THE

# AMERICAN

# JOURNAL OF SCIENCE.

EDITORS
JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS
PROFESSORS ASA GRAY, JOSIAH P. COOKE, AND
JOHN TROWBRIDGE, OF CAMBRIDGE,

PROFESSORS H. A. NEWTON AND A. E. VERRILL, OF
NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

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VOL. XXXIII.—[WHOLE NUMBER, CXXXIII.]

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### SCIENTIFIC INTELLIGENCE.

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### ERRATUM.

Vol. xxxiii, p. 291, in foot-note, Jahrb. Berg-Hütt., for "1877" read "1887."

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Chas. D. Walcott

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

## ART. I.—*The Muir Glacier;* by G. FREDERICK WRIGHT.

### 1. *Description of Glacier Bay.*

THE Muir glacier enters an inlet of the same name at the head of Glacier Bay, Alaska, in latitude 58° 50′, longitude 136° 40′ west of Greenwich. (See fig. 1.)* Glacier Bay is a body of water about thirty miles long and from eight to twelve miles wide (but narrowing to about three miles at its upper end) projecting in a northwest direction from the eastern end of Cross Sound. The peninsula inclosed between Glacier Bay, Cross Sound and the Pacific Ocean is from thirty to forty miles wide and contains numerous lofty mountain peaks. Mount Crillon, opposite the head of the bay, is 15,900 feet high, and Mount Fairweather, a little farther north, is 15,500 feet. Mounts Lituya and LaPerouse, lying on either side of Crillon, are not far from 10,000 feet above the sea. To the east, between Glacier Bay and Lynn Channel, is a peninsula extending considerably south of the mouth of the bay, and occupied by the White mountains, whose height I am unable to ascertain, but probably having no peaks exceeding 10,000 feet.

Near the mouth of Glacier Bay is a cluster of low islands named after Commander Beardslee, of the U. S. Navy. There are twenty-five or thirty of these, and they are composed of

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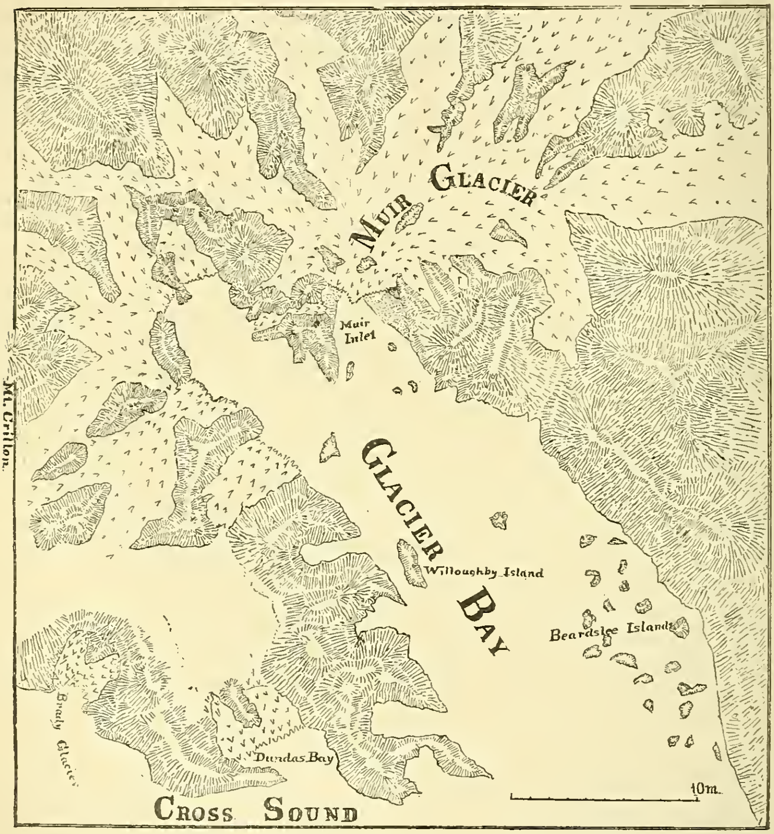
* The maps have been largely made from original data. They are square with the compass, which bears here, however, 28° east of north.

loose material,—evidently glacial debris,—and are in striking contrast to most of the islands and shores in southeastern Alaska. These, also, like all the other land to the south, are covered with evergreen forests, though the trees are of moderate size. The islands and shores in the upper part of the bay are entirely devoid of forests. Willoughby Island, near the middle of the bay, is a bare rock, about two miles long and 1,500 feet high, showing glacial furrows and polishing, from the bottom to the top. Several other smaller islands of similar character in this part of the bay show like signs of having been recently covered with glacial ice.

1.



The upper end of the bay is divided into two inlets of unequal lengths, the western one being about four miles wide and extending seven or eight miles (estimated) in the direction of the main axis of the bay to the northwest. The eastern, or Muir, inlet is a little over three miles wide at its mouth, and extends to the north about the same distance, narrowing, at the upper end, to a little over one mile, where it is interrupted by the front of the Muir glacier. The real opening between the mountains, however, is here a little over two miles wide, the upper part on the eastern side being occupied with glacial debris covering a triangular space between the water and the mountain about one mile wide at the ice-front and coming to a point three miles below, beyond which a perpendicular wall of rock 1,000 feet high rises directly from the water. The moun-

2.

tain on the west side of Muir inlet, between it and the other fork of the bay, is 2,900 feet high. That on the east is 3,150 feet high, rising to about 5,000 feet two or three miles back. The base of these mountains consists of metamorphic slate whose strata are very much contorted,—so much so that I found it impossible, in the time at command, to ascertain their system of folds. Upon the summits of the mountains on both sides are remnants of blue crystalline limestone preserved in synclinal axes. In the terminal moraine deposited in front of the glacier on its eastern side are numerous bowlders of very pure white marble coming in medial moraines originating in mountain valleys several miles to the east. Granitic bowlders are also abundant.

### 2. *Dimensions and characteristics of the Muir Glacier.*

The width of the ice where the glacier breaks through between the mountains is 10,664 feet—a little over two miles. But, as before remarked, the water-front is only about one mile. This front does not form a straight line, but terminates in an angle projecting about a quarter of a mile below the northeast and northwest corners of the inlet. The depth of the water 300 yards south of the ice-front is (according to the measurement of Capt. Hunter of the steamer *Idaho*) 516 feet near the middle of the channel; but it shoals rapidly toward the eastern shore. According to my measurements, taken by leveling up on the shore, the height of the ice at the extremity of the projecting angle in the middle of the inlet was 250 feet; and the front was perpendicular. Back a few hundred feet from the projecting point, and along the front nearer the shores, the perpendicular face of the ice was a little over 300 feet. A little farther back, on a line even with the shoulders of the mountains between which the glacier emerges to meet the water, the general height is 408 feet. From here the surface of the glacier rises toward the east and northeast about 100 feet to the mile. On going out in that direction on the ice seven miles (as near as I could estimate) I found myself, by the barometer, 1,050 feet above the bay.

The main body of the glacier occupies a vast amphitheatre with diameters ranging from thirty to forty miles. This estimate was made from various views obtained from the mountain summits near its mouth when points whose distances were known in other directions were in view. Nine main streams of ice unite to form the grand trunk of the glacier. These branches come from every direction north of the east-and-west line across the mouth of the glacier; and no less than seventeen sub-branches can be seen coming in to join the main streams from the mountains near the rim of the amphitheatre, making twenty-six in all. Numerous rocky eminences also rise above the surface of the ice, like islands from the sea. The two of these visited, situated about four miles back from the front, showed that they had been recently covered with ice,—their surfaces being smoothed and scored, and glacial debris being deposited everywhere upon them. Upon the side from which the ice approached these islands (the stoss side) it rose, like breakers on the seashore, several hundred feet higher than it was immediately on the lee side. A short distance farther down on the lee side, however, the ice closes up to its normal height at that point. In both instances, also, the lee side of these islands seemed to be the beginning of important subglacial streams of water;—brooks running into them as into a funnel, and causing a backward movement of ice and moraine material, as where there is an eddy in the water. In both these cases the lee sides of these islands were those having greatest exposure to the sunshine. The surface of the ice on this side was depressed from one to two hundred feet below the general surface on the lee side.

The ice in the eastern half of the amphitheatre is moving much more slowly than that in the western half. Of this there are several indirect indications. First, the eastern surface is much smoother than the western. There is no difficulty in traversing the glacier for many miles to the east and northeast. Here and there the surface is interrupted by superficial streams of water occupying narrow, shallow channels, running for a short distance and then plunging down into "*moulins*" to swell the larger current, which may be heard rushing along in its impetuous course far down beneath and out of sight. The ordinary light-colored bands in the ice parallel with its line of motion are everywhere conspicuous, and can be followed on the surface for long distances. When interrupted by crevasses they are seen to penetrate the ice for a depth of many feet, and sometimes to continue on the other side of a crevasse in a different line, as if having suffered a lateral fault. The color of the ice below the surface is an intense blue, and over the eastern portion this color characterizes the most of the surface. Numerous holes in the ice, penetrating downward from an inch or two to several feet and filled with water, are encountered all over the eastern portion. Sometimes there is a stone or a little dirt in the bottom of these, but frequently there is nothing whatever in them but the purest of water. In the shallower enclosures on the surface containing water and a little dirt, worms about as large around as a small knitting needle and an inch long are abundant.

### 3. *The Moraines.*

The character and course of the moraines on the eastern half of the glacier also attest its slower motion. There are seven medial moraines east of the north-and-south line, four of which come in to the main stream from the mountains to the southeast. (See fig. 2.) Near the rim of the glacial amphitheatre these are long distances, in some cases miles, apart; but, as they approach the mouth of the amphitheatre, they are crowded closer and closer together near its eastern edge, until in the throat itself they are indistinguishably mingled. The three more southern moraines unite some distance above the mouth. One of these contains a large amount of pure marble. This moraine approaches the others on either side until the distance between them disappears, and its marble unites in one common medial moraine a mile or more above the mouth. The fifth moraine from the south is about 150 yards in width, five miles back from the mouth. It is then certainly as much as five, and probably eight, miles from the mountains from which the debris forming it was derived. All these moraines contain many large blocks of stone, some of which stand above the general mass on pedestals of ice, with a tendency always to fall over in the direction of the sun. One such block was twenty feet square and about the same height, standing on a pedestal of ice, three or four feet high. It is the combination of these moraines, after they have been crowded together near the mouth, which forms the deposit now going on at the northeast angle of the inlet just in front of the ice. Of this I will speak more fully in connection with the question of the recedence of the glacier. Similar phenomena, though on a smaller scale, appear near the southwest angle of the amphitheatre.

### 4. *Indirect evidences of Motion.*

The dominant streams of ice in the Muir glacier come from the north and the northwest. These unite in the lower portion to form a main current, about one mile in width, which is moving toward the head of the inlet with great relative rapidity. Were not the water in the inlet deep enough to float the surplus ice away, there is no knowing how much farther down the valley the glacier would extend. The streams of ice from the east and southwest have already spent the most of their force on reaching the head of the inlet; and, were it not for this central ice-stream, a natural equilibrium of forces would be established here independent of the water, and no icebergs would be formed. The surface of this central current of motion is extremely rough, so that it is entirely out of the question to walk far out upon it. On approaching this portion of the glacier from the east the transverse crevasses diagonal to the line of motion increase in number and size until the whole surface is broken up into vast parallelograms, prisms and towers of ice, separated by yawning and impassable chasms scores and hundreds of feet in depth. Over this part of the ice the moraines are interrupted and drawn out into thinner lines, often appearing merely as patches of debris on separate masses of ice. This portion of the ice-current presents a lighter colored appearance than other portions, and the roughened lines of motion can be followed, as far as the eye can reach, through distant openings in the mountains to the north and the northwest.

The comparative rapidity of the motion in this part of the ice is also manifest where it breaks off into the water at the head of the inlet. As already said, the perpendicular front of ice at the water's edge is from 250 to 300 feet in height. From this front there is a constant succession of falls of ice into the water, accompanied by loud reports. Scarcely ten minutes either day or night passed during the whole month without our being startled by such reports, and frequently they were like thunder-claps or the booming of cannon at the bombardment of a besieged city, and this though our camp was two and a half miles below the ice-front. Sometimes this sound accompanied the actual fall of masses of ice from the front, while at other times it was merely from the formation of new crevasses or the enlargement of old ones. Repeatedly I have seen vast columns of ice, extending up to the full height of the front, topple over and fall into the water. How far these columns extended below the water could not be told accurately, but I have seen bergs floating away which were certainly 500 feet in length. At other times masses would fall from near the summit breaking off part way down, and splashing the spray up to the very top of the ice, at least 250 feet. The total amount of ice thus falling off could not be directly estimated, but it is enormous. Bergs several hundred feet long and nearly as broad, with a height of from twenty to sixty feet, were numerous and constantly floating out from the inlet. The steamer met such one hundred miles away from the glacier. The smaller pieces of ice often so covered the water of the inlet miles below the glacier that it was with great difficulty that a canoe could be pushed through. One of the bergs measured was sixty feet above water and about four hundred feet square. The portion above water was somewhat irregular, so that probably a symmetrical form thirty feet in height would have contained it. But even at this rate of calculation, the total depth would be two hundred and forty feet. The cubical contents of the berg would then be almost 40,000,000 feet. Occasionally, when the tide and wind were favorable, the inlet would for a few hours be comparatively free from floating ice; at other times it would seem to be full.

### 5. *Subglacial Streams.*

The movements of the glacier in its lower portions are probably facilitated by the subglacial streams issuing from the front. There are four of these of considerable size. Two emerge in the inlet itself, and come boiling up, one at each corner of the ice-front, making a perceptible current in the bay. There are also two emerging from under the ice where it passes the shoulders of the mountains forming the throat of the glacier. These boil up, like fountains, two or three feet, and make their way through the sand and gravel of the terminal moraine for about a mile, and enter the inlet 250 or 300 yards south of the ice-front. These streams are perhaps three feet deep and from twenty to forty feet wide, and the current is very strong, since they fall from 150 to 250 feet in their course of a mile. It is the action of the subglacial streams near the corners of the inlet which accounts for the more rapid recession of the glacier front there than at the middle point projecting into the water south of the line joining the east-and-west corners. It was also noticeable that the falls of ice were much more frequent near these corners, and the main motion of the ice as afterwards measured was, not toward the middle point projecting into the inlet, but toward these corners where the subglacial streams emerged below the water.

### 6. *Direct measurement of the Velocity.*

No small difficulty was encountered in securing direct measurements of the motion; and, as the results may be questioned, I will give the data somewhat fully. As it was impossible to cross the main current of the glacier, we were compelled to take our measurement by triangulation. But even then it seemed at first necessary to plant flags as far out on the ice as it was safe to venture. This was done on the second day of our stay, and a base-line was established on the eastern shore, about a mile above the mouth, and the necessary angles were taken. But on returning to repeat the observations three or four days afterwards it was found that the ice was melting from the surface so fast that the stakes had fallen, and there were no means at command to make them secure. Besides they were not far enough out to be of much service. It appeared also that the base-line was on a lateral moraine, which was, very likely, itself in motion. But by this time it had become evident that the masses of ice uniting to compose the main stream of motion retained their features so perfectly from day to day that there was no difficulty in recognizing many of them much farther out than it was possible to venture to plant stakes. Accordingly another base-line was established on the east side opposite the projecting angle of ice in the inlet. From this position eight recognizable points in different portions of the ice-field were triangulated,—the angles being taken with a sextant. Some of the points were triangulated on five different times, at intervals from the eleventh of August to the second of September. Others were chosen later and triangulated a fewer number of times. In all cases given the angles were taken independently by Mr. Prentiss Baldwin of Cleveland and myself and found to agree.

The base-line finally chosen (marked B on fig. 2) was at the foot of the mountain exactly east by the compass from the projecting angle of ice in the inlet. The elevation of the base-line was 408 feet above tide,—corresponding to that of the ice-front. The distance of this projecting point of ice (marked C on fig. 2) from the base-line was 8,534 feet, and it remained very nearly stationary during the whole time,—showing that the material breaking off from the ice-front was equal to that pushed along by the forward movement. Satisfactory observations were made upon eight other points numbered and located on fig. 2.

No. 1 was a pinnacle of ice 1,476 feet N. by 30° E. from C. The movement from Aug. 14 to Aug. 24 was 1,653 feet E. by 15° S. After this date the pinnacle was no longer visible, having disappeared along the wasting line of front between C and the subglacial stream at the northeast corner of the inlet.

No. 2 was a conspicuous pinnacle of ice 2,416 feet N. by 16° E. of C. Observations were continued upon this from Aug. 11 to Sept. 2. The total distance moved during that time was 1,417 feet, or about sixty-five feet per day. From Aug. 14 to Aug. 24 the movement was 715 feet, or about seventy-one feet per day. The difference is, however, perhaps due to the neglect to record the hours of the day when the observations were taken. As these observations were wholly independent of each other, their substantial concordance demonstrates that there was no serious error in the observations themselves. The direction of movement of this point of ice was very nearly the same as that of the preceding, namely, E. 16° S. This also is towards the subglacial stream emerging from the northeast corner of the inlet.

No. 3 was observed only from Aug. 20 to Aug. 24. It was situated 3,893 feet N. by 62° E. of C, and moved 105 feet in a westerly direction. The westerly course of this movement probably arose from its being near where the easterly and northeasterly currents joined the main movement.

No. 4 was 5,115 feet N. 42° E. of C, and moved from Aug. 20 to Aug. 24, 143 feet in a southeasterly direction.

No. 5 was 5,580 feet N. 48° E. of C, and moved 289 feet from Aug. 20 to 24 in a direction E. by 39° S.

No. 6 was 5,473 feet N. 70° E. of C, and moved 232 feet from Aug. 11 to Sept. 2 in a direction S. 66° E.

No. 7 was 6,903 feet N. 59° E. of C, and moved 89 feet between Aug. 14 and Aug. 24 in a direction S. 3° E., about nine feet per day.

