in the natural series of the elements of a regular alternation of intervals of 3 and 1 substantially as referred to by Dr. Gladstone in a recent issue of Nature.† Thus in round numbers and with a few changes we have the following series:

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* There is, however, one real difficulty which it may be well to meet as far as can be done at present. As the atomic volume is the quotient of specific gravity into atomic weight we have these volumes: $F=15$? $A=13{\cdot}3$ and $Na=23{\cdot}7$, with the volumes of the metals of Group VIII varying from 6·7 to 9·2. Why then should not Argon have a volume approximately that of Group VIII, and since its volume is about that of F can we infer close aggregation in the Argon molecule in view of the known chemical activity of Fluorine?

We may say in reply that the volumes of Group I are about double those of Group VII, although their chemical activities (force of aggregation within the molecule) are about equal, thus we have these volumes: $F=15$,? $Na=23{\cdot}7$; $Cl=25{\cdot}6$, $K=45{\cdot}4$; $Br=26{\cdot}9$, $Rb=56{\cdot}1$; $I=25{\cdot}6$, $Cs=70{\cdot}6$. Now Argon if transitional from F to Na should have its volume a mean value or about 19·5, whereas it actually has a volume of 13·3, the difference indicating the strong force of aggregation within the Argon molecule which the theory requires. That is, the force of aggregation, weak in F and Na is strong in Argon, and the repulsive force in Argon is a mean of that in F and Na with its value in Na about double that in F.

† Quite curiously in an article which I prepared on this subject but did not publish I almost duplicated Dr. Gladstone's remarks about this relation and its bearing on the atomic weight of Argon some days before his article was received in this country.

$$\frac{?}{0}3\ \frac{?}{3}1\ \frac{?}{4}3\ \frac{\text{Li}}{7}1\ \left(\frac{\text{Be}}{8}\right)3\ \frac{\text{B}}{11}1\ \frac{\text{C}}{12}3\ \left(\frac{\text{N}}{15}\right)1\ \frac{\text{O}}{16}3\ \frac{\text{F}}{19}1\ \frac{\text{A}}{20}3\ \frac{\text{Na}}{23}1\ \frac{\text{Mg}}{24}3$$

$$\frac{\text{Al}}{27}1\ \frac{\text{Si}}{28}3\ \frac{\text{P}}{31}1\ \frac{\text{S}}{32}3\ \left(\frac{\text{Cl}}{35}\right)1\ \frac{?}{36}3\ \frac{\text{K}}{39}1\ \frac{\text{Ca}}{40}3\ \frac{?}{43}1\ \frac{\text{Sc}}{44}3\ \frac{?}{47}1\ \frac{\text{Ti}}{48}3\ \frac{\text{V}}{51}1$$

$$\frac{\text{Cr}}{52}3\ \frac{\text{Mn}}{55}1\ \frac{\text{Fe}}{56}3\ \frac{\text{Co}}{59}1\ \frac{\text{Ni}}{60}3\ \frac{\text{Cu}}{63}1\ \left(\frac{\text{Zn}}{64}\right)3\ \frac{?}{67}1\ \left(\frac{\text{Ga}}{68}\right)3\ \frac{?}{71}1\ \frac{\text{Ge}}{72}3\ \frac{\text{As}}{75}1$$

$$\frac{?}{76}3\ \frac{\text{Se}}{79}1\ \frac{\text{Br}}{80}3\ \frac{?}{83}1\ \left(\frac{\text{Rb}}{84}\right)3\ \frac{\text{Sr}}{87}1\ \left(\frac{\text{Yt}}{88}\right)3\ \frac{\text{Zr}}{91}1\ \frac{?}{92}3\ \left(\frac{\text{Nb}}{95}\right)1\ \frac{\text{Mo}}{96},$$

$$3\ \frac{?}{99}1\ \frac{?}{100}3\ \frac{\text{Ru}}{103}1\ \frac{\text{Ro}}{104}3\ \frac{\text{Pd}}{107}1\ \frac{\text{Ag}}{108}3\ \frac{?}{111}1\ \frac{\text{Cd}}{112}3\ \left(\frac{\text{In}}{115}\right)1\ \frac{?}{116}3$$

$$\frac{\text{Sn}}{119}1\ \frac{\text{Sb}}{120}3\ \frac{?}{123}1\ \left(\frac{\text{Te}}{124}\right)3\ \frac{\text{I}}{127}1\ \frac{?}{128}3\ \frac{?}{131}1\ \frac{\text{Cs}}{132}3\ \frac{?}{135}1\ \left(\frac{\text{Ba}}{136}\right)3$$

$$\frac{\text{La}}{139}1\ \frac{\text{Ce}}{140}3\ \frac{\text{Di}}{143}, \text{ etc.}$$

I have, in the main, used the nearest whole numbers, bracketed those values that might seem forced, and inserted a few numbers (possible blanks) to complete the series.

There is, I think, some other law or laws besides this simple one, effective in the matter, but there are many things justifying the view that this ideal arithmetical series, which on the whole is so closely attained (all things duly considered) expresses the chief of perhaps several laws, all jointly effective in limiting the mass of the elements.

One of the strongest objections thus far to the use of round numbers in such atomic theories, as well as to Prout's hypothesis in general, has been the irrationality of the ratio of H to 0. Now Lord Rayleigh has shown that at 13° C. water absorbs 4 per cent of its volume of Argon and that gases handled over water in the usual way almost invariably become contaminated with the Argon held in solution. Moreover, it is quite likely that in reactions for the production of gases where water is used as a reagent (e. g. evolution of H by electrolysis of water or action of dilute acid on Zn), Argon contamination might result from the Argon so dissolved, and that such contamination once acquired, would not be removed by any ordinary reagents through which the gas was passed. A simple calculation will show that with hydrogen contaminated by only $\frac{4}{100}$ths of one per cent of Argon, the ratio H to O would be reduced from 1 : 16 to 1 : 15·879 which is about the latest values deduced from direct weighings of the two gases. And in those determinations based upon the synthesis of water, by passing H over red hot oxide of copper, with Argon in the water from which the H was evolved and contamination having occurred, the Argon, unabsorbed by any subsequent reagents, might finally turn up dissolved in the water formed by synthesis, and if this water were saturated with Argon the effect on the ratio would be to reduce it from 1 : 16 to 1 : 15·98.*

Probably it will be difficult to handle gases over the water bath without the risk of such contamination. In the case, however, of density determinations it would seem advisable after the weighing to absorb the gas by suitable reagents, and then if any residual gas, Argon or any other, be found, to apply the proper correction to the weights already obtained; I believe that when this has been done the ratio of H to O will be found nearer to the value 1 to 16 than is at present supposed.

It would be interesting to go more deeply into the question of the laws governing the masses of the elements to which I have barely alluded, and to which I have given attention for some years past, but this paper would then be extended far beyond all proper limits. At some future time I may discuss this matter also.

Art. XXXIII.—*An Improved Rock Cutter and Trimmer;*

by Edgar Kidwell.

Over a year ago the Michigan Geological Survey required a rock cutter, and consulted me regarding the matter. I therefore designed one, and as a year's use has shown this cutter to be fully capable of doing the work required of it, a detailed description may be of value to those having need of a similar machine.

The cutter had to be suitable for heavy and accurate work, hence ample strength of parts, power in the mechanism, and freedom from lost motion were absolutely necessary. Previous experience in our shops had shown me that a No. 4 parallel swivel railway chipping vise, with wrought bar, as made by Merrill Brothers, possessed all these qualifications, and I therefore made in one of their vises such changes as were necessary to convert it into a cutter. The vise itself needed but few alterations, as it was necessary only to cut away the jaws to give the operator more room, and provide suitable openings for inserting the steel cutters. Provision was also made for holding cutters in place, and changing them quickly when necessary. Fig. 1 shows all necessary details.

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* It is rather significant that the best determinations by these two different methods closely approximate to these two values of 15·88 and 15·98 respectively.

Two forms of cutter were made, and a duplicate set of each was provided. The working drawings, fig. 2, show the details of cutters so clearly that further description is unnecessary. The specification required that these cutters should be of the best quality Jessop's, Stubb's, or Mushet's steel, tempered very hard. It might be better for some kinds of work to have another form of cutter, with edges at an angle of 45° with top edge of jaws, but the two forms already mentioned have so far answered all requirements.

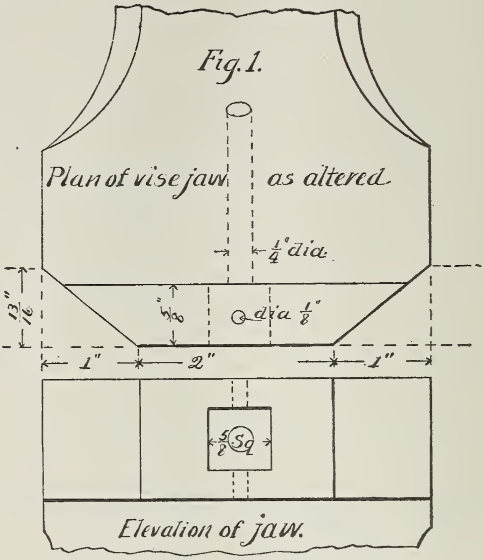
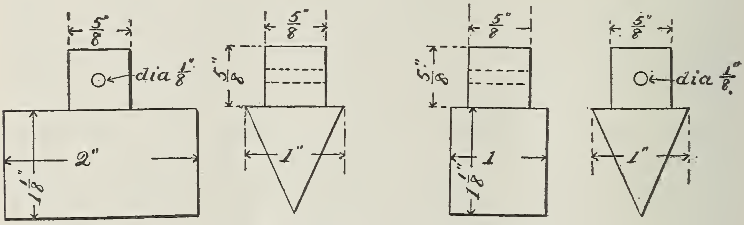


FIG. 2.



A, B, Cutters with horizontal edge. C, D, Cutters with vertical edge.

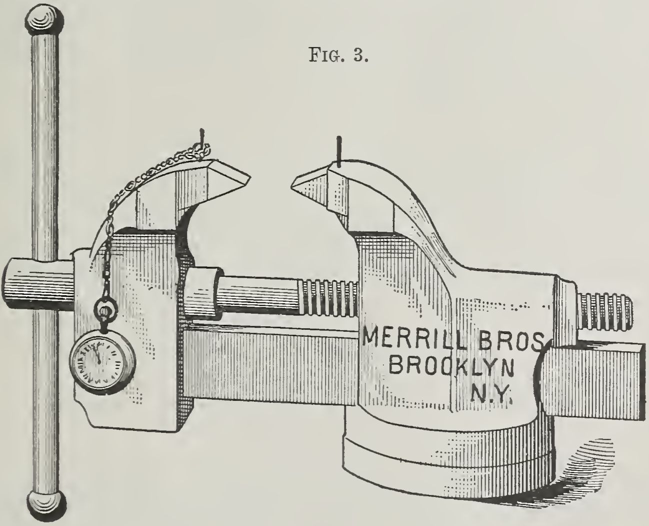
There should be also two pins, $\frac{1}{8}''$ diameter, 2″ long, for holding cutters; one pin $\frac{3}{16}''$ diameter, 4″ long, for removing cutters.

Unless a large amount of work is to be done, it will be advisable to order only a single set of cutters. This will make a material reduction in the first cost of the machine, and one set of cutters, if properly cared for, will last for years.

If very rapid work is desired any of the various forms of quick-acting vise might be employed as a basis for the machine, but I do not think the change would be a good one. The quick-acting vises are provided with weaker screws, and the parallel bars are invariably of cast iron, cored hollow, and sadly deficient in strength, hence a cutter made from a vise of this kind would be liable to complete collapse when used for heavy work. No matter what form of vise is used, if the machine is to be satisfactory it is absolutely essential that the screw be accurately cut, to prevent lost motion, and that each cutter be carefully fitted to its seat, shaped so that cutting edges will exactly meet when brought together, and be made of the very best tool steel, properly tempered. If these precautions are taken, the result will be a machine that is free from every trace of ricketiness, and amply able to stand up to any work that can be put on it. During the last year the Michigan Geological Survey has made with one pair of jaws from 2500 to 3000 cuts, on such specimens as conglomerates, sandstones, amygdaloids, traps, felsites, porphyries, silicified tufas, prehnite and datolite veinstone with copper, and its jaws show practically no signs of wear on the cutting edges.

Fig. 3 shows the machine ready for use.

Fig. 3.



In conclusion I would state that none of the features here mentioned are patented, and are free to all who may care to use them. The complete machine, from my drawings, can be got of Merrill Brothers, 465 Kent ave., Brooklyn, N. Y.

Michigan Mining School, Houghton, Michigan.

ART. XXXIV.—*Relation of the plane of Jupiter's orbit to the mean-plane of four hundred and one minor planet orbits;* by H. A. NEWTON.

ABOUT nine years ago (this Journal, III, xxxi, p. 319) I called attention in a brief note to the fact that the mean-plane of the orbits of the then known two hundred and fifty-one minor planets was inclined to the plane of Jupiter's orbit by a very small angle. In fact no minor planet out of the whole 251 had its plane so near to the mean-plane as did the planet Jupiter. Since that time we have added to the list of planets between Mars and Jupiter one hundred and fifty newly discovered ones, and it seems worth while to find whether the same relation of the large planet to the entire group of four hundred and one small ones holds true.

The plane of an orbit is determined by the longitude of the ascending node and the inclination, and its place may be represented to the eye by a plot in which the inclination is the radius vector and the longitude of the node is the polar angle. The point thus plotted is of course the pole of the plane.

The mean-plane of the 401 planes, regarding each plane as a unit, may be determined with sufficient accuracy for the present purpose by the formulas for computing the center of gravity of the 401 points plotted, viz:

$$401\, I \cos \Omega = \Sigma\, i \cos \text{☊}, \text{ and } 401\, I \sin \Omega = \Sigma i \sin \text{☊}:$$

where i and ☊ are the inclination and longitude of ascending node of any orbit, and I and Ω are the same functions of the mean-plane of all the orbits. Computing I and Ω for the 401 orbits as given in the *Annuaire du Bureau des Longitudes* for 1895, adding three later orbits from the *Astronomische Nachrichten*, we have

$$I = 0^{\circ}{\cdot}93, \text{ and } \Omega = 109^{\circ}{\cdot}3.$$

The corresponding quantities for Jupiter are

$$i = 1^{\circ}{\cdot}31,\ \ \text{☊} = 98^{\circ}{\cdot}9,$$

so that the inclination of the mean plane to Jupiter's plane is 0°·43. The three minor planets whose planes are nearest to the mean-plane are 1893 Y, (27) and (149). These planes make angles with the mean-plane severally equal to 0°·65, 0°·74, and 0°·77. The planet 1893 Y, was photographically discovered and has not yet a place in the numbered series of planets. Its plane will doubtless be much changed when the orbit is definitely known, and it may or may not be found to be nearer the mean-plane than at present.*

The reason for the relation of Jupiter's plane to the minor planet planes is evident. The secular perturbation of the orbit of a minor planet by Jupiter is such that the inclination of the orbit plane is not greatly changed, but the node has a constant motion. The pole of the planet's plane therefore is constantly describing a curve, not widely departing from a circle, around the pole of Jupiter's plane. This motion is greater for some minor planets than for others. Hence whatever be the distribution of the poles at one epoch, the tendency of the secular perturbation by Jupiter is to finally distribute the minor-planet poles symmetrically around the pole of Jupiter's plane.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Presence of Argon and of Helium in Uraninite.*—At a meeting of the Chemical Society of London on March 27th, RAMSAY announced that he had discovered both argon and helium in the mineral clevéite, a variety of uraninite. His attention was first called to this mineral by Miers of the British Museum, since Hillebrand had shown† that when treated with dilute sulphuric acid and warmed, the uraninite gave off two per cent or more of a gas which from the tests he applied to it appeared to be nitrogen. On sparking with oxygen however, in presence of soda, Ramsay found that the gas which he obtained from this mineral contained only a trace of nitrogen introduced probably during its extraction. In a Plücker tube its spectrum showed all the more prominent argon lines and in addition a brilliant line close to, but not coincident with, the D lines of sodium. Besides these there were a number of other lines, one in the green being especially prominent. Moreover argon obtained from the atmosphere shows three lines in the violet which are not to be seen apparently in the gas from clevéite. Hence the author suggests that possibly atmospheric argon contains some other gas in admixture, not yet separated, which may possibly account for the anomalous position of argon in its numerical relations with other elements. Further results are promised, especially in relation to the density of the mixture, a point of very great interest.

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* If we consider the planes of the orbits of the eight principal planets, Jupiter's plane is not the nearest to the mean-plane of the system. But by omission of the plane of Mercury, the mean-plane of the seven other principal planets is a little nearer to Jupiter's plane than it is to any other planetary plane.

† This Journal, III, xl, 384, November, 1890.

At the same meeting, Crookes reported upon the spectrum of this gaseous mixture from clevéite, two Plücker tubes containing it having been sent to him by Ramsay, the nitrogen in which had been previously removed by sparking. By far the most prominent line was a brilliant yellow one occupying apparently the position of the sodium lines. With higher dispersion, however, the lines remained single under conditions which would have widely separated the lines of sodium. Moreover, on throwing sodium light simultaneously into the spectroscope, the spectrum of the new gas was seen to consist almost entirely of a bright yellow line, a little to the more refrangible side of the sodium lines, and separated from them by a space a little more than twice that which separated the two components of the sodium line. This line appeared as bright and as sharp as D_1 and D_2. Careful measurements gave 587·45 as its wave-length; the wave-lengths of the sodium lines being for D_1 589·51 and for D_2 588·91. So that while the difference between the D lines is 0·60, that between D_2 and the new line is 1·46. It appears, therefore, that this line is the spectrum of the hypothetical element helium, discovered by Lockyer in the chromosphere of the sun and indicated as D_3. Its wave-length according to Ångström is 587·49 and according to Cornu 587·46. Besides this line of helium, there were seen traces of the more prominent lines of argon. Comparing the visible spectrum of the new gas with the band and the line spectrum of nitrogen, they were found to agree closely at the red and the blue ends, and to differ entirely between these points through a broad space in the green. The complete spectrum of the helium tube is as follows:

		Wave-lengths.		
(a)	D_3 yellow	587·45	Very strong.	Sharp
(b)	Yellowish green	568·05	Faint.	"
(c)	" "	566·41	Very faint.	"
(d)	Green	516·12	Faint.	"
(e)	Greenish blue	500·81	"	"
(f)	Blue	480·63	"	"

Photographs of this spectrum at first glance show in the violet portion, a close resemblance to the band spectrum of nitrogen. But a more careful examination shows that some of the bands and lines of the nitrogen spectrum are absent from the spectrum of the helium tube, while there are many fine lines in the latter spectrum which are absent from the spectrum of nitrogen. Measurements of these lines are in progress.—*Nature*, li, 512, March, 1895. *Chemical News*, lxxi, 151, March, 1895. G. F. B.

2. *On the Combination of Argon with Benzene vapor.*—By means of the silent electric discharge, Berthelot has succeeded in effecting the combination of argon with the vapor of benzene. The argon was received from Ramsay and had been circulated in the apparatus for the absorption of nitrogen until the nitrogen bands disappeared and there was no further contraction. The

density of the gas thus purified was 19·95 and the ratio of its specific heats was 1·65. Its volume was 37 cubic centimeters. In order to bring about the combination of argon with other substances, the author used the silent discharge, since he had found it, in his experience, much more effective than the spark in securing the permanence of unstable compounds. Thus nitrogen in presence of hydrocarbon vapors gives rise under these conditions to the most varied products of condensation—products, too, which decompose with elevation of temperature; while under the influence of the spark, hydrogen cyanide, because of its stability at high temperatures, is the sole product. Again the silent discharge, acting on a mixture of nitrogen and hydrogen, produces several per cent of ammonia, while the spark gives only infinitesimal quantities. Under the action of the silent discharge nitrogen reacts with water vapor to produce ammonium nitrite, a compound which, on standing, is decomposed at the ordinary temperature. Moreover the vapor of benzene was employed for the first experiment, because the author had found it very effective in the case of nitrogen. The apparatus used was that already employed in similar experiments (*Ann. Chem. Phys.*, V, x, 76–79, 1877), and the conditions were those described in the author's "Essai de Mechanique Chimique," the silent discharge being effected with the variable potential producible with an induction coil. With this apparatus the author had succeeded in bringing about the direct union of free nitrogen with hydrocarbons, carbohydrates and other organic substances. On submitting the mixture of argon and the vapor of benzene to the action of the silent discharge, combination took place though with more difficulty than in the case of nitrogen. The action is accompanied with a faint violet glow visible in darkness. In one of the five experiments there was finally formed a fluorescent substance which gave out a magnificent greenish light and afforded a special spectrum. A careful quantitative experiment, made with 10 c. c. of argon, yielded the following results: 100 volumes of this gas, put in contact with a few drops of benzene (by which its volume was increased about one-twentieth), was introduced into the discharge-tube and subjected to the discharge for ten hours under moderate tensions. After removing the benzene vapor by concentrated sulphuric acid, the remaining gas occupied 89 volumes; showing a condensation of 11 per cent. It was again mixed with benzene vapor and again subjected to the discharge, much higher tensions being employed. The diminution in volume was much more rapid, amounting in three hours to 25 per cent. The 64 remaining volumes was mixed anew with benzene vapor and again exposed for several hours to the discharge under still higher tensions. There remained 32 volumes of gas, consisting of hydrogen 13·5, benzene vapor 1·5 and argon 17·0 volumes. So that of 100 volumes of argon, benzene had condensed 83 into a state of chemical combination under the action of the silent discharge; or about five-sixths. The quantity of the products was too small to permit of any extended examination. They resemble those produced by the similar action of the silent discharge on nitrogen mixed with benzene vapor and consist of a yellow resinous odorous substance condensed on the surface of the two glass tubes between which the electric action is exerted. Submitted to the action of heat this substance decomposes, yielding volatile products and leaving a bulky carbonaceous residue. The volatile products turn red litmus paper blue. Evidently therefore the conditions under which argon is condensed by hydrocarbons tend to affiliate it still closer to nitrogen. Indeed if it be permissible to increase its molecular mass from 40 to 42—which seems not unreasonable—this mass would represent one and a half times that of nitrogen; so that argon would bear to nitrogen the same reaction that ozone does to oxygen. Thus far, however, argon and nitrogen are not transformable the one into the other. Under the conditions now described it is evident that the supposed inactivity of argon ceases to exist.—*C. R.*, cxx, 581, March, 1895; *Chem. News*, lxxi, 151, March, 1895. G. F. B.