No. 8 was 7,507 feet N. 62° E. of C, and moved 265 feet from Aug. 14 to Aug. 24 in direction S. 56° E. These last three points lay in one of the moraines on the east side of the line of greatest motion and parallel with it. These moraines are much interrupted in their course by gaps.

Not having a logarithmic table with me in camp these points brought under observation proved much nearer the eastern side than I supposed at the time. But the distances are so great that nothing better could be done from the base-line chosen. I should also have established another base-line on the western side, but stormy weather, and the difficulty of crossing at the times set for doing so, interfered. As the problems are worked out it is observable that the points chosen were all east of the center of the main line of most rapid motion, and are tending with varying velocity toward the northeast corner of the inlet, where the powerful subglacial stream emerges from below the water level Doubtless on the other side of the center of motion, and at the same relative distance from the front, the ice would be found tending toward the southwest corner, where a similar subglacial stream emerges. I could but wish that some of the points observed had been farther back from the front, but must take the facts as they are. I supposed some of them were farther away, but as they were projected on the distant background the true position could not be told until the actual working out of the problems.

From these observations it would seem to follow that a stream of ice presenting a cross section of about 3,500,000 square feet (5,000 feet wide by about 700 feet deep) is entering the inlet at an average rate of forty feet per day (seventy feet in the center and ten feet near the margin of movement), making about 140,000,000 of cubic feet per day during the month of August. The preceding remarks upon the many indirect evidences of rapid motion render the calculation perfectly credible. What the rate may be at other times of the year there are at present no means of knowing.

### 7. *The Retreat of the Glacier.*

The indications that the Muir glacier is receding, and that its volume is diminishing, are indubitable and numerous. Little regard need to be paid to the record of Vancouver a hundred years ago, for he did not attempt to enter the bay at all, finding it so full of ice near its mouth as to deter him from it; hence his testimony that the opening was full of ice is so indefinite that it has little bearing upon the condition of the upper portions of the bay at that period of time. Nor need any reliance be placed on the traditions of the Indians to the effect that within the memory of their grandfathers the ice extended several miles farther down than at the present time. The Indians now rarely visit the head of the inlet, and the quantity of ice floating on the surface varies so much from day to day, and presumably from month to month, that great diversity of impressions might be received at times separated by even short intervals. The convincing evidence of the recent retreat of the glaciers of this bay from ground formerly occupied by them is of physical character.

The islands of Southern Alaska are ordinarily covered with forests of cedar, hemlock and fir up to the level of perpetual snow. To this rule the shores and islands of the upper part of Glacier Bay are a striking exception. Near the mouth of the bay forests continue to occur as in other parts, only on a diminished scale; but in the upper half of the bay all shores and islands are perfectly bare of forests, and the rocks retain in the most exposed situations fresh grooves and striæ of glacial origin. It would be impossible for rocks so exposed in such a climate, to retain these for an indefinite length of time. Far up on the mountains, also, there are remnants of glacial debris in situations such that the material could not have resisted erosive agencies for any great length of time. The triangular shaped terminal moraine on the eastern side, just below the ice-front, presents some interesting features bearing on the same point. This extends three miles below the glacier, and in its lower portions is thinly covered with vegetation. This covering becomes less and less abundant as the glacier is approached, until, over the last mile, scarcely any plants at all can be found. Apparently this is because there has not been time for vegetation to spread over the upper portion of the moraine since the ice withdrew, for on the mountains close by, where the exposure has been longer, there is a complete matting of grass, flowering plants, and shrubs. Again, in this triangular moraine-covered space, there are five distinct transverse ridges marking as many stages in the recession of the ice-front. (See fig. 2.) These moraines of retrocession run parallel with the ice-front on that side, and at about equal distances from each other, each one rising from the water's edge to the foot of the mountain, where they are 408 feet above tide. An inspection of the upper moraine ridge shows the manner of its formation. This transverse ridge is one-half mile below the ice-front, and is still underlaid in some portions with masses of ice thirty feet or more in thickness, which are melting away on their sides and allowing the debris covering them to slide down about their bases. Kettle-holes are in all stages of formation along this ridge. The sub-glacial stream emerging from the southeast corner of the glacier next the mountain rushes along just in the rear of this moraine ridge and in front of a similar deposit in process of formation on the very edge of the ice where the medial moraines spoken of terminate. Eventually this stream will break out in the rear of that deposit, also, and leave another ridge similar to the one now slowly settling down into position south of it. This first ridge south of the sub-glacial stream, with its ice still melting in exposed positions under its covering of gravel, can not be many years old.

Still another sign of the recent date of this whole moraine appears at various places where water courses coming down from the mountain are depositing superficial deltas of debris upon the edge of the older glacial deposit. These deltas are very limited in extent, though the annual deposition is by no means insignificant. At the southern apex of the moraine, three miles below the ice-front, and but one or two hundred yards from our camp, great quantities of debris came tearing down in repeated avalanches during a prolonged season of rain. Twenty-five years would be ample time for the formation of the cone of debris at the foot of this line of avalanches. Thus there can be no reasonable doubt that during the earlier part of this century the ice filled the inlet several miles farther down than now. And there can be scarcely less doubt that the glacier filled the inlet, as recently as that, 1,000 or 1,500 feet above its present level near the front. For the glacial debris and striæ are very marked and fresh on both mountains flanking the upper part of the inlet up to 2,500 feet, and the evidences of an ice movement in the direction of the axis of the bay are not wanting as high as 3,700 feet on the eastern mountain, upon which I found fresh striæ running north by south and directly past the summit, which rises 1,000 or 1,500 feet still higher just to the east.

### 8. *A Buried Forest.*

All this is necessary to a comprehension of one of the most interesting of problems, presented by the buried forests near the southwest corner of the glacier. (See A, fig. 2.) Below this corner, and extending for about a mile and a half, there is a gravel deposit, similar to that on the eastern side, except that it is not marked by transverse ridges, but is level-topped, rising gradually from about 100 feet at its southern termination to a little over 300 feet where it extends north and west of the ice-front. (See fig. 2.) The sub-glacial stream entering the inlet just below the southwest corner of the ice emerges from the ice about a mile farther up, on the north side of the projecting shoulder of the western mountain which forms that side of the gateway through which the ice enters the inlet. This stream comes principally from the decaying western branch of the glacier before alluded to, and, after winding around the projecting shoulder of the mountain (this shoulder is 315 feet A. T.), has worn a channel through the gravel deposit lying between the lower mile of the glacier and the mountain a short distance to the southwest. About half-way down, a small brook, coming from between this latter mountain and that whose shoulder forms the western part of the gateway just north of it, joins the main stream issuing from the glacier on this side. Where these streams unite at A they are now uncovering a forest of cedar trees in perfect preservation, standing upright in the soil in which they grew, with the humus still about their roots. An abundance of their cones, still preserving their shape, lies about their roots; and the texture of the wood is still unimpaired. One of these upright trunks measured ten feet in circumference about fifteen feet above the roots. Some of the smaller upright trees have their branches and twigs still intact, preserving the normal conical appearance of a recently dead cedar tree. These trees are in various stages of exposure. Some of them are uncovered to the roots, some are washed wholly out of the soil, while others are still buried and standing upright, in horizontal layers of fine sand and gravel, some with tops projecting from a depth of twenty or thirty feet, others being doubtless entirely covered. The roots of these trees are in a compact, stiff clay stratum, blue in color, without grit, intersected by numerous rootlets as long as a knitting needle, which is, in places, twenty feet thick. There is also, occasionally in this substratum of clay a small fragment of wood, as well as some smooth pebbles from an inch to two feet in diameter. The surface of this substratum is at this point 85 feet above the inlet. The deposit of sand and gravel covering the forest rises 115 feet higher and is level-topped at that height, but rising toward the north till it reaches the shoulder of the mountain at an elevation of 300 feet. The trees are essentially like those now growing on the Alaskan mountains. Many of them have been violently broken off from five to twenty feet above their roots. This has been done by some force that has battered them from the upper side at the point of fracture. Evidently cakes of ice brought down by the streams indicated in the map, when flowing at various higher levels than now, have accomplished this result. For the trunks in the main stream were battered on the north side, while those in the gully worn by the lateral stream were battered from the west side.

From this description the explanation of this buried forest would seem to be evident enough. At some period, when the ice occupied only the upper part of the valley to the north of this point, forests grew over all the space lying southwest of the present ice-front. As the ice advanced to near its present position, the streams carrying off the surplus water from the western half of the advancing glacier were suddenly turned into the protected space occupied by this forest, where they deposited their loads of sand and gravel. A cause very likely combining to facilitate deposition in this spot has not yet been spoken of, but is evident when on the ground, and from a glance at the map. A transverse valley passes just below this point from Muir inlet to the western inlet into which Glacier Bay divides. This transverse valley is at present occupied by a decaying glacier opening into both inlets, and sending a sub-glacial stream, through a long, narrow series of moraines, into Muir inlet about two miles to the south. Now, when a general advance of the ice was in progress, this transverse stream probably pushed itself down into the inlet across the path of the ice moving from the north, and so formed an obstruction to the water running from the southwest corner of the main glacier, thus favoring the rapid deposition which so evidently took place. When this enclosed place was filled up, and the advancing ice had risen above and surmounted the projecting shoulder of the mountain just to the north, that rocky barrier protected a portion of the forest from the force of the ice movement, causing the ice to move some distance over the top of the superincumbent gravel before exerting its full downward force. Thus sealed up on the lee side of this protecting ridge of rock, there would seem to be no limit to the length of time the forest might be preserved. I see no reason why this forest may not have antedated the Glacial period itself.

The existence of other forests similarly preserved in that vicinity is amply witnessed to by many facts. One upon the island near the west shore, four miles south, is now exposed in a similarly protected position. Furthermore, the moraine, already described on the east side of the inlet, contains much wood ground up into slivers and fragments. Indeed, our whole dependence during the month for fuel was upon such fragments lying exposed in the moraine. Occasional chunks of peat or compact masses of sphagnum formed a part of the debris of this moraine. These also occurred on some of the medial moraines on the eastern side. I did not go up them far enough to learn directly their origin. But, as no forests were visible anywhere in that direction, it is presumable that they had been recently excavated from preglacial forests similar in situation to that now exposed on the west below the ice-front.

The capacity of the ice to move, without disturbing them, over such gravel deposits as covered the forests, is seen in the present condition of the southwestern corner of the glacier itself. As the ice-front has retreated along that shore, large masses of ice are still to be seen lapping over upon the gravel. These are portions of the glacier still sustained in place by the underlying gravel while the water of the inlet has carried the ice from the perpendicular bank clear away. This phenomenon, and that of the general perpendicular front presented by the ice at the water's edge, accords with the well-known fact that the surface of the ice moves faster than the lower portions. Otherwise the ice columns at the front would not fall over into the water as they do.

### 9. *Kamès and Kettle-holes.*

The formation of kames, and of the knobs and kettle-holes characteristic both of kames and of terminal moraines, is illustrated in various places about the mouth of Muir glacier, but especially near the southwest corner just above the shoulder of the mountain where the last lateral branch comes in from the west. This branch is retreating, and has already begun to separate from the main glacier at its lower side, where the sub-glacial stream passing the buried forest emerges. Here a vast amount of water-worn debris covers the ice, extending up the glacier in the line of motion for a long distance. It is evident from the situation that, when the ice-stream was a little fuller than now, and the sub-glacial stream emerged considerably farther down, a great mass of debris was spread out on the ice at an elevation considerably above the bottom. Now that the front is retreating, this sub-glacial stream occupies a long tunnel, twenty-five or thirty feet high, in a stratum of ice that is overlaid to a depth in some places of fifteen or twenty feet with water-worn glacial debris. In numerous places the roof of this tunnel has broken in, and the tunnel itself is deserted for some distance by the stream, so that the debris is caving down into the bed of the tunnel as the edges of ice melt away, thus forming a tortuous ridge, with projecting knolls where the funnels into the tunnel are oldest and largest. At the same time, the ice on the sides at some distance from the tunnel, where the superficial debris was thinner, has melted down much below the level of that which was protected by the thicker deposit; and so the debris is sliding down the sides as well as into the tunnel through the centre. Thus three ridges approximately parallel are simultaneously forming. When the ice has fully melted away, this debris will present all the complications of interlacing ridges, with numerous kettle-holes and knobs characterizing the kames; and these will be approximately parallel with the line of glacial motion. The same condition of things exists about the head of the sub-glacial stream on the east side, also near the junction of the first branch glacier on the east with the main stream, as also about the mouth of the independent glacier shown on the map lower down on the west side of the inlet. (See fig. 2.) The formation of kettle-holes in the terminal ridges has already been referred to. (See p. 12.)

### 10. *Transportation and waste by Water.*

Considerable earthy material is carried out from the front by the bergs. Pebbles and dirt were frequently seen frozen into them as they were floating long distances away. Just how many of the bergs were formed from ice that originally rested on the bottom of the inlet I have no means of telling. That some were so formed seems exceedingly probable, if for no other reasons because of the great amount of debris that was sometimes seen frozen into them. It is by no means certain that the subglacial streams boiling up near the upper corners of the inlet were beneath the lowest stratum of ice. Some small streams were seen pouring out from the face of the ice half way up from the water. It seems likely that a great amount of sediment becomes incorporated in cavities in the center of the glacier through the action of these subglacial streams; and so is ready for transportation when the masses break loose.

There were two pretty distinct lines of motion in the currents of the inlet, corresponding to those originating in the subglacial streams, so that ordinarily the ice-floes arranged themselves in the inlet along definite lines. But the tides were so high as sometimes to cause much irregularity. Frequently large icebergs would be seen moving up the lines of current or diagonal to them. The upper part of the inlet was filled with the muddy water coming from the subglacial streams. The line separating this muddy water from the clear water of the bay was driven now one way and now another, according to the influence of the tide. The steamer's screw brought up much muddy water from below the surface some distance down the bay, and where the surface was clear. The sediment forming over the bottom of the bay must resemble the loess of the Missouri and Mississippi valleys.

### 11. *Other Glaciers reaching the Bay.*

Besides the Muir glacier there are four others of large size entering the longer inlet to the west, (see fig. 1.) These have their origin on the flanks of Mounts Crillon and Fairweather. They have never been studied, but are apparently as accessible as the Muir. Professor Muir and Rev. Mr. Young are the only well-informed persons who have visited them, and their stay was brief. I went about half way up the inlet, on its east side, and took some photographs from points where the whole outlines could be seen. I also saw them from the mountains on the east side. The general appearance does not differ materially from that of the Muir glacier. To complete the study one needs a small steam launch, and more ample time and preparation than we could command.

The moisture of the climate is a serious drawback to investigations in all that region, though this is very favorable to the growth of glaciers. The annual precipitation over southeastern Alaska averages from eighty to one hundred inches. The average number of days per annum on which rain or snow has fallen at Sitka during the last fifty years is 198, while some years it has been as high as 264. Fifteen of the twenty-nine days we were in Glacier Bay (from Aug. 4 to Sept. 2) were so rainy as to render observation impossible. The other days were however, clear and beautiful beyond description. The absence of forests also renders it easy to climb the mountains and observe from them. It is to be hoped that other expeditions better fitted than ours, and prepared to spend a longer time, will soon make a more complete study of this now easily accessible and most fruitful field for glacial investigation.

### 12. *Temperature.*

I append the record of the thermometer from Aug. 20 to Aug. 31, giving the mean of three readings each day taken at 8 A. M., 2 P. M., and 8 P. M. The temperature of the water in the upper part of the inlet was uniformly 40° F.

| | | | |
|---|---|---|---|
| Aug. 20 | 49·4° F. | Aug. 26 | 51·9° F. |
| Aug. 21 | 48·9° F. | Aug. 27 | 46·1° F. |
| Aug. 22 | 46·1° F. | Aug. 28 | 50·5° F. |
| Aug. 23 | 44·6° F. | Aug. 29 | 45° F. |
| Aug. 24 | 49·8° F. | Aug. 30 | 54·8° F. |
| Aug. 25 | 52·7° F. | Aug. 31 | 50·5° F. |

### 13. *Flora.*

The following is the list of plants, as identified by Professor Asa Gray, found in bloom about Muir inlet during the month of August. Where the altitude is not given they were found near the tide.

| | | |
|---|---|---|
| Arabis ambigua, Brong. | Aug. 26 | 1600 A. T. |
| Arenaria peploides, L. | 28 | |
| Astragalus alpinus, L. | 7 | |
| Hedysarum boreale, Nutt. | 28 | |
| Sanguisorba Canadensis | 6 | |
| Lutkea sibbaldioides, Brong. | 27 | |
| Saxifraga Lyalli, Engl. | 26 | 1600 A. T. |
| stellaris, L. | 27 | 3000 A. T. |
| Parnassia fimbriata, Small | 27 | 3000 A. T. |
| palustris, L. | 6 | |
| Epilobium latifolium, L. | 6 | 1600 A. T. |
| origanifolium, Lam. (?) | 28 | |
| Solidago multiradiata, Ait. | 27 | |
| Erigeron salsuginosus, Gray, arctic form | 27 | 3000 A. T. |
| Antennaria margaritacea, arctic form | 27 | |
| Achillea millefolium, L., arctic var. | 27 | |
| Arnica obtusifolia, Les. | 27 | 1200 A. T. |
| Campanula rotundifolia, L., var. Alaskana | 28 | |
| Gentiana platypetala (?) | 27 | |
| " Menziesii (?) | 27 | |
| Mertensia maritima | 7 | |
| Castilleja parviflora, Brong. | 28 | |
| Salix vestita, Pursh | 6 | |
| Habenaria hyperborea, R. Br. | 27 | 2650 A. T. |
| Luzula parviflora, Meyer | | |
| Poa alpina, var. vivipara | 26 | 1500 A. T. |
| Poa alpina, L. | 26 | 1600 A. T. |
| Poa laxa, Hænke | 26 | 1500 A. T. |
| Phleum alpinum, L. | 26 | 1600 A. T. |
| Elymus mollis | 6 | |
| Hordeum, sp. (?) | 6 | |

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## ART. II.—*On the Age of the Coal found in the region traversed by the Rio Grande;* by C. A. WHITE.