3. *On the Presence of Argon lines in the Spectrum of Atmospheric Air.*—In a communication to the Royal Society on February 21st, NEWALL has called attention to a line spectrum which appeared frequently upon the photographs of the air spectrum taken by him a year ago, and which he called "the low pressure spectrum." The lines of this spectrum were then unknown, but it now appears that they belong to argon, constituting seventeen out of the sixty-one lines of the air spectrum. To obtain this argon spectrum, a glass bulb was sealed hermetically to a Hagen-Töpler mercury pump, having a layer of strong sulphuric acid above the mercury. On reducing the pressure to $0{\cdot}14^{mm}$ (about 180 millionths of an atmosphere) a bright alternating discharge could be passed through the residual gas simply by surrounding the bulb with a coil of wire carrying the current from a condenser. After 30 minutes the pressure fell from $0{\cdot}13^{mm}$ to $0{\cdot}085^{mm}$ (from $174\ \overline{M}$ to $112\ \overline{M}$) and the photograph then taken showed the bands of nitrogen strong, mercury and nitrocarbon lines strong, hydrogen weak and no oxygen or argon lines. After thirty minutes more, the pressure has fallen from $0{\cdot}76^{mm}$ to $0{\cdot}015^{mm}$ (from $100\ \overline{M}$ to $20\ \overline{M}$) and in the photograph the nitrogen spectrum had faded considerably and a number of fine new lines appeared, constituting this "low pressure spectrum." Recent measurements show the practical coincidence of seventy-two lines belonging to this spectrum with the lines of argon as measured by Crookes. A table of the wave-lengths of these lines is given, with those of the red and blue spectrum of argon in parallel columns as given by Crookes. "It is interesting," says the author, "to find argon asserting itself unsolicited in quite new circumstances, and under conditions which practically constitute one more mode of separating argon from nitrogen—namely the getting rid of nitrogen by passing electric discharges through it in

the presence of hydrogen, or moisture and acid."—*Proc. Roy. Soc.*, Feb. 21, 1895: *Chem. News*, lxxi, 115, March, 1895.

G. F. B.

4. *On the Spark Spectrum of Argon as it appears in the Spark Spectrum of Air.*—On the 21st of March, HARTLEY read to the Royal Society a paper pointing out that certain lines obtained by himself and Adeney in 1884, in their photographs of the air spectrum, now appear to be due to argon. In their investigations, they used electrodes of aluminum, copper, platinum and palladium, and a condensed spark produced with a coil with a Leyden jar in circuit; the partial pressure—since argon constitutes about 1 per cent of the atmosphere—being about $7{\cdot}5^{mm}$. Since these are practically the conditions which as Crookes has shown give the brightest and purest spectrum of argon, the author thought it reasonable to expect the recognition of the blue and ultra-violet lines of this substance among some of the weaker lines in the spectrum of air. A table containing the wave lengths of 50 or more lines thus observed in the air spectrum is given in the paper, with the characteristic lines of the blue and the red spectra of argon in parallel columns for comparison. He considers of little importance the fact that argon gives two spectra; the red being apparently the spectrum of the first order or of the corresponding lower temperature, while the blue is the line spectrum at the higher temperature. "It is therefore more likely," he concludes, "that argon is one substance and not two. Whether it is a compound or an element is a question into which the following considerations may enter. There are at present no gaseous substances known which can withstand the temperature of the condensed spark without exhibiting the spectra of one or other of the elements of which it is composed. If therefore, argon were N_3 it would disclose the spectrum of nitrogen. As the spectrum is not that of any known substance it follows that if a compound, it must be a compound of a new element."—*Proc. Roy. Soc.*, March 21, 1895. (From advance sheets received from the author.)

G. F. B.

II. GEOLOGY.

1. *Reconnoissance of the Bahamas and of the elevated reefs of Cuba in the Steam Yacht "Wild Duck,"* January to April, 1893; by ALEXANDER AGASSIZ. 204 pp. 8vo, with 47 plates. Bulletin of the Mus. Comp. Zoöl. of Harvard College, vol. xxvi, No. 1.—The coral reefs of the West India seas may be regarded as the subject of Prof. Agassiz's Report, although only the Bahamas and Cuba are mentioned in the title. For, after the very full descriptions relating to the region of more special study, the report devotes 20 of its 200 pages to the coral reefs and banks of the Caribbean district, including therein the reefs of the north shore of South America, the Yucatan Bank and British Honduras. The origin of coral reefs is the concluding

subject. A brief review of the author's facts and conclusions have been given in volume xlv (p. 358) of this Journal, in a letter from the author. The many plates contain various contour maps, and views of reef regions, of æolian bluffs and rock, and illustrations of other subjects. Plate VIII is a colored contour map of the Caribbean Sea.

Prof. Agassiz, in discussing the origin of coral reef limestones, states objections to the subsidence theory of Darwin. Without touching here on the special arguments in its favor, two or three general facts may be stated.

In geological history, many limestones have been made exceeding 1000 feet in thickness which show by their fossils that they are not of deep water origin. Whether derived from coral and shell sediment like coral reef rock, or from shell sediment chiefly makes no difference; subsidence was required.

Subsidences of one or two scores of thousands of feet in depth have taken place in past time, over the region of the Appalachians, Alps, and other mountain regions; and in the sinking trough, sediments were formed successively at the water's level, or not far below it, to the thickness of the depth of subsidence; and some of the sediments were calcareous, making now thick limestone strata.

After the Cretaceous period, and in the Pliocene Tertiary chiefly, or the Tertiary and Glacial period, the whole region of the Rocky Mountains was elevated; the elevation was 16,000 feet in part of Colorado, 10,000 feet at least in the region of the Sierra Nevada, 10,000 feet in Mexico, and over 17,000 feet in British America, latitude, 49° to 53° and less to the north. The region of the Andes, at the same time, was raised to a maximum amount of 20,000 feet; the Alps, 12,000; the Himalayas, 20,000 feet. Moreover, at the close of the Champlain period there was another epoch of smaller elevation, introducing the Recent period. These elevations, affecting a large part of the continental areas, could not have taken place without a counterpart subsidence of large areas over the oceanic basin; profound oceanic subsidence was hence in progress during the growth of coral reefs. The subsidence cannot be questioned. J. D. D.

2. *Formation of Dolomite.*—C. Klement, has a paper on the formation of dolomite in the "Bulletin de la Société Belge de Géologie, Paléontologie et Hydrologie," Volume viii, Brussels. 1894. In experiments, proceeding on the ground that the calcium carbonate of corals is in the state of aragonite, he digested in a covered platinum capsule, at a temperature of 90° to 92° C., finely pulverized aragonite, with a concentrated solution of common salt and magnesium chloride and sulphate in the proportions occurring in sea-water.

In his several trials he obtained a compound containing, besides lime and carbonic acid, 15 to 32·5 per cent. of magnesia, corresponding to 31·5 to 68·3 per cent. of magnesium carbonate. During the operation, the solution employed was gradually concentrated even to an abundant deposition of common salt. On account of the minuteness of the crystals, he was not able positively to prove their rhombohedral character, but believes that there is little doubt of this. The author deduces from his experiments, that the massive dolomite limestones have been produced in closed lagoons along a sea bottom through the action of the sea-water, concentrated by the sun's heat, on coral-made sediments, conforming, as he says, to Dana's views on Dolomization.

It should be here understood that Dana has never supposed that the dolomized calcareous sediments were always, or generally, those of coral reef origin; but that any calcareous sediments, whether from shells or corals, or any other source, would undergo the chemical change, under the conditions stated. It is important, therefore, to note that the shells of most Gastropods and Cephalopods, and the inner pearly layer of many Lamellibranchs, are aragonite; and that such shells contribute to the material of coral reef rocks, as well as to ordinary limestones. J. D. D.

3. *On Dolomite-making and dolomitic calcareous organisms.*—Under this title, A. G. Högbom, of Stockholm, discusses (Jahrb. f. Min., Geol. und Pal., 1894, vol. i, p. 272), the question as to the origin of the magnesia of dolomitic limestones. He finds by analysis that the common incrusting Nullipores of coral reefs—species of the genus *Lithothamnion*—commonly contain a large percentage of magnesium carbonate. He gives the results of fourteen analyses—1 by himself, 9 by N. Sahlbom, 3 by R. Mauzelius, and 1 by J. Guinchard, and he deduces for the mean of the whole, 10 parts of magnesium carbonate to 100 of calcium carbonate.

Mr. Högbom also cites results from analysis of Bermuda corals, by G. Forsstrand, in which the amount of magnesium carbonate and calcium carbonate, was, for a *Porites*, 0·62 and 95·94; for an *Oculina*, 0·36 and 96·20; for *Millepora alcicornis*, 0·41 and 95·86; for another *Millepora*, 0·77 and 94·39; for the reef rock of the Bermudas, 1·64 and 95·43; for 10 species of shells of Gastropods and Lamellibranchs from the outer edge of the reef, 0·19 and 97·32; but for a fine mud of terra cotta color from the lagoon, 4·04 and 92·93.

The author concludes that the magnesia of dolomite has probably come from an organic source; and that consequently the hypothesis of Dana, which derives it from the sea-water of evaporating basins, appears to be unnecessary.

We add here some additional facts.

Damour, in 1850, published an analysis (Bull. G. S. de France, vii, 675) of a specimen from Bréhat, on the coast of northwestern France, which he called a *Millepora* (M. cervicornis), but also said it was one of the *Algæ*, and of concretion-like form. It afforded him 8·51 per cent of magnesium carbonate and 87·32 of calcium carbonate.

The common *Millepora alcicornis*, of the West Indies, afforded S. P. Sharples 97·46 p. c. of calcium carbonate with 0·27 of calcium phosphate and 2·54 of water and organic matters. (This Journal, III, i, 168, 1871). In his analyses of *Oculina arbuscula*, *Manicina areolata*, *Siderastrea radians*, *Madrepora cervicornis*, and *M. palmata*, he obtained no magnesia but in each some calcium phosphate. It is to be noted that other analysts have overlooked apparently the calcium phosphate.

Forchhammer, analyzing a mixture of corals, found about half a per cent of magnesium carbonate; but in the Alcyonarian, *Isis nobilis* 6·36 per cent, and *Corallium nobile* 2·1 per cent.

4. *Bahama Expedition of the State University of Iowa. Narrative and Preliminary Report;* by Professor C. C. NUTTING. 252 pp. 8vo, No. 1 and 2 of Vol. III of the Natural History Bulletin of the University.

This volume is an account of a cruise to the Bahama Banks and the islands in their vicinity, by the members of a class in Natural History of the Iowa University, with Professors Nutting, G. L. Houser and H. F. Wickham as the executive committee, in all a party of twenty-one. It proved to be eminently satisfactory, both personally and as regards accessions to the University collections.

The Report contains brief notes on some of the species dredged or otherwise collected, with several figures in illustration; but the final descriptions are to appear later, specimens having been placed in the hands of different specialists. The volume has great value to any who may plan such expeditions on account of the descriptions of its outfit, the information to be gathered from the experiences of the cruise, and many facts observed along the way. J. D. D.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—At the annual meeting held at Washington, April 16–19, Dr. Wolcott Gibbs, one of the original charter members of the Academy, was elected president for a term of six years, Professor Marsh, president for the last two terms, having declined to be a candidate. The Academy voted unanimously "That the thanks of the Academy be tendered to the retiring president for the zeal and ability with which he has administered, in succession, the offices of Vice-president and President of the Academy during a period of seventeen years." Prof. Alexander Agassiz was elected foreign secretary, and Prof. Asaph Hall, reëlected home secretary.

Three foreign associates, Professor R. Leuckart of Leipzig, Professor Julius Sachs of Würzburg, and Professor Sophus Lie of Leipzig, were elected; also four new members.

The Barnard gold medal was awarded by the Academy to Lord Rayleigh for the discovery of argon, and the Watson gold medal to Seth C. Chandler for his researches on the variation of latitude, on variable stars and for his other works in astronomy.

The president announced the death of Professor James D. Dana, one of the original members of the Academy, and appointed Dr. E. S. Dana to prepare the biographical memoir. The president also appointed a special committee to represent the Academy at the funeral.

The following papers were read :

A. Agassiz and W. McM. Woodworth: On some variations in the genus Eucope.

A. Agassiz: Notes on the Florida Reef. The progress of the publications on the expedition of 1891 of the U. S. Fish Commission Steamer "Albatross," Lieut. Commander Z. L. Tanner, commanding.

M. P. Ravenel: On soil bacteria.

A. M. Mayer: A linkage showing the laws of the refraction of light.

M. Carey Lea: On the color relations of atoms, ions and molecules.

R. S. Woodward: Mechanical interpretation of the variations of latitude.

S. C. Chandler: On a new determination of the nutation-constant, and some allied topics.

L. A. Bauer: On the secular motion of a free magnetic needle.

J. S. Billings: On the composition of expired air, and its effect upon animal life.

Th. Gill: Systematic catalogue of European fishes.

E. D. Cope: The extinct Cetacea of North America.

G. Brown Goode: On the application of a percentage method in the study of the distribution of oceanic fishes; (A.) Definition of eleven faunas and two sub-faunas of Deep Sea fishes; (B.) The relationships and origin of the Carribeo-Mexican and Mediterranean sub-faunas.

Ira Remsen: On the two isomeric chlorides of ortho-sulpho-benzoic acid. On some compounds containing two halogen atoms in combination with nitrogen.

B. A. Gould: Biographical memoir of Dr. Lewis M. Rutherfurd.

H. A. Newton: Relation of Jupiter's orbit to the mean plane of four hundred and one minor planet orbits. Orbit of Miss Mitchell's comet, 1847 VI.

2. *Penck's Morphologie der Erdoberflache.**– Professor Penck has added in his Morphologie der Erdoberfläche another notable number to Ratzel's series of geographical handbooks. The numbers already issued include Ratzel's Anthropogeographie, Hann's Klimatologie, Boguslawski and Krümmel's Ozeanographie, and Heim's Gletscherkunde; all standard works on their respective subjects. Penck's contribution is fully up to the high quality of its predecessors.

The plan of the present work may be fairly inferred from an abstract of its table of contents, as follows :—The form and size of the earth; area of land and water, mean altitude of lands and depth of seas, volume of lands and seas; continents and oceans and their permanence. Land surfaces; weathering and denudation by wind, rivers, and ice; deformations of the surface. The forms of the surface; plains, hills of accumulation, valleys, basins, mountains, depressions, caverns. The sea; its movements, coasts, and bottom; islands.

Under most of these subjects, the processes of form production, and the forms thus produced are separately considered; the general accounts of denudation found in geological treatises not

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* Morphologie dor Erdoberfläche von Dr. Albrecht Penck, Professor der Geographie an der Universität Wien. Stuttgart, Engelhorn, 1894. 2 vols. 8vo. 471 and 696 pp. Author and subject indexes.

serving the author's purpose in his special treatment of the land. Much of the book is therefore *Morphogenie*, rather than *Morphologie.* Throughout both volumes, the citations of geological and geographical literature are remarkably numerous, and must serve an excellent purpose to those who wish to carry their studies to original sources. W. M. D.

3. *Orbit of Miss Mitchell's Comet*, 1847, *VI;* by H. A. Newton. —The computation of a definitive orbit for the Comet 1847, VI, is the subject of a memoir by Miss Margarita Palmer, being her thesis presented for the degree of Doctor of Philosophy conferred on her in 1894 by Yale University. Her work is published in the Transactions of the Yale Observatory. She found that a hyperbolic orbit better satisfied all the observations than did a parabola, though the best parabolic orbit does not do great violence to the observations. The best hyperbola has an eccentricity of 1·0001727.

A cursory examination shows that the position of Jupiter for a few years before 1847 was such as to increase the eccentricity of the comet's orbit. Herr Thraen has shown (*Astronomische Nachrischten*, No. 3249), that the action of Jupiter and other planets upon the Comet 1886, II, previous to its period of visibility was enough to explain a change from a parabolic orbit to the hyperbola demanded for that comet by the observations. It seemed worth while to compute the like perturbations for the Comet 1847, VI.

I find that from June, 1843, to November, 1847, the action of Jupiter and Saturn combined increased the eccentricity by ·000151. The action of Saturn was about one-thirtieth that of Jupiter. Previous to June, 1843, the action of Jupiter was to diminish the eccentricity of the orbit. Thus between February, 1838, and June, 1843, it changed the eccentricity by ·000034. During the whole period of ten years the change, therefore, was ·000117.

This explains so large a part of the computed excess of eccentricity over unity that it is fair to assume that a parabola to which these perturbations shall be applied would represent satisfactorily all the observations of the Comet 1847, VI.

OBITUARY.

Dr. Gideon E. Moore of New York City died on April 13th at the age of fifty-three. He was a well known chemist, who had made some valuable contributions to the science, particularly in the line of mineral analysis.

Prof. James E. Oliver, the distinguished mathematician, who had been connected with Cornell University since 1871, died March 27. He was the author of a number of standard mathematical works.

Francesco Sansoni, Professor of Mineralogy at the University of Pavia and author of many scientific papers, died about a month since.

It is announced in a recent number of "Nature" that the reported death of Professor H. Wild of St. Petersburg (see p. 328 of this volume), was happily a mistake, due to a confounding of similar names.

TILLY FOSTER MINERALS.

Two visits were made during April to the Tilly Foster Mine, and two entire collections were purchased, besides many smaller lots from the miners. We thus secured a marvelously fine series of Chondrodites and Clinochlores, and as that portion of the mine in which they were found will very soon be abandoned, it is probable that no more good specimens of these minerals will be obtained. Our purchases fill twenty drawers, besides a number of large specimens, and embrace, 1st. A magnificent collection of Chondrodites in groups of brilliant and complex crystals, both large (up to 3 inches) and small; also a number of good loose crystals. Prices for fine specimens $1.00 to $5.00; one extra fine group of large, bright crystals, $20.00. Excellent little crystals and groups, also large specimens of inferior quality, 10 cents to 50 cents. 2d. A grand collection of groups of Clinochlore in lustrous bluish-green tabular crystals inserted edgewise on the matrix, crystals averaging about ¾ inch up to 3 inches or more in diameter and about ¼ inch thick. Price for best quality, 50 cents to $4.00. Also a lot of small groups and single crystals at 10 cents to 50 cents. Nothing to compare with these specimens has ever before been found elsewhere. 3d. A few good groups of striated dodecahedrons of Magnetite at 25 cents to $3.50. 4th. One very fine large group of *Serpentine pseudomorphs after Chondrodite*, $10.00, and a few smaller specimens at $1.00 to $2.50. 5th. A few interesting *Fluorites*, *Apophyllites*, *Brucites*, *Pyroxenes*, etc.

This is by far the largest and best series of the rare Tilly Foster minerals ever brought together, and though some 200 specimens were sold within a few days after we received them, our stock is still replete in specimens of the very highest grade. This will very likely be the last opportunity of securing these minerals, and certainly no such marvelous collection of them is likely to be again offered for sale.

A GREAT FIND OF RARE QUARTZ CRYSTALS.

Mr. English visited a new locality in North Carolina and secured probably the most interesting pocket of Quartz crystals and groups ever obtained in that great mineral producing state. The find weighed over 1400 lbs. and one mammoth group of splendid crystals 15 x 32 x 10 inches and weighing about 200 pounds, another splendid group 14 x 20 x 8 inches, more than a score of other museum groups, a splendid lot of medium sized and small groups and a grand collection of loose crystals. The most interesting feature of the crystals is the exquisite etching which is sprinkled over some of their faces or bevels off or serrates their edges. Rare planes, especially low rhombohedrons abound and frequently air bubbles course through large cavities containing liquid. There are also many crystals with huge caverns in them, crystals grouped in parallel position, lustrous smoky crystals, beautiful rutilated amethystine groups of crystals, etc., etc. Give us permission to send you a carefully selected box on approval and you will not regret it.

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In consequence of the unusual length of this number, that for June will be made somewhat shorter than customary.

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Chas. D. Walcott.

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THIRD SERIES.

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Erratum for the June number.

Attention is called to a serious error in the June number, which escaped notice in reading proofs.

On page 475 in the title of the 3d article, Illinois is twice misused in place of Missouri. It should read *Geological Survey of Missouri, vol. iv, Paleontology of Missouri, etc.* Also in the Index, p. 487, under Geological Reports and Surveys, the third entry should be Missouri, not Illinois; and on p. 489, the first line should read, Keyes, C. R., Paleontology of Missouri, not Illinois.

Chas. D. Walcott.

THE AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXXV.—*Daily March of the Wind Velocities in the United States;* by FRANK WALDO, Princeton, New Jersey.

[The following matter is extracted from a paper prepared by the writer for the Weather Bureau of the Agricultural Department, and is published with the kind permission of the proper authorities.]

IN the Appendix No. 14 to the Chief Signal Officer's Annual Report for 1890, the average wind movement is given, for a large number of stations, in miles per hour for each hour of the day (1 to 24), for each month of the year, and also the averages for all of the months of the seven years 1883–89.

This presents most valuable data and is certainly the most unique of the tabular compilations published by the Weather Bureau. Hitherto we have relied mainly on the papers published by Hann and Köppen for collected data concerning the daily period of wind velocities, and even in these there are comparatively few places of observation taken into account. The publication of such data as those which we are considering, from a large number of stations having a variety of immediate exposures, and distributed over so large a portion of an entire continent, furnishes material for a very complete treatment of the subject of hourly winds. The present paper is mainly devoted to a view of the conditions of the geographical distribution of some important phases of the daily march of the wind velocities. The material is sufficiently rich to serve as a basis for a number of similar and more complete investigations.

The hourly wind velocities as originally published are arranged according to synchronous hours of the 75th meridian time. It is inconvenient in that form for many kinds of investigation and so I have arranged the data for the four mid-seasonal months and for the year, according to the local times; and, moreover, have converted the published anemometer miles (with constant 3·00) into true miles by means of Marvin's Table published by the Signal Service. I have also grouped the stations geographically and not alphabetically as given in the original table of hourly winds. This table cannot be reproduced here on account of its length, but I may remark that the relations of the maxima and minima have been investigated; and in the unpublished table are given the amplitudes or ranges in miles per hour, the excesses and deficiencies in terms of the average, and the amplitudes in terms of percentage of the averages. An account of this will shortly appear in the American Meteorological Journal.