DURING the past few years many discoveries of coal have been made within the region which is traversed by the lower portion of the Rio Grande, besides those which were made by the members of the United States and Mexican Boundary Commission and other early government expeditions. In Texas, coal has been found in Webb, Maverick, Presidio and El Paso counties; and in Mexico, in the States of Nuevo Leon and Coahuila. By certain local geologists and mining experts, whose reports have fallen under my observation, a part of these coals have been referred to Carboniferous age, and others to Triassic* age. From personal examination in the field, extending over a large part of the region in question, and an examination of fossils which have been collected by different persons† from strata associated with the coals, I am satisfied, however, that none of them are of earlier than late Cretaceous age.

In some cases the coal of this region is worthless for practical use, but in others it is of good quality; all of it having the general characteristics of the coals which are obtained from the Laramie and Fox Hills formations in Colorado, Utah and Wyoming. From the data and observations just mentioned I do not hesitate to refer all the known coal of the region under consideration to one or the other, or both, of those formations.

In the region of the Lower Rio Grande these two formations appear to be as intimately associated with each other as they are to the northward. Their strata are so similar in general character that it is usually difficult to define a plane of demarkation between them, and in the absence of paleontological evidence it is often difficult or impracticable to distinguish the one from the other.

I have at present no evidence of the presence of the Laramie formation in Webb and Maverick counties, Texas, the coal which has hitherto been found there belonging to the equivalent of the Fox Hills Group of the Cretaceous period. The mines at Santa Tomas, some forty miles above Laredo, and those seven miles above Eagle Pass, are the principal ones on the Texas side of the river. The equivalent of the latter coal is also found on the Mexican side, a few miles from Piedras Negras, opposite Eagle Pass.

From data furnished by Mr. Gardiner, I also learn that both the Laramie ‡ and Fox Hills formations exist on the Mexican side of the Rio Grande, in the northern part of the State of Nuevo Leon and the adjacent eastern portion of the State of Coahuila, and that both formations are coal-bearing there.

On the occasion of a late journey in Coahuila, I found both these formations to be well developed in the region which is

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*In an otherwise important article by W. H. Adams, M.E.; in the Trans. Inst. Mining Engineers, vol. x, pp. 270–273, entitled Coals in Mexico, Santa Rosa District, he refers the coal-bearing rocks there to Triassic age; and those at Eagle Pass to the Permian, both of which references are erroneous.

†The collections referred to were made by Mr. James T. Gardiner, of New York, Mr. W. F. Cummins, of Dallas, Texas, and Mr. R. T. Hill, of the U. S. Geological Survey.

‡ See this Journal, III, vol. xxv, pp. 207 et seq.

traversed by the Rio Sabinas, a tributary of the Rio Grande. I traced the Laramie strata along the north side of the Sabinas valley for a distance of nearly forty miles, beginning a few miles above Sabinas station of the Mexican and International Railroad, and going down the valley to the southeastward. At the hamlet of San Felipe, about fifteen miles below Sabinas station, some important mines have been opened in the Laramie Group on both sides of Rio Sabinas; and the presence of coal in the same formation has been proved at several other localities in the same district.

On the south side of the river, some twenty miles southwestward from Sabinas station, and westward from the railroad, exposures of coal were observed in strata equivalent with the Fox Hills Group, but no important mines have yet been opened there.

Little is yet known of the character of the coal deposits in the southern part of Presidio and El Paso counties, Texas, respectively; but the coal which is found at White Oaks in Southeastern New Mexico, some 75 miles northeastward from El Paso, is reported to be of good quality. Coal of either Laramie or Fox Hills age, or both, is also well known to exist at many localities in New Mexico and Colorado, along the eastern base of the mountains. It will thus be seen that there is a belt of these two coal-bearing formations extending nearly or quite continuously from the valley of the South Platte in Colorado to the State of Nuevo Leon in Mexico.

It is not necessary to inform the practical geologist that this series of strata is entirely distinct from the coal-bearing rocks of Carboniferous age which extend southward through the Indian Territory into Northern Texas, and also distinct from the Tertiary lignite beds which range through eastern Texas and portions of other Gulf States.

## ART. III.—*The Viscosity of Steel and its Relations to Temper;* by C. BARUS and V. STROUHAL.

[Continued from vol. xxxii, page 466.]

*Miscellaneous experiments.*—1. In tables 27 and 28 we cite the results obtained when one of the steel rods is replaced by a fiber of glass. The mean thickness or the diameter $2\rho_g$ of glass was intended to be that of the steel rod $2\rho_s$; but it is smaller in table 27 and considerably larger in table 28. It is impossible to store a greater total torsion than $\psi_1-(-\psi_2)=90°$ in the given system without breaking the glass fiber. The equality of $\psi_1$ and $\psi_2$ is assumed merely for convenience in designation (cf. p. 30). In table 28, moreover, the glass-hard rod used during the first half of the experiment is replaced by an annealed rod in the second half, leaving the glass fibre unaltered. The suspension here is practically unifilar, since it is nearly impossible mechanically to clutch the glass fiber without breaking it.

TABLE 27.—APPARATUS I.

$R=215^{cm}$; $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 35, glass-hard steel, $\psi_1=+45°$; No. *a*, glass fiber, $\psi_2=-45°$; $\rho_s=0{\cdot}082^{cm}$; $\rho_g=0{\cdot}070^{cm}$.

| Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ | Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ |
|---|---|---|---|---|---|---|---|
| 29/6, $3^h\,20^m$ | (*) | 0·00 | (*) | 3/7, $8^h\,17^m$ | 0·974 | 88·95 | 1·075 |
| 3 42 | −0·129 | 0·37 | −0·028 | 12 12 | 0·991 | 92·87 | 1·092 |
| 4 20 | −0·101 | 1·00 | ±0·000 | 6 27 | 1·026 | 99·12 | 1·127 |
| 5 30 | −0·052 | 2·17 | +0·049 | 4/7, $9^h\,45^m$ | 1·098 | 114·42 | 1·199 |
| 5 51 | −0·031 | 2·52 | 0·070 | 12 09 | 1·109 | 116·82 | 1·210 |
| 30/6, $8^h\,50^m$ | +0·351 | 17·50 | 0·452 | 3 06 | 1·116 | 119·77 | 1·217 |
| 12 23 | 0·413 | 21·05 | 0·514 | 5 59 | 1·145 | 122·65 | 1·246 |
| 1 57 | 0·440 | 22·62 | 0·541 | 5/7, $9^h\,39^m$ | 1·213 | 138·32 | 1·314 |
| 5 22 | 0·486 | 26·03 | 0·587 | 12 00 | 1·228 | 140·67 | 1·329 |
| 1/7, $8^h\,37^m$ | 0·652 | 41·28 | 0·753 | 4 43 | 1·257 | 145·38 | 1·358 |
| 2 12 | 0·706 | 46·87 | 0·807 | 6/7, $8^h\,40^m$ | 1·318 | 161·33 | 1·419 |
| 4 36 | 0·732 | 49·27 | 0·833 | 1 52 | 1·339 | 166·53 | 1·440 |
| 5 37 | 0·741 | 50·28 | 0·842 | 5 15 | 1·355 | 169·92 | 1·456 |
| 6 57 | 0·753 | 51·62 | 0·854 | 7/7, $8^h\,49^m$ | 1·420 | 185·48 | 1·521 |
| 2/7, $9^h\,19^m$ | 0·854 | 65·98 | 0·955 | 1 27 | 1·443 | 190·12 | 1·444 |
| 1 45 | 0·879 | 70·42 | 0·980 | | | | |
| 5 09 | 0·899 | 73·82 | 1·000 | | | | |

TABLE 28.—APPARATUS I.

$R=223^{cm}$; $L=23^{cm}$. Rods: No. 36, glass-hard steel, $\psi_1=+45°$; No. *b*, glass fiber, $\psi_2=-45°$. $2\rho_s=0{\cdot}082^{cm}$; $0{\cdot}085^{cm}<2\rho_g<0{\cdot}120^{cm}$.

| Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ | Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ |
|---|---|---|---|---|---|---|---|
| 7/7, $4^h\,15^m$ | (*) | 0·00 | (*) | 12/7, $7^h\,35^m$ | 3·100 | 111·33 | −0·235 |
| 4 26 | 2·995 | 0·18 | −0·130 | Glass-hard rod replaced by soft steel rod, viz: No. 42, annealed, 450°, $1^h$, $\psi_1=+45°$, $2\rho=0{\cdot}082^{cm}$. | | | |
| 4 38 | 2·934 | 0·38 | −0·069 | | | | |
| 5 15 | 2·865 | 1·00 | ±0·000 | | | | |
| 8/7, $9^h\,14^m$ | 2·823 | 16·98 | +0·042 | 12/7, $9^h\,39^m$ | (*) | 0·00 | (*) |
| 12 41 | 2·841 | 20·43 | 0·024 | 9 49 | 1·358 | 0·17 | −0·023 |
| 4 07 | 2·858 | 23·87 | 0·007 | 10 54 | 1·331 | 1·25 | +0·004 |
| 5 47 | 2·863 | 25·53 | 0·002 | 5 25 | 1·303 | 7·77 | 0·032 |
| 9/7, $8^h\,33^m$ | 2·912 | 40·30 | −0·047 | 13/7, $8^h\,26^m$ | 1·278 | 22·78 | 0·057 |
| 12 10 | 2·928 | 43·92 | −0·063 | 12 27 | 1·270 | 26·80 | 0·065 |
| 5 16 | 2·940 | 49·02 | −0·075 | 5 6 | 1·270 | 31·45 | 0·065 |
| 10/7, $8^h\,04^m$ | 2·983 | 63·82 | −0·118 | 14/7, $8^h\,50^m$ | 1·258 | 47·18 | 0·077 |
| 12 08 | 2·996 | 67·88 | −0·131 | 12 48 | 1·258 | 51·15 | 0·077 |
| 5 18 | 3·010 | 73·05 | −0·145 | 4 40 | 1·255 | 55·02 | 0·080 |
| 11/7, $9^h\,07^m$ | 3·053 | 88·87 | −0·188 | 15/7, $10^h\,45^m$ | 1·245 | 73·10 | 0·090 |
| 11 23 | 3·058 | 91·13 | −0·193 | 4 25 | 1·245 | 78·77 | 0·090 |
| 5 21 | 3·077 | 97·10 | −0·212 | 16/7, $9^h\,16^m$ | 1·237 | 95·62 | 0·098 |
| 6 59 | 3·081 | 98·73 | −0·216 | 1 42 | 1·237 | 100·05 | 0·098 |
| | | | | 5 54 | 1·236 | 104·25 | 0·099 |

* Adjusted.

2. Tables 29, 29A, 30, contain a part of our results in which one steel wire is replaced by a wire of wrought iron, annealed or drawn as specified. That the amounts of torsion are equal in angle ($\psi$) is again assumed for convenience of designation only. $\rho_s$ is the radius of steel, $\rho_i$ of the iron wire. The applied couple twists soft iron beyond the limits of elasticity and the amount of instantaneous detorsion is here probably as large as $\frac{1}{2}(\psi_1+\psi_2)$. In case of steel instantaneous detorsion is nearly zero.

TABLE 29.—APPARATUS I.

$R=223^{cm}$; $L=26^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 37, steel, annealed, 450°, $1^h$, $\psi=+180°$; No. $c$, wrought iron, drawn, $\psi=-180°$. $2\rho_s=0{\cdot}082^{cm}$; $2\rho_i=0{\cdot}083^{cm}$.

| Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ | Date. | $\phi+10^3$ | $h_0$ | $\phi_0\times10^3$ |
|---|---|---|---|---|---|---|---|
| 17/7, $4^h\ 20^m$ | 1·955 | 0·20 | −0·387 | 18/7, $8^h\ 27^m$ | 2·177 | 16·32 | −0·165 |
| 4 23 | 2·032 | 0 25 | −0·310 | 2 24 | 2·122 | 22·27 | −0·220 |
| 4 27 | 2·113 | 0·32 | −0·229 | 19/7, $9^h\ 37^m$ | 2·032 | 41·48 | −0·310 |
| 4 51 | 2·285 | 0·72 | −0·057 | 12 19 | 2·025 | 44·18 | −0·317 |
| 5 20 | 2·342 | 1·20 | ±0·000 | 5 10 | 2·014 | 49·03 | −0·328 |
| 6 01 | 2·362 | 1·88 | +0·020 | 20/7, $8^h\ 29^m$ | 1·984 | 64·35 | −0·358 |
|  |  |  |  | 3 45 | 1·977 | 71·62 | −0·364 |

* Adjusted $\tau-b-f$.

TABLE 30.—APPARATUS II.

$R=200^{cm}$ $L=27^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 38, steel, annealed 450°, $1^h$, $\psi=+180°$; No. $d$, wrought iron, soft, $\psi=-180°$. $2\rho_s=0{\cdot}082^{cm}$; $2\rho_i=0{\cdot}112^{cm}$.

| Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ | Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ |
|---|---|---|---|---|---|---|---|
| 16/7, $9^h\ 40^m$ | (*) | 0·00 | (*) | 18/7, $8^h\ 33^m$† | 0·146 | 15·12 | (0·153) |
| 9 48 | 0·714 | 0·13 | −0 026 | 2 35 | 0·151 | 21·15 | (0·148) |
| 11 14 | 0·745 | 1·57 | +0·005 | 19/7, $9^h\ 38^m$ | 0·128 | (40·20) | (0·171) |
| 1 48 | 0·758 | 4·13 | 0·018 | 12 20 | 0·119 | (42·90) | (0·180) |
| 5 47 | 0·750 | 8·23 | 0·010 | 5 10 | 0·110 | (47·73) | (0·189) |
| 17/7, $8^h\ 47^m$ | 0·731 | 23·12 | −0·009 | 20/7, $8^h\ 28^m$ | 0·082 | (63·03) | (0·217) |
| Thick iron wire replaced by thin wire. Rod No. 9, wrought iron, soft; $\psi=-180°$; $2\rho=0{\cdot}083^{cm}$. |  |  |  | 3 44 | 0·064 | (70·32) | (0·235) |
| 17/7, $5^h\ 26^m$ | 0·755 | *0·00 | −0·019 |  |  |  |  |
| 5 30 | 0·745 | 0·07 | −0·009 |  |  |  |  |
| 5 36 | 0·736 | 0·17 | ±0·000 |  |  |  |  |
| 6 00 | 0·718 | 0·57 | +0·018 |  |  |  |  |

* Accident, new adjustment, data otherwise good, but distinguished by parentheses

† Adjusted $\tau-l-f$. ‡ Adjusted $\tau+l+f$, but the time not accurately noted.

TABLE 30A.—APPARATUS II.

$R=202^{cm}$; $L=26^{cm}$; $l<0{\cdot}2^{cm}$. Rods: No. 50, annealed 350°. $1^h$, $\psi=+180°$; No. $k$, wrought iron drawn, $\psi=-180°$. $2\rho_i=0{\cdot}084^{cm}$; $2\rho_s=0{\cdot}082^{cm}$.

| Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ | Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ |
|---|---|---|---|---|---|---|---|
| 23/8, $2^h\ 00^m$ | (*) | 0·00 | (*) | 27/8, $9^h\ 10^m$ | 1·483 | 96 38 | 0·114 |
| 2 13 | 2·052 | 0·22 | −0·452 | 7 36 | 1·490 |  |  |
| 2 20 | 1·914 | 0·33 | −0·314 | 28/8, $9^h\ 21^m$ | 1·492 | 120·13 | 0·107 |
| 3 11 | 1·599 | 1·18 | +o·001 | 6 55 | 1·494 |  |  |
| 5 37 | 1·417 | 3·62 | 0·183 |  |  |  |  |
| 7 11 | 1·392 | 5·18 | 0·208 | 29/8, $10^h\ 11^m$ | 1·500 | 144·23 | 0·100 |
| 24/8, $9^h\ 17^m$ | 1·385 | 19·28 | 0·215 | 6 17 | 1·501 |  |  |
| 5 13 | 1·411 | 27·22 | 0·189 | 30/8, $9^h\ 11^m$ | 1·505 | 163·18 | 0·095 |
| 25/8, $9^h\ 05^m$ | 1·435 | 43·08 | 0·165 | 31/8, $1^h\ 19^m$ | 1·515 | 193·66 | 0·085 |
| 7 00 | 1·448 | 53·02 | 0·152 | 6 00 | 1·515 |  |  |
| 26/8, $9^h\ 10^m$ | 1·460 | 70·65 | 0·135 | 1/9, $9^h\ 19^m$ | 1·517 | 211·32 | 0·083 |
| 4 08 | 1·469 |  |  | 2/9, $9^h\ 05^m$ | 1·524 | 237·29 | 0·074 |
|  |  |  |  | 1 30 | 1·528 |  |  |

* Adjusted $\tau+l+f$.

3. Tables 31 and 32 contain our results with the tubular apparatus. $\rho_1$ is the inner radius, $\rho_2$ the outer radius of the tube. $Q$ and $q$ denote the right sections of brass tube and steel wire respectively. Of course sections of metallic surface are meant. The inclosed wire is twisted alternately in opposite directions as is indicated by the sign of $\psi$. The result is similarly indicated by the sign of $\varphi$. Subscripts $s$ and $b$ refer to steel and brass respectively. Table 31 contains results for a thick tube, table 32 for a thin tube. Hard or soft rods are inserted, as indicated.

Table 34 is mentioned below.

TABLE 31.—APPARATUS (tubular) II.

$R=260^{cm}$; $L=22^{cm}$. Rods: No. $e$, brass, $\begin{matrix}2\rho_1=0{\cdot}188^{cm}.\\ 2\rho_2=0{\cdot}320^{cm}.\end{matrix}$ No. 89, steel, glass-hard, $2\rho=0{\cdot}127^{cm}$; $Q=0{\cdot}053^{cm^2}$; $q=0{\cdot}0127^{cm^2}$; $Q/q<4{\cdot}5$.

| Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ |
|---|---|---|---|
| 7/7, $9^h\ 02^m$ | 0·308 | *0·00 | +0·002 |
| 12 15 | 0·390 | 3·22 | −0·080 |
| 5 18 | 0·420 | 8·27 | −0·110 |
| 8/7, $9^h\ 19^m$ | 0·460 | 24·28 | −0·150 |
| 12 48 | 0·465 | 27·77 | −0·155 |
| 5 50 | 0·476 | 32·80 | −0·166 |
| 9/7, $8^h\ 30^m$ | 0·500 | 47·47 | −0·190 |
| 9/7, $8^h\ 50^m$ | 0·456 | †0·00 | −0·056 |
| 12 12 | 0·337 | 3.37 | +0·063 |
| 5 20 | 0·283 | 8·50 | +0·117 |
| 10/7, $8^h\ 09^m$ | 0·222 | 23·32 | +0·178 |
| 12 09 | 0·208 | 27·32 | +0·192 |
| 5 18 | 0·191 | 32·47 | +0·209 |
| 11/7, $9^h\ 20^m$ | 0·160 | 48·50 | +0·240 |
| 11 35 | 0·151 | 50·75 | +0·249 |
| 4 15 | 0·142 | 55·42 | +0·258 |
| 11/7, $4^h\ 15^m$ | 0·540 | *0·00 | +0·060 |
| 4 45 | 0·575 | 0·50 | +0·025 |
| 5 23 | 0·597 | 1·13 | +0·003 |
| 7 00 | 0·630 | 2·75 | −0·030 |
| 12/7, $7^h\ 39^m$ | 0·718 | 15·40 | −0·118 |
| 5 29 | 0·743 | 25·23 | −0·143 |
| 13/7, $8^h\ 30^m$ | 0·779 | 40·25 | −0·179 |

Glass-hard rod replaced by a soft steel rod, viz: No. 40, annealed, 450°, $1^h$, $2\rho=0{\cdot}127^{cm}$.

| Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ |
|---|---|---|---|
| 13/7, $10^h\ 04^m$ | 0·876 | *0·00 | +0·004 |
| 12 30 | 0·886 | 2·43 | −0·004 |
| 5 05 | 9·890 | 7·02 | −0·010 |
| 14/7, $8^h\ 55^m$ | 0·894 | 22·85 | −0·014 |
| 14/7, $8^h\ 57^m$ | 0·248 | *0·00 | ±0·000 |
| 10 27 | 0·248 | 1·50 | ±0·000 |
| 12 45 | 0·248 | 3·80 | ±0·000 |
| 4 45 | 0·250 | 7·80 | +0·002 |
| 15/7, $10^h\ 46^m$ | 0·250 | 25·82 | +0·002 |
| 15/7, $10^h\ 46^m$ | ---- | *0·00 | ---- |
| 12 35 | 0·310 | 1·82 | −0·005 |
| 4 27 | 0·306 | 5·68 | −0·009 |
| 16/7, $9^h\ 20^m$ | 0·299 | 22·57 | −0·016 |

Original hard steel rod, No. 39, again inserted.

| Date. | $\phi\times10^3$ | $h_0$ | $\phi_0\times10^3$ |
|---|---|---|---|
| 16/7, $9^h\ 25^m$ | 0·948 | *0·00 | +0·032 |
| 11 26 | 1·009 | 2·02 | −0·029 |
| 1 45 | 1·028 | 4·33 | −0·048 |
| 5 58 | 1·052 | 8·55 | −0·072 |
| 17/7, $8^h\ 50^m$ | 1·093 | 23·42 | −0·113 |
| 12 55 | 1·102 | 27·50 | −0·122 |
| 6 04 | 1·125 | 32·65 | −0·145 |
| 18/7, $8^h\ 27^m$ | 1·151 | 47·03 | −0·171 |
| 2 28 | 1·160 | 53·05 | −0·180 |
| 19/7, $9^h\ 41^m$ | 1·185 | 72·27 | −0·205 |
| 12 20 | 1·186 | 74·92 | −0·206 |
| 5 15 | 1·186 | 79·83 | −0·206 |
| 20/7, $8^h\ 28^m$ | 1·207 | 95·06 | −0·227 |
| 20/7, $10^h\ 50^m$ | 0·458 | †0·00 | −0·062 |
| 11 18 | 0·416 | 0·47 | −0·020 |
| 11 50 | 0·396 | 1·00 | ±0·000 |
| 1 53 | 0·354 | 3·05 | +0·042 |
| 3 44 | 0·330 | 4·90 | +0·066 |
| 6 35 | 0·303 | 7·75 | +0·093 |
| 21/7, $10^h\ 02^m$ | 0·247 | 23·20 | +0·149 |
| 12 18 | 0·239 | 25·47 | +0·157 |

* Total twist $\psi_s-(-\psi_b)=180°$, twist of steel $\psi_s$, positive.

† Total twist $-\psi_s+(-\psi_b)=180°$, twist of steel, positive.

TABLE 32.—APPARATUS (tubular) V.

$R=260^{cm}$; $L=22^{cm}$. Rods: No. *f*, brass tube, $\left\{\begin{array}{l}2\rho_1=0·19^{cm}.\\2\rho_2=0·24^{cm}.\end{array}\right.$ No. 41, steel, annealed 450°, $1^h$, $2\rho=0·082^{cm}$. $Q=0·0155^{cm^2}$; $q=0·0054^{cm^2}$; $Q/q>2·5$.

| Date. | $\phi \times 10^3$ | $h_0$ | $\phi_0 \times 10^3$ |
|---|---|---|---|
| 22/7, $3^h\ 38^m$ | ---- | †0·00 | ---- |
| 3 48 | 3·602 | 0·17 | +0·032 |
| 5 39 | 3·541 | 2·02 | −0·029 |
| 7 13 | 3·518 | 3·58 | −0·053 |
| 23/4, $7^h\ 54^m$ | 3·465 | ‡16·27 | −0·105 |
| 12 02 | 3·435 | 20·40 | −0·135 |
| 23/7, $12^h\ 57^m$ | 1·026 | *0·00 | −0·074 |
| 3 37 | 1·147 | 2·67 | +0·047 |
| 24/7, $9^h\ 28^m$ | 1·289 | 20·52 | 0·189 |
| 1 03 | 1·300 | 24·10 | 0·200 |
| 4 23 | 1·307 | 27·43 | 0·207 |
| 26/7, $9^h\ 08^m$ | 1·398 | 68·18 | 0·298 |
| 12 17 | 1·409 | 71·33 | 0·309 |
| 3 58 | 1·417 | 75·02 | 0·317 |
| 27/7, $9^h\ 08^m$ | 1·433 | 95·71 | 0·337 |
| 12 38 | 1·437 | | |
| 4 13 | 1·441 | | |
| 28/7, $9^h\ 32^m$ | 1·476 | 120·14 | 0·392 |
| 1 18 | 1·498 | | |
| 4 26 | 1·502 | | |
| 29/7, $9^h\ 04^m$ | 1·511 | 143·86 | 0·417 |
| 12 48 | 1·518 | | |
| 4 33 | 1·521 | | |
| 30/7, $9^h\ 01^m$ | 1·651 | *167·90 | 0·533 |
| 1 15 | 1·654 | | |
| 4 16 | 1·660 | | |
| 31/7, $9^h\ 54^m$ | 1·671 | 191·94 | 0·572 |
| 12 44 | 1·672 | | |
| 4 03 | 1·672 | | |
| 2/8, $9^h\ 04^m$ | 1·689 | 239·95 | 0·592 |
| 1 27 | 1·692 | | |
| 4 11 | 1·695 | | |
| 5/8, $1^h\ 42^m$ | 1·727 | 338·63 | 0·627 |
| 5 27 | 1·727 | | |

* Adjusted anew. † Total twist $\psi_s-(\psi_b)=180°$, twist of steel positive.
‡ Total twist $-\psi_s+(+\psi_b)=180°$, twist of steel, negative.

TABLE 34.—APPARATUS III.

$R=370^{cm}$; $L=26^{cm}$; $l<0·2^{cm}$. Rods: No. 51, soft, $\psi=-180°$; No. 52, annealed 450°, $\psi=+180°$. $2\rho=0·082.^{cm}$

| Date. | $\phi \times 10^3$ | $h_0$ | $\phi_0 \times 10^3$ |
|---|---|---|---|
| 20/8, $12^h\ 35^m$ | * | 0·00 | * |
| 12 50 | 0·291 | 0·25 | −0·004 |
| 6 44 | 0·306 | 6·15 | +0·011 |
| 21/8, $9^h\ 07^m$ | 0·314 | 20·53 | 0·019 |
| 5 00 | 0·311 | 28·42 | 0·016 |
| 21/8, $5^h\ 15^m$ | † | 0·00 | † |
| 5 25 | 0·546 | 0·16 | −0·002 |
| 7 08 | 0·551 | 1·88 | +0·003 |
| 22/8, $9^h\ 57^m$ | 0·556 | 16·70 | 0·008 |
| 6 54 | 0·561 | 25·65 | 0·013 |
| 23/8, $9^h\ 08^m$ | 0·561 | 39·88 | 0·013 |
| 5 37 | 0·561 | 48·36 | 0·013 |
| 24/8, $9^h\ 18^m$ | 0·581 | 68·00 | 0·033 |
| 5 13 | 0·581 | | |
| 25/8, $9^h\ 05^m$ | 0·581 | 92·80 | 0·027 |
| 7 01 | 0·568 | | |
| 26/8, $9^h\ 10^m$ | 0·568 | 115·40 | 0·014 |
| 4 08 | 0·556 | | |
| 27/8, $9^h\ 10^m$ | 0·548 | 144·13 | −0·009 |
| 7 36 | 0·530 | | |
| 28/8, $9^h\ 20^m$ | 0·530 | 164·87 | −0·023 |
| 6 55 | 0·520 | | |
| 29/8, $10^h\ 12^m$ | 0·515 | 188·99 | −0·037 |
| 6 17 | 0·507 | | |
| 30/8, $9^h\ 11^m$ | 0·505 | 207·93 | −0·043 |

* Adjusted $\tau-b-f$. † Re-adjusted $\tau+b+f$.

We have not yet made the tubular apparatus as sensitive in its indications as is the bifilar. The results are nevertheless sufficiently sharp and pronounced and are cited here for their important bearing in the inferences to be drawn for steel. Fine glass tube is to be preferred to brass.

## DISCUSSION.

*Viscosity and temper.*—1. The results of tables 1 to 26 may be discussed in two ways: We may either accept some definite and applicable law like that of Weber or of Kohlrausch, and calculate the mean constants for each set of results; or we may construct them graphically and then calculate the coördinates of the mean curve for each set. The latter is decidedly the better way, because it is less arbitrary and more convenient. In table 33 the mean results in question are thus summarized. The first three columns indicate the tables from which in each case the selections are made, the rods selected, and their tempers. The remaining columns contain the differences of viscous detorsion, $\varphi_0$, in radians per centimeter of length of the bifilar, one of the wires of which is invariably glass-hard, the other annealed as stated. $\varphi_0$ is arbitrarily fixed at zero, for one hour after a twist of +180° and −180° has been imparted to the soft and hard wire, respectively.

TABLE 33.—*Digest of the mean results, Tables 1 to 26.*

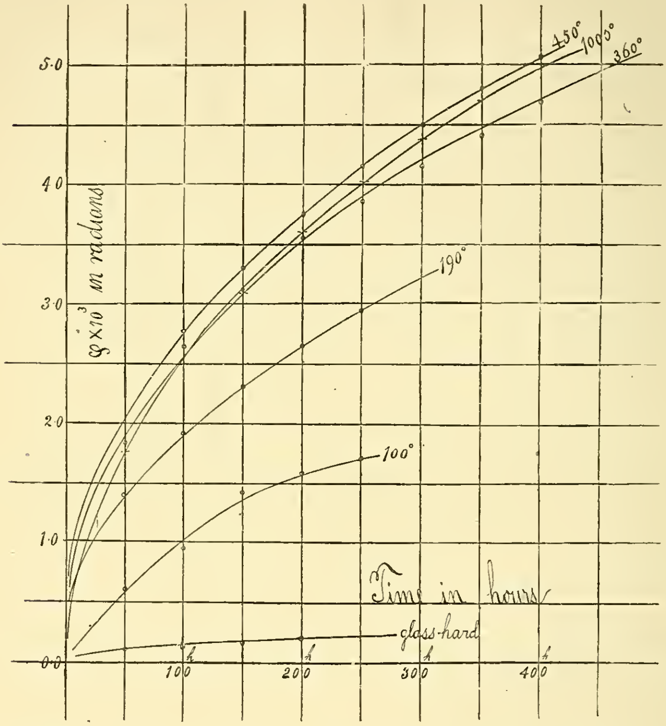
| Table No. | Rods Nos. | Annealed at | $\phi_0 \times 10^3$ in radiaus per centimeter of length at | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $50^h$ | $100^h$ | $150^h$ | $200^h$ | $250^h$ | $300^h$ | $350^h$ | $400^h$ |
| 1, 2 | 1, 2<br>47, 43 | 20°, $\infty^h$ (glass-h'd) | 0·08 | 0·11 | 0·15 | 0·19 | ---- | ---- | ---- | ---- |
| 5A, 6A, 7, 8 | 3, 4, 5, 6, 7, 8<br>9, 10, 43, 44,<br>45, 46 | 100°, $10^h$ | 0·59 | 0·96 | 1·41 | 1·58 | 1·71 | --- | ---- | ---- |
| 10, 13, 13A, 14 | 11, 12, 13, 14<br>15, 16, 19, 20 | 190°, $1^h$ | 1·38 | 1·89 | 2·27 | 2·63 | 2·95 | --- | ---- | ---- |
| 16, 18 | 17, 18<br>21, 22 | 360°, $1^h$ | 1·80 | 2·61 | 3·13 | 3·53 | 3·84 | 4·14 | 4·42 | 4·70 |
| 19, 20 | 23, 24<br>25, 26 | 450°, $1^h$ | 2·01 | 2·76 | 3·31 | 3·75 | 4·14 | 4·49 | 4·80 | 5·07 |
| 23, 24, 25, 26 | 27, 28, 29<br>30, 31, 32<br>33, 34 | 1000° | 1·76 | 2·51 | 3·10 | 3·61 | 4·04 | 4·40 | 4·67 | ---- |

All radii identically $2\rho = 0{\cdot}082^{cm}$. Like signs of $\phi$ and of $\psi$ refer to the same angular direction.

The results of table 33 are graphically constructed in figure 3, time in hours as abscissa, difference of angular detorsion $\varphi_0$, in radians, as ordinate.

Table 23 and figure 3 lead to this curiously remarkable result: If we abstract for the moment from the states of temper extreme hard and extreme soft, *the viscosity of steel decreases in proportion as the hardness of the metal increases.* We call to mind here that the torsion imparted was not sufficiently large to produce marked permanent set. If we express its intensity by

3.



$(0{\cdot}4E)\frac{\pi\rho^4}{2L}\phi$, and introduce the constants of the apparatus

$$\phi=\pi,\ L=30^{\mathrm{cm}},\ 2\rho=0{\cdot}082^{\mathrm{cm}},$$

we find that the moment of the applied torsion couple did not exceed 0·5 kg. on centimeter of arm. (Cf. remark on stress value, p. 30.) If following Sir William Thomson,* we agree that "the molecular friction in elastic solids may properly be called viscosity of solids," then our deduction may be stated, *the molecular friction in case of steel is greater in proportion as the metal is softer.*† Examples of such relations in divers substances are not unknown. Hard steel as regards viscosity and

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* Thomson: l. c., or Thomson and Tait, Natural Philos., II, p. 303, 1883. Our present conception of the viscosity of liquids, as well as the hypotheticated proportionality of frictional resistance and velocity were introduced by Newton (Principia, L. II, Sect. ix, "resistentia quæ oritur ex defectu lubricitatis").

† Degrees of thermo-electric hardness are here specially in place. Cf. U. S. Geolog. Survey, Bull. 14, p. 65.

hardness may be typified by sealing-wax; soft steel by tallow.* Nevertheless the continuous variations of these properties exhibited by steel is as unique as it is striking. Indeed we felt diffidence in reporting this result and have taken pains to substantiate it.

The motion of the bifilar body of the above apparatus can be interpreted from two standpoints: Either it is due to the torsional couple and the result of viscous yielding of the harder wire relatively to the softer; or it may be due to the bifilar and flexural couple and is then the result of viscous yielding of the softer wire relatively to the harder (xxxii, p. 466). But the bifilar and flexural couples have been proved to be zero and to produce a zero effect. Hence the inference above italicized is alone admissible. Again, in the bifilar apparatus where steel is twisted against glass (table 28) the soft steel is demonstrably more viscous than glass. Hard steel, as shown by its behavior with the same fibre, is less viscous than soft steel. We do not wish to say that it is less viscous than glass because the sectional area of the latter fiber is larger. Again, in table 31, which contains the data obtained with the tubular apparatus, soft steel yields viscously at about the same rate as the brass tube of more than *four* times the sectional area of the steel wire. Hard steel under the same circumstances yields at a very much greater rate than brass.

Our results for degrees of hardness higher than "Annealed 100°, $10^h$" are to be regarded incomplete because of the magnetic importance of those degrees. As steel passes in hardness from "Annealed 450°" to "Annealed 1000°" (soft), it probably marches through pronounced maximum viscosity. This result is pretty clearly indicated by table 33 and figure 3. Here also the results are to be regarded incomplete because of the magnetic importance of the (soft) degrees of hardness in question. Our methods of annealing between 500° and 1000° are not as yet satisfactory.