The curves showing the daily march of the hourly wind velocities for *January*, *July* and the *Year*, I have also drawn for individual stations, but these cannot be reproduced here on account of the expense of drawings. The characteristics of these curves show marked variations with changes of geographical position, as we should expect: and while the number of years of observations which have been employed, which for the most cases is 7, is not sufficient to remove all irregularities from some of the curves, yet in most cases a sufficiently good idea of the daily march is given. I have however given the curves for January and July for 20 stations more or less representative of the various sections of the U. S. See the curves and explanation of the diagram at the end of this paper. This material is of such importance that the curves deserve to be taken up for discussion for individual stations, but it is only possible, in the present instance, to treat them in groups. Without further preliminary remarks I will give the main characteristics of these curves in what seems to me to be a proper order. In counting the hours, midnight is given as 0^h. The wind velocities are given in miles per hour: written m. p. h. In mentioning the characteristics of these curves, it will be remembered that a sharp ascent or descent indicates a rapid change in the wind velocity from hour to hour; a flat curve indicates no change; a sharp crest or trough shows an extreme maximum or minimum of short duration, while when well rounded they indicate a period of several hours during which the conditions at these phases continue to prevail before the swing to the opposite phase sets in.

Atlantic Coast.—On the *exposed* Atlantic Coast (Curve 1) there is in *January* but a slight variation in the wind velocity from hour to hour during the whole day, the average wind being 15 or 16 m. p. h.; but for *July* there is a strongly defined maximum (12 or 13 m. p. h.) at about 16^h, and a minimum (9·5 m. p. h.) at 4^h on the northern and 6^h on the Central Coast (7·5) and preceded in this last case by a slight secondary maximum at 3^h; while for the *Year* the maximum is well defined at 16^h on the northern (14·5 m. p. h.) and at 15^h on the southern (12·5 m. p. h.) coasts, and the minima occur at 0^h and 5^h for the former (nearly 13 m. p. h.) and about 22^h and 4^h for the latter (10·5 m. p. h.), and in both cases there is a slight secondary maximum at 3^h.

For the ordinary or partially sheltered Atlantic Coast stations (Curve 2) at which the land influence is strongly felt, there are in *January* well defined primary phases of max. (about 12 m. p. h.) and min. (about 9 or 10 m. p. h.), but the secondary phases are very weak and the curves become quite flat at these times. The max. phase becomes more marked with the southward progress from the north, not only on account of actual increase in the absolute height of the curves (which increase perhaps does not extend to places south of the Carolina Coast) but also on account of the fact that the crest of the curve becomes sharper and the rise and fall more abrupt. The daily curve during the hours of deficiency of wind (below the average) becomes more flattened out and of greater extent in the south. For *July* the upward swell of the curve is very much broader than for January, throughout the whole coast, but it is especially so at the south. The extreme maximum is more pronounced in all cases, but is most so at the north. At this season there is a remarkable similarity in the length of the swell of the curves (about 16 hours duration) throughout the whole coast.

For the *depressions* of the curves (i. e. periods of least wind) a greater irregularity is noticeable at the north, where slight secondary phases are visible.

For the *Year*, as might be expected, the curves possess characteristics between those for January and July; but they resemble the latter very much more closely than they do the former. The crest of the curve is, however, more rounded for the Year than for July; but the amplitude is not quite so great, nor the period of excess above the nearly level portion of the curve at the minimum quite so long, the latter for the Year being about half of the twenty-four hours.

Gulf of Mexico Coast.—The eastern, western, and northwestern coasts are represented (Curves 3 and 4). For *January* there is but slight absolute change in the irregular curves for these three coast sections. The curves for the extreme eastern and western coasts are somewhat similar as to the times of the phases, but the early afternoon maximum (at about 15^h) is much more strongly marked in the west than in the east. In the northwestern part (Galveston, Texas) the amplitude is not so great, and the ill defined crest is several hours earlier than in the other sections just mentioned.

For *July*, in the eastern part, a well defined and gradual but not excessive maximum rises above a fairly level period of deficiency, there being no strongly marked individual minimum; but in the northwestern part the maximum and minimum are very sharply marked, in each case the curve comes to a point, the amplitude is rather large for a coast exposure and the time of maximum (at 17^h) is considerably retarded as compared with that in the eastern part (at 12^h). In the extreme western part (at Corpus Christi) a curve of very marked peculiarities presents itself; it has a single rather sharply defined minimum of 5 m. p. h. at (5^h) about the same time as in the northwestern part, and a very high but round-crested maximum of nearly 15·5 m. p. h. (at 14^h to 18^h) with very steeply inclined sides which extend to the sharp angle of the minimum with as rapid a slope throughout the whole length as is ordinarily observed for inland stations at about (or a little after) the noon hour. It is seen that the whole amplitude of fluctuation thus becomes enormously great (over 10 m. p. h.).

For the *Year*, in the eastern and northwestern parts the maximum is well marked but the crest of the curve is very much flattened; and there is in both cases a nearly level minimum for about half of the twenty-four hours, with a rather steep but slight increase to a nearly level maximum which lasts for six hours. At the extreme west there is an open and very well rounded maximum and a well rounded minimum with a steep ascent, but with a more gradual descent connecting the two: the amplitude is about the same as that for an ordinary inland station.

The Great Lakes (Curve 5).—In *January* the curves are nearly all irregular, but the amplitudes of the irregularities are not great. The early afternoon maximum, although slight, is plainly marked in all cases: it is sometimes rounded and sometimes sharp-crested; that for the lesser absolute wind velocity being usually the more rounded, and that for the greater wind, which indicates a better water exposure, becoming sharper. The nearly flat minimum portion of the curve is usually somewhat lower for the hours succeeding midnight, than for the hours just preceding it. Secondary phases are quite plainly shown in some of the curves.

In *July* the max. is well rounded and strongly marked on all of the curves, and this period covers more than half of the twenty-four hours in most cases. When the minimum portion follows midnight it is in many cases a little higher than when preceding it, and is consequently somewhat of a reversal of the conditions for January. Secondary phases are not present.

For the *Year*, as is usually the case, the curves form a sort of mean between those for January and July. There is a nearly level min. period and a very well marked max.; this last with characteristics very similar to those for July. The period of the mid-day rise above the level minimum is about half of the twenty-four hours. Secondary phases are not noticeable.

Some peculiarities which distinguish the Upper from the Lower Lake Regions are mentioned farther along in their proper place among inland stations, and the above remarks are offered for comparison with those pertaining to the Gulf coast.

Pacific Coast (Curves 6, 7 and 8).—For *January*, at the *north* there is a nearly mid-day principal minimum, with a slight min. shortly after midnight, and with two nearly equal maxima from four to six hours before and after midnight; the changes are gradual and relatively small. On the *Central coast* the rise of the single max. above a somewhat level min. period is gradually accomplished in about twelve hours, the slope of the curve being gentle but the actual crest sharp. At the *south* a single early afternoon max. rises rapidly from a nearly level minimum; the slopes of the sides of the max. which separate to eight hours apart at the base are steep, and the actual crest slightly rounded. (On the high bluff at Cape Mendocino, near the center, the sharp crested max. occurs shortly after noon, and the sharp pointed trough of the min. at about midnight; and while the descent from the max. is steep and regular, the ascent is at first steep and then from 4^h to 11^h there is little change, then another steep ascent; the whole range being excessive and greater than that for mid-summer.)

For *July*, at the *north* there are both primary and secondary phases of max. and min.; but the secondary ones are slight, and the primary occur at nearly a reversal of the times for January, although the amplitude is slightly greater in July. On the *central coast* there is a single max. and min., but with an enormous amplitude. The crest is slightly rounded, but with a very steep slope, while the trough is more rounded, and the slope of descent becomes more gradual as the trough is approached. At the *south* there is a high max. with rather rounded crest, and steep sides, especially for the ascent; the curve for the period of minimum wind is quite flat during seven or eight hours, when the rise for the max. begins abruptly and finally ends nearly as abruptly. (The curve for the high bluff at Cape Mendocino, near the center of the coast, is quite similar in shape to that for the *south*, but the maximum is not quite so pronounced.)

For the *Year*, at the *north* the reversion of the phases noticed for January and July is such as to cause practically almost an erasure of the phases of max. and min., and the curve nearly becomes merely an irregular line with little variation of level. For the *central coast* the curve is quite similar to that for July, but the phases are not so great in amplitude and the slopes of the max. are not so steep. At the *south* there is a well rounded max. which rises for half the day above a nearly level min. period; the whole curve exhibiting phases about half way between those for January and July.

At the high station of Cape Mendocino the curve for the first half of the day resembles that for July, while for the latter half of the day it is similar to that for January for the same hours; but the amplitudes are less than for those months.

Having mentioned the *Coast* regions, we now pass to the various *Inland* sections of the U. S.

Inland: Northeastern U. S. (Curve 9).—For *January* there is a well marked maximum rising, for about ten hours of the day, above an irregular min. period, which has in some cases faint secondary phases. The crest of the max. is fairly well rounded, but flattens out (showing less rapid changes) with progress southward.

For July the maximum period is above the nearly flat min. period for about fourteen hours; in most cases the crest is well rounded but it becomes flatter toward the south.

For the *Year* the minimum period is usually still more flattened out than in the cases just mentioned, and the maximum portions of the curves are nearly as pronounced as for July but do not extend over quite as many hours. The curves for the Year are unusually similar to those for July, and in each very little secondary influence is noticeable.

Southeastern U. S.—For *January* the maximum rise is well marked, but does not cover a period of over eight to ten hours, and the minimum is rather more regularly level than is usual in mid-winter. For the relatively high exposure at Atlanta (Curve 10) there is but slight absolute variation, although there is a noticeable max. succeeded almost immediately by a rapid descent to a narrow minimum.

For *July* the max. covers a wider period than for January, and is more strongly marked (except at Jacksonville), while the curve of descent becomes steeper and the max. retarded until a later hour. The minimum period is hardly as level as for January. At the high exposure of Atlanta a slight secondary minimum is present.

For the *Year* the maximum is well developed and the curve well rounded, with a gradual ascent and a slightly sharper descent, and extends for about twelve hours above the smooth, slightly sloping, minimum period. At the high exposure of Atlanta the curve resembles that for July but has a more rounded maximum with slight secondary phases.

Lower Mississippi River Region (Curves 11 and 12).—For January the curves are very irregular and suffer but slight absolute changes; usually the max. occurs at 14^h to 16^h. The irregularity is greatest along the Mississippi River, at Vicksburg and Memphis, where the maximum is so slightly developed that the secondary maximum is nearly or quite as great as the primary; this is not due to the greater development of the secondary but the lack of development of the primary. For Vicksburg, the minimum has about the same absolute value in both phases, but for Memphis the afternoon minimum (at about 19^h) is slightly the lower of the two. On the lower Arkansas River, with a more east-westerly river exposure, the primary maximum at 13^h or 14^h is well developed, but the secondary phases are hardly perceptible, and the principal minimum is hardly to be distinguished since it is but little below the long, nearly level, period of minimum wind.

For *July*, there appears to be but a single well defined maximum culminating about the middle of the afternoon, at about 16^h, and a minimum is reached just before or about midnight. The slight traces of secondary phenomena can hardly be ascribed to other than accidental errors of exposure, etc.

The curves for the *Year* are very similar to those for July, but the amplitudes are not quite so great, and the minimum period is more nearly a uniform level. In all cases the descent from the culminating maximum is steeper than the ascent to it. The absolute maximum is at about 15^h and the minimum at or just before midnight.

Ohio River Region (Curve 13).—For *January* the maximum, at about 14^h, is well defined and with a rounded crest in some cases, and in others a pointed crest, but the slopes on either side are symmetrical. There is just a trace of a secondary maximum at some of the stations, which becomes best defined at Knoxville; while the minimum occurs for some of the stations before midnight, and for others after midnight, so that the usual times of both primary and secondary minima are represented in speaking of the principal minimum, and at Knoxville minima of about equal magnitudes occur for both primary and secondary phases.

For *July* the maxima are well developed, and usually with rounded, rather symmetrical crests; and the period of excess above the somewhat level period of deficiency is about fourteen or fifteen hours. The time of extreme maximum covers most of the afternoon hours, extending from 13^h or 14^h to 17^h or 18^h. There is but little more than a suspicion of a secondary maximum phase at about midnight, and although it can be noticed in some cases, yet it is entirely wanting in others. The minimum occurs a little before sunrise, and consequently just precedes the beginning of the ascent to the principal maximum.

For the *Year*, the maximum curves are remarkably symmetrical and have an absolute maximum at about 15^h, and while the amplitude is not quite so great as for July, yet the period during which the curve is above the very nearly level minimum is but little less than for July, and what shortening there is, is due to there being an earlier descent to the minimum level. The time of minimum is still in the early morning hours. Secondary phases are not noticeable.

Lake Region (Curve 5).—On the *Lower Lakes* for *January*, the curves are generally very irregular, but there is, in every case, a well defined, though short, principal maximum at about 14^h. The time of the principal minimum is variable; for Rochester and Cleveland it occurs only about four or five hours after the time of maximum, consequently at about 18^h, and for Buffalo, Detroit and Toledo it occurs shortly after or at midnight. Slight, secondary maxima occur for Rochester at about midnight; for Toledo two hours earlier, and probably for Cleveland at about 23^h.

For *July* a fairly well rounded maximum culminates at 14^h, but the time of minimum is by no means regular, for it occurs at about 4 hours before midnight in some cases, and 4 hours after midnight in others. In those cases in which the maximum is the best developed, the minimum occurs after midnight, both of which characteristics belong to the stations having greater land influence.

For the *Year*, a moderately sized maximum with gentle, regularly sloping, sides culminates at about 14^h. The minimum period covers about half the twenty-four hours, and the absolute minimum follows closely the relations just given for July, but the absolute change is so much smaller than for that month that the whole minimum period varies but little from a fixed level.

For the *Upper Lakes* for *January* there is a principal maximum at times varying from 12^h to 15^h and the crest is the more pointed, the better the water exposure. While the principal minimum occurs in the early morning hours (4^h and 8^h) for most of the stations, yet at Duluth a secondary minimum occurs at 17^h or 18^h, and this is of the same magnitude as the primary. The minimum period is very irregular and broken in all cases, and there are traces of secondary phenomena, which are well marked only in the case of Duluth, where the maximum nearly equal to the primary occurs near, or shortly before, midnight, and the minimum as just mentioned.

For *July* there is a well marked, rather rounded maximum at 15^h in most cases, but at 14^h at Alpena, with minimum at about 3^h for Alpena and Chicago, but with the principal minimum just before and at midnight at Milwaukee and

Duluth. For these last mentioned places a secondary maximum occurs at 3^h or 4^h and a second minimum at about 6^h, while for Duluth there is a slight tertiary maximum at 22^h and minimum at 20^h. For the early hours of the descent from the maximum the slope is steeper than in the ascent.

For the *Year*, the maxima of the curves are nearly as well developed as for July, but the amplitude is not quite so great, and the period that the maximum is above the nearly level minimum period is only about 12^h, which is less than for July. In most cases the minimum occurs at about 3^h or 4^h, but the whole minimum period is nearly the same, although for Milwaukee it is very irregular, and secondary phases are probably present.

Upper Mississippi River Valley Region (Curve 14).—For *January* there is a rather sharp-crested narrow maximum rising for about 9^h above a somewhat irregular though level minimum period, and having a small amplitude. The minimum usually occurs at about sunrise, although a near approach to the absolute minimum occurs at about sunset or a little later. Traces of secondary phenomena are present about three hours after midnight for Dubuque, and three hours before midnight for Keokuk. At the high exposure of St. Louis there is a low flat-crested maximum during the time from 9^h to 15^h and a secondary sharp-crested maximum of nearly the same amplitude at midnight; the principal minimum is at 18^h and secondary at about 6^h. The extreme amplitude is very slight, during the whole month.

For *July* there is a well developed maximum at from 14^h to 16^h and in most cases a secondary maximum at about midnight (sometimes a little before, and sometimes a little later). The times of minima are variable but usually at 6^h and 21^h, or a little later; in some cases the first is the primary and in others the secondary. The secondary phases are slight in comparison with the primary.

For the *Year*, there are well developed maxima at about 14^h and very slight secondary maxima at St. Louis, at or just before midnight. The minima occur at or about daybreak, with very slight secondary minima at St. Louis at 20^h. The minimum period is quite level. Secondary phases are hardly noticeable except at St. Louis.

Great Plains (Curves 15 and 16).—For *January* in the north, the maximum period culminating at 13^h or 14^h or 15^h is short (about 8^h above minimum level), but well marked; and the main minimum is at from 5^h to 8^h. Most of the stations show secondary maxima, near midnight, and secondary minima at about 18^h or 19^h and of nearly equal level with the principal minima. In the *south* the principal maximum extends over a longer period and is more flattened at the crest, which reaches from about noon to four hours after, but has not a greater amplitude than in the north. Secondary maxima rather better marked than usual are present, just before midnight at Abilene and Palestine; and the secondary minima for these stations at 18ʰ and 20ʰ are a little *lower* than those at about sunrise in the morning, so that the secondary phase really becomes the primary in these cases.

For *July*, the maxima culminating at 14ʰ or 15ʰ are large and well rounded, with the exceptions of Abilene and Palestine which have flat irregular crests; and the curve of the minimum is a sharply defined trough (at 5ʰ or 6ʰ) in some cases but rather flattened out in others, no law appearing to hold good. Secondary phases are present except in the extreme south, and in Dakota. At Palestine the usual secondary minimum is lower than the primary, and so in this case becomes the primary. Abilene and Palestine have flattened irregular crests at the principal maxima, and these show a slight recession at about noon.

For the *Year* the curves are quite similar to those for July except that the maximum period (culminating at 14ʰ or 15ʰ) is not so long or the amplitude so great. The minimum is at 5ʰ or 6ʰ. Secondary phases are lacking or are barely perceptible, except at Palestine, where the usual secondary minimum is so low as to really become the primary. The crest of the maximum is much flattened out at the south, showing little change for several hours about noon and later.

Great Plateau (Curves 17, 18, and 19).—For *January* at the *south*, there is a single abrupt, narrow, steep sided, but slightly round crested maximum with level or slightly sloping minimum but no secondary phases; near the *center* there is still a principal though less marked maximum, varying from 12ʰ to 16ʰ, and usually secondary or even tertiary phases. While the minima are about equal, yet the customary secondary minimum phases (in the early evening) are usually slightly the lowest and thus become the primary. At the high station of Winnemucca the curve is irregular and has three sets of phases; while at the *north* the curves have relatively slight amplitudes and are irregular, having at least two sets of phases, and the usual secondary minimum becomes the primary in about half the cases.

For *July*, in the *south*, the maximum (at 14ʰ or 15ʰ) becomes relatively great in Central Arizona, but is not usually large elsewhere, while a sharply defined minimum occurs at 6ʰ to 8ʰ; and but single phases occur where the amplitude is so excessive, while for the other stations secondary phases occur, but the minimum at about sunrise remains the primary minimum with a single exception, in which case the minimum occurs at midnight. Near the *center* the maximum period (culminating at

15^{h} to 17^{h}) is of rather long duration but the amplitude is not excessive, and the principal minimum occurs at about 6^{h} to 8^{h}. The high station of Winnemucca is the only one with pronounced secondary phases. In the *north*, the characteristics of the curves are similar to those near the center, except that at Ft. Assiniboine and Helena there is a secondary minimum at 21^{h} to 22^{h} and maximum at 24^{h}.

For the *Year*, in the *south*, the maxima (culminating at about 15^{h}) are about an average between those for January and July, and a single minimum occurs at 6^{h} or 8^{h}, except for Phœnix which, as in July, has an absolute minimum in the afternoon: the minimum period is rather level. Near the *center*, but a single moderately sized maximum occurs at about 15^{h} and the minimum is at 6^{h} to 8^{h}. Winnemucca has two maxima, a slight secondary one near midnight; and the morning minimum, although it remains the primary, is not much different from the secondary. At the *north*, the maxima are usually fairly well marked (crest at about 15^{h}) and cover a long period with no secondary phases except at Ft. Assiniboine.

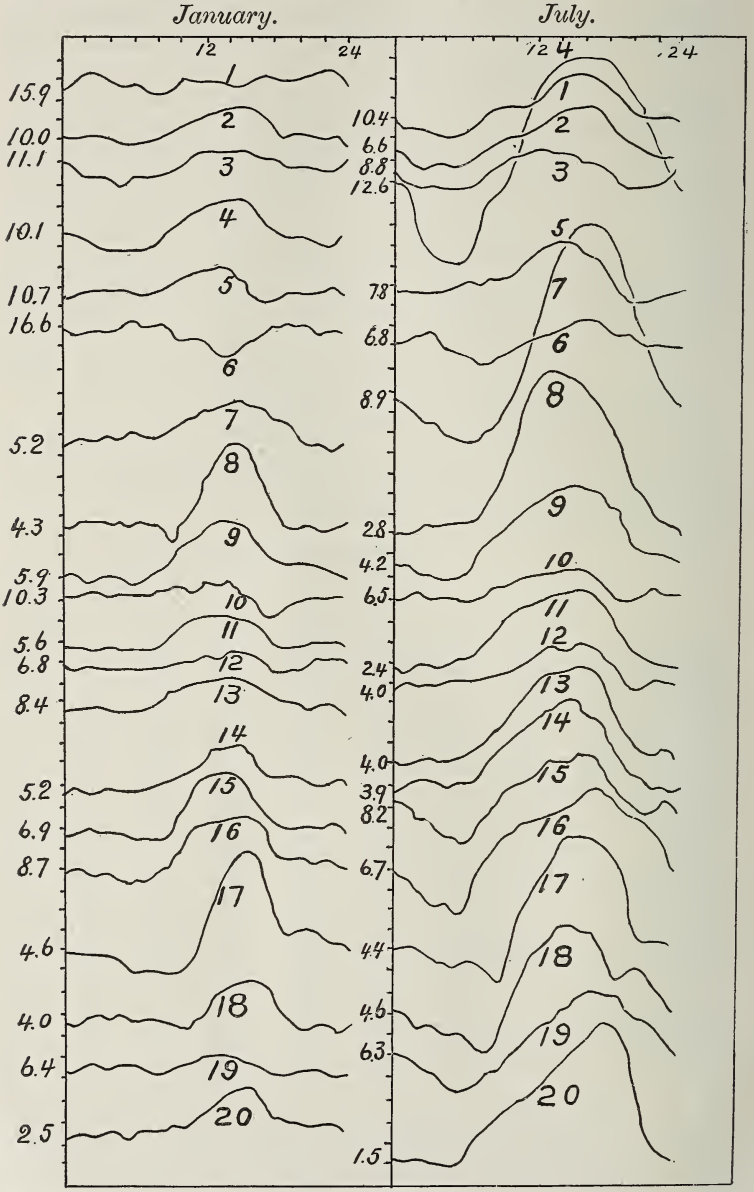
The curves (p. 442) showing the daily march of the wind velocities for January and July for characteristic stations of twenty regions in the U. S. are numbered from 1 to 20 and the following list will identify stations by name:

Daily Wind, miles per hour.

	JANUARY.				JULY.			
	At 0^{h}.	Max.	Min.	Daily average.	At 0^{h}.	Max.	Min.	Daily aver.
1. Block Island,	15·9	16·8	15·5	16·2	10·4	12·7	9·7	10·9
2. New York City,	10·0	11·5	9·7	10·4	6·6	9·1	5·7	7·3
3. Key West,	11·1	11·7	9·9	10·8	8·8	11·1	8·8	10·3
4. Corpus Christi,	10·1	10·4	11·8	9·4	12·6	15·7	11·5	13·7
5. Cleveland,	10·7	12·0	10·2	10·9	7·8	8·4	5·1	9·0
6. Tatoosh Island,	16·6	17·0	15·3	16·4	8·8	8·2	5·9	7·1
7. San Francisco,	5·2	7·7	5·0	6·2	8·9	17·9	6·7	11·4
8. San Diego,	4·3	8·4	3·5	5·1	2·8	10·7	2·8	5·8
9. Albany,	5·9	8·5	5·3	6·6	4·2	8·0	3·6	5·6
10. Atlanta,	10·3	11·2	9·4	10·5	6·5	7·8	6·1	6·8
11. Little Rock,	5·6	6·9	5·3	5·9	2·4	6·3	2·3	4·1
12. Vicksburg,	6·8	7·4	6·2	6 7	4·0	6·2	3·8	4 7
13. Louisville,	8·4	9·7	8·1	8·9	4·0	8 4	3·8	5·7
14. St. Paul,	5·2	7·2	5·1	5·8	3·9	8·2	3·9	5·6
15. North Platte,	6·9	9·7	6·4	7·5	8·2	10·6	6·5	8·8
16. Palestine, Texas,	8·7	10·5	8·3	9·3	6·7	7 9	5·4	6·8
17. Ft. Apache,	4·6	9·2	3·3	5·3	4·4	10·1	2·9	6·0
18. Salt Lake City,	4·0	6·0	3·7	4·5	4·5	8·9	2 8	5·7
19. Ft. Custer,	6·4	7·5	6·4	6·7	6·3	9·3	4·7	6·9
20. Roseburgh,	2·5	4·6	2·5	3·0	1·5	8·1	1·3	4·0

In the little table are given for January and July the wind in miles per hour at 0^{h} (midnight), at the time of maximum and minimum wind, and for the average of all the hours of the day.

These curves begin and end at 0^h (midnight) and are all in the same scale. At the top of the diagram giving the curves the two hour spaces are indicated by short lines, but the miles per hour have been indicated only in general by vertical scales at the sides of the curves because it would make the reproduction of the diagram less simple to place the scales properly opposite each curve. The miles per hour of wind at 0^h is given at the beginning of each curve.


January. *July.*

ART. XXXVI.—*The Preparation of Perchloric Acid and its Application to the Determination of Potassium;* by D. ALBERT KREIDER.

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

VARIOUS methods for the preparation of perchloric acid have been developed through the long felt want of a process in which the elements of time and danger would be reduced to a minimum and the product increased to quantities commensurate with the growing use of the acid in analytical chemistry. Most of these methods have been found impracticable because of the incidental formation of the dangerously explosive oxides of chlorine, or the time required in refining the product from the impurities introduced with the reagents employed.

Doubtless the best process thus far offered is that of Caspari,* which, however, is to an objectionable degree exacting of time and labor. The product has to be treated and retreated for the removal of potassium and then for the extraction of the hydro-fluo-silicic-acid and at several stages is for this purpose to be left standing for from twenty-four to forty-eight hours. Under the most favorable circumstances it could not be prepared in less than five or six days, and during a great many hours of that time it requires close attention.

The great difficulty has always been with the necessity of a perfect separation of potassium from the perchloric acid, which has been prepared by the ignition of the potassium chlorate. If, for the manufacture of the perchlorate, the chlorate of sodium—which, if not upon the shelves of every laboratory, is nevertheless in the market, almost, if not entirely free of potassium—be used instead of the potassium salt, the complete removal of the base will be unessential; since its presence in the determination of potassium will exert no influence other than that which is beneficial. It is well known that because of its deliquescence and the almost equal solubility of sodium perchlorate with that of the chloride, its separation from the latter by recrystallization from an aqueous solution, as in the case of potassium, is impossible. But the insolubility of the chloride of sodium in strong hydrochloric acid, with the aid of the acid-proof Gooch crucible, affords a means for the liberation of the perchloric acid and the removal of the greater part of the sodium in one operation. Upon this basis, therefore, the following simple method was elaborated.

A convenient quantity of sodium chlorate, from 100 to 300 grms., is melted in a glass retort or round-bottomed flask and

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* Zeitschr. für Ang. Chem., 1893, p. 68.

gradually raised to a temperature at which oxygen is freely, but not too rapidly evolved, and kept at this temperature till the fused mass thickens throughout, which indicates the complete conversion of the chlorate to the chloride and perchlorate, and requires between one and one-half to two hours: or the retort may be connected with a gasometer and the end of the reaction determined by the volume of oxygen expelled, according to the equation

$$2NaClO_3 = NaCl + NaClO_4 + O_2.$$

The product thus obtained is washed from the retort to a capacious evaporating dish where it is treated with sufficient hydrochloric acid to effect the complete reduction of the residual chlorate, which, if the ignition has been carefully conducted with well distributed heat, will be present in but small amount. It is then evaporated to dryness on the steam bath, or more quickly over a direct flame, and with but little attention until a point near to dryness has been reached, when stirring will be found of great advantage in facilitating the volatilization of the remaining liquid and in breaking up the mass of salt. Otherwise the perchlorate seems to solidify with a certain amount of water, and removal from the dish, without moistening and reheating, is impossible.

After triturating the residue, easily accomplished in a porcelain mortar, an excess of the strongest hydrochloric acid is added to the dry salt, preferably in a tall beaker where there is less surface for the escape of hydrochloric acid and from which the acid can be decanted without disturbing the precipitated chlorid. If the salt has been reduced to a very fine powder, by stirring energetically for a minute, the hydrochloric acid will set free the perchloric acid and precipitate the sodium as chloride, which in a few minutes settles, leaving a clear solution of the perchloric acid with the excess of hydrochloric acid. The clear supernatant liquid is then decanted upon a Gooch filter, through which it may be rapidly drawn with the aid of suction, and the residue retreated with the strongest hydrochloric acid, settled, and again decanted, the salt being finally brought upon the filter where it is washed with a little strong hydrochloric acid. A large platinum cone will be found more convenient than the crucible, because of its greater capacity and filtering surface. When the filter will not hold all the sodium chloride, the latter after being washed may be removed by water or by mechanical means, with precautions not to disturb the felt, which is then ready for the remainder. Of course, if water is used, the felt had better be washed with a little strong hydrochloric acid before receiving another portion of the salt. This residue will be found to contain only an inconsiderable amount of perchlorate, when tested by first heating to expel the free acid and then treating the dry and powdered residue with 97 per cent alcohol, which dissolves the perchlorate of sodium but has little soluble effect on the chloride.

The filtrate, containing the perchloric acid with the excess of hydrochloric acid and the small per cent of sodium chloride which is soluble in the latter, is then evaporated over the steam bath till all hydrochloric acid is expelled and the heavy white fumes of perchloric acid appear, when it is ready for use in potassium determinations. Evidently the acid will not be chemically pure because the sodium chloride is not absolutely insoluble in hydrochloric acid; but a portion tested with silver nitrate will prove that the sodium, together with any other bases which may have gone through the filter, has been completely converted into perchlorate, and unless the original chlorate contained some potassium or on evaporation the acid was exposed to the fumes of ammonia, the residue of the evaporation of a portion is easily and completely soluble in 97 per cent alcohol and its presence is therefore unobjectionable. One cubic centimeter of the acid thus obtained gave on evaporation a residue of only 0·036 grm., which was completely soluble in 97 per cent alcohol.

Caspari's acid under similar treatment gave a residue in one case of 0·024 grms. and in another 0·047 grms. If, however, a portion of pure acid be required, it may be obtained by distilling this product under diminished pressure and, as Caspari has shown, without great loss providing the heat is regulated according to the fumes in the distilling flask.

Some modification of the above treatment will be found necessary in case the sodium chlorate contains any potassium as an impurity, or if the latter has been introduced from the vessel in which the fusion was made. Under these circumstances the hydrochloric acid would not suffice for the removal of potassium, since a trace might also go over with the sodium and thus on evaporation a residue insoluble in 97 per cent alcohol be obtained. To avoid this difficulty, the mixture of sodium perchlorate and chloride, after being treated with hydrochloric acid for the reduction of the residual chlorate, being reduced to a fine powder, was well digested with 97 per cent alcohol, which dissolves the sodium perchlorate but leaves the chloride as well as any potassium salt insoluble. By giving the alcohol time to become saturated, which was facilitated by stirring, it was found on filtering and evaporating that an average of about 0·2 grm. of sodium perchlorate was obtained for every cubic centimeter of alcohol and that the product thus obtained was comparatively free of chlorides, until the perchlorate was nearly all removed, when more of the chloride seems to dissolve. This treatment with alcohol is continued until, on evaporation of a small portion of the latest filtrate, only a small residue is found. The alcoholic solution of the perchlorate is then distilled from a large flask until the perchlorate begins to crystallize, when the heat is removed and the contents quickly emptied into an evaporating dish, the same liquid being used to wash out the remaining portions of the salt. When the distillation is terminated at the point indicated, the distillate will contain most of the alcohol employed, but in a somewhat stronger solution, so that it requires only diluting to 97 per cent to fit it for use in future preparations. The salt is then evaporated to dryness on the steam bath and subsequently treated with strong hydrochloric acid for the separation of the perchloric acid.

One cubic centimeter of the acid prepared in this way, on evaporation gave a residue in one case of 0·0369 grms., and in another 0·0307 grm., completely soluble in 97 per cent alcohol, which was then ignited and the chlorine determined by silver from which the equivalent of perchloric acid in the form of salts was calculated as 0·0305 grm. By neutralizing the acid with sodium carbonate, evaporating, igniting in an atmosphere of carbon dioxide till decomposition was complete, collecting the oxygen over caustic potash, allowing it to act on hydriodic acid by intervention of nitric oxide, according to a process soon to be published, titrating the iodin liberated, with standard arsenic and calculating the equivalent of perchloric acid, after subtracting the amount of acid found in the form of salts, the amount of free acid per cubic centimeter proved to be 0·9831 grms.

The whole process, even when the separation with alcohol is necessary, can not well require more than two days and during the greater part of that time the work proceeds without attention.

In applying perchloric acid, thus prepared, to the determination of potassium according to the treatment suggested by Caspari* very satisfactory results were obtained. Briefly, the method is as follows: The substance, free from sulphuric acid, is evaporated to the expulsion of free hydrochloric acid, the residue stirred with 20 cm^3 of hot water and then treated with perchloric acid in quantity not less than one and one-half times that required by the bases present, when it is evaporated with frequent stirring to a thick, syrup-like consistency, again dissolved in hot water and evaporated with continued stirring till all hydrochloric acid has been expelled and the fumes of per-

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* loc. cit.

chloric acid appear. Further loss of perchloric acid is to be compensated for by addition of more. The cold mass is then well stirred with about 20 cm³ of wash alcohol—97 per cent alcohol containing 0·2 per cent by weight of pure perchloric acid—with precautions against reducing the potassium perchlorate crystals to too fine a powder. After settling, the alcohol is decanted on the asbestos filter and the residue similarly treated with about the same amount of wash alcohol, settling and again decanting. The residual salt is then deprived of alcohol by gently heating, dissolved in 10 cm³ of hot water and a little perchloric acid, when it is evaporated once more with stirring, until fumes of perchloric acid rise. It is then washed with 1 cm³ of wash alcohol, transferred to the asbestos, preferably by a policeman to avoid excessive use of alcohol, and covered finally with pure alcohol: the whole wash process requiring about 50 to 70 cm³ of alcohol. It is then dried at about 130° C. and weighed.

The substitution of a Gooch crucible for the truncated pipette employed by Caspari will be found advantageous; and asbestos capable of forming a close, compact felt should be selected, inasmuch as the perchlorate is in part unavoidably reduced, during the necessary stirring, to so fine a condition that it tends to run through the filter when under pressure. A special felt of an excellent quality of asbestos was prepared for the determinations given below and seemed to hold the finer particles of the perchlorate very satisfactorily.

A number of determinations made of potassium unmixed with other bases or non-volatile acids are recorded in the following table:

KCl taken. grms.	Volume of filtrate. cm³.	$KClO_4$ found. grms.	Error on $KClO_4$. grms.	Error on KCl. grms.	Error on K_2O. grms.
0·1000	54	0·1851	0·0008—	0·0004—	0·0003—
0·1000	58	0·1854	0·0005—	0·0002—	0·0002—
0·1000	51	0·1859	0·0000	0·0000	0·0000
0·1000	50	0·1854	0·0005—	0·0002—	0·0002—
0·1000	48	0·1859	0·0000	0·0000	0·0000
0·1000	52	0·1854	0·0005—	0·0002—	0·0002—

Considerable difficulty, however, was experienced in obtaining equally satisfactory determinations of potassium associated with sulphuric and phosphoric acids. As Caspari has pointed out, the sulphuric acid must be removed by precipitation as barium sulphate before the treatment with perchloric acid is attempted, and unless the precipitation is made in a strongly acid solution, some potassium is carried down with the barium. Phosphoric acid need not be previously removed; but to secure a nearly complete separation of this acid from the potassium, a considerable excess of perchloric acid should be left upon the potassium perchlorate before it is treated with the alcohol. When these conditions are carefully complied with, fairly good results may justly be expected. Below are given a number of the results obtained.

Compounds taken. grms.	Vol. of filtrate. cm³.	$KClO_4$ found. grms.	Error on $KClO_4$. grms.	Error on KCl. grms.	Error on K_2O. grms.
KCl = 0·1000					
$CaCO_3$ = 0·13	50	0·1887	0·0028+	0·0014+	0·0009+*
$MgSO_4$ = 0·13	82	0·1875	0·0016+	0·0008+	0·0005+*
Fe_2Cl_6 = 0·05	80	0·1861	0·0002+	0·0001+	0·0001+†
$Al_2(SO_4)_3$ = 0·05	80	0·1843	0·0016−	0·0008−	0·0005−†
MnO_2 = 0·05	92	0·1839	0·0020−	0·0010−	0·0006−†
$HNa_2PO_4 \cdot 12H_2O$ = 0·40	60	0·1854	0·0005−	0·0002−	0·0002−†

In the last three experiments of the above table the amount of perchloric acid was about three times that required to unite with the bases present and the phosphoric acid subsequently found with the potassium was hardly enough to appreciably affect the weight, although its absolute removal was found impossible.

The kindly direction and frequent advice of Professor F. A. Gooch, during the investigation, is gratefully acknowledged.

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* The residue showed phosphoric acid plainly when tested.

† Only traces of phosphoric acid found in the residue.

Chas. D. Walcott,

ART. XXXVII.—*On the Crystal Form of Borneol and Isoborneol;* by WM. H. HOBBS.

IN a recent paper by Bertram and Walbaum* on an isomer of borneol ($C_{10}H_{18}O$) which they have called isoborneol, Traube has described both this substance and borneol from a crystallographical standpoint. The borneol examined was obtained by reduction of camphor, had a melting point of 206°–207°, and was dextro-rotatory. The symmetry of both borneol and isoborneol as determined by Traube is hexagonal, the combination in each case being the basal pinacoid with the pyramid and prism. The chief differences between the two substances he finds to be the greater double refraction of isoborneol, and its positive optical character, borneol being optically negative. The axial ratio of borneol he determined to be exactly double that of isoborneol.

Three samples of the alcohol $C_{10}H_{18}O$ were given me for examination to determine whether they are borneol or isoborneol. They were prepared in the School of Pharmacy of the University of Wisconsin by Mr. Carl G. Hunkel, whose study of them will be published in the *Pharmaceutische Rundschau.* The samples were prepared, one from the oil of black spruce (*Picea nigra*) in which the alcohol is contained as acetic ester, a second from the oil of the fir balsam (*Abies balsamia*), and the third from the oil of turpentine in benzine. The crystals in all these samples are larger and more highly modified than those described by Traube, and their examination has brought out new facts concerning their crystallography and physical properties. The surest basis of comparison with the crystals described by Traube has been the degree of double refraction. The crystals obtained from *Picea nigra* and *Abies balsamia* in this respect correspond exactly with the borneol of Traube's study. The crystals in the sample obtained from turpentine, on the other hand, correspond with his isoborneol so far as the degree of double refraction is concerned, *but they are always optically negative,* in this respect agreeing with borneol. It is therefore not certain that this substance is identical with the isoborneol of Bertram and Walbaum, but it seems best from all the facts to refer to it for the present as isoborneol. All the samples examined have rhombohedral symmetry. This is clearly shown by the partial occurrence of pyramids, and in the case of the crystals from *Picea nigra* by the tri-symmetric character of pittings on the basal pinacoid. Of the nine pyramidal forms which have been made out on the two substances

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* Ueber Isoborneol, Journ. f. prakt. Chemie, vol. xlix (1894), pp. 1–19.

no one occurs in both positive and negative dodecants on the same crystal. The habit of both substances is broadly tabular parallel to the basal pinacoid and the plates have generally a regular hexagonal outline. One variety of isoborneol is, however, observed whose crystals take the form of rhomboidal plates owing to the disappearance of all planes from two of the opposite vertical pairs of dodecants. Although these crystals are identical with the normal variety in regard to their optical properties, they nevertheless represent an entirely different crystal combination. Crystals from all the samples have their faces more or less rounded and the measurements are as a result subject to considerable variations, but they are, nevertheless sufficiently accurate for a determination of all the forms. It is very probable that the axial ratios of borneol and isoborneol are different, since the substances differ so much in their double refraction, but they are certainly nearly identical and the difference is within the limits of error in the reading of angles on the crystals examined. I have therefore used for both substances the axial ratio determined on crystals of borneol from *Picea nigra.*

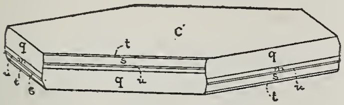
Borneol from Picea nigra. The crystals of this substance examined are thin, colorless, hexagonal plates having a diameter of $\frac{1}{2}$–1^{cm}. and a thickness of 0·5–1^{mm}. The larger plates have a wide peripheral zone which is occupied by cavities generally filled with mother liquor. The shape of these cavities is somewhat irregular, but they are oriented roughly parallel to the boundaries of the plate. Besides the basal pinacoid the prominent forms are a steep rhombohedron making nearly 83° with the base and a smaller rhombohedral face of opposite sign which makes nearly 73° with the same form. This latter form is undoubtedly the pyramid observed on the substance by Traube and it is therefore chosen for determining the axial ratio. The average of four measurements of the angle included between this face and the base (limits 71° 25′ and 74° 6′) is 72° 46′ and if considered the fundamental rhombohedron the axial ratio would be $\dot{c} = 2·79$ (2·83, Traube). It is, however, more convenient to consider this form 3R $(30\bar{3}1)$, which makes the axial ratio $\dot{c} = 0·93$.

The observed forms are *c*, oP (0001); *s*, 3R $(30\bar{3}1)$; *q*, −8R $(80\bar{8}\bar{1})$; *m*, ∞P $(10\bar{1}0)$; *t*, $\frac{2}{3}$R $(20\bar{2}3)$; *u*, 4R $(40\bar{4}1)$. Figure 1 represents a crystal of borneol. These forms have been determined by the following measurements:

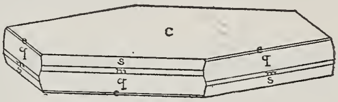
	Measured.		Calculated.
$c \wedge s$,	72° 46′	(limits 71° 25′ and 74° 6′)	72° 46′
$c \wedge q$,	82 42	(limits 81 13 and 83 47)	83 22
$c \wedge m$,	90 6		90 0
$c \wedge u$,	77 11	(limits 76 47 and 77 35)	76 54
$c \wedge t$,	34 38		35 37

The crystals have very perfect cleavage parallel to the base and the rhombohedron *q*. They are very flexible and care must be used in handling them before measurement. Pittings on the basal pinacoid are trisymmetric with the lines of symmetry meeting at angles of 120°.

1.



2.



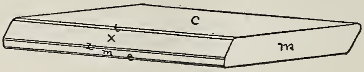
Examined under the polarizing microscope basal sections of these crystals appear isotropic and afford no interference figure. Sections parallel to the prism exhibit very weak double refraction. In sections 2^{mm}. in thickness the double refraction is faintly perceptible without the use of a quartz plate. In sections 3^{mm}. in thickness the double refraction is easily determined with use of the quarter undulation mica place. A considerable number of sections were tested and all were found to be negative. In these sections the interference color only reaches the yellow of the first order when the corresponding axes of the crystal and the mica plate are parallel. These characters therefore agree well with those determined for this substance by Traube. The borneol prepared from *Abies balsamia* is optically identical with this.

Isoborneol from Turpentine. As already stated, the symmetry of this substance is the same as that of borneol and the axial ratio is also so nearly identical that the measurements afforded essentially the same results. The determined axial ratio $c = 0{\cdot}93$ of borneol is therefore assumed for this substance. The observed forms on the normal type of crystals are: *c*, oP (0001); *s*, 3R $(30\bar{3}1)$; *q*, −8R $(80\bar{8}\bar{1})$; *m*, ∞P $(10\bar{1}0)$; and *e*, −4R $(40\bar{4}\bar{1})$. A crystal of this type is represented in figure 2. The above forms were determined by the following measurements:

	Measured.	Average.	Calculated.
$c \wedge s$,	71° 52′		
	73 24	72° 38′	72° 46′
$c \wedge q$,	81 23		
	81 58	81 41	82 42
$c \wedge m$,	90 32	90 32	90 08
$c \wedge e$,	75 10	75 10	77 11

The crystals of this substance possessing rhomboidal habit represent quite a different crystal combination from the normal type of crystals. The prominent forms on these crystals (after the base) are the rhombohedron *x*, $\frac{5}{3}$R $(50\bar{5}3)$ and the prism *m*, ∞P $(10\bar{1}0)$. Quite frequently the former appears forming two opposite sides of the rhomboid, the other two sides being formed by the prism alone (see figure 3). The form *x* may be the one from which Traube determined the axial ratio of this substance. Determined from the writer's measurements of the position of this plane the axial ratio would be (considering it the fundamental rhombohedron) c = 1·589, Traube's value being c = 1·41. The observed forms comprising this combination are: *c*, oP (0001); *x*, $\frac{5}{3}$R $(50\bar{5}3)$; *m*, ∞P $(10\bar{1}0)$; *t*, $\frac{2}{3}$R $(20\bar{2}3)$; *z*, 5R $(50\bar{5}1)$; and *e*, −4R $(40\bar{4}\bar{1})$. The forms *y*, $\frac{1}{6}$R and *r*, R (or $\frac{12}{11}$R) were also observed on one crystal but their sign was not determined. The above forms were identified by means of the following measurements:

3.