2. If we compare the results of table 33 or of fig. 3 with the known thermo-electric behavior† of steel wires, we detect a very striking similarity in contour and position of corresponding members of the viscous and thermo-electric families of curves. Both phenomena practically subside in the first phase of annealing; the effect of temperature becomes rapidly less as higher degrees are approached.

3. The relations between hardness and viscosity here encountered may perhaps be conceived somewhat as follows: Suppose stress to be so distributed in a solid that its applica-

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* These examples (tallow, sealing wax) are given by Maxwell: Heat, p. 296, Appleton, N. Y., 1883.

† U. S. Geol. Survey, Bull. 14, pp. 54, 55.

tion at any interface is nowhere sufficient to produce rupture. Then that property of a solid in virtue of which it resists very small forces (zero-forces) acting through very great intervals of time ($\infty$-times) may be termed the viscosity of the solid. That property in virtue of which it resists the action of very large forces ($\infty$-forces relatively) acting through zero-time may be termed the hardness of the solid. Since the application of forces in such a way as accurately to meet either of these cases is rare, we have in most practical instances mixtures of viscous resistances and of hardness to encounter. We may reasonably conceive that in the case of viscous motion the molecules slide into each other or even partially through each other per interchange of atoms, so that the molecular configuration is being continually reconstructed; that in the other case (hardness) the molecules are urged over and across each other and that therefore the intensity of cohesion is in this case more or less thoroughly impaired. The interpenetration of the molecules of a viscous substance is necessarily favored by temperature. Hence we infer the experimental result that the viscous influence of temperature is marked. If Clausius's theory of electrolysis be correct, then a certain instability or imperfect uniformity in the molecular structure of solids follows at once from the fact that many solids, notably glass,* may be electrolyzed even at moderately high temperatures (300°).

4. The stored torsional stress imparts a strain to the solid. Viscous detorsion therefore is accompanied by a residual phenomenon. The observed deformation will continue until the applied tendency to change of form is reduced in value to the evoked and increasing tendency against change of form. If the applied stress be removed, the reciprocating stress becomes apparent and produces viscous effects of its own kind, as Kohlrausch has shown. The result has many magnetic and electrical analogies, among which the phenomenon of residual static charge is most obvious. In the tubular apparatus (table 31), the residual deformation of the preceding twist may be superimposed on the deformation immediately in progress. Whether the two residual phenomena here annul each other so that the primary detorsion is alone exhibited remains to be seen.

In liquids there is no such reaction unless it be the reciprocating force of galvanic polarization. In polarization, however, the mechanism is of an obviously chemical kind. In solids it is believed to be not chemical.

*Sectional areas of bifilar wires.*—The essential peculiarity of the bifilar apparatus is this, that the two wires are twisted by

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* Warburg: Wied. Ann., xxi, p. 622, 1884. Literary notes are there given. Warburg is able to replace $\frac{6}{7}$ of the sodium of glass by sodium of the anode.

identical couples.* The absolute value of these couples during the experiment remains constant to 2 or 3 per cent. If the sectional areas of the wires be identical our apparatus leads to results which come very close to Newton's definition of viscosity. Newton suggested that the internal friction of liquids is *cæt. par.* directly proportional to the difference of velocity between nearly contiguous surfaces. In the bifilar apparatus the torsional viscosities of two substances are equal if for identical strains and equal sectional areas torsional change of form occurs at like rates per unit of length This is the condition of rest or zero-motion of the suspended body.

We do not at present wish to do more than advert to an important deduction here: it is obvious that if the sections of the wires be so chosen that the motion of the bifilar body is zero, the viscosity of the wires must be inversely related to those sections. This principle apparently enables us to arrange solids in a scale of viscosity. We may formulate it approximately thus:

Consider an elementary ring of either wire, whose height is $dz$ and whose right sectional area is $2\pi rdr$. Let $df$ be the amount of tangential force uniformly distributed over this area. At the time $t$ let the velocity of the upper surface relatively to the lower be $cr$, where $c$ is a time-function and *cæt. par.* a characteristic of the viscosity of the wire. Then if $\mu_t$ be the coefficient of viscosity at the time $t$ we have

$$df = \mu_t \frac{cr2\pi rdr}{dz} = 2\pi\mu_t \frac{cr^2}{dz} dr$$

If we multiply by $r$ and then integrate between zero and $\rho$ (thickness $= 2\rho$), the numerical result is the part of the impressed torsional couple which corresponds to the length $dz$. A similar integral holds for the other wire, to distinguish which it is merely necessary to accentuate $f$, $\mu_t$, $c$, $r$, $\rho$, The sum of the two integrals is zero. If, moreover, we put $c=c'$ in view of the state of rest of the bifilar body, we find that the viscosities ($\mu_t$, $\mu'_t$) of the two substances (wires) are to each other inversely as the squares of the respective sectional areas by which the motion of the bifilar suspension is annulled.

Unfortunately the problem is much more complex than it here appears. The dependence of torsional deformation on time in case of a single wire is obviously related to the character of the molecule. When two different substances in wire form are twisted bifilarly against each other, the effect will

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* Many years ago we compared the longitudinal resilience of hard and soft steel by fastening one end of thin wires in a vise and bending them with a weight applied at the other. We found but insignificant differences. Hence the stored torsions of two steel wires, hard and soft, produced by equal couples are *cæt. par.* of equal angular value.

rarely be such that the torsional yieldings continually equalize each other, no matter what relations of section may be chosen. The motion-curve of the bifilar-suspension will show maxima or even points of circumflexion, such as have been actually encountered in tables 28, 29, 29A, and the definition of relative viscosities of the two wires will become correspondingly involved.

Again, $\mu_t$ for solids is not merely a function of time but very essentially a function of stress. Above we show (xxxii, p. 452) how by simply adjusting the lengths of the bifilar wires, viscosities may be compared at a given temperature, as time-functions with identical values of the parameters stress, strain (sectional area). We do not believe that viscous detorsion in this full relation has ever been rigidly investigated. The results would lead to families of curves.

Given a quadrifilar arrangement of four viscously identical wires. Let the twist $\phi_{12}$ be stored between any two of them and then let the twist $\phi_{12,34}$ be additionally stored between these two as one, and the third and fourth wire as one. Such a device enables us in the above way to study viscosity in its simple dependence on strain, for all values of stress. We have not, after some searching, been able to find definite evidence of a viscous strain-effect.

*Viscosity and strain.*—1. When we commenced the present research a comparison of the viscosity of glass and steel appeared desirable. In tables 27 and 28 such comparisons have been attempted, though we regret that our available time has not permitted us to pursue them further. In table 27, the sectional area of glass fiber is less than that of steel wire; nevertheless the viscous yielding of the fiber is so much more rapid than that of the wire, that we may reasonably infer degrees of viscosity of the same order in the two substances. In table 28, the sectional area of glass exceeds that of steel. Hence these data prove that the torsional viscosity of annealed steel is greater than that of glass. The viscosity of hard steel during the first ten hours of detorsion is certainly very much greater than that of glass. During the remainder of the time it is decidedly less. The curve passes through a maximum for which point the rates of viscous detorsion of glass and of glass-hard steel exactly coincide. Since the sectional area of glass is greater, we safely infer that the viscosity of glass is not uniformly greater than that of glass-hard steel. It is well to call to mind, however, that the sum of the torsions is here only $\phi_s+\phi_g=90°$. Moreover, since for equal couples and dimensions $E_g\phi_g=E_s\phi_s$, where $E$ is Young's modulus* of resilience for

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* To obtain an estimate it is sufficient to accept the same ratio of modulus of torsion to modulus of longitudinal resilience for each case. Poisson's ratios for glass and steel are about as 26 to 30.

glass and for steel respectively and $\psi$ the corresponding torsion; and since $E_g/E_s=1/3$ approximately, it appears that $\psi_g=3\psi_s$ nearly. Hence for equal stresses, strains are thoroughly unequal, and in the same measure are these comparisons not thoroughly just. Cf. xxxii, p. 30.

2. A similarly important desideratum is the comparison of the viscosities of steel and of iron. In tables 29, 29A and 30 such comparisons are made, though further results are not superfluous. It appears distinctly that during the first five or ten hours of detorsion the viscosity of iron is in a strikingly pronounced manner less than that of steel. As detorsion continues the viscosity of soft iron continually remains below that of steel, whereas the viscosity of drawn iron grows temporarily greater than steel but finally reaches the same value. In this case the motion-curve passes through an exceedingly sharp maximum, at which the viscous yielding of iron and of steel occurs at like rates. Having exhibited greater viscosity in drawn iron it finally, per circumflexion, merges into a horizontal asymptote, which probably indicates subsidence of motion in each wire. These unexpected results show that the viscosity of steel is not uniformly greater than that of iron. Obviously glass-hard steel for the given stress is very much less viscous than iron.

The sum of the twists is here nominally $\psi_s-(-\psi_i)=360°$. Particularly in the case of soft iron its efficient value is very decidedly less, however. The applied torsion carries the iron wire much beyond the limits of elasticity; and so much of the stress vanishes instanter that the "after-action" subsides within relatively small limits. The viscosity of (soft) iron is either less or greater than that of hard steel according as the applied torsional stress surpasses or falls below a certain critical value. This result again shows the importance of stress-measurement, as a means of coördinating the lingering of purely viscous deformation and the instantaneous (?) deformation.

In the above results the curvature of the (absolute) motion curve for a *single* wire increases uniformly from hard steel to soft steel; increases, moreover, from soft steel to iron. Curvature is greater in the glass curve than in hard steel curves. So far as we have observed (steel, iron, glass) viscous deformation occurs more nearly at uniform rates (linearly) in proportion as hardness is greater. Curvatures for early time are meant, the later parts of curves being asymptotes.

3. The remarks just made on the viscosities of glass and iron suggest this plausible inference: if glass and steel be alike subjected to a stated process of quenching, and if after the operation has been performed glass be found to have retained a very high intensity of strain (Rupert's drop), then, *a fortiori*, steel,

the substance of greater viscosity, must have retained a similarly high intensity of strain. This reasoning, however, is incomplete and must be approached with caution. We pointed out* that the low degrees of thermal conductivity possessed by glass were favorable to the retention of strain. We also remarked† that the occurrence of Gore's phenomenon of sudden expansion at red heat distinguished iron and steel from all other metals, and that in spite of relatively good thermal conductivity, iron and steel possessed virtually all the favorable conditions of glass for retaining strain. Whether differences of viscosity are sufficient to account for the unlikeness of behavior during quenching we are unable to say. It will be necessary to compare iron and steel at higher than ordinary temperature and also under greater values of applied stress than was easily feasible in the above experiments. In other words, iron and soft steel are nearly equally viscous for small values of stress. After stress exceeds a certain intensity, the permanent set suddenly imparted to iron is enormously great as compared with steel. Similar relations are true for soft steel when compared with hard steel. It is this class of "sudden" phenomena which come into play during quenching. The primary effect of quenching steel is chemical hardness. Strains are retained in the steel so modified, just as they are in glass; whereas in soft steel or soft iron the result would be permanent set. The occurrence of sudden and gradual deformation in a single substance suggests that ordinary *static* friction is probably a viscous phenomenon.

We add in passing that the observed inefficiency of temperatures less than 200° in producing marked viscous deformation in a Rupert's drop proves that mere interference of thermal expansion with the conditions of strain cannot be the primary cause of its variations; that strain variations essentially depend on diminished viscosity.

We also add in passing that the importance of strain as associated with glass-hardness is emphasized by the mass-constants of the cast-irons. The densities of these metals‡ range between the maximum of ca. 7·6 for white cast iron and the minimum of ca. 6·9 for gray cast iron. Hence density increases in marked degree in proportion as total carbon is more and more nearly combined. Quite the reverse of this is true for steel where density decidedly decreases as total carbon is more and more nearly combined. This discrepancy we interpreted as a strain of dilitation and carefully compared it with the analogous behavior of glass in our earlier papers

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* This Journal, xxxi, p. 451, 1886.

† Bull. 14, p. 99.

‡ Cf. Bloxham's Chemistry, p. 342, Lea, Philad., 1873. Bull. 14, pp. 76, 77.

We add finally the following data from the elastics of glass and of steel. The æolotropic expansion produced by quenching glass or steel we showed elsewhere[*] to amount to 0·005. The volume resilience of glass and of steel, according to Professor Everett's measurements,[†] is $4\times10^{11}$ and $2\times10^{12}$ respectively. Hence if per square centimeter $p$ be the stress-value for the given expansion, we find aproximately $p=10\times10^9$ dynes for steel and $2\times10^9$ dynes for glass. Now per square centimeter the tenacity of steel is $8\times10^9$ dynes; the tenacity of glass $0·6\times10^9$ dynes. The approximate ratio of stress to tenacity is therefore estimated at 1·3 for steel and 3·3 for glass. This shows that in both cases stress and tenacity are of the same order; that stress is in excess; that but for the peculiarly favorable, symmetrically arched structure of the quenched globule, rupture would ensue in glass certainly; probably also in steel. This accords with the explosive tendency of a P. R. drop and with the less pronounced liability of steel to crack on quenching.[‡] If therefore quenched glass and quenched steel are under mean stress intensities of several thousand atmospheres, then in discussing the corresponding viscous properties they must be brought into relation with these high values of peculiar stress.

*Magnetic relations.*—1. If again we abstract from the extreme states of hardness, we find that both the viscosity and the moment of linear magnetization per unit of mass, of a permanently saturated steel rod, increase in marked degree from hard to soft. This is a singularly striking result, inasmuch as the conditions of magnetic stability (following Hopkinson we shall call them coercive force), conditions which at first sight we would be inclined to associate with viscosity, decrease as viscosity increases. Hence permanently saturated linear magnetic intensity and viscosity on the one hand, magnetic stability or coercive force and hardness on the other, seem to belong together.

2. The minimum of permanent linear intensity of saturated steel rods has no viscous equivalent; but we have not yet studied the viscosity of extremes of hard steel minutely, nor have we as yet sufficiently sharp data for the magnetization of very long rods (length/diameter$>$100) in its relation to temper. In the extreme soft region, on the other hand, the occurrence

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[*] This Journal, xxxii, pp. 190, 191, 1866. By æolotropic expansion we refer to the part of the total expansion which produces explosiveness and the polariscopic phenomenon.

[†] Everett: Phil. Trans, p. 369, 1866. The above numbers are rounded from Everett's values.

[‡] Mr. J. M. Batchelder has just communicated to us his interesting results (Journal Franklin Inst., (3) viii, p. 133, 1844), in which of twelve massive pieces of quenched steel, eight subsequently cracked and one actually exploded.

of a unique maximum of magnetization seems certainly to be coincident with the occurrence of maximum viscosity. The magnetic maximum so far as our results go is apparently much more clearly pronounced than the viscous maximum. We remark in general that as the ratio of length to diameter increases, the minimum of permanent magnetization shows a tendency to move from soft to hard. Furthermore, it is proved that the permanent magnetization of soft rods is greater in proportion as they are more and more nearly linear.* Hence as our march approaches the linear limit we observe an unmistakable tendency toward more detailed similarity between the variations of the magnetic and the viscous properties of steel.

Mr. Hopkinson† in his memoir on the magnetization of iron introduces a definition of coercive force, defining it as "that reversed magnetic force which just suffices to reduce the induction to nothing after the material has been subjected temporarily to very great magnetizing force." There is a slight objection to this definition, inasmuch as it introduces a somewhat vaguely complex state of zero-magnetization.‡ But the feature in question is as hard to improve as the definition is valuable. Mr. Hopkinson's extensive experiments show that coercive force is invariably increased by hardness. Together with others we have proved that hard steel is alike well adapted to withstand the influence of percussion.

3. These general relations between viscosity and maximum permanent linear intensity observed for steel are sustained by iron. According to data contained in a paper of the lamented Dr. L. M. Cheesman§ the permanent magnetization of drawn iron exceeds that of soft iron. The magnetic intensity of permanently saturated drawn iron is comparable with that of soft steel and quite equal to that of hard steel. More recently and even more elaborately Ewing has discussed the subject. He finds "in the absence of mechanical or other disturbance, soft iron is far more retentive than either hard iron or steel," an exceedingly remarkable result.‖ Our experiments show that the intensity of applied stress is an important factor in determining the viscous behavior of iron; that for moderate

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* Bull. 14, pp. 240 to 143.

† Hopkinson: Phil. Trans., ii, 463, 1885.

‡ The unmagnetic state, though dependent on the details of the process of tempering, is a distinct magnetic state. Similarly we may regard the saturated magnetic state, though allowance must here be made for the occurrence of cyclic magnetization, a phenomenon suggested by Fromme (Wied. Ann., iv, p. 89, 1878) and (Wied. Ann., xiv, p. 308, 1881), concisely interpreted by Warburg (Wied. Ann., xiii, p. 141, 1881) and which Ewing (Phil. Trans., ii, p. 545, 1885) has recently discussed generically under the name of "hysteresis."

§ Cheesman: This Journal, xxiv, p. 183, 1882. Lengths 100 diameters and less.

‖ Ewing: l. c., p. 541.

stress values it *ultimately* approaches very closely to or even exceeds the maximum viscosity of steel; that it is much greater than the viscosity of hard steel.

4. With these accordances before us, we may venture a final suggestion. The viscosity of iron increases with great rapidity with the amount of deformation. For a certain interval of (low) values of applied torsional stress it even exceeds the maximum viscosity of steel. Hence if there be an inherent bearing of viscosity on retentiveness, there is given us in iron a condition of magnetic instability: if relatively to the (decreasing) amount of deformation or of magnetization viscosity decreases rapidly, then a mere shock may at once deprive the magnet of the whole of its induction. The retarded curvature of the steel curves (tables 1 to 26) does not invalidate this inference, since retardation is here an expression of the fact that the absolute amount of change of form for each rod decreases as time increases.

We do not wish to push these inquiries into further detail at present because we have experiments with iron now in progress. Nevertheless we invite the reader to peruse for comparison Mr. Ewing's magnetic results as summarized by him, l. c., pp. 562, 563.