	Measured.	Average.	Calculated.
$c \wedge m$,	89° 58′		
	89 59	89° 59′	90° 0′
$c \wedge x$,	62 31		
	60 17		
	61 26	61 25	60 49
$c \wedge e$,	76 44	76 44	76 54
$c \wedge y$,	10 30		
	10 43	10 36	10 9
$c \wedge z$,	79 31	79 31	79 27
$c \wedge t$,	36 54	36 54	35 37
$c \wedge r$,	49 31	49 31	R, 47 3 $\frac{12}{11}$R, 49 32

As regards color, enclosures, and cleavage, isoborneol seems to differ but little from borneol. The great difference between the two substances is seen when they are examined in prismatic sections in parallel polarized light. A section of borneol in which double refraction is not perceptible, would if prepared from isoborneol yield yellow of the first order. Sections of isoborneol 2^{mm}. in thickness yield, when the interference of the crystal is added to that of the quarter undulation mica plate, violet of the second order, whereas similar sections of borneol yield under the same conditions yellow of the first order. The optical character has been tested on a considerable number of crystals and found to be always negative. The substance examined by Traube is reported to be positive.

In conclusion I would express my thanks to Professor Edward Kremers and Mr. Carl G. Hunkel of the Department of Pharmacy, University of Wisconsin, for supplying me with the material studied.

Mineralogical Petrographical Laboratory, University of Wisconsin.

ART. XXXVIII.—*Synopsis of the Mode of Growth and Development of the Graptolitic Genus Diplograptus;*[*] by R. RUEDEMANN.

THE main results of the observations made upon a large collection of specimens of the genus *Diplograptus* found near Dolgeville, N. Y., are the following:

(1) *Diplograptus pristis* Hall (= *D. foliaceus* Murch. sp.) and *Diplograptus pristiniformis* Hall (= *D. dentatus* Brgt. sp.), two typical graptolites of the Utica shale, which were hitherto known to grow only in single stipes, have been found growing in compound colonial stocks which appear in the fossil state as stellate groups. The compound fronds of *D. pristis* Hall reach a diameter of four inches and are composed in some specimens of as many as forty stipes, those of *D. pristiniformis* Hall are only an inch in diameter and have about a dozen of stipes.

(2) The virgulæ are joined to a central connecting stem, the "funicle" of Hall, which is mostly extended to a vesicle of quadrangular shape. The funicle is inclosed in a thick chitinous capsule, which is identical with the "central disc" of the compound fronds of numerous *Monograptidæ.* The central disc, too, is drawn out at the four corners where most of the virgulæ leave, so as to appear subquadrangular in the compressed state.

(3) The central disc is surrounded by a verticil of oval capsules, which number from four to eight and probably still more. The latter appear mostly as oval impressions; in a few specimens a thin chitinous film is discernible; in some fossils, however, the oval appendage is made up of distinct siculæ which radiate from an axial club-shaped protuberance within the vesicle, to which they are joined by the filiform prolongation of their pointed ends. The mature siculæ are found near the base, the younger ones toward the top of the vesicle. The section of the test of the vesicle appears sometimes as a chitinous ring.

The enclosed siculæ give evidence that the vesicles were organs of reproduction which are to be compared with the "gonangia" of recent hydrozoa. In some specimens the compound frond is surrounded by a dense crowd of siculæ, most of which are pointing with the broad ends outwards, so as to make it obvious that they took their origin in the center of the frond. In this case the gonangia were apparently opened shortly before the covering of the fossil.

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[*] Abstract of a paper on the genus *Diplograptus* to be published in the Report of the State Geologist of New York for the year 1894.

(4) The majority of the fossils present a large subquadratic impression which overlaps the gonangia, and sometimes even the proximal ends of the stipes. Some specimens of *D. pristiniformis* Hall, found in a limestone-layer which is interpolated in the shale, reveal the fact that this impression belongs to an organ which was made up of a large spherical segment on the upper side and a smaller one on the under side of a quadrangular plate. The latter has a system of furrows parallel to the margin. The author compares the whole organ with the air-bladder or pneumatocyst of the *Discoideæ*, a family of the *Siphonophoræ*, on account of its size, its being the topmost organ, and on account of the apparent absence of any structure—besides the furrowing in the plate which reminds much of the system of canals in the float of the *Discoideæ*.

We may infer from the preceding observations that the colonial stock was carried by a large air-bladder, to the underside of which was attached the funicle. The latter was enclosed in the central disc and this was surrounded by a verticil of vesicles, the gonangia, which produced the siculæ. Below the verticil of gonangia and suspended from the funicle was the tuft of stipes.

(5) A close observation of the siculæ, which are found so numerously on the slabs, detected the fact that the siculæ, at the time of developing the first two hydrothecæ, possessed a quadrangular plate, joined by a small node in the center to the end of the filiform proximal process. On young stipes with seven hydrothecæ on one side and six on the other, can be already discerned four oval, distinctly furrowed impressions around the central node.

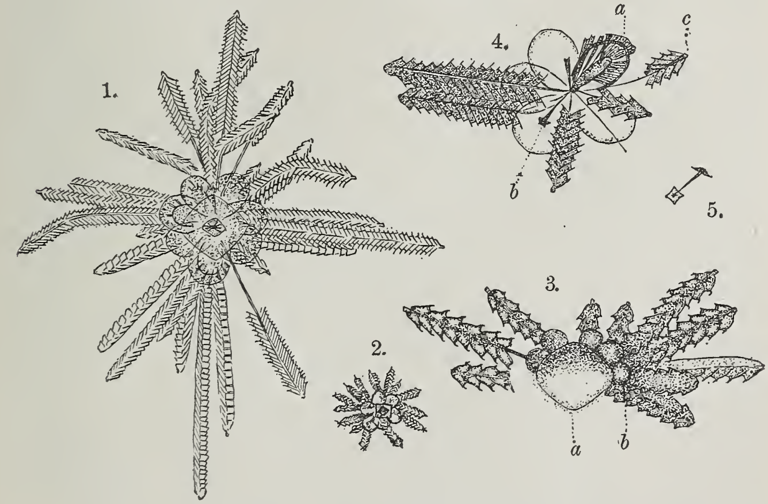
The first appearing quadrangular plate—or probably vesicle—develops into the pneumatocyst, the central node into the funicle and central disc; and in the small oval impressions we most probably see the budding gonangia. The sicula, therefore, which grows out to the primary stipe develops first the floating organ and then the central organs.

It deserves to be noted that the new hydrothecæ of the primary stipe sprout in the direction towards the central organs while the sicula remains in all stages of development at the opposite end of the central organs, i. e., at the distal end.

Whether the primary stipe produces first new siculæ, some of which remain in connection with the center, forming new stipes and by these the compound frond, or whether other detached siculæ gain connection with the new center of the first stipe, could not be decided. The fact, however, is that fronds with one full-grown stipe, the primary one, and several young ones are a rather common occurrence, further that fronds have been found to the center of which siculæ without any hydrothecæ and stipes in all stages of development were joined.

(6) A most astonishing feature of the compound fronds is the position of the siculæ at the remote end of the stipes, so that the so-called "proximal" sicula-bearing end of the single stipes appears in the compound colonial stock as the distal one. This is accounted for by the observation that the first hydrothecæ of each stipe sprout at the distal, broad end of the sicula and that all following hydrothecæ make their appearance more proximally. The stipe, therefore, is growing backward, towards the center, or like a leaf at the base, and the sicula is carried to the distal end.

(7) By the possession of a pneumatocyst and the arrangement of the reproductive organs at the bases of the stipes, the colonial stocks of *Diplograptus* had a general similarity to those of certain *Siphonophoræ*, while the chitinous structure of the hydrothecæ and gonangia can be only referred to the Sertularians. It thus becomes evident that the genus *Diplograptus*, like so many palæozoic fossils, has the combined properties of different groups, thus giving valuable hints in regard to the common ancestors of these groups.



EXPLANATION OF FIGURES.

Fig. 1.—Diplograptus pristis Hall. Natural size.
Fig. 2.—Diplograptus pristiniformis Hall. Natural size.
Fig. 3.—Diplograptus pristiniformis Hall. Enlarged six times. Specimen from the limestone. *a.* Pneumatocyst. *b.* Gonangium.
Fig. 4.—Diplograptus pristis Hall. Enlarged four times.
  a. Gonangium filled with siculæ.
  b. Sicula developing into a stipe.
  c. Young stipe with distinct sicula at the distal end.
Fig. 5.—Detached sicula of D pristis Hall with pneumatocyst.

Art. XXXIX.—*A Newly Discovered Dike at De Witt, near Syracuse, New York. Geologic notes by* N. H. Darton, U. S. Geological Survey. *Petrographic description by* J. F. Kemp, Columbia College.

In November, 1894, I received intelligence of an occurrence of intrusive rock penetrating the Salina formation near Syracuse, and soon after had an opportunity to visit the locality. The materials obtained were submitted to Prof. J. F. Kemp for microscopic study, and an analysis of the rock was made in the laboratory of the U. S. Geological Survey.

The locality is at the new reservoir on the top of an isolated hill, a half mile south of Dewitt Center (De Sono station on the West Shore railroad), 3 miles east of Syracuse. Mr. Phillip F. Schneider, a professor in the High School at Syracuse, was the discoverer of the dike, and to him also we are indebted for information regarding its relations. The dike was exposed by the excavations for the reservoir and does not appear to reach the natural surface. It was buried under a mantle of glacial drift, and in part, at least, was covered by shales and limestones of the Salina formation. Unfortunately the reservoir was practically completed and filled with water before Mr. Schneider learned of the dike, so that he was unable to observe the relations. According to the statements of the contractor, the rock occurred in masses imbedded in a greenish-yellow earth which underlaid the entire area of the excavation, which was about 200 by 250 feet. The masses varied greatly in size. Some were 20 by 50 feet and afforded an adequate supply of building stone for the walls of the reservoir. A considerable amount of the excavated materials now remains on the banks and it was from that source that I secured specimens. The greenish-yellow earth in which the rock masses occurred is undoubtedly a product of the decomposition of the intrusive rock. The original surfaces of all the rocks are more or less deeply decomposed to a serpentinous matter, and some of the smaller rocks are filled with calcite veins and other secondary products. Whether the mass was really a dike or mainly an intruded sheet was not determined. No traces of the rock have been found on the surface or in wells in the vicinity.

The dike at Dewitt is in the upper portion of the Salina formation which consists of shales and limestones. A short distance south, rise the slopes of the Helderberg escarpment, and to the north are wide plains of the lower Salina beds. The dip is a gentle monocline to the southward. The rocks adjoining the intrusive were thrown out in considerable amount in the excavation of the reservoir. They present signs of slight metamorphism, consisting of increase in hardness and darkening in color. Mr. Schneider has called my attention to an exposure 600 yards north of the reservoir, in which there is considerable flexing in the shales, but this was the only signs of disturbance noted and may not be due to the intrusion.

The intrusive rock contains many inclusions of various rocks which will be referred to by Prof. Kemp. They were of course brought up from below by the dike.

The relations of the Dewitt dike to the Syracuse occurrence are not known, but as the rocks and relations are so similar it is probable that they are connected underground. It is very desirable that a careful search should be made in the region for other dikes at the surface.

Petrography of the Dewitt Dike.

J. F. Kemp.

The interest of geologists was greatly excited when Dr. G. H. Williams announced, in 1887, the undoubted igneous nature of the serpentine, which, in 1839 had been recorded by Vanuxem as occurring in the Salina salt group at Syracuse, N. Y. The region of undisturbed sedimentary strata of central New York was generally regarded, with much reason, as one of the least likely of all localities to contain intrusive rocks; and although scattered mention of dikes had been made for at least two other localities, the microscopic determinations of Dr. Williams were the first really conclusive evidence of their igneous character. In but two particulars did this paper leave anything to be further desired; first, the specimens, as stated in the paper, were of weathered material, such that the larger minerals, with the exception of a few small cores of enstatite had to be determined from the alteration products and the ground-mass was represented by a mass of carbonates and serpentine; and, second, Dr. Williams was unable to obtain, either from his own collections or those at Hamilton College, the "granitic" and "syenitic" (or micaceous and hornblendic) "accretions," mentioned by Vanuxem.

Somewhat later in further excavations, additional material was obtained, on which a brief note was presented to the Geological Society of America, at New York, December, 1889.* The geological relations proving the intrusive character, are set forth, and the general statement is made that the minerals of the rock are not all altered to serpentine, but beyond this, no further determinations are recorded than were given in the

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* Bulletin, vol. i, p. 533.

earlier paper. Dr. Williams also found abundant inclusions—doubtless Vanuxem's "accretions"—even of the acidic crystallines on which the sedimentary series must rest. It is evident, however, from comparative remarks made upon the peridotite described by R. N. Brackett,* from Pike Co., Ark., that abundant and unaltered little augites in the ground-mass were also noted.

It would appear that in some respects the material collected by Mr. Darton is in an even fresher and less altered state than any yet examined, and as it occurs some three miles from the former locality, a few additional notes are not out of place. The writer is fortunate in having had for comparison some of the original specimens collected by Prof. Oren Root, the discoverer of the outcrop, and also a representative set of pieces from Dr. Williams's collection, given him by the latter in 1889. Comparisons have also been made with slides of some other allied rocks, as indicated below.

The Dewitt rock belongs to the porphyritic type of Williams. While in some specimens much altered, yet in others it contains olivine, as fresh and unchanged as if it had come from the most recent of basalts. Almost no traces of serpentinization are present in some of the slides. In addition to the olivine, whose crystals vary from 1^{mm} to 8^{mm} in diameter, the only other large phenocrysts are biotite and one or two crystals of augite. In the ground-mass are innumerable small augites, which seem to have made it up in largest amount, shreds of biotite, magnetite, apatite and perofskite. It is probable that there was also an original glass, now mostly devitrified by alteration.

The olivine is often idiomorphic, and the elongated, lozenge-shaped cross-sections are common. It is practically colorless. The figure given on page 142 of Dr. Williams's paper, would answer excellently for the new occurrence. The phenocrysts of biotite are smaller, 1^{mm} being the general diameter. They are hexagonal, and the outer portions are thickly set with included grains of magnetite. The color is the usual rich brown of the biotite in basic rocks, and there is a slight separation of the optic axes. The augite is a rather rare phenocryst, but two or three crystals having been seen in a half dozen slides. It is, however, well marked, has an extinction ranging from 30°–40°, and is perfectly fresh.

The little rods of augite in the ground-mass are very small, $\cdot 05^{mm}$ or less in diameter, and perhaps twice as long. They are faint green, have a high extinction, and are normal in their properties. The ground-mass is practically like that of the basic

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* This Journal, July, 1889, p. 57, second paragraph and top of p. 59.

dikes called monchiquite, and the resemblance is very close in this respect to those met by the writer on Lake Champlain.*

The shreds of biotite are irregular and small. It is not certain that they are not, in large part, secondary. One vein of yellowish-brown biotite was found running across a thoroughly serpentinized olivine crystal, and hence must have been secondary. The occurrence casts a doubt over the shreds in the more or less decomposed ground-mass, and gives ground for thinking them likewise secondary. The magnetite and apatite deserve no special comment, although the analysis indicates that as regards the former, some chromite is also present. Dr. Williams came to the conclusion that the greater part of the black opaque grains met at Syracuse were chromite; but as so little Cr_2O_3 is shown by the analysis of the Dewitt material, and as the grains are quite abundant, and the rock magnetic, it is probable that most of them are magnetite. They show no alteration to leucoxene. Not a few of the small grains, on being highly magnified in a strong light, are seen to be translucent and brown. They are undoubtedly perofskite, and a close parallel to the occurrence at Syracuse. The translucency was not detected in the hasty examination made by the writer prior to the meeting of the Geological Society of America in Baltimore last December, and it was then stated verbally, that no perofskite had been detected. The minuteness of the grains and their high refraction led to this erroneous inference from study with low powers. The web of apparently devitrified glass in which these small crystals of the ground-mass are caught, is an unsatisfactory subject of study. Some clear patches are perfectly isotropic, while others show irregular spherulitic crosses, and even colors of the first order. Where the network of small augites is thick, the interstitial masses are too minute to be satisfactorily studied. Careful search was made for melilite, because the abundant perofskite and the interesting occurrence of this mineral at Manheim, N. Y., described by C. H. Smyth, Jr.,† gave some ground for suspecting it, but none could be detected.

The Dewitt rock might, with perfect propriety, be called a picrite, as a porphyritic form of peridotite, or a monchiquite as a dike rock without feldspar and containing olivine, there being no real need for both these names. It corresponds to picrite as used by Rosenbusch, except that it has abundant biotite, and therefore is related to the mica-peridotite of J. S. Diller,‡ from the very similar Flanary dike of Crittenden Co., Ky., but biotite, as shown by a comparison of slides, is less

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* Kemp and Marsters, Bulletin 107, U. S. Geological Survey, p. 33.

† This Journal, Aug., 1893, p. 104.

‡ Ibid, Oct., 1892, p. 289.

abundant at Dewitt, while augite, even in the ground-mass, is absent in the Kentucky occurrence. It is practically the same as the peridotite of Pike Co., Ark., referred to above, and both Williams in the original papers on the Syracuse occurrence, and Brackett in the one earlier cited, on the Arkansas exposure, were abundantly justified in placing these rocks with Lewis' kimberlite* from South Africa. The writer has compared the Dewitt rock with slides of all the American related dikes, and with others of the dike in the De Beers mine of South Africa. It is practically the same rock as the last, except that in the specimens at hand, the latter appears to have had a glassy ground-mass now devitrified, which lacks augite. The writer is in thorough sympathy with the growing opinion, that rocks should be classified on texture, and, broadly speaking, into granitoid, porphyritic and glassy groups: that dikes should be referred to their nearest granitoid or porphyritic relatives, and called by their names. Taking plutonic rocks as practically the granitoid, and volcanic as the porphyritic, the Dewitt rock is a basaltic dike of the same composition and texture as limburgite, and should be called limburgite, even if it is not a surface flow. It would probably simplify matters in a commendable degree if all the other names of feldspar-free, olivine-bearing dikes with a glassy ground-mass, be allowed to drop out of use, and if in this and other similar cases, large resemblances, rather than small differences, were brought out in our nomenclature.

At Mr. Darton's request, the following analysis was made of the Dewitt rock, in the laboratory of the U. S. Geological Survey, by Dr. H. Stokes. With it are placed analyses of the Syracuse serpentine, made by T. S. Hunt† in 1858, and of the mica-peridotite from Crittenden Co., Ky., made by W. F. Hillebrand for J. S. Diller.‡ Although an analysis of the badly-weathered Ithaca dike was made for the writer, and published, it is here omitted, because it is clearly untrustworthy, the high Al_2O_3 and low MgO, being unlikely.

Mr. Darton collected a coarsely crystalline rock, which occurred with the fragments of peridotite. In thin sections it is seen to contain brown, basaltic, quite idiomorphic hornblende, plagioclase, one large untwinned feldspar with parallel extinction, apparently orthoclase, and many quite large bits of magnetite. This is probably one of the syenitic accretions of Vanuxem, and an inclusion of wall rock in the peridotite, brought up from great depth. It may be, it should also be stated, a drift-boulder, as it was found with the loose, blasted peridotite,

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* Geol. Mag., 1887, 22.
† This Journal, Sept., 1858, 237.
‡ Ibid., Oct., 1892, 288.

but the indications were that it came from the excavation. In studying a series of slides, however, from the material received five years ago from Dr. Williams, one slide contained a crystal of brown hornblende like the above, and another had in the midst of the porphyritic peridotite, a chance inclusion about 10^{mm} across which consisted of microperthitic orthoclase, in largest part, with some plagioclase, brown hornblende and titaniferous magnetite. It is undoubtedly a fragment of the underlying Archæan crystallines, picked up by the intrusive peridotite, for its edges are sharp and all the associations are of this character. Mr. Darton also gathered specimens with undoubted inclusions of sedimentary rock. One of these is an argillaceous sandstone formed of quartz grains and interstitial clay; and the others are earthy limestones showing, under the microscope, sections of small brachiopod shells. No appreciable evidence of contact metamorphism could be detected.

	Dewitt.	Syracuse.	Kentucky.
SiO_2	36·80	40·67	33·84
TiO_2	1·26	----	3·78
Al_2O_3	4·16	5·13	5·88
Cr_2O_3	0·20	----	0·18
Fe_2O_3	----	----	7·04
FeO	8·33	8·12	5·16
MnO	0·13	----	0·16
NiO	0·09	----	0·10
CoO	----	----	trace
CaO	8·63	----	9·46
BaO	0·12	----	0·06
SrO	trace	----	----
MgO	25·98	32·61	22·96
K_2O	2·48	----	2·04
Na_2O	0·17	----	0·33
H_2O	----	12·77	7·50
P_2O_5	0·47	----	0·89
CO_2	2·95	----	0·43
Cl	----	----	0·05
F	----	----	?
SO_3	0·06	----	----
S	0·95	----	----
H_2O below 110°	0·51	----	----
H_2O above 110°	6·93	----	----
	100·22		
Less O=S	·47		
	99·75	99·30	99·86

It is interesting to note the thickness of sedimentary strata through which this dike must have come from its source in or below the old crystallines. F. E. Englehardt* gives as the result of the State well at Syracuse, 1969 feet from the surface Salina to and 154 feet into gray Medina sandstone. Forty miles due west, at Clyde,† a well, begun in the Salina, went 1792 feet and stopped, being then 92 feet into the Hudson River shales. A few miles north of Clyde, a well at Walcott† penetrated from the Niagara on the surface 2700 feet, and stopped 750 feet into, but not through the Trenton. While at Rochester,‡ beginning in the Niagara, a well was put down 3078 feet, ending in white ferruginous quartz, supposed to be Archæan. Ashburner's generalized section along the meridian of Clyde, gives 4800 feet from the Helderberg to the Archæan, and the dike must have come up through some such section as this, until it stopped in the Salina strata.

NOTE:—The following igneous intrusions have now been determined microscopically in central New York. At Syracuse, peridotite, G. H. Williams, this Journal, Aug., 1887, p. 37, Bull. Geol. Soc. Amer., I, 533; at Ithaca, 75 miles south of Syracuse, presumably peridotite, like preceding, J. F. Kemp, Idem., Nov., 1891, p. 410. The analysis given in this paper, as regards Al_2O_3 and MgO is undoubtedly untrustworthy. At Manheim, 75 miles east of Syracuse, alnoite, C. H. Smyth, Jr., Idem. Apr., 1892, 322, Aug., 1893, 104. At Dewitt, 3 miles east of Syracuse, as above. In addition, boulders of a most interesting rock have been found at Aurora, N. Y., about 25 miles north of Ithaca, which consisted of great crystals of pyroxene and hornblende in a glassy ground-mass, and with no certain olivine. (J. F. Kemp, Trans. N. Y. Acad. Sci., XI, 126, 1892.) Boulders of the same rock with attached, fossiliferous Trenton limestone, have been found by J. M. Clarke, on Canandaigua lake, 30 miles west of Aurora, and have been described by B. K. Emerson. (12th Ann. Rep., N. Y. State Geologist, 1892, published 1893.) We may expect other dikes of these curious basic rocks to be discovered in the New York Palæozoic series, as time goes by.

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* N. Y. Assembly Doc., 1885, No. 32, p. 15. Quoted by Ashburner in Trans. Amer. Inst. Min. Eng., XVI, 944.

† C. S. Prosser, Amer. Geol., Oct., 1890, 203–204. The same figures are given by Ashburner, loc. cit.

‡ H. L. Fairchild, Proc., Rochester Acad. Sci. I, 184, 1891.

ART. XL.—*Note on the amount of Elevation which has taken place along the Rocky Mountain Range in British America since the close of the Cretaceous period;* by DR. G. M. DAWSON. (Reply of March 18 to a letter from J. D. Dana.)

BETWEEN latitudes 49° and 52° (or thereabouts) numerous infolds of Cretaceous rocks occur in the Rocky Mountains proper, or Eastern range of the Cordillera. (Laramide Range.) These consist chiefly of earlier Cretaceous (Kootanie) but in places strata as high up as Lower Laramie (St. Mary River beds) still remain. The actual elevation of these rocks is now in many places from 6000 to 8000 feet above sea-level. In the adjacent belt of foothills, to the east, the same Cretaceous rocks are found, but here still including strata as high as Upper Laramie. The actual elevation is here often between 5000 and 6000 feet above sea-level.

In the mountains, the Cretaceous rocks have been involved in all the flexure, faulting and overthrust suffered by the Palæozoic; and both in the mountains and foothills these rocks are found at all angles up to vertical and even overturned.

It is thus difficult to know to what elevations these rocks may have been thrust up in some places, but a minimum estimate may be arrived at by tracing the continuations of the beds over the less disturbed anticlinals or by adding their volume to the elevation of flat-lying ranges of the older rocks. About latitude 50° it may thus be shown that the *base* of the Cretaceous must in several places have considerably exceeded 10,000 in altitude, while in Mr. McConnell's section along Bow Pass (51° 15′) to the north of Devil's Lake, the same horizon must have been about 15,500 feet above sea-level, the beds at this place being nearly flat.

To ascertain the uplift of the beds which were at sea-level at the *close* of the Cretaceous, the volume of the Cretaceous strata must of course be added to such figures as the above. This was, in the eastern part of the mountains, at least 17,000 feet and may well have been 20,000 feet (See G. S. C. Report, 1885, p. 166 B), giving as a minimum estimate of greatest uplift for the region say 32,000 to 35,000 feet.

Farther north, Cretaceous infolds in the Rocky Mountains become less common, so far as known, but the foothills retain the same general character to Peace River and beyond. Probably the uplift was somewhat less in these latitudes, as the Rocky Mountain range proper is less important and narrower.

Still farther north, opposite the Mackenzie delta, Mr. McConnell describes the range as composed in its highest part of Cretaceous rocks, but there only about 4000 feet above the sea. Several thousand feet have doubtless been removed by denudation, but we have no exact knowledge of the thickness of the Cretaceous in that region.

There are also some evidences of slight or moderate uplift in the Rocky Mountains proper of Alberta previous to or during the Laramie, such as the supply of material from the red rocks of the Triassic to the middle zone of the Laramie, opposite that part of the range in which these rocks occur, (see G. S. C. Report, 1882–84, p. 113 C.) as well as in the materials of the older Cretaceous conglomerates, although these last may in part have been derived from elevations west of the Laramide Range.

It is probably impossible to ascertain exactly how long the main uplifting process continued or to what extent its effect was counteracted by concurrent denudation, but some facts may be cited in this connection.—No deposits referable to the Eocene, as distinct from the Laramie, have been found in the foothills or over the Great Plains of Western Canada. It is probable that none such exist, and it may therefore be assumed that free eastward drainage, without arrest, obtained during this period. In the Early Miocene (White River) we find evidence that strong rivers were carrying coarse gravels from the mountains out over the plains to a depression some 200 miles east of the present base of the mountains, forming there a deposit of which outliers, like that of the Cypress Hills, still remain. These deposits, in their relation to the Laramide Range, resemble the Upper Siwalik Conglomerates of India, and it is probable that at this time a range comparable to the Himalayas in height, bordered the Great Plains of Alberta on the west.

During the Eocene and Miocene, orographic uplift may have been continuous, but sometime long before the close of the Pliocene it came to an end. Evidence of this is found in the following circumstances.—The Oldman, Highwood, Bow and other rivers flowing from the mountains, occupy notably wider valleys where they cross the eastern foothill belt. In these valleys Cretaceous and Laramie rocks, arranged often in compressed and complicated folds, are cut sharply off on planes nearly corresponding with the slopes of the present streams and upon the basset edges of these rocks bowlder-clay and other glacial deposits are spread. Since the Glacial period, the streams have cut out narrow new trenches in the floors of these valleys. The main valleys are therefore not only pre-glacial, but also involve a long antecedent period of erosion, during which the conditions changed little if at all. Had orogenic movements continued in the Pliocene, the flexed Cretaceous beds of the foothills (intimately connected with the general folding of the mountains) must have participated in them, and no such uniform cutting out of wide valleys would have been possible. It was no doubt at this time also that much of the denudation of the Great Plains to the eastward occurred. In the vicinity of the western end of the Cypress Hills the general surface of the plain is now about 2200 feet lower than the Miocene capping of these hills.

ART. XLI.—*On Three New Analyses of Sodalite, from three new localities;* by L. McI. LUQUER and G. J. VOLCKENING.

Sodalite from Hastings Co., Prov. Ontario, Canada.

THE massive sodalite from this locality was collected by Mr. T. D. Ledyard of Toronto. It was found in the northern part of Hastings County, Prov. Ontario, about 180 miles N.E. of Toronto. According to Mr. Ledyard's statement the sodalite does not appear to be very plentiful, takes a beautiful polish and occurs in the Laurentian formation. He also states that he has secured the mining rights of all the land on which the mineral is known to occur. The specimen examined has a very distinct cleavage, vitreous luster, cobalt-blue color, hardness of 5 to 6, and a colorless streak. It loses color, fuses with intumescence to a colorless glass, giving a strong soda flame, and is soluble in hydrochloric acid with separation of gelatinous silica. A thin section in parallel polarized light appeared of a pale blue color, and showed by a few cloudy patches traces of decomposition. Between crossed nicols it was perfectly isotropic.

The other known occurrences of sodalite in this country are: Litchfield, Me. (blue); Salem, Mass. (violet-blue); Beemerville, N. J. (colorless grains in elæolite syenite)*; Crazy Mountains, Mont.; Brome, Montreal and Belœil, Canada†; and Ice River, a branch of the Beaver Foot River, near Kicking Horse Pass in the Rocky Mountains, B. C.

Prof. Harrington of McGill University, Montreal, is at present preparing a report on Ontario sodalite and other Canadian minerals.

Sodalite from the Ural Mountains, Asia.

The specimen examined from this locality was obtained from a mineral dealer in Ekatherinburg. It is massive, almost

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* J. F. Kemp, Trans N. Y. Acad. Sci., vol. xi. p. 60.

† B. J. Harrington, Trans. Roy. Soc. Canada, Sect. III, p. 81, 1886.

free from impurities; and its color, physical characters and blowpipe reactions are the same as in the Canadian sodalite.

A thin section showed the presence of very perfect cleavage, and the commencement of decomposition, especially along the cleavage cracks. Microlitic inclusions of hornblende and a few grains of what appeared to be elæolite were also noticed. Between crossed nicols it was perfectly isotropic. Two sides of the specimen were polished.

Sodalite from the Congo State, Africa.

The specimen examined was collected by Brazza, the explorer, and, so far as is known, is the only noted occurrence of this mineral in Africa. The cleavage is not very apparent macroscopically, but its color, physical characters and blowpipe reactions are the same as in the Canadian sodalite. A decomposed iron mineral (chiefly limonite) and a decomposed feldspar or clay are associated with the sodalite. A thin section showed rather a more advanced state of decomposition than in the Ural specimen, and the presence of only imperfect cleavage. Little patches of oxide of iron were noticed, and between crossed nicols the section was completely isotropic. One side of the specimen was beautifully polished.

The specimens from the Ural Mountains and the Congo were loaned for examination by Tiffany & Co., through the courtesy of Mr. G. F. Kunz; but unfortunately no details could be obtained as to exact occurrence, associated minerals, etc.

CHEMICAL ANALYSES.

Ontario, Sp. Gr. 2·303.		Urals, Sp. Gr. 2·328.		Congo, Sp. Gr. 2·363.	
Cl	6·79	Cl	6·65	Cl	6·46
SiO_2	37·34	SiO_2	37·28	SiO_2	37·85
Na_2O	25·01	Na_2O	24·74	Na_2O	25·43
Al_2O_3	31·25	Al_2O_3	31·60	Al_2O_3	30·87
CaO	·38	CaO	·46	CaO	·51
K_2O	·74	K_2O	·93	K_2O	·22
	101·51		101·66		101·34
Deduct oxygen equivalent for Cl,	1·53		1·50		1·46

E. Bamberger and K. Feussner note the occurrence of sodalite in Tiahuanaco, Bolivia. Zeit. f. Kryst., 1881, v, 580.

Mineralogical Laboratory, Columbia College, March 27th, 1894.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On Solution and Pseudo-solution.*—Some years ago LINDER and PICTON concluded from their examination of various grades of arsenous sulphide solution, that there is no defined boundary line between suspension on the one hand and perfect solution on the other; the difference being one of degree of aggregation only. They have now added another grade of this solution, having found that on pouring a two per cent arsenous oxide solution into hydrogen sulphide water, the mixture is not only diffusible but can be filtered through a porous pot. Of the As_2S_3 solutions already prepared therefore, grade (α) is made up of aggregates visible under the microscope, (β) is invisible but not diffusible, (γ) is diffusible but not filterable and (δ) is both diffusible and filterable, although it scatters and polarizes a beam of light. Experiments with the higher grade solutions chiefly (γ) show that as regards their power of coagulating these solutions, metallic salts can be divided into well defined groups depending upon the valency of the metal; trivalent metals having the highest coagulative power, bivalent metals only one tenth of this power and univalent metals, including hydrogen and ammonium, less than one five-hundredth. Moreover these differences are shown by the same metal when its valence varies. And the authors have observed that silver and thallium (in its thallous salts) fall in the same group as copper and the bivalent metals, while mercury and lead belong in the trivalent group with aluminum and iron. From a table giving the relative quantities needed for coagulation it appears that one molecule of aluminum chloride $AlCl_3$ possesses the same coagulative power as 16·4 molecules of cadmium chloride or 750 molecules of sulphuric acid. As to the nature of coagulation it was observed that when effected by barium chloride the arsenous sulphide contained barium not removable by water, though exchangeable for another metal when digested with a cold solution of it, such as calcium nitrate. Since coagulation is due to the positive constituent of a salt, the authors were led to inquire whether the coagulative power of salts of the same metal is proportional to the number of free positive ions in the solution. And a comparison of the molecular conductivities of the chlorides, bromides, iodides, nitrates and sulphates of potassium, hydrogen, sodium and ammonium, which are due to the free ions present, with the coagulative power, appears to indicate that this power is entirely controlled by the number of free positive ions present.—*J. Chem. Soc.*, lxvii, 63, February 1895. G. F. B.

2. *On the Fluidity of Metals below their Melting Points.*—It has been pointed out by SPRING that many metals exhibit properties characteristic of the liquid state, even when at temperatures

much below their melting points. In his experiments, the metals were in the form of cylinders with perfectly plane ends, placed end to end in an iron holder, and forced together by means of a screw, while heated in an air bath or in a bath of an indifferent gas. The metals used were aluminum, bismuth, cadmium, copper, tin, gold, lead, zinc, antimony and platinum. In the earlier experiments both cylinders were of the same metal, and the temperature was kept at from 200° to 400° for from four to eight hours. It was then found that, with the exception of the platinum and antimony, the cylinders had alloyed so perfectly that when one end was fixed in a lathe the entire cylinder could be turned, and when broken in a vise the fracture was not through the line of separation. When different metals were employed, as copper or lead with certain others, an alloy of a considerable thickness was produced, 18^{mm} in the case of zinc and copper and 15^{mm} in that of cadmium and copper. When lead and tin were used a cavity was made at one end of the cylinder and filled with mica, in order that contact should take place only at the edge. The alloy formed had a thickness of 15^{mm}, nine millimeters being in the tin and six in the lead. With cylinders of copper and zinc having a central cavity at the ends in contact, the surface of the copper next to the cavity was colored yellow, resembling the alloy formed when copper is exposed to zinc vapor. The author explains these results upon the assumption that the molecules of solids, like those of fluids, have not all the same velocity.—*Zeit. physikal. Chem.*, xv, 65, September 1894. G. F. B.

3. *On the Light emitted during Crystallization.*—The emission of light during the crystallization of certain salts has been examined by Bandrowski, who considers it to be in all probability electrical and to be due to the union of electrified ions. If this is the case it should be most decided in the sudden crystallization of strongly dissociated compounds. He suggests the following experiments in proof of this, which are suitable also for the lecture table. A glass cylinder is half filled with a warm saturated solution of sodium chloride and into it is poured an equal volume of hydrochloric acid of specific gravity 1·12, the whole being mixed by means of a glass rod. A bluish green light fills the entire cylinder. The experiment may be modified by pouring in the two liquids separately and carefully and then strongly shaking the cylinder. A flash of light occurs. In place of the acid, alcohol may be used and the results may be obtained with potassium bromide or chloride in place of the sodium salts. When potassium chloride was used with alcohol the effect was very marked, the light being stronger and greener than that given by sodium chloride.—*Zeit. physikal. Chem.*, xv, 323, November, 1894.
G. F. B.

4. *On the Two-fold Spectra of Oxygen.*—In a paper to the Royal Society, Baly has sought to account for the two-fold spectra of oxygen. These spectra are of a different nature ; they behave differently and there are reasons why in all probability

they are spectra of different gases. These spectra may be produced by different vibrations of the oxygen molecule, or they may be the spectra of two different modifications of oxygen, or the spectra of two distinct gases resulting from a dissociation of oxygen. In order to test the last hypothesis, oxygen was sparked in an apparatus with hollow platinum electrodes, connected with a Sprengel pump. The distance between the electrodes was 35^{mm} and the highest pressure consistent with the production of the two spectra was initially employed, being 380^{mm}. The fractions of the gas obtained from the anode and kathode were weighed and compared with the oxygen before sparking. With long sparks a lighter fraction was obtained at the kathode and with short sparks a heavier fraction. With long sparks the density of the kathode oxygen was 15·78, 15·79, 15·80, 15·79; with short sparks 16·00, 16·01, 16·02, 16·04, 16·06, 16·05. The density of the unsparked oxygen was 15·88, 15·87, 15·89, 15·88, 15·88. The fractions from the anode showed a difference in the same direction, though not as definite. Further results are promised.—*Nature*, li, 550, April, 1895. G. F. B.

5. *Kräfte der Chemischen Dynamik;* 3 Vorträge von Dr. LUDWIG STETTENHEIMER. 8vo, pp. 88. Frankfurt-a-M. 1895. (H. Bechhold.)—These lectures appear to be aimed against the molecular constitution of matter, every substance being regarded as homogeneous and its atoms interacting mechanically with all other atoms. The reasoning seems to be loose and the conclusions altogether hypothetical. G. F. B.

6. *Physical Constants of Hydrogen.*—Professor RAMSAY has received a letter from Professor OLSZEWSKI in which he says: "I have at last succeeded in determining the critical temperature and the boiling point of hydrogen. I have found for the former −233° and for the latter −243°. I have used the dynamical method which I described in the Phil. Mag. A thermal couple proved of no use and I was obliged to avail myself of a platinum wire thermometer, measuring the temperatures by the alteration in resistance of the wire. I have obtained satisfactory results and intend to publish an account of them in English.—*Nature*, March 21, 1895. J. T.

7. *Color Photography.*—At a meeting of the Physical Society in Berlin, Feb. 8, Dr. NEUHAUS exhibited a series of color photograph's taken by Lippmann's method with prolonged exposure. Spectra show, if the exposure is sufficiently long, a greenish band in the infra red as well as in the ultra violet, in addition to ordinary colors. The colored band was very markedly displaced by both over and under exposure. The photographs of objects with mixed colors, such as fruits, flowers, butterflies, etc., were good: but their production was extremely difficult and only one plate in twenty-five was, on an average, successful. It was found easier to photograph naturally mixed than artificially mixed colors. Some substance such as eosin or cyanin must be added to the films to make them more sensitive to red rays and less sensitive

to blue. The theory of the method is still unsettled.—*Nature*, March 21, 1895. J. T.

8. *Silvering Glass.*—To a physicist any method of silvering glass which will replace the method with Rochelle salts or the Martin process is of especial interest. M. M. AUGUSTE and LOUIS LUMIÈRE describe the following method : To 100 cubic centimeters of a 10 per cent solution of silver nitrate ammonia is added drop by drop until the precipitate formed is redissolved. Too much ammonia must not be added at first, for this might prevent the formation of the precipitate. The volume of the solution is increased to a liter by the addition of distilled water. This is solution A. Solution B is made by diluting commercial Formaldehyde of 40 per cent with distilled water so as to form a 1 per cent solution. Solution B can be kept for some time. Two volumes of A are rapidly mixed with one volume of B and the mixture is rapidly poured over the glass to be cooled. In five or six minutes, at a temperature of 15° to 19°, all the silver in the solution is deposited in a brilliant layer which can then be washed with water.—*Journal de Physique*, January, 1895. J. T.

9. *A Form of Sensitive Galvanometer.*—In a note to the French Academy, presented by Prof. Mascart, M. PIERRE WEISS describes a new method of making the suspended magnetic system of a galvanometer. The system is formed of long vertical needles, placed parallel to the axis of rotation in such a manner that they constitute with their opposed poles almost a closed magnetic circuit. Each one of the two systems of poles is placed at the center of suitably constructed bobbins. The almost complete absence of demagnetizing force, allows the maximum magnetization of the steel: and one can by changing the distance of the needle change at will the ratio of the magnetic moment to the moment of inertia. If the sensibility of a galvanometer is defined as the number of divisions which it indicates for one micro-ampere divided by the square root of the resistance, the scale being at a distance from the mirror equal to 2000 divisions and the duration of the oscillation being five seconds, M. Weiss obtains $S = 1500$. This sensibility can be increased by greater care in the mechanical construction of the instrument. The author states that Mr. Wadsworth, Phil. Mag., No. 38, 1894, describes a galvanometer of more difficult construction which gave $S = 1300$.—*Comptes Rendus*, No. 13, April, 1895. J. T.

10. *On the Diselectrification of Air.*—Lord KELVIN has continued his experiments on this subject with the assistance of Messrs. MAGNUS MACLEAN and ALEXANDER GALT. It was found that positive or negative electricity given to air by an electrified needle-point can be conveyed through 3 or 4 meters of small metal tube (1^{cm} diameter) and shown on a quadrant electrometer by a receiving filter. A filter of 120 wire gauges only reduced the electrical indication to a little less than half of what it was

with the 12 gauges which were first tried. In general air electrified negatively by bubbling through water and caused to pass through a metallic wire gauge strainer—gives up some, but not a large proportion of its electricity to the metal.—*Proceedings Royal Society*, March 21, 1895; *Nature*, April 11, 1895. J. T.

11. *Beitraege zur Kenntniss des Wesens der Saecular Variation des Erdmagnetismus;* by L. A. BAUER. Inaugural Dissertation University of Berlin. Large 8vo, 56 pp. and 2 plates. 1895. Abstract prepared by the author.—If we suppose a magnetic needle so suspended that it is free to move in every possible direction, it will, under the influence of terrestrial magnetism, assume at any particular time a definite direction. This direction is a tangent to the geomagnetic lines of force. As is well known these lines are constantly shifting. They are subject to diurnal, seasonal, annual, 11⅓-year, etc., variations, also to non-periodic fluctuations. The most striking one of all the changes, however, is that due to the so-called secular variation whereby the direction of the needle suffers in the lapse of time most remarkable changes. This variation has been known now for over two and a half centuries; it has been the subject for speculation by some of the most brilliant minds. The great riddle, however, is still unsolved.

This phenomenon owing chiefly to the asymmetrical distribution of geomagnetism is a most complex one. But the method of treatment heretofore employed has done its share, also, to deepen the mystery. Namely, it has been customary to treat separately the secular variation of the different magnetic elements, declination, inclination, or intensity, as the case may be, as though these were different effects of operative forces, instead of component ones. The consequence has been that not a single law governing the secular variation as applying to all parts of the earth could be established.