*Conclusion.*—Among the chief results of this paper is the light thrown on the crucial importance of the physical changes which steel undergoes during annealing at high temperatures, i. e. when subjected to the action of temperatures between 500° and 1000°. It is within this interval that a variety of nearly coincident phenomena occur: Gore's* sudden volume expansion; Tait's† sinuously broken thermoelectric diagram-line; we infer an irregular behavior of electrical resistance; Gore-Baur's‡ sudden disappearance of magnetic quality; the passage of carbon from uncombined to combined; Jean's§ critical cementation temperature. Furthermore, Chernoff-Barus'‖ sudden appearance of hardness in quenched steel, Fromme's¶ maximum density, Chwolson's** minimum resistance, our own unique maximum of magnetization†† and probable maximum of viscosity, are all referred to this interval, approximately to the

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* Gore: Proc. Roy. Soc., xvii, p. 260, 1869.

† Tait: Trans. Roy. Soc., Edinburgh, xxvii, 1872–73, p. 125.

‡ Gore: Phil. Mag., IV, xxxviii, p. 59, 1869; Baur. Wied. Ann., xi, p. 408, 1880; Ibid., xl, p. 170, 1870.

§ Jeans: "Steel, its history, etc." London, Spon, 1880.

‖ Chernoff: Vortrag. geb. in der Russ. techn. Ges., April and Mai, 1878. Barus: Wied. Ann., vii, p. 405, 1879.

¶ Fromme: Wied. Ann., viii, p. 354, 1879. We were unable to find Fromme's maximum: but we shall search again. All these results are crucially dependent on the method of annealing, as stated in the text.

** Chwolson: Carl's Rep., xiv, p. 26, 1878.

†† Barus and Strouhal: U. S. Geol. Survey, Bull. 14, pp. 145, 198.

same temperature. To determine the interdependence of these important phenomena it is obviously first necessary to devise methods of operating on steel adapted to the interval in question. In other words, our introductory problem is the annealing of steel without oxidation and without carburation, at measured (high) temperatures, during stated times. It is in this direction that we propose to have our investigation proceed.

Washington-Prague, September, 1886.

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## Art. IV.—*The nature and origin of Lithophysæ and the lamination of acid lavas*;* by Joseph P. Iddings.

The Yellowstone National Park with its thousands of square miles of rhyolitic lavas, presents a splendid field for the study of the various forms of structure and crystallization assumed by acid lavas in cooling. And it is the investigation of these phenomena, observed while prosecuting the work of the U. S. Geological Survey within this region in charge of Mr. Arnold Hague, that has furnished the writer with the data upon which the conclusions here stated are based.

Among the many phases of crystallization so richly developed in the rhyolitic obsidian forming Obsidian Cliff, the most characteristic is the spherulitic, producing spherulites from microscopic dimensions to several inches in diameter. They are crystalline bodies with a radially fibrous structure, which is often accompanied by a banding in concentric layers of different color and density. In thin section under the microscope they are seen to be composed of sectors of fibers, which between crossed nicols do not extinguish the light parallel to the length of the fibers which would produce a distinct shadow-cross, but at different angles, making many rays of shadow, which in the smallest spherulites frequently approach the form of a cross. These spherulites have been traced through gradations of microstructure to groups of granophyre feldspars of extreme minuteness, which appear to be composed of intergrown quartz and acid feldspar, and enclose trichites and microlites which also occur in the spherulites, so that the mineral composition of the spherulites is most probably quartz, acid feldspar and trichites of magnetite with augitic microlites. Chemical analyses of the spherulites and the obsidian in which they occur show that the two are identical, and that a spherulite is only a particular form of crystallization of the once molten glass. The largest spherulites have an earthy texture and in thin section

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* Extract from article to appear in the Seventh Annual Report of the Director of the U. S. Geological Survey; published by permission of the Director.

are seen to be made up of jointed fibers composed of microscopic feldspar crystals; between these fibers are scales of tridymite with scattered grains of magnetite and microlites, besides innumerable gas cavities. Frequently the tridymite is aggregated into pellets which enclose several feldspar fibers, leaving quite porous spaces between. The centers of these larger spherulites often have the same structure as the smaller spherulites, and the fibers of one appear to be continued into the other, but to have formed under somewhat different conditions, since the cementing mineral is quartz in one case and tridymite in the other.

In the porous portions of the large spherulites, intergrown with the feldspar fibers and appearing to be of later crystallization is an occasional individual of yellow iron-olivine or fayalite. So that the association of minerals here developed, tridymite, acid feldspar and fayalite, is quite an uncommon one for an igneous rock.

The spherulites are frequently so porous as to be hollow in places. Sometimes a large cavity is situated in one side of a radially fibrous spherulite. In this case the fibers project into the cavity and are distinctly visible without the aid of a magnifying lens, the pellets of tridymite being also recognizable. The cavity may be near the circumference of the spherulite and adjoining the enclosing matrix, or lie nearer the center leaving a dense periphery or crust like the rind of a melon. This is the more usual form. Very often the central portion appears to have shrunken and cracked apart, the surface markings on the opposite sides of the gaping cracks corresponding exactly, and showing that the walls had once been united in a continuous mass. Another variety has the cavities in concentric layers, with delicate partition walls between them forming thin concentric shells. When these have been developed in a lava to which there is a laminated structure, marked by layers of microlites and other forms of crystallization, the concentric shells of the hollow spherulites are traversed by thin layers of crystals in continuance of the lamination in the matrix.

The large hollow spherulites are generally hemispherical, and the concentric shells and cavities produce very beautiful structures, which when broken across present roselike centers surrounded by delicate encircling rings. These forms are especially characteristic of the lithoidal portion of the obsidian flow at Obsidian Cliff and are the typical structures which have been called *lithophysæ* by von Richthofen* because they appear to have been inflated by expanding gas, the word being derived

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* "Studien aus den ungarisch-siebenbürgischen Trachytgebirgen." Jahrb. d. k. k. geol. Reichsanst., 1860, p. 180. Also, The Natural System of Volcanic Rocks, San Francisco, 1868, p. 14.

from *λιθος*, a stone, and *φυσα*, a bubble. The term applies equally well to all the concentrically chambered varieties, and may be extended to all forms of hollow spherulites.

The substance of the lithophysæ occurring at Obsidian Cliff is usually light colored and distinctly crystalline with a beautiful frosted appearance. It is made up of minute crystals in well developed forms, which in places attain a considerable size, from 1 to $2^{mm}$. The minerals recognized are: quartz and tridymite, feldspar, fayalite and magnetite. The feldspar in some cases has the crystal habit of adular, and in others is in thin tabular crystals with the simplest combination of faces, flattened parallel to the base. They appear to hold an anomalous mineralogical position, being soda-orthoclase in composition (Al, Or,) and having the crystallographic habit of sanidin but an asymmetric optical character. The fayalite was described in this Journal for July, 1885. It appears to be identical in crystal form with the mineral occurring in the lithophysæ of the obsidian of Cerro de las Navajas which was measured by Gustav Rose,* and determined to be olivine in 1827. The angles and habit of the crystals figured by him are almost identical with those obtained by Mr. S. L. Penfield from the fayalite at Obsidian Cliff, and it is highly probable that the mineral determined by Rose is also an iron olivine or fayalite. The magnetite occurs as microscopic grains and crystals.

Since the first application of the term lithophysæ to these hollow, chambered structures, and the expression of von Richthofen's views as to their probable mode of formation, petrographers have discussed their origin, wandering more or less from the position first held by von Richthofen, and it is with the belief that the material on which these recent observations have been made furnishes better ground on which to build a theory of the origin of lithophysæ than any heretofore studied, that the writer has endeavored to throw some light upon so obscure a subject.

It was von Richthofen's† opinion, expressed in the year 1860, that the concentric shells were produced while the rock was in a molten or plastic condition, by the expansion of gas bubbles which were successively disengaged from certain portions within the mass, in consequence of the diminution of pressure accompanying the eruption of the lava. The gases which were in large part aqueous, having most likely been absorbed, thereby forming a hydrated glass. He considered lithophysæ as quite distinct from spherulites, and suggested that only careful chemical analyses would settle their true nature.

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* "Ueber den sogenannten krystallisirten Obsidian." Pogg. Ann., 1827, Band 10, pp. 323–326.

† Loc. cit.

Six years later Dr. Joseph Szabó* expressed the opinion that lithophysæ were only a stage in the mechanical and chemical alteration of spherulites, the bases being removed by chemical means, the insoluble particles mechanically, and silica being concentrated in the cavity.

In the same year Karl von Hauer† published the analyses of four rhyolites and the lithophysæ contained in them, which showed that the chemical composition of the lithophysæ and rhyolites were the same. He therefore held to von Richthofen's view that the cavities were the result of expanding gases, but thought that these gases had no metamorphosing action on the groundmass of the rock. Later on Justus Roth‡ adopted Szabó's views and recently repeated them in the second volume of his Algemeine und Chemische Geologie.

Dr. Ferdinand Zirkel§ in 1876 described certain spherulites in the rocks from Shoshone Mesa, Idaho, which "have developed by decomposition a hollow concentric layer structure." These he considered the same as the lithophysæ of von Richthofen and that they in like manner were only the result of chemical alteration.

Dr. Ch. E. Weiss‖ in 1877 suggested that the cavities of hollow spherulites play the same rôle as a solid body around which a spherulite forms, that the chambered spherulites were caused by several gas bubbles being near together when the spherulites were developed.

Mr. Grenville A. J. Cole,¶ in a paper recently published, concluded that the hollows are due to the decomposition of solid spherulites by chemical agents, the material having been carried out through cracks in the rocks.

Mr. C. A. Tenne,** in describing the lithophysæ in the obsidian of Cerro de las Navajas, Mexico, says that the substance of the lithophysæ must be devitrified obsidian, and gives chemical analyses which show that both have the same chemical composition.

Mr. Whitman Cross,†† in a paper "On the Occurrence of Topaz and Garnet in Lithophysæ of Rhyolite" points out the fact that these minerals are not of secondary formation in the cavities, but primary, "produced by sublimation or crystallization from

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* "Die Trachyte und Rhyolite der Umgebung von Tokaj." Jahrb. d. k. k. geol. R.-anst., 1886, p. 89.

† "Die Gesteine mit Lithophysenbildungen von Telki-Banya in Ungarn." Verhandl. d. k. k. geol., R.-anst., 1886, p. 98.

‡ "Beiträge zur Petrographie der plutonischen Gesteine, 1869, p. 168.

§ "Microscopical Petrography," Washington, 1876, p. 212.

‖ "Quarz porphyren aus Thüringen," Zeitschr. Deutsch. geol. Gesellsch., 1877, xxix, p. 418.

¶ "On Hollow Spherulites," etc. Quart. Journ. Geol. Soc., May, 1885.

** Zeitschr. Deutsch. geol. Gesellsch., 1885, p. 610.

†† This Journal, June, 1886.

presumably heated solutions, contemporaneous or nearly so with the final consolidation of the rock. The lithophysal cavities seem plainly caused by the expansive tendency of confined gases or vapors, while the shrinkage cracks in the walls and white masses of the Nathrop rock suggest the former presence of moisture."

It is seen from the foregoing that two distinct views of the origin of the cavities within the lithophysæ have been taken; one, that the hollows were of primary origin, formed while the lava was still plastic, and were due to enclosed gases or vapors. Among those who held this opinion some considered the lithophysæ as wholly distinct from spherulites, while others thought them simply hollow varieties. The second view was that the hollows had been produced in solid spherulites by chemical decomposition and alteration and were subsequent to the solidification of the lavas in which they are found. With the latter view, which may apply to some hollow spherulites in particular cases of decomposed rocks, the lithophysæ in the obsidian from the Yellowstone National Park have nothing to do. The extreme freshness of the whole rock and the absence of secondary alteration prevents the confusion which arises when these hollow forms are associated with decomposition products or subsequent metamorphism, as is the case with many ancient lavas, or even with recent ones which have been attacked by solfataric or hot spring agencies.

What, then, from a study of this exceptionally fresh and beautiful material, seems to be the most probable origin of lithophysæ, and how nearly the writer's views accord with those of von Richthofen will appear from the following considerations.

The association of fayalite, an iron-olivine, with abundant quartz and tridymite, and acid feldspar in a highly siliceous, igneous rock, containing less than two per cent of iron oxide, is quite contrary to ordinary experience and is not in accord with the generally accepted laws which appear to govern the crystallization of igneous magmas. Moreover, two of the accompanying minerals, prismatic quartz and acid feldspar, have not been reproduced artificially by simple igneous fusion, as has been demonstrated by the repeated experiments of MM. Fouqué and Michel-Lévy,* who, though successful in obtaining most of the minerals found in igneous rocks, have failed to reproduce by dry fusion quartz, orthoclase and albite in forms similar to those in which they are found in acid eruptive rocks.

On the other hand quartz, tridymite, orthoclase and albite have all been obtained artificially by aqueo-igneous processes, on heating their chemical elements in the presence of water in

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* "Synthèse des Mineraux et des Roches," Paris, 1882.

sealed tubes. The experiments of MM. Friedel and Sarasin,* upon the reproduction of orthoclase and albite are especially applicable to the case of lithophysæ. Among the forms of orthoclase produced was that of adular, also observed in the hollow spherulites. Along with orthoclase they obtained quartz and at higher temperatures tridymite. Other experiments, especially those of K. von Crustschoff,† have established the same relation between quartz and tridymite when formed in closed tubes. Tridymite being produced at a higher temperature than quartz, and frequently both occurring together within the same closed tube.

Magnesia olivine and magnetite have each been reproduced by aqueo-igneous methods, and fayalite is a common product of puddling furnaces. So that the group of minerals composing the lithophysæ in this obsidian are such as may be formed through aqueo-igneous processes.

The well-known experiments of Daubrée,‡ on the effect of superheated steam on a glass tube, have a special bearing on the question under consideration. The glass used by Daubrée differed in chemical composition from that of the obsidian, but the general nature of the results bears a striking similarity to many characteristic features of lithophysæ. The anhydrous glass was partly converted into a hydrous silicate, accompanied by considerable increase of volume; part was reduced to a white mass distinctly fibrous with a delicate banding parallel to the surface of the glass tube and across the direction of the fibres. The surface of the tube was in places warped, blistered and excoriated, and often full of cracks. There was, also, a delicate foliation parallel to the surface of the tube. Under the microscope the altered glass contained minute spherulites, microlites, and small crystals of pyroxene (diopside), and larger spherulites, probably chalcedony. The surface of the glass was covered with prismatic crystals of quartz. The transformation was wholly produced by the influence of superheated steam.

In the case of the obsidian from Obsidian Cliff, chemical analyses show a loss upon ignition of 0·66 per cent. That this loss is mostly due to water seems probable from the researches of MM. Boussingault and Damour, and others, whose very careful tests have shown the presence of water and a little chlorine in a number of obsidians. That this amount of volatile matter is sufficient to convert the dense obsidian into pumice like that on the surface of this lava flow, is shown by melting a frag-

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* Bull. Soc. Min., 1879, ii, p. 158, and 1880, iii, p. 171; also Comptes Rendus, 1881, xciii, p. 1374, and 1883, xcvii, p. 290, 294.

† Amer. Chem., 1883. Also Tscherm. miner. u. petrogr. Mitth. iv, p. 536.

‡ Etudes Synthetiques de Geologie Experimentale, 1879, p. 154 to 179.

ment of the obsidian in the flame of an oxyhydrogen blowpipe, when it becomes a greatly inflated white glass filled with gas bubbles which arise from the expansion of the liberated vapors. This shows that the gases which escaped at the surface with the formation of pumice were imprisoned in the dense obsidian which solidified lower down in the mass. As already stated, the larger spherulites are filled with multitudes of gas cavities recognizable under the microscope.

These vapors were, undoubtedly, absorbed by the molten lava before its eruption, and were the only gases which may have taken part in the production of lithophysæ, for chemical analyses of the obsidian, spherulites and lithophysæ show that they have essentially the same chemical composition. The analyses of spherulites and lithophysæ which occurred isolated in dense, unfractured obsidian are enough alike to be duplicates. The composition of both being the same, the transformation of a spherulite into a lithophysa, can only be a modification of its structure or a rearrangement of its minerals without any chemical addition or loss. Moreover, it is evident that such a transformation was in many cases effected by agencies entirely within the area of the lithophysæ, for they often occur isolated in the dense obsidian having no connection with other cavities or sources of vapor.

The change took place before the surrounding matrix had solidified, for in some instances the lithophysæ have been crushed, probably from a change of equilibrium in the lava, and the plastic matrix has been forced part way into the cavity of the lithophysa, which indicates that the matrix was still viscous and at a high temperature when the modification of the spherulite took place. And finally, though the matrix was plastic at the time of the formation of the cavities of lithophysæ the liberation of gases did not expand or distend the substance so as to form the concentric shells, for where a lamination is present in the matrix it is also seen traversing the shells of a lithophysa without change of direction.

From the foregoing it seems reasonable to infer that these lithophysæ, composed of prismatic quartz, tridymite, soda-orthoclase, fayalite and magnetite, *are of aqueo-igneous origin, and have been produced by the action of the absorbed gases upon the molton glass from which they were liberated during the crystallization consequent upon cooling.*

Instances where the layers of thinly laminated rock arch over hollow lithophysæ and seem to have been pushed back by expanding gases, to which von Richthofen calls attention, are more probably slight flexures in the layers of the rock which have occasioned local relief of pressure and the disengagement of vapors which might give rise to the lithophysa, than the result of the expansion of such vapors. For the field study of the rock at Obsidian Cliff shows that in places it was so stiff and viscous before coming to its final rest that some layers which were pulled apart in descending the underlying slope never closed together again. Hence it is likely that local inequalities of pressure might be brought about by the crumpling of so viscous a lava.