At the meeting of the A. A. A. S. in Aug., 1892, the writer presented a preliminary paper "On the Secular Motion of a Free Magnetic Needle." This paper had for its object to investigate the total change suffered by the needle by drawing the actual curve described in space by the north end of a free magnetic needle in the course of centuries. That is, both the declination and the inclination changes were considered. The intensity changes are not taken into account as the purpose was to investigate solely the total change in direction of terrestrial magnetic lines of force. This paper announced some novel conclusions, chief of which being number one stated below. The present paper is a continuation and amplification of the A. A. A. S. communication. The writer enjoyed the use of the Washington and the Berlin libraries.

Chapter I deals with the secular motion of a free magnetic needle. The observation data for twenty-four stations distributed over the earth have been carefully collected and discussed. The curves described by the north end of the free magnetic needle have been constructed and plotted on Plate I. They correspond to a length of needle of 40^{cm} (15·8 inches). The main conclusions drawn are:

1. *In consequence of the secular variation of geomagnetism, the north end of a freely suspended magnetic needle viewed from the center of suspension of the needle moves on the whole earth in the direction of the hands of a watch.*

II. *The secular variation period (if there be such) is different for various portions of the earth or the secular curve is not a single closed curve, but consists of loops.*

No. I has been tested at more than 100 stations scattered over the face of the earth with the result that the writer believes it can be considered as a safely established result. It virtually embraces two laws, first, the clockwise motion, secondly, the uniformity of this motion in both magnetic hemispheres. This law is playing an important role in the differentiation of the operating causes.

Chapter II is devoted to a comparison of the phenomena of the secular variation with those due to the actual distribution of terrestrial magnetism. It was noted in this chapter that the incomplete secular variation curve at any particular station could be apparently completed by a consideration of the parts of curves described at the stations passed in making an easterly circuit of the earth. This led to the following conclusions:

III. *The north end of a free magnetic needle viewed from the center of suspension of the needle moves clockwise in making an instantaneous circuit of the earth along a parallel of latitude*; or, as I have put it later:

The north end of a free magnetic needle whose center of suspension is fixed in space close to the earth's surface will describe a curve as the earth rotates under it which as viewed from the center of suspension of the needle moves anti-clockwise.*

IV. *The secular variation and the prevailing distribution of geomagnetism appear to be closely related, i. e. seem to be subject to similar laws.*

The five subsequent chapters contain preliminary announcements of additional investigations of the secular variation. The paper will be found fully abstracted, as also the curves given, in the Physical Review, May, '95, and subsequent number.

L. A. B.

12. *A Text Book of the Principles of Physics;* by Alfred Daniell. Third edition (sixth thousand), 782 pp., 8vo, 1894. New York and London (Macmillan & Co.)—Daniell's Text Book of Physics has become so widely known as a work of high scientific grade, carefully developed throughout on a uniform and consistent plan, that it hardly needs now to be commended anew. The present third edition, a few advance copies of which have

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* The curves resulting thus are termed the "instantaneous curves" and have been laid down on Plate II for the epochs 1780, 1829 and 1885 and for the parallels of latitude 40° north, equator and 40° south.

been distributed, has been thoroughly worked over and improved in minor details, as well as largely added to where the development of the science has called for this. The amount of new matter added will be appreciated from the statement that the work has been increased one-fifth in size since it was first issued.

II. GEOLOGY AND MINERALOGY.

1. *Discovery of a dicotyledonous Flora in the Cheyenne sandstone.*—In a letter to the editors of the Journal, Mr. ROBERT T. HILL of the United States Geological Survey, reports "the discovery of a typical dicotyledonous flora in the Cheyenne sandstone at the base of the beds belonging to the Comanche Series in Comanche and Barber counties of Southern Kansas. This sandstone has hitherto been referred to the Trinity Division of Texas by Prof. F. W. Cragin, but the flora as determined by Prof. F. H. Knowlton of the U. S. Geological Survey consists entirely of species hitherto supposed to be peculiar to the Dakota Group, while the flora of the Trinity Division of Texas as has been reported by Prof. Fontaine is all of the non-dicotyledonous Potomac type. The Cheyenne sandstones are separated from the true Dakota sands of Kansas by nearly 200 feet of shale, containing a molluscan fauna composed of fifteen species characteristic of the Washita Division of the Comanche Series in Texas, and about twenty littoral species peculiar to the locality, thus extending the hitherto known downward range of the Dakota flora from the Dakota position to the base of the Washita." The details and results of Mr. Hill's observations will be published in an early number of the Journal.

2. *On the Geological Aspects of Variation.*—An interesting and suggestive paper on the relation of varietal modification of form to the geological range of a fossil species is contributed by M. GOSSELET in his memoir on the variation of *Spirifer verneuili.** M. Gosselet has accumulated large collections of this common species of the Upper Devonian formations of northern Europe, has made exact and minute study of the various elements of their morphological characters, has classified them into groups on the basis of their differences and has given a beautiful series of illustrations of the varieties and of the most closely allied species.

From his studies he draws the following important generalizations, viz: (Translated from the French).

"From the comparison of diverse forms of *Spirifer verneuili*, either among themselves, or with allied species, the conclusion is reached that this Spirifer is a very polymorphic species, of which all the elements vary, except the character of the plications, which remain always simple upon the sides while they multiply by bifurcation or by intercalation on the fold and on the sinus.

There are insensible passages between all the varieties. The

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* Étude sur les variations du *Spirifer verneuili* par J. Gosselet. Mém. Soc. Géol. du Nord, [France] Tome iv, I, pp. 1–61, Plates I–VII. 1894.

groups which have been made of them, are altogether artificial. Not only do they run the one into the other in a gradual manner, but the same individual passes successively from the one into the other during the course of its existence. It is also to be noted that they are not restricted (*cantonnées*) to any particular geological horizon. It is necessary to make exception in the case of the Spirifers with extended wings of Barvaux, which seem to be peculiar to one facies of the Upper Frasnien. These Spirifers are not only characterized by great production of the wings, but also by the imbricated scales which cover their plications, forming small tubercles on the surface. Nevertheless, although this peculiarity is often associated with the enlargement of the wings, it does not necessarily accompany it.

I do not believe therefore that there are varieties in the species called *Spirifer verneuili*, but rather groups of forms. These groups are essentially distinguished from zoological varieties because the same individual is able to pass successively through several of them before attaining its definitive form.

It is in the upper part of the Frasnien, i. e. in the middle of its specific duration, that the *Spirifer verneuili* presents the widest variations. It is there, where in some sense it is in all its prime, that the richness of form is added to abundance of numbers. It peopled the seas, exceeding in numbers all the other fossils, *Atrypa reticulatis* excepted. However none of these forms gave birth to a new species, not even to a constant variety. The more remarkable forms appeared rather as local varieties; they constituted a kind of tribe or physiological family having its circle of habitat, but which did not propagate itself either in time or space. The lower Famennien is already less rich in varieties than the Frasnien. When we rise in the formation, the *Spirifer verneuili* presents more and more intermediate characters. It becomes extinct finally in the upper Famennien without its being possible to admit that it is transformed into another species.

Is it the ancestor of *Spirifer attenuatus* and of Spirifers of the group of *Mosquensis?* It is possible, for the difference between the two types is not extreme; but there is no passage from the one to the other. From the point when *Spirifer attenuatus* arises it assumes immediately its distinctive characters: all the ribs of the wings are bifurcated. But, never, from the lowest beds to the schists of Etrœungt [the uppermost Devonian horizon] has *Spirifer verneuili* shown an indication of bifurcation of the ribs, never, spite of its numerous variations, has it presented a tendency to pass into the *attenuatus;* if there is filiation here, the transformation has been rapid and complete. It is impossible to say what relation there is between *Spirifer verneuili* and *Spirifer Orbelianus* and *aperturatus*. The characters which distinguish these two species are of slight importance and when they are attenuated they become almost *verneuili*. It may be questioned whether they ought to be considered as species or only simple varieties, the passage from one to the other is not less real and their filiation is an established hypothesis. It is also a curious fact that these two species or varieties are brusquely produced at the same time throughout the whole basin, that they are preceded by no attempt of the species to acquire these new forms, that they arose when *Spirifer verneuili* had not yet reached any important variation, and possessed all its primitive uniformity, that they disappear finally very rapidly and brusquely as they arose, and that their descendants, if they are not lost, returned to the general type of the species *verneuili*.

As to the Spirifer called *bifidus*, if it possessed some forms which may be compared with *verneuili*, it differs from it by an essential character which it manifests even in its young age. It should also be borne "in mind that the forms of passage, of doubtful determination, were produced only when the true *Spirifer bifidus* of the Frasnien limestone was departing from the geological arena, at least in the Ardenne;" p. 61.

The methods employed in this investigation and the results obtained will suggest to the thoughtful paleontologist problems of the deepest interest and promising rich reward to those who will thoroughly investigate them. (Missouri H. S. W.

3. *Geological Survey of ~~Illinois~~*, vol. iv, *Paleontology of* Missouri ~~*Illinois*~~, Parts I and II, by Chas. R. Keyes, State Geologist, pp. 1–271, plates xii–xxxii, colored geological map of the state, scale 1 in. to 18 miles, and pp. 1–266, plates xxxiii–lvi. Jefferson City, Mo. 1894.—This is a valuable contribution to the Paleontological literature of the Mississippi valley formations, giving as it does a carefully compiled list of the already described invertebrate forms of the rocks of Missouri, with descriptions of many, full references to synonomy in most cases, and illustration of many already figured forms and of several new species. We regret to note that there are still numerous species named and described by Swallow but without figures, which the author of this work still leaves unfigured. If he, having access to the type collections, is unable to furnish typical figures, it is time to discard from synonomy such unidentifyable references.

In the early part of the first volume on the geological formations the author proposes to substitute another name for the Osage group which for several years has been in use to indicate the general formation which locally has been called Burlington and Keokuk limestone on account of the continuous fauna which appears to characterize them. The argument, that because there has been found a more complete section near Augusta, Iowa, than in the region through which the Osage river flows, the first name may therefore be discarded, is quite contrary to the general principle of priority in the application of scientific names. So long as the meaning is accepted, understood and applicable in the region from which the name was derived, the Osage group has the priority. H. S. W.

4. *Geological Survey of New Jersey: Ann. Rept. of the State Geologist for* 1894, pp. 1–457 with five maps, plates i–x, figures

1–28, Trenton, N. J. 1894.—The following papers are included: Administrative Report by T. C. Smock, State Geologist, pp. 1–32; Part I, Surface Geology, report progress by R. D. Salisbury, pp. 33–328 (including Section VI, a chapter on Lake Passaic,—an extinct glacial lake, by R. D. Salisbury and Henry B. Kümmel, pp. 225–328); Part II, Cretaceous and Tertiary Geology, Report of Progress by Wm. B. Clark, pp. 329–356; Part III, Report on Archaean Geology by J. E. Wolff, pp. 357–370; Part IV, Water Supply and Water Power by C. C. Vermeule, pp. 371–386; Part V, Artesian Wells in Southern New Jersey by Lewis Woolman, pp. 387–422; Part VI, Minerals of New Jersey with notes on mineral localities, pp. 423–444. H. S. W.

5. *Geological Survey of Iowa.* Vol. III. 2d Ann. Report, 1893, with accompanying papers. Des Moines, 1895.—In addition to the ordinary administrative reports this volume contains a bundle of separate papers by members of the survey staff, viz: Work and Scope of the Geological Survey, by C. R. Keyes; Cretaceous Deposits of the Sioux Valley, by H. F. Bain; Certain Devonian and Carboniferous outliers in Eastern Iowa, by Wm. H. Norton; Geological Section along Middle River in Central Iowa, by J. L. Tilton; Glacial Scorings in Iowa, by Chas. R. Keyes; Thickness of the Paleozoic Strata of Northeastern Iowa, by Wm. T. Norton; Composition and Origin of Iowa Chalk, by Samuel Calvin; Buried River Channels in Southeastern Iowa, by C. H. Gordon; Gypsum Deposits of Iowa, Geology of Lee County, and Geology of Des Moines County, by Chas. R. Keyes. The volume is illustrated by 37 plates and 34 smaller figures, many of them fine reproductions of photographic views, illustrating the character of outcrops of particular geological formations, and presenting a vivid representation of the geology of the country described. H. S. W.

6. *Ueber devonische Pflanzen aus dem Donetz-Becken;* J. Schmalhausen. Mém. Comitégéologique, St. Petersburg, vol. viii, No. 3, 1894, pp. 1–36, pl. i, ii, (Russian and German.)—The interesting collection which forms the basis of this brief memoir by the late Dr. SCHMALHAUSEN was obtained from Karakuba in the Donetz basin, at the horizon of the *Productus fallax*, *Rhynchonella aff. Stephani*, *R. multicostata*, and *R. Domgeri*, published by Tschernyschew in 1885. The Devonian age indicated by the above named invertebrates is fully demonstrated by the plants, although, as frequently happens in Devonian rocks, the flora is rich in individuals but relatively poor in species. Six species are described, all of which are new. *Archæopteris archetypus*, compared by the author with *A. Gaspiensis* Dn. and *A. hibernica* (Forbes) Lx., exhibits a great range in the forms of the pinnules and is especially characterized by the arrangement of the sporangia in a row on either side of the reduced lower portion of the lamina of the pinnule, the terminal portion of the pinnule being fringed out. Each spore case has its distinct pedicel. *Archæopteris fissilis*, compared by the author to *Sphenopteris*

petiolata Goepp., is allied to the *A. sphenophylloides* and *A. macilenta* published without illustration by Lesquereux. The fructification of this species described by Schmalhausen with considerable detail, resembles that of *A. minor* Lx. and others, but the sporangia are few. Being unable to find satisfactory family connections between the genus *Archæopteris* and any other living or fossil type of ferns, the author proposes the group Archæopteridæ. It is not unlikely that the spiral arrangement of the leaves in the Russian species noted by Schmalhausen is also indicated in our American species of *Archæopteris* by the alternation of pinnules with pinnæ in the ramification.

The Karakuba flora is remarkable in having more fertile than sterile species. On certain clavate or bivalvate "capsules" strongly resembling the fruit of *Sphenopteris Harveyi* Lx. or *Zeilleria*, the author founds the new genus *Dimeripteris*. *D. gracilis* and *D. fasciculata* are compared by Schmalhausen with *Sphenopteris Hitchcockiana* Dn. and *S. condrusorum* Gilk. The first is very suggestive of the fertile *S. Harveyi* of the Pottsville series in this country, while the other reminds one at first glance of the fruit of *Calymmatotheca bifida* (L. and H.) Kidst. from the Calciferous sandstone series of Scotland. The author compares his *Lepidodendron Karakubense* with *L. Gaspianum* Dn. and *L. nothum* Ung. The flora as a whole is considered as indicating an Upper Devonian age. D. W.

7. *Contributions a l'Étude des Feldspaths des Roches Volcaniques* par F. Fouqué. 8vo, pp. 336. Paris (Imprimerie Chaix) 1894.—This excellent work is another token of the manner in which the demands of petrography have in recent years stimulated research in mineralogy along certain lines. Along with the work of Michel Lévy, Federov, and Becke, the petrographer has now placed at his disposal a variety of means by which the problem of the determination of the feldspars by optical methods can be successfully attacked.

The volume under consideration is divided into four parts. In the first the author points out the methods by which the determination of the feldspars, especially the plagioclase group in thin sections, may be resolved. His method is chiefly by the measurement of the angle of extinction with the edge of *c*(001) on *b*(010) in sections perpendicular to bisectrices; in the second part are given the facts obtained from a chemical, optical and crystallographic study of a large number of species, on which the process is based. In the third portion is presented the petrographic study of a large number of volcanic rocks chiefly from the Haute Auvergne which furnish examples of the author's methods and contain moreover many facts of petrographic interest.

The last portion contains a general discussion of the nature of the soda-lime feldspars with respect to their chemical constitution. The author does not view this group as a case of isomorphism with all possible mixtures of the albite and anorthite molecules, but from the frequency of certain extinction-angles and other facts believes that a certain number of definite mineral species of intermediate nature exist between the extremes. They thus constitute in fact a "morphotropic" series, whose gradation of properties would lead to the same practical results as the views now generally held but which would be more in accord with chemical principles. L. V. P.

8. *Analcite-Diabase from San Luis, Obispo Co., Cal.*; by H. W. FAIRBANKS. Bull. Dept. Geol. Univ. of Cal., vol. i, No. 9, pp. 273–300, Pls. 15–16. Berkeley, Cal., 1895.—This is a careful study both in the field and laboratory of a number of peculiar basic dike rocks, which are allied to teschenites. They contain augite with a peculiar parting, a soda-lime feldspar and a considerable proportion of analcite which occurs crystallized and lining cavities in the rock, filling angular spaces between other components, replacing feldspar and in hexagons. The occurrence of the analcite is studied and discussed and the conclusion is drawn that it is secondary, replacing nephelite which was primarily present. L. V. P.

9. *Gold in Serpentine;* by H. W. TURNER (communicated).—In an article by the writer in the May number of this Journal, it is stated that quartz veins are rare in the serpentine areas of the Sierra Nevada. Mr. W. Lindgren in a valuable paper on "Characteristic Features of the California Gold-Quartz Veins"* speaks of the occurrence of quartz veins in serpentine as an ordinary phenomenon, and as Mr. Lindgren and the writer are both working in the same mountain range, it would appear as if there were an error in one of the above papers. The writer therefore desires to state that the occurrence of quartz veins along narrow serpentine dikes, or cutting small bodies of serpentine, is not uncommon. Mr. Lindgren has made a careful study of the gold mines in the neighborhood of Nevada City, Cala., and he has there found several quartz veins entirely in serpentine, but these are in comparatively small masses of that rock which moreover contain lenses of sedimentary material and are therefore of a more or less complex character. It was the intention of the writer rather to indicate that quartz-filled fissures formed with difficulty where the country rock is purely serpentine, and in this statement Mr. Lindgren concurs. The writer's observations in the paper in the May number of the Journal moreover refer only to that portion of the range which he has particularly studied.

10. *Brief Notices of some recently described Minerals.*—LORANDITE.—This is a mineral of rare interest since it is the second known native compound of thallium. A preliminary description has been giving by Krenner. It occurs in tabular or short prismatic crystals belonging to the monoclinic system. The color is cochineal-red to kermes-red color; it is transparent and is flexible like gypsum, and has three cleavages parallel to planes in the orthodome zone. An analysis by Loczka is given below (1) and

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* Bull. Geol. Soc. Am., vol. vi, pp. 221–240.

also the percentage composition (2) calculated from the formula TlAsS.

	S	As	Tl	
1.	19·02	[21·47]	59·51	= 100
2.	18·67	21·87	59·46	= 100

The locality is Allchar in Macedonia where it occurs implanted upon realgar.—*Math. Nat. Ber. Ungarn*, xii, 1895.

Kylindrite. A new lead mineral from the Mina Santa Cruz at Poopó, Bolivia. It occurs in cylindrical forms and in capillary crystals. The luster is metallic; color blackish lead-gray; hardness 2·5 to 3; specific gravity 5·42. An analysis gave the results below (1) which are compared (2) with the percentage composition for the formula $Pb_6Sb_2Sn_6S_2$.

	S	Sn	Sb	Pb	Ag	Fe	
1.	24·50	26·37	8·73	35·41	0·62	3·00	= 98·63
2.	23·46	24·90	8·36	43·28			= 100.

The description is given by Frenzel in *Jahrb. Min.*, ii, 125, 1893.

Andorite. A new silver ore described by Krenner from Felsöbánya. It occurs in short prismatic crystals belonging to the orthorhombic system; luster metallic; color dark lead-gray or steel-gray to black. An analysis by Loczka is given below (1) and also the percentage composite in (2) required by the formula $AgPbSb_3S_6$.

	S	Sb	Pb	Ag	Cu	Fe(Zn, Mn)	insol.	
1.	23·32	41·91	22·07	11·31	0·69	0·70	0·04	= 100·04
2.	22·14	41·52	23·88	12·46				= 100·

It is named for Andor von Semsey.—*Zeitschr. Kryst.*, xxiii, 497.

Magnetostibian. A supposed new mineral from the Sjögrufva, Wermland, Sweden. It resembles magnetite in external appearance, and occurs in feebly magnetic grains imbedded in crystalline limestone. An analysis was made of material consisting largely of impurities (68·6 p. c.); after deducting these the results given below were obtained:

Sb_2O_5	As_2O_5	FeO	MnO	Fe_2O_3
9·83	1·54	17·16	59·11	12·36

Described by Igelström in *Zeitschr. Kryst.*, xxiii, 212.

Hydrocalcite. Fine crystalline needles with strong double refraction, observed in a mountain milk from a cave near Wolmsdorf, Silesia, have received this name; the author, K. Kosmann, assigns to them the composition $CaCO_3+2H_2O$.—*Zeitschr. Kryst.*, xxiv, 196.

Stibiotantalite. A name given by G. A. Goyder to a partially examined substance occurring in the tin-bearing sands of Greenbush, West Australia, and containing Ta_2O_5 51·13, Nb_2O_5 7·56, Sb_2O_3 40·23.—*Ibid.*, p. 205.

XIPHONITE. A name given by Dr. Gaetano Platania to a variety of amphibole occurring with hematite in cavities in a scoriaceous mass (from Mt. Etna) at Acicatena, Sicily. It is found in minute prismatic crystals of a honey-yellow color. The occurring planes are those of ordinary amphibole and the angles given do not vary very widely considering the striated character of some of the faces; the angle *ac* ($= \beta$) was found to be 73° 10′. No analysis is given, so that the grounds for regarding this as a distinct variety worthy of a name are not clear. The name is from Xiphonia, an ancient Greek city in Sicily.—*Accad. Sci. Acireale*, vol. v, 1893.

KAUAIITE. A basic sulphate of aluminum, potassium and sodium described by GOLDSMITH from a specimen collected in 1893 in the island of Kauai by Professors Sharp and Libbey. It appears as a soft, amorphous chalk-like mass, for which the specific gravity 2·566 was obtained. An analysis yielded :

$Al_2(SO_4)_3$	Al_2O_3	K_2SO_4	Na_2SO_4	H_2O	X
7·18	33·40	17·00	4·91	31·57	[5·94] = 100.

X. Carbonaceous impurity by difference.

The paper is accompanied by a plate giving an admirable view, reproduced from a photograph, of a lava cavern with multitudes of pendant stalactites. The statements of the author require revision in several particulars, especially as regards the locality. This is stated to be the crater of Kilauea ("Kilauii"); we learn from Professor Libbey, however, that the cavern is, on the contrary, situated in the lava stream near Hilo, the same spot which afforded the specimens more fully described in 1889 in this Journal (vol. xxxvii, 441) where drawings of the stalactites are given. The method of formation of the stalactites suggested on the assumption of their occurrence in the Kilauea crater has evidently no basis in fact.—*Proc. Acad. Nat. Sci.*, Philadelphia, p. 105, 1894.

11. *Elements of Mineralogy, Crystallography and Blowpipe Analysis* from a practical standpoint by ALBERT J. MOSES and CHARLES LATHROP PARSONS, 342 pp. 8vo, New York, 1895. (D. Van Nostrand Company.)—This volume, as stated on the title page, is written from a practical standpoint and includes "a description of all common or useful minerals, the tests necessary for their identification, the recognition and measurement of their crystals and a concise statement of their uses in the arts." The work is on the whole well carried out on these lines; it closes with a series of determination tables.

III. BOTANY.

1. *A Students' Text-Book of Botany;* by SYDNEY H. VINES, M.A., F.R.S., Professor of Botany in the University of Oxford. (London: Swan, Sonnenschein & Co.; New York: Macmillan & Co. 1895, pp. 821.)—The first volume of this work has already been noticed at some length in this Journal. The second volume is now at hand. It resumes the subject of Classification at Phanerogamia, and devotes to this above two hundred pages. The work closes with a short treatise on the physiology of plants, and with two indexes to the whole.

It would be but scant praise to speak of Professor Vines's textbook as a well-written, careful handbook: it is much more than this: it is also well proportioned throughout and constructed with constant reference to the pressing needs of modern students. It is therefore a distinct contribution to our aids in teaching botany.

The arrangement and treatment of Phanerogams appear to be more convenient for the use of students than any with which the writer is acquainted. It is suggestive of LeMaout and Decaisne's French treatise, inverted so that the Compositæ come last and are, by implication, made highest in rank.

The physiological portion of the work deserves the warmest commendation for its lucidity and comprehensiveness. Here and there a few more details would be acceptable to the average student, as for instance, when the matter of water-culture is treated, the percentages of the prescribed substances might have been given. There are very few errors to be detected: the principal one being a misplacement of roots for shoots in the account of Knight's wheel experiment.

To show how succinctly and clearly difficult and doubtful subjects are presented, a short extract of the account of the relations of plants to atmospheric nitrogen is herewith given:

"Although it is generally true that plants cannot assimilate uncombined nitrogen, nevertheless certain plants (*Papilioneæ*, such as peas, beans, etc.), will grow and flourish in a soil from which all traces of nitrogen-compounds have been carefully removed. The nature of the means by which this result is attained is not yet completely determined, but the principal facts are briefly as follows: In the first place, the roots of these papilionaceous plants have been found to bear peculiar gall-like outgrowths termed tubercles, which seem to be more numerous and larger the smaller the proportion of combined nitrogen contained in the soil. The tubercles are the result of the attack of a fungus which penetrates into the root through the root-hairs. The green plant and the fungus appear to exist in a state of symbiosis, as in the case of the mycorhiza already mentioned, with the result that the green plant is adequately supplied with combined nitrogen although growing in a soil from which such compounds are originally absent. In explanation of these facts there can, first, be no doubt that the supply of combined nitrogen obtained by the green plant is ultimately derived from the free nitrogen of the atmosphere, and, secondly, that the supply is not obtained from the atmosphere directly by the leaves, but indirectly by the roots through the soil. Nor can there be much doubt that the tubercles are associated with the process of the assimilation of the free nitrogen: but it is a question whether this process takes place in the tubercle itself, or whether it is not carried on in the soil by a Schizomycete, which may either be derived from the tubercles, or be an independent organism. It seems probable that the latter suggestion is nearer the truth. It is, in fact, known that a bacterioid organism exists in the soil having the property of forming nitrogenous compounds from free nitrogen in the presence of non-nitrogenous organic substance (e. g. glucose). It may be that the development of this organism is especially favored by the presence of the tubercular roots of the *Papilioneæ* in the soil, and that the nitrogenous substances which it produces are absorbed by the roots after having undergone nitrification.

"The tubercles are structures formed by the hypertrophy of the cortex of the root, resulting from the attack of the fungus at various points: their cells are rich in sugar and starch: the branches of the mycelium penetrate most of the cells, and there bud off innumerable gemmules (sometimes called bacterioids). The tubercle eventually becomes disorganized; the gemmules are then set free into the soil, and are doubtless the means by which other roots become attacked by the fungus."

The subjects following are remarkably well treated: the transfer of water, and movements. G. L. G.

2. *Cellulose. An outline of the Chemistry of the structural elements of plants, with reference to their Natural History and Industrial Uses;* by C. F. Cross, E. J. Bevan, and C. Beadle. 8vo., pp. 320. London and New York (Longmans).—For many years the two chemists whose names are first in the order above given, have been associated together in the practical investigation of cellulose. Their contributions to the literature of the subject have been numerous, but these publications have been widely scattered and hence partially unavailable to American students. The present work brings together such of their results as may not properly be regarded as trade secrets, and it embodies a good deal of the voluminous literature of the whole subject. Some of their remarkable discoveries, especially in regard to the cellulose thiocarbonates, are incorporated into the body of the work without even a reference to the important fact that science owes these recent acquisitions mainly if not wholly to them. To the botanist the monograph possesses a high degree of interest, since the typical cellulose and the three compound celluloses are adequately discussed from all points of view. The most important phases presented are the following: (1) the colloidal aspects of cellulose, (2) the relation of vegetal to animal cellulose, (3) new methods of acting on the compound celluloses. While the treatise is of value

in the biological laboratory, its highest practical use will be found in the technical laboratories which are rapidly revolutionising the industrial applications of wood pulp. G. L. G.

3. *An Interesting Method of Dissemination.*—In the last number of *Botaniska Notiser,* Dusén describes a curious peculiarity detected by him in the Cameroon species of the genus Calymperes. This genus possesses a calyptra which remains permanently attached to the base of the capsule, instead of separating from it in either the mitriform or cuculiform fashion. The calyptra thus constitutes a sort of bag fitting the capsule rather loosely, and therefore permitting enough play for the elevation of the operculum. When the operculum lifts a little, and the spores escape into the limited space between the capsule and the calyptra, they are as closely confined as if they had not been freed from the capsule itself. Just here comes in the surprising peculiarity observed by Dusén. The calyptra now becomes slit near its apex, and when the surroundings are dry, these slender slits are wide enough to permit the spores to be sprinkled out. On the approach of moisture the slits close tightly and keep the spores in. Moreover the operculum becomes wedged into the top of the calyptra and is lifted or shut as may be, with changes in the dryness or moisture of the whole. The complicated nature of the structure suggests that the mode of dissemination in mosses should be again examined in the field. As is well known, many species are provided with means for dispersion, depending on the condition of the atmosphere ; it is probable that a reinvestigation may throw light on many more cases. In connection with this, it is interesting to observe that recent observations by Goebel have enlarged the range of function in the elaters of Hepaticæ.

G. L. G.

4. *Australian Narcotics.*—In the presidential address of Mr. J. H. Maiden, the untiring investigator of the useful plants of the Australasian colonies, it is said that the "native tobacco," *Nicotiana suaveolens,* although possessing the same physiological action as ordinary smoking tobacco, appears never to have been used by the blacks. But, on the other hand, Pituri (*Duboisia Hopwoodii*), the principal narcotic of the aborigines, has the same physiological action as nicotine. Two other plants are also used for smoking, namely, *Adriana acerifolia,* a Euphorbiaceous species, and *Amorphophallus variabilis.* These have not yet been carefully studied. G. L. G.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Science of Mechanics*, by Dr. ERNST MACH, Professor of Physics in the University of Prague. Translated from the second German edition by THOMAS J. MCCORMACK, pp. 534, with 250 cuts, 1894, Chicago (The Open Court Publishing Co.).—Every student and still more every teacher of mechanics or any subject akin to it needs to regard his work from the standpoint of this book. The fundamental notions of mechanics are presented in the form of a history of their development accompanied by a critical analysis of the reasoning by which each contributor to the science made his deductions.

The purpose of the author, as stated by himself, is to show "how the principles of mechanics have been ascertained, from what sources they take their origin and how far they can be regarded as permanent acquisitions."

The story of the labors of the pioneers of thought in opening paths into the unknown is no small part of their legacy to mankind. The author tells this story for mechanics, not superficially but after the manner of the Germans. Of especial interest to teachers of mechanics is his forcible presentation of the opinion that the true relation of its principles is the historical one. Many will find in it a clew to a natural method of teaching, and its influence ought to be evident in the text-books of elementary mechanics hereafter published. W. B.

2. *Dynamics;* by R. T. GLAZEBROOK, F.R.S., pp. 256, 99 illustrations. (The Cambridge Natural Science Manuals.)—This book presents very attractively the system of teaching followed by the author in the Cavendish Physical Laboratory, and marks a great advance on the method still too prevalent of presenting mechanics as a branch of pure mathematics. A series of carefully arranged experiments, many of them new and inexpensive and suitable for the average student to perform with his own hands, carry the reader along the line of the historical development of the science far enough to prepare his mind to receive willingly and intelligently its fundamental principles in their most general form. The theory is thus developed rigorously and with unusual clearness. W. B.

3. *A Few Chapters in Astronomy*, by CLAUDIUS KENNEDY, M.A., pp. 150, 1895, London (Taylor & Francis).—Several topics, which most text-books necessarily ignore or dismiss with a few paragraphs, are here treated very copiously and instructively, e. g. the deviation of projectiles caused by the rotation of the earth. W. B.

4. *North American Birds*, by H. NEHRLING; with 36 colored plates after water-color paintings by Prof. ROBERT RIDGWAY, Smithsonian Institution, Washington, D. C., Prof. A. GOERING, Leipzig, and GUSTAV MUETZEL, Berlin. Milwaukee, Wisconsin (George Boumder). The first volume of this attractive popular

work has already been issued as well as three parts of the closing second volume; Parts xii to xvi will complete it. The aim is to give a complete history of all the songbirds, flycatchers, hummingbirds, swifts, goatsuckers, woodpeckers, kingfishers, trogons, cuckoos, and parrots of North America. The text is written in a clear entertaining style suited to the general reader; the typographical work is excellent and the same can be said of the colored plates.

OBITUARY.

Mr. John H. Redfield, one of the co-editors of the "Preliminary Flora of Mount Desert Island"—a model contribution to Geographical Botany—died at his home in Philadelphia, on the 28th of February in his 80th year. He had scarcely received the congratulations of the friends of the amenable science, before he quietly passed away under an attack of influenza. For nearly twenty years previously he had served as Conservator of the Herbarium of the Academy of Natural Sciences of Philadelphia, to the care of which he gave much of his spare time, except the three months of each summer devoted to the exploration of Mount Desert Island. In the department of vascular Cryptogams he ranked among the highest authorities. He was the son of the well known Redfield who discovered the rotatory motion of tornadoes, and was born at what is now Cromwell, Connecticut. Moving with his parents to New York, he became among the younger of those who founded the New York Lyceum of Natural History. Marrying into the family of the Whitneys, who established the great car wheel works in Philadelphia, he removed to that city in 1861, and took an active part in all that tended to the growth of the Academy. The Hookers, Torrey, Gray, Sargent, and many eminent scientific men were among his intimate friends, who honored him for his many manly virtues as for his scientific worth. He was one of the founders of the American Association for the Advancement of Science. His modesty led him to decline many tendered honors, his only ambition being to leave behind him, in the Herbarium of the Academy, something that should be useful to others for all time. T. M.

Dr. Lothar von Meyer, Professor of Chemistry at Tübingen, died on the 12th of April in his sixty-fifth year. He was one of the most prominent chemists of Germany, at once as investigator, author and teacher. The discovery of the periodic law is largely due to him.

Dr. Carl Vogt, the famous German naturalist, died in Geneva, Switzerland, on the 5th of May in his eighty-second year.

INDEX TO VOLUME XLIX.*

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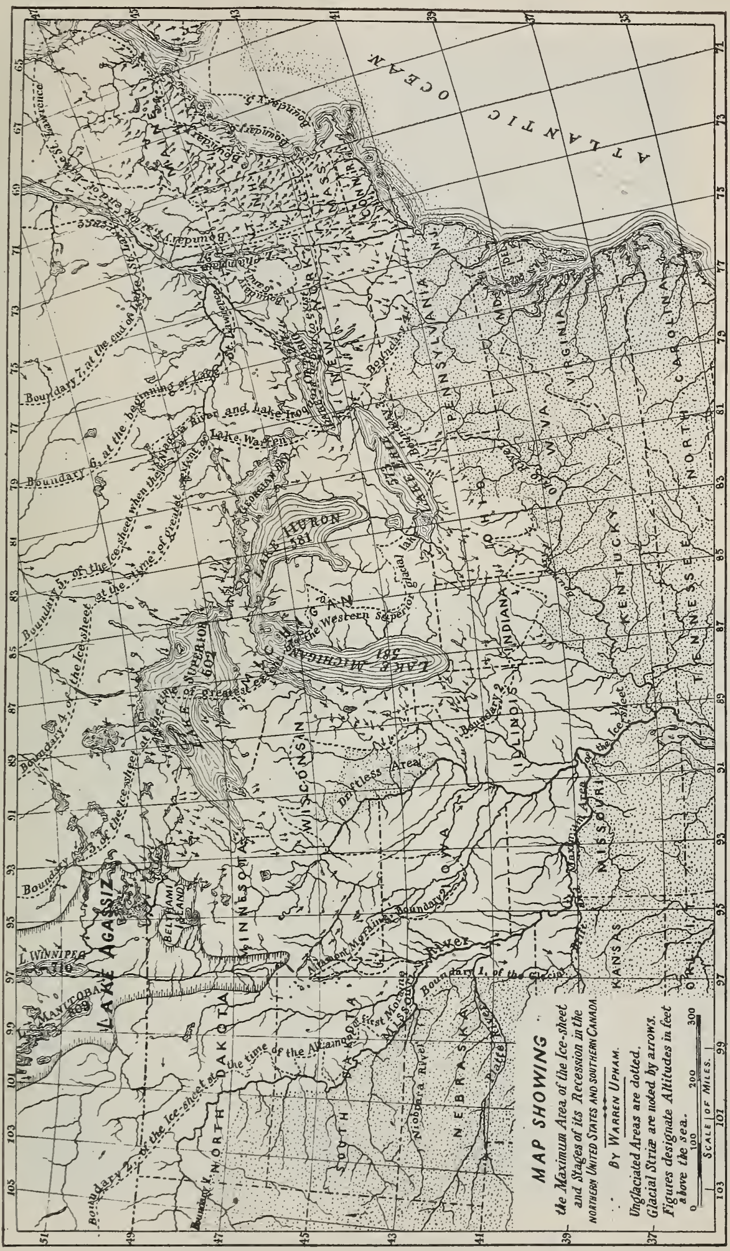
* This Index contains the general heads, BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, and under each the titles of Articles referring thereto are mentioned.



STAGES OF RECESSION OF THE NORTH AMERICAN ICE-SHEET.

1.

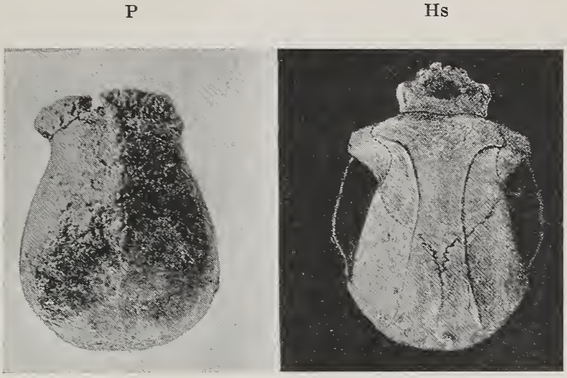
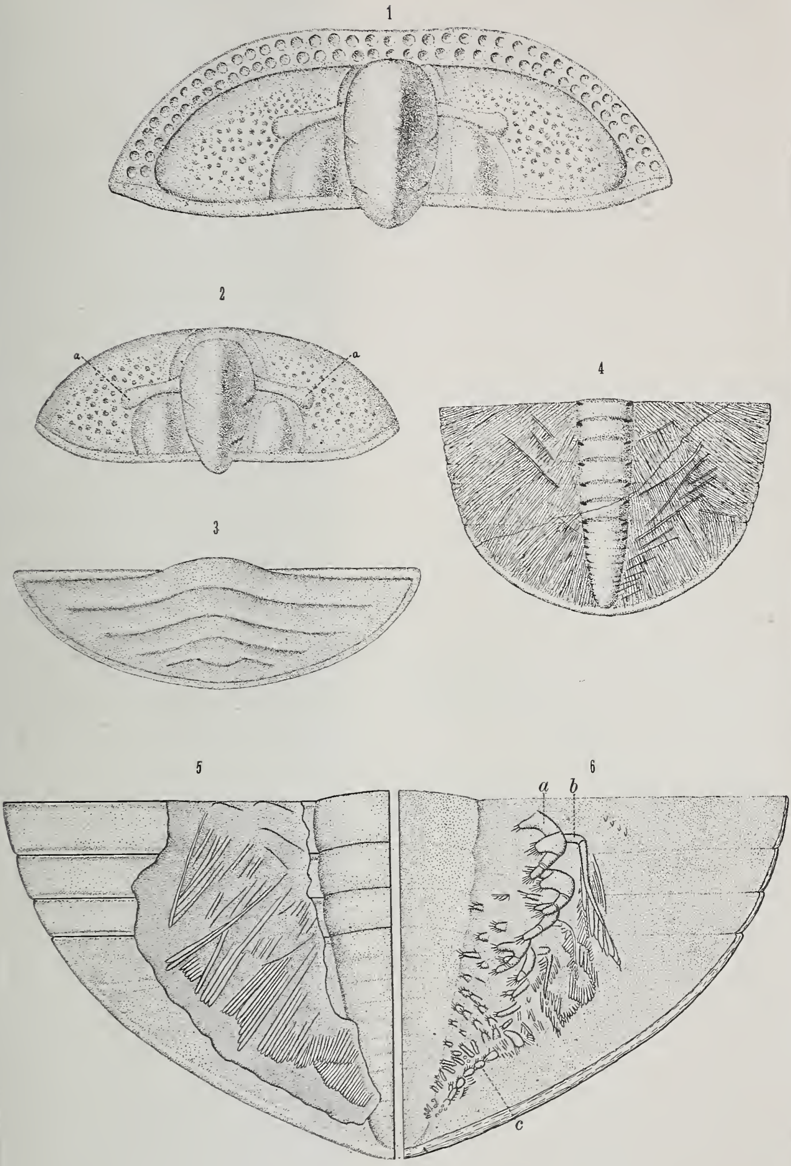


FIGURE 1.—P. Cranium of *Pithecanthropus erectus*, $\frac{1}{6}$.
Hs. Skull of *Hylobates syndactylus*, $\frac{1}{3}$. (After Dubois.)

3.

FIGURE 3.—P. Left femur of *Pithecanthropus erectus*, $\frac{1}{6}$.
H. Left femur of man, $\frac{1}{6}$. *a*, front view; *b*, exterior view. (After Dubois.)

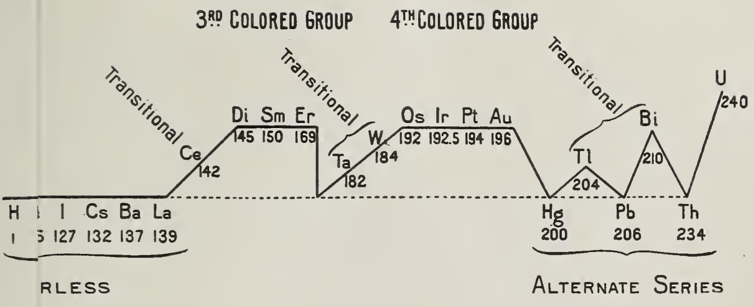


TRINUCLEUS CONCENTRICUS Eaton.

1, 2. Cephala of young individuals. × 40.
3. Pygidium of young individual. × 40.
4, 5, 6. Appendages. 4, × 4; 5, 6, × 11.

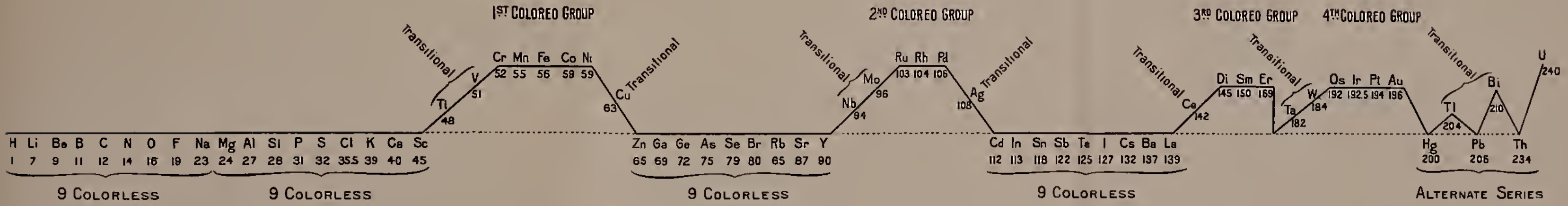
Am. Jour. Sci., Vol. XLIX, 1895. Plate IV.

L ORDER



PERIODIC LAW OF COLOR

COMPRISING ALL THE ELEMENTS IN NUMERICAL ORDER



DR. F. KRANTZ,

RHENISH MINERAL OFFICE,

BONN ON THE RHINE, GERMANY.

ESTABLISHED 1833.

NEW MINERALS.

Andesine, Darapskite, Elpidite, Hintzeïte, Hohmannite, Huantayaite, Jodchromate, Knopite, Koninckite, Kylindrite, Lautarite, Lorandite, Lossenite, Neptunite, Richellite, Soda niter, Sulfoborite, Tarapacaite.

NEW CRYSTAL-MODELS IN WOOD.

Petrographic-crystallographic collection of 100 crystal-models arranged according to Professor Dr. H. Rosenbusch's "Mikroskopische Physiographie der petrographisch wichtigen Mineralien." III edition, Stuttgart, 1893. Price, $25.00.

Collection of 56 models of distorted and pseudosymmetric forms of crystals, arranged by Professor Dr. Hirschwald. Average size, 2 inches. Price, $11.25.

This collection contains single crystal-models well appropriate for study and practice. Since they show equivalent faces in disproportionate distance from the centre or present a pseudosymmetric character in the relations of the combination, the system can be determined only by means of the goniometer.

Such instruments will be furnished at the rate of 65c. (5 goniometers, $2.75); the models having a size of about 2 inches, these instruments will allow an exactness in measuring of 1°.

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