We may imagine the process of formation of a lithophysa to have been somewhat as follows: In the still plastic glass from a center of crystallization a multitude of incipient microlites of feldspar radiated through a sphere of glass. As these anhydrous microlites increased in size the nature of the cementing paste was changed. Being impoverished of alumina and alkalies, it became more siliceous and relatively more hydrated. A point was reached where the absorbed vapors could no longer be retained in combination, but were released in innumerable bubbles which were either uniformly disseminated through the paste or aggregated into larger bubbles. The gas thus liberated acted as superheated steam and eventually produced the separation and crystallization of all the elements of the original sphere of plastic glass. Before the final crystallization of the paste when the hydrated glass gave up its combined vapors and became anhydrous, it shrank in consequence of the reduction of volume and produced in some cases the cracks so frequently observed. That these cracks were formed before the final crystallization of the cementing paste is shown by the deposition on their walls of crystals of quartz, tridymite and fayalite. The conditions which produce a concentrically banded structure in some solid spherulites are most likely the same as those which lead to the formation of concentric shells in many lithophysæ. It is evident that the development of lithophysæ in a lava will depend upon a number of conditions both chemical and physical, the discussion of which is omitted from this paper.

*Laminated structure.*—The lithoidal portion of the obsidian flow which forms Obsidian Cliff is beautifully laminated in thin layers of light and dark shades of a purplish gray color, which differ in their relative denseness and degrees of crystallization. The more crystalline layers are full of minute cavities and thus become planes of weakness in the rock, which splits into thin plates, often not more than $\frac{1}{16}$ of an inch thick. So that the lithoidal rock is traversed by a multitude of nearly horizontal cracks which follow the planes of flow through all their contortions. It is this inherent lamination or layer structure, so commonly observed in the more acid lavas and especially the rhyolites of the Yellowstone National Park, which was alluded to in the paper on columnar structure published in this Journal in May, 1886 (page 325.) It was there considered to be of different origin from the tabular parting produced by rapid cooling near the surface of a body of molten rock.

The origin of the more general lamination which in one form or another usually extends throughout the whole mass of many lava flows will be readily understood from the following:

In a fluid free to flow over a horizontal surface the movement of its molecules will meet with least resistance in directions parallel to the plane of that surface, the fluid will therefore spread horizontally, and its molecules will move in planes parallel to the underlying surface. Particles suspended in the fluid will be carried along these planes, and portions of the fluid which contain different amounts or different kinds of suspended matter will be spread out in layers along these planes of flow.

In volcanic lavas the production of such layers will depend on the lack of homogeneity and viscosity of the magma, and the distance over which the lava flows. The more basic lavas are usually more liquid and consequently more homogeneous at the time of eruption, and show little if any signs of layer-structure in the solidified rock. But acid lavas such as rhyolite appear to be more viscous and less homogeneous when erupted, and slight variations in the consistency or composition of the mass show themselves as bands and streaks of colors or as layers of differing microstructure and degree of crystallization. These layers of different consistency were probably lenticular or quite irregularly shaped portions of the magma near the place of its eruption, and are more perfectly and thinly laminated the farther from the source.

The nature and cause of such local differences in the magma is suggested by a consideration of the structure of the various layers of the rock forming Obsidian Cliff. The lithoidal rock presents layers which differ in their degree of crystallization, some being wholly uncrystallized and glassy. Some are finely spherulitic, others coarsely so and porous; and others are quite granular and full of cavities. In the obsidian the differences find expression in layers of spherulites, and bands of lithophysæ; in layers more or less rich in granophyre feldspars, microspherulites, microlites and trichites; that is, in the different phases and amount of crystallization developed. Nearer the surface of the obsidian flow there is less crystallization, but the lamination of the rock is quite as noticeable in the more marked differences in the amount of microlites in the various layers and in the abundance of gas cavities which produce alternating bands of vesicular and dense glass and pumice. While at the surface of the flow the whole rock is openly pumiceous.

From the different extent to which the various layers of this glassy rock have been inflated by the expansion of gas near the surface of the flow it is evident that there was a difference in the amount of vapors previously absorbed by these layers. And from the part which superheated water has undoubtedly played in the development of lithophysæ and the larger, porous spherulites, and from the aqueo-igneous conditions deemed necessary for the production of the granophyre groups of quartz and feldspar, it seems highly probable that *the differences in consistency and in the phases of crystallization producing the lamination of this rock were directly due to the amount of vapors absorbed in the various layers of the lava and to their mineralizing influence.*

## ART. V.—*The latest Volcanic Eruption in Northern California and its peculiar Lava;* by J. S. DILLER.

IN making a geological survey of the northern terminus of the Sierra Nevada range in California, under the direction of Captain C. E. Dutton, to determine its relations to the volcanic phenomena farther northward, several opportunities were afforded to visit and study the phenomena resulting from the latest volcanic outburst in that region. It occurred at a place which is now pretty well known in that part of the world as "The Cinder Cone" near Snag Lake, about ten miles northeast of Lassen Peak, in Northern California. The newness of all the phenomena connected with this volcanic eruption is so striking when compared with those of other outbursts in the same vicinity that many of the country people and tourists are led annually to visit the locality, but until recently it has not been carefully investigated.

The Cinder Cone is a remarkably regular truncated cone rising about six hundred and twenty feet above the lowest portion of its base, and is composed almost exclusively of small scoria and lapilli. Its slopes are from 30° to 35°, just as steep as it is possible for such material to lie. The original form of the crater, which is marked by a pit over two hundred feet deep in the summit of the cone, is perfectly preserved. Upon its barren slopes the only vegetation seen is one small bush, but within the crater rim hidden from general view, there are a few pines whose trunks are several inches in diameter.

The lava field resembles an immense tabular stone pile covering an area of about three square miles, and ending upon all sides with steep slopes like a terrace over a hundred feet in height. Its surface, although champaign, is extremely rough, being formed by a mass of broken angular blocks of lava, and completely impassable to beasts of burden. The fragmental stony character of the lava flow resulted from its extreme viscosity at the time of the eruption. The crust was repeatedly broken up by the friction and pressure of the moving viscous lava beneath, and shoved along in such a way as to round some of the fragments by attrition.

About the lava field, and extending away from it in all directions, for a distance of from ten to twelve miles is the field of volcanic ashes. It is covered with pine forest which has attained the maximum development for that region. Close to the base of the Cinder Cone the thickness of the ashes could not be readily ascertained. One-fourth of a mile away, however, they are over seven feet in depth and gradually thin out to the border of the field. In the immediate neighborhood of the cone a trunk of *Pinus ponderosa* growing directly upon the upper surface of the sand has a circumference of over twelve feet. There are numerous dead trunks of the same pine standing near by which were evidently killed at the time of the eruption. Excavations at the bases of these trees show that they extend down through the volcanic sand to the original soil over seven feet beneath the present surface. Many of the trees killed at the time of the eruption have decayed and disappeared, but their positions are marked by numerous pits upon the surface where the sand has slid in to take the place of the decayed wood.

It is obvious that the volcanic sand of the ash field is continuous with the material of the Cinder Cone, and that both are products of the same eruption, and older than the lava with which they are associated. The lava plainly belongs to two periods of effusion separated by a time-interval during which over six feet of infusorial earth was deposited upon the older portion. At the time of the final eruption, when the ancient lake bed was in many places raised above the present level of Lake Bidwell and Snag Lake was formed, the great mass of the lava was quietly extravasated without any ejections whatever from the Cinder Cone.

The lava is readily recognized as basalt, one of the commonest of all types of late volcanic rocks. It has all the essential constituents of ordinary basalt, i. e. plagioclase feldspar, augite and olivine together with accessory magnetite and a large proportion of unindividualized material which is generally globulitic. In addition to all these characteristic constituents of basaltic lava this basalt is remarkably anomalous in containing numerous grains of quartz.

Only four probable hypotheses suggest themselves in explanation of the origin of these quartz grains in the basalt. They may be regarded: (1) as remnants of the rock from which the basalt may have been derived deep in the earth by fusion; (2) as inclusions picked up by the lava on its way to the surface at the time of the eruption; (3) as crystallizations from the magma itself; (4) as of secondary origin derived by the alteration of other minerals.

The absolutely fresh unaltered condition of the basalt forbids the belief that the quartz is of secondary origin and the character of the quartz is such as to render equally untenable the view which regards it as a remnant of the original rock from which the basalt may have been derived by fusion. So we have left to determine whether the quartz grains are inclusions or secretions.

The fractures in the quartz grains and the border of glass and pyroxene by which they are surrounded have been considered characteristic of quartz inclusions, but in fact such phenomena are equally common to some other minerals which are universally regarded as early secretions in the magma. The quartz always occurs without well defined crystallographic form in clear, vitreous, roundly-corroded grains just as in some of the more acid porphyritic rocks where all observers agree that it is indigenous to the lava. If the quartz grains are regarded as inclusions and we consider their multitude we would expect to find a greater range in their size and in the kind of included material. Fragments of any other sort in the basalt have been diligently sought for in vain. These considerations lend much support to the view which conceives the quartz to be an early secretion in the magma, but a more impressive argument in its favor is based upon the uniform distribution of the quartz grains throughout the entire mass of the lava including all its fragmental forms. It is as intimately intermingled with the other constituents of the basalt as the feldspar and the olivine, only somewhat less abundantly. To fully appreciate this fact the basalt must be examined in the field where it appears impossible to explain the omnipresence of the quartz satisfactorily on any other supposition than that it originated in the magma itself. We must bear in mind also that this particular basalt was very viscous and stiff at the time of its eruption, so that it broke up and shoved along over the surface as a great pile of stones. On account of the high degree of viscosity, inclusions would be found only in the basalt which came up very close to the side of the volcanic chimney and they would not spread into other parts of the lava. Of this I was fully convinced by an examination of the volcanic necks near Mt. Taylor in New Mexico. They are of basalt, which at the time of its eruption was apparently more liquid than that containing the quartz at the Cinder Cone near Snag

Lake. Before reaching the surface the basalt of the necks traversed several thousand feet of horizontal shales and sandstones which in some places are so friable as to easily crumble in the hand. A more favorable opportunity than this cannot be imagined for the basalt at the time of its extrusion to become thoroughly impregnated with grains of sand. Nevertheless no trace of quartz grains or small fragments of sandstone is found a short distance inside of the boundary of the neck.

The abundance of the quartz grains in the large volcanic bombs is a fact of special significance. It is evident that at the time of the eruption the bombs were thrown up into the air and falling upon the steep slopes of the Cinder Cone they tumbled to its base, where they collected in great numbers. The bombs vary in size from half a dozen inches to over eight feet in diameter. They are nearly round, and toward the center are very compact and jointed frequently in such a manner that the fissures radiate from the center of the bomb. The surface is rough, often vesicular and pumiceous. If the bombs had been soft at the time of their ejection as is frequently the case, they would have flattened out when they struck the ground, but from the fact that they remained round it may be inferred that they were already solid at the time of the eruption, having previously floated around as clots in the magma. These bombs are undoubtedly the oldest portion of the lava, having solidified previous to the eruption or in its earliest stage, before the magma in which they were suspended reached the surface. The fact that the grains and lumps of quartz are abundant to the very center of the largest bombs demonstrates that they are early secretions from the magma at a time when it was under enormous pressure. During the eruption the pressure was relieved and the consequent conditions of solubility changed, so that the quartz secretions, like those of the more acid lavas, were partially redissolved or fused, giving rise to the zone of glass and pyroxene by which the quartz is surrounded.

The quartz basalt is younger than any of the many basalts about it. There are numerous cinder cones and recent flows of basalt upon all sides of the one under consideration, and yet, although they were extravasated through the same formations and under the same conditions as the quartz basalt, they contain no quartz. This fact indicates clearly that the source of the quartz is to be found in that of the basalt itself.

Until recently I had supposed that there was only one locality of quartz basalt in that region, but later investigations in the field have discovered another near Silver Lake, twenty-five miles northwest of Lassen Peak, about an entirely distinct volcanic center. It has all the peculiar features of the quartz basalt at the Cinder Cone and like it is the youngest lava of that vicinity.

Grains of quartz have been noticed by other observers in basalts from various parts of the world, but they have been almost invariably considered to be inclusions of entirely foreign quartz picked up at the time of the eruption.

The great difficulty which has stood in the way of considering the quartz as indigenous to the basalt is of a chemical nature, and on account of it, petrographers generally are disinclined to admit that it is possible for quartz to crystallize in a magma which yields olivine. It must be borne in mind, however, that the quartz and the olivine did not crystallize synchronously nor under the same conditions. The quartz is older than the olivine and crystallized under great pressure far beneath the surface in that region where the conditions of physical and chemic equilibrium are as yet so largely conjectural. The crystallization of the olivine was rendered possible by the earlier secretion of free silica.

*Chemical Analysis of quartz basalt from the Cinder Cone.*

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|---|---|
| $SiO_2$ | 57·25 |
| $TiO_2$ | 0·60 |
| $Al_2O_3$ | 16·45 |
| $Fe_2O_3$ | 1·67 |
| $FeO$ | 4·72 |
| $MnO$ | 0·10 |
| $CaO$ | 7·65 |
| $SrO$ | *trace* |
| $BaO$ | 0·00 |
| $MgO$ | 6·74 |
| $K_2O$ | 1·57 |
| $Na_2O$ | 3·00 |
| $Li_2O$ | 0·00 |
| $H_2O$ | 0·40 |
| $P_2O_5$ | 0·20 |
| | 100·35 |

The accompanying chemical analysis of the quartz basalt from the Cinder Cone near Snag Lake has been made for me in the laboratory of the U. S. Geological Survey by W. F. Hillebrand. The high percentages of silica and magnesia are to be noticed in connection with the low percentages of the oxides of iron.

Corroded quartz is abundant in the quartz porphyries and rhyolites, less abundant in the andesites and rare in the basalts, nevertheless its presence is an essential feature of the basalt in which it occurs and may be used as one of the means of distinguishing certain lavas as quartz-basalts, just as it is used in other cases to characterize quartz andesite. The separation of the basalts into ordinary basalts and quartz basalts is not a purely mineralogical classification but is founded upon their chemical composition as well as upon their genetic relations expressed in their *natural order* of eruption—the quartz basalts in every case known being younger than the other basalts of the same region just as the quartz andesites (dacites) are younger than the other andesites of the same volcanic center.

Petrol. Lab. U. S. Geol. Survey, Washington, D. C., Nov. 19, 1886.

## ART. VI.—*The Texture of Massive Rocks*; by GEORGE F. BECKER.

AN opinion has been gaining ground among geologists for some years past, that the principal differences in the texture of massive rocks are due to differences in the rate of cooling and differences in the pressure under which the masses have consolidated. That slow cooling will convert into a partially crystalline mass a magma which, if rapidly chilled, would remain substantially in the form of glass is known experimentally* and observations on volcanic flows are accordant with experiment; for it is certain that glass is often abundant at the surface of lava streams and that it is chiefly confined to moderate distances from the original surfaces of eruptive masses, although minute particles of glass may frequently be found at considerable depths. It may readily be granted, that at a sufficient depth all trace of glass would disappear; or that an ordinary, homogeneous, eruptive magma may be cooled so slowly and under such pressures as to yield a holocrystalline product. Whether or not the pressure is influential in this respect is questionable.

It is supposed to be a mere extension of this thesis to maintain that the difference between porphyritic structure and granular structure is due to a similar difference in the physical conditions to which the fluid magma has been subjected. The inference has thus been drawn, that if the material constituting a given holocrystalline porphyry had been cooled sufficiently slowly and under sufficient pressure, it would have assumed the granular structure of typical granite or diorite.

This appears to me to be a wholly different and almost an unrelated proposition rather than a legitimate extension of the preceding. The immediate origin of granular structure is the

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* The best example is perhaps "basaltified" iron blast-furnace slag, which has been used to a large extent for street pavements.

simultaneous development of different crystalline grains, each of which, as it increases in size, interferes with the growth of others. A porphyry, on the other hand, is produced when only one or two minerals, crystallize from a homogeneous fluid in advance of the remainder and individual crystals of these favored species are afforded an opportunity to reach a comparatively large size and a good crystallographic development. Porphyritic structure is thus certainly due to what chemists would call "fractional" crystallization. Granting that a given homogeneous fluid may be cooled so slowly and under such pressures as to yield a holocrystalline porphyritic product, it certainly does not follow as a matter of logic, that if it were cooled still more slowly and under a still greater pressure, the various ultimate compounds would crystallize simultaneously. Neither does this conclusion follow as a matter of chemical or physical theory. The solidification of minerals must proceed, as I have shown in a former paper,* in obedience to the principle that the particular compound, the formation of which in the solid state liberates heat at the highest rate, will be the first to separate. Now it is certain that, in general, the formation of different solid compounds is attended by the liberation of heat at different rates; and the more slowly the conditions change the more perfect will be the divisions between the intervals of time during which different compounds will be precipitated. If a chemist desires to separate salts by partial crystallization, he will cool or evaporate his solutions as slowly as possible. It would thus appear both from experiment and from theory that if a homogeneous eruptive magma were cooled very slowly indeed, one or two minerals would be most likely to crystallize at first, or early in the process, and to attain good crystallographic development; that if these minerals constitute a fairly large portion of the mass, they would eventually build up a framework full of interstices; that as the solidification proceeded beyond this point and other compounds crystallized out, these could no longer develop symmetrically but must be crippled by the interference of earlier crystals and by mutual opposition. In short one would expect to obtain a holocrystalline porphyry as the product of a homogeneous fluid glass slowly cooled.

Geological observations bearing upon this subject are readily accessible. Every microscopical lithologist knows that some minerals show the clearest evidence of early separation from eruptive magmas, being imbedded in other crystals; and that such minerals, for example apatites, are very usually well-developed crystals; indeed irregular crystalline grains of apatites are very rare in lavas. Eruptive magmas do then separate out

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* A new Law of Thermochemistry, this Journal, 1886, vol. xxxi, p. 120.

some minerals before others ("crystals of primary consolidation," as they are called by Messrs. Fouqué and Michel Lévy), and the earliest of these crystals have good crystallographic development. Eruptive magmas thus obey a similar law to that observed experimentally in artificial fluids. It is usually accepted that many of the crystals of primary consolidations are formed prior to the eruption of lavas; indeed I cannot remember to have seen this denied, and yet it may be advisable to dwell somewhat upon the evidence of the fact.

Darwin,* Mr. Clarence King † and others before them have observed that when small branches are thrown out from lava streams of active volcanos and rapidly chilled, crystals of feldspar and augite are found accumulated at the lower surface, while the upper portions consist of nearly pure isotropic glass. It is substantially certain that these crystals cannot have formed during the short interval elapsing between the rise of the material to the surface and the moment of complete consolidation. Hence the crystals must have been suspended in the lava as it came to the surface and must have formed at a distance from the surface which is to be measured by miles. There is also other evidence nearly or quite as strong. Near the Comstock I found (in a slide) a crystal of hornblende, bounded on all sides but one by sharp crystallographic outlines. The remaining side appeared to represent a fractured or rather split surface, about one-half of the cross section of the prism being gone.‡ This fractured crystal is solidly imbedded in the groundmass of the rock, and the fracture must consequently have taken place while the groundmass was still fluid. It is almost or quite impossible to suppose any conditions under which this crystal can have been broken excepting those attending the actual rush of the lava from a profound depth to the surface. Hence it is as nearly certain as possible that this hornblende must have formed before eruption and under the pressure of miles of rock.§ The fact that "flow structure" is common immediately about porphyritic crystals in eruptive rocks, is by itself almost sufficient to show that the formation of these crystals antedates eruption. The larger the crystals of primary consolidation the less probable it is that they were formed after the eruption of a porphyry. In the Washoe district there is an area of hornblende andesite in which the rock is studded with unusually large and very finely developed hornblendes.‖ An immense number of these are an inch and

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* Volcanic Islands, chap. VI.

† Systematic Geology, p. 716.

‡ Geology of the Comstock Lode, p. 59 and Plate III. The double black border shows clearly that the crystal must have been split.

§ Others have also observed fractured or bent crystals in lavas.

‖ Geology of the Comstock Lode, p. 57.

a half in length and proportionately thick, while I found one specimen four inches in length and about three-quarters of an inch in thickness. It seems unnecessary to insist that crystals of such a size cannot have formed after ejection. The groundmass of this andesite did not differ essentially from that of an ordinary hornblende andesite.

Suppose that this rock had remained in its original position at least five miles below the surface and under the pressure of some 30,000 pounds per square inch until, by gradual refrigeration, the entire mass had become solid. There would probably have been no residual glass, or the mass would have become holocrystalline. But, as the interstices between the hornblendes gradually filled with other minerals, and after a certain portion of the entire mass had become solid, the growing crystals must have been crippled by mutual interference and the opposition of the already completed crystals. In short it is not possible that a more or less granular groundmass should have been entirely absent and, even if this rock had cooled at an imperceptible rate and under a stupendous pressure, it would still have yielded a porphyry and not a rock of granitoid structure.

Evidence of this kind could be indefinitely adduced and it is in the hands of every geologist. It appears to me to lead inevitably to the conclusion that porphyries may be formed from homogeneous fluid magmas at pressure however great, and at temperatures which sink at never so small a rate. If so, the formation of rocks of the structural type of granite from homogeneous fluid magmas must represent only extreme and highly exceptional cases of a curious neutral chemical equilibrium.

Conditions the very opposite of those attending the consolidation of fluid eruptive magmas are present in sedimentary rocks undergoing crystallization as a feature of metamorphism. The chemical composition of a sedimentary rock usually varies from millimeter to millimeter. If it is permeated by a chemically active fluid, the reaction which will liberate heat most rapidly varies with the locality as rapidly as the composition. Hence innumerable centers of a whole range of reactions are simultaneously established, a number of minerals equal to that of the reactions begins to crystallize at once, and no one mineral has, as a rule, an opportunity to exhaust the materials of which it is built up before it is interfered with by others. Thus among metamorphic crystalline rocks a granular structure should be the rule and a porphyritic structure should represent rare exceptions. This is of course true. The commonest partial exception is in the case of garnet and is due to the power which garnet possesses to an unusual degree of including solid foreign material. There are cases however which I have carefully studied, in which a metamorphic mass for a few cubic inches possesses as good a porphyritic structure as a true eruptive rock, just as granular patches may sometimes be found in typical porphyries.

It would appear then that a porphyritic structure should be the rule among rocks which have attained a high degree of fluidity, while a granular structure should be characteristic of metamorphic rocks. So far as geologists are fully agreed, this is true, for opinions are divided as to the origin of granite and allied rocks.

Many geologists, and I am among the number, do not question that there are both eruptive and metamorphic granites, diorites and diabases. If this is granted, or assumed to be true for the sake of argument, either the intrusive, granular rocks of typical habitus have been as fluid as lavas, and therefore represent the extreme case in which various reactions liberate heat at exactly the same rate; or else, like the metamorphic rocks, sometimes quite indistinguishable from them, they have never been sufficiently fluid to reach substantial homogeneity. Of these two suppositions the former seems very improbable, because granular rocks are not exceptionally rare and must have been formed under widely prevailing conditions. The alternative supposition, that granular rocks as a whole have never been thoroughly fluid, does not represent a strange chemical equilibrium and is not *à priori* improbable.

The rapid variation in texture and mineral composition of many granites is familiar to all geologists and they can draw their own conclusions from the evidence which this rock presents as to the former fluidity of the granitic magma. Scheerer and others long ago maintained that granite had never been raised to a high temperature or been reduced to a condition of perfect fluidity. I prefer to employ as an illustration the diorite of Mt. Davidson, which forms the foot wall of the Comstock lode in the mines known as the central group, between Spanish ravine and Bullion ravine. It forms a bare, unbroken exposure from the top of the mountain to the croppings of the lode, a vertical distance of 1300 feet and has been open to my observation at several points in the mines down to a depth of 3,000 feet below the croppings. The horizontal distance between the two ravines is about three-fourths of a mile. Geologists have perhaps seldom had an opportunity of examining a single rock-mass of this kind over a vertical distance of 4,300 feet within a horizontal distance of just about one mile. The exposures in the mines are no longer accessible and will probably never again be opened up.

From top to bottom this mass presents the same general character. The earlier visitors to the region called this rock granite, but as it contains little or no quartz, Baron von Richthofen designated it as syenite. It continued to be thus classed until Professor Zirkel showed by microscopic examination that it is a plagioclase rock. These facts are cited to show that it is substantially a granular rock of the granitic type. So nearly as I can estimate, about 95 per cent of the mass is granular, the remainder consisting of more or less porphyritic matter. While the general character of the rock is everywhere the same, there are considerable and rapid changes in the composition and the texture of the material from point to point; but the same varieties occur over and over again within short distances and are everywhere confined to substantially the same range. Thus during the summer of 1885 I studied with care the excellent and extensive exposures which had just been made on the 3000-foot level of the Chollar mine. Here I collected every variety of the rock exposed, and of these six or eight were distinguishable either by coarseness of grain, or by a more or less pronounced porphyritic texture. I carried these specimens to the west wall of the croppings, 3,000 feet above the same claim, or in the same vertical plane, and found neither any general difference nor any difficulty in matching each specimen from below by others from the surface. For the interval between the croppings and the summit of the mountain similar statements hold true. There is throughout, no indication of a tendency to a change varying with depth below the summit.

The bare, faulted slopes of Mt..Davidson afford an admirable opportunity for a study of the relations which exist between the porphyritic and granular forms of diorite. Patches of porphyritic rock are surrounded by granular material, and patches of granular matter are surrounded by a porphyritic rock. Neither one nor the other form inclusions. They resemble the dark spots so constantly met with in granite and, in innumerable instances, show a transition from one structure to the other. In some cases this transition is rapid though unmistakable, in others it is so gradual that it would be impossible to decide within some inches where to draw the line between the granular and porphyritic forms. Only a very small portion of this mass is micaceous. Here may be found a single flake of biotite, there a group of flakes fading out from a centre into the ordinary granitoid mass.

It is manifest that where a spot which is a few inches in diameter fades out into the surrounding granular mass, the material of which each is composed must have been subjected to identical physical conditions. Neither can have chilled more rapidly than the other and the pressure on each must have been the same. But the differences between rocks can be due only to physical or chemical conditions. The porphyritic portions of this rock must therefore have a different composition from the granular portions, and the constitution of the micaceous portions must be different from that of either of the others. In short, original differences in composition are necessary and sufficient to explain the differences in texture; and since the composition varied enough to produce striking differences in texture, the magma can never have been homogeneous and therefore it can also never have been thoroughly fluid. It also seems quite clear, from the results reached in preceding paragraphs, that those portions which were more fusible and became fluid, solidified as porphyry, while those portions which were only reduced to a pasty condition and which consisted of rather intimate mixtures of somewhat heterogeneous material, solidified as a granular rock. The melting point of most bodies rises with the pressure.* It is therefore in so far conceivable that a column of homogeneous eruptive rock of uniform temperature should exist, the upper portion of which is fluid and the lower portion pasty. Such a column might solidify to a porphyry near the upper end and to a granitic mass at the lower end. The lack of knowledge of the relation between melting points and pressures of minerals makes it impossible to assert that such cases may not sometimes occur in nature, but, if so, they must be exceptional. Positive evidence has been given above that porphyries such as andesites must be fluid enough to allow of free crystallization before eruption and at pressures which I believe must greatly exceed those at which any rocks accessible to dwellers on the surface of the earth can have solidified. A column of andesite of which the lower portion was rendered pasty by mere pressure would have to exceed in length the distance from its point of eruption to the source of the lava, probably not less than five miles and very likely much more. Again if the lower end of a column, say 10,000 feet in length, were rendered pasty by mere pressure, it would

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* Lavas not seldom contain crystals of primary consolidation which appear to be rounded, as if they had been partially fused after crystallization. The formation of black borders on hornblende may also indicate a partial fusion or softening of these crystals. These phenomena are almost certainly attendant upon eruption, and if they indicate real fusion, lead to the conclusion that the melting point of such minerals actually falls with diminishing pressure. Bodies, the melting point of which varies in the same sense as the pressure, are denser in the solid than in the fluid state at the melting point, and this question consequently has a bearing on the problem of the solidity of the earth. In the Hawaiian lavas the glass ejected has substantially the composition of basalt and the fact that, as Mr. King observed, the chief constituent minerals sink in and are heavier than this glass, points in the same direction; though unless there are really indications of fusion of the crystals it remains uncertain how far from this melting point the separation by density took place. Other purely geological phenomena also tend to the same conclusion. Thus Captain Dutton has observed that the crusts which form on the melted lavas in the craters of Hawaiian volcanoes often break up and sink. These crusts are of course largely glass, but glass is certainly as a rule less dense than the minerals which crystallize from it, so that were the crusts holocrystalline they would sink only the more readily.

become still less fluid if it were subjected to several times this pressure. Such material at a distance below the surface of five or more miles, would lose so much of its plasticity that it may be doubted whether it could furnish the material for an ordinary volcanic eruption. Finally, if the influence of pressure on the fusibility were such as to make a notable difference in the fluidity of a column of lava 10,000 feet in height, the melting point of crystals which had separated out five miles below the surface would be so much reduced by the relief of pressure attendant upon eruption that they would completely fuse. The preceding paragraphs show that this is not the case with those minerals which form the larger individuals in porphyries. But hornblende, pyroxene, mica, plagioclase and orthoclase all play this part in the porphyries, and they are also the chief mineral constituents of the granular rocks. The supposition that a column of lava 10,000 feet high of uniform and representative composition, which is fluid near the top, can become pasty near the base through mere pressure thus conflicts with well-ascertained facts. It is easy to see that if the opposite law of fusibility prevailed, or if the melting point rose as the pressure diminished, there could be no tendency to the disappearance of porphyries with increasing depth.

On the other hand the diorite of Mt. Davidson and many granites are known to overlie sedimentary rocks later than the Archæan and must, therefore, have solidified within a moderate distance from the surface; so that while no amount of pressure is known to be sufficient to prevent the formation of porphyry, granular rocks may form at very moderate pressures.

The foregoing considerations seem to me to justify the following conclusions:

The relation between holocrystalline porphyries and granular rocks is of very different character from that which exists between glassy rocks and those which are completely devitrified. Porphyries may form at any depth and no matter how slowly the temperature of the magma may sink. Granular rocks, except in a just conceivable limiting case which must be exceedingly rare, can never have been thoroughly fluid or homogeneous, but have often consolidated at pressures extremely moderate compared with those at which it is certain that porphyries would form. When granular and porphyritic forms of a rock are associated, as at Mt. Davidson, the cause of difference in texture is usually a variation in chemical composition, and the temperature to which the rock has been subjected must have been sufficient to melt portions of the mass but not the whole. The indications are that granular rocks have been formed at a lower temperature than porphyries of exactly the same chemical composition, and that the granular rocks as a group have been less intensely heated than the porphyries.

It is well known to those who are likely to read the foregoing pages, that Messrs. Hague and Iddings have drawn very different conclusions* from a study of my collections from the neighborhood of the Comstock lode; and that they have disputed many of the results both lithological and structural reached in my memoir on that great ore-deposit.† I have replied to their conclusions elsewhere;‡ but I may be permitted to repeat here, that I have re-examined the district and mines with their paper in hand and am only the more convinced that my elucidation was substantially correct. The diorite, diabase and augite andesite are not a single eruption or series of eruptions, as they maintian; but constitute three and probably four eruptions which took place at long intervals of time. There is very strong evidence that the diorite and diabase are pre-Tertiary rocks both at the Comstock and that Steamboat Springs, six miles distant, where diabase pebbles are included in metamorphic conglomerates of pre-Tertiary (probably Jura-Trias) periods. The earlier hornblende andesite of my report is intermediate in age between the diabase and the augite andesite. The quartz porphyry is pre-andesitic, orthoclastic and does not intersect the Sutro tunnel. The Washoe district presents no valid argument for asserting a progressive increase of crystallization in the rocks, while it offers the strongest arguments in favor of the conclusions drawn in this paper.

U. S. Geological Survey, Washington, D. C., Oct. 1886.

## ART. VII.—*A fifth mass of Meteoric Iron from Augusta Co., Va.*; by GEORGE F. KUNZ.

THIS mass of meteoric iron was given to the late Colonel W. B. Baldwin, of Staunton, Augusta Co., Va., and was found at or near the place where the largest of the three masses from Augusta Co., first described by Professor Mallet,§ was found. Col. Baldwin was under the impression that it was a detached part of the largest mass. Professor Mallet received it from him at a considerably later date than the large mass, and having chipped and filed a small flat surface, he found, after etching, that the Widmanstätten figures were like those on the large mass. A careful examination satisfied him that this piece of iron had not been in any way artificially detached from any one

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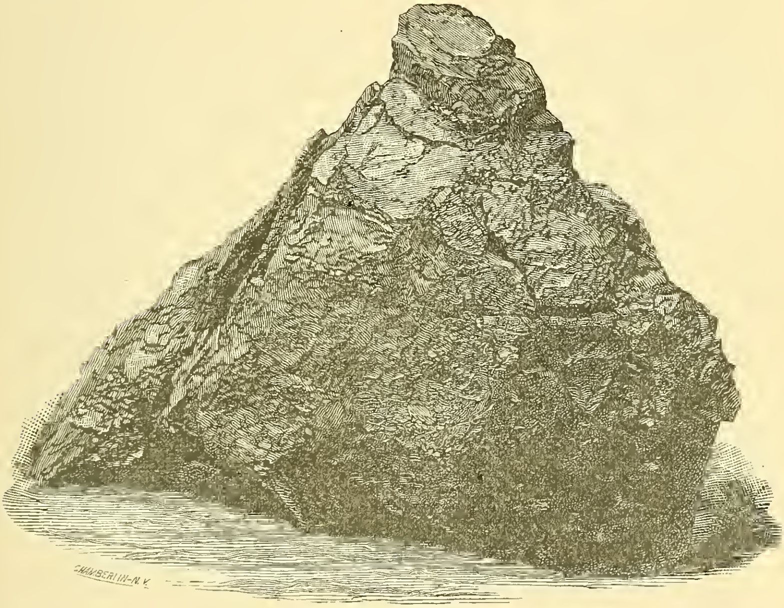
* Bull. U. S. Geol. Sur., No. 17.

† Geology of the Comstock Lode, etc., U. S. Geological Survey, Monograph III.

‡ Bulletin of the California Academy of Sciences, No. 6, p. 93.

§ This Journal, III, ii, 10, 1871.

of the previously discovered masses, though there is no doubt that all the other four meteoric irons from Augusta Co., including the one now described, are portions of a meteorite which probably exploded in mid air. Its present dimensions are $8{\cdot}5^{cm}$ by $6{\cdot}5^{cm}$, $7^{cm}$ at the widest end and $3^{cm}$ at the smaller end. This, like the other masses, contains ferrous chloride which, by its deliquescence, has caused much of the mass to exfoliate and crack off, so that this mass is only a nodular remnant of what was formerly a much larger mass. At one end (see figure) there is a large fragment weighing several hundred grams, that is in part separated by a fissure $4^{mm}$ wide—a result of oxidation. Several fracture pieces show from four to six faces of the octahedron. The following analysis of the mass is kindly furnished by Professor J. W. Mallet:



| | | | |
|---|---|---|---|
| Iron | 90·293 | Phosphorus | ·243 |
| Nickel | 8·848 | Sulphur | ·012 |
| Cobalt | ·486 | Chlorine | trace |
| Copper | ·016 | Carbon | ·177 |
| Tin | ·005 | Silica | ·092 |
| Manganese | trace | | |
| Chromium | trace | | 1000·72 |

## ART. VIII.—*Note on the origin of Comets*; by DANIEL KIRKWOOD.

HAVE comets originated in the solar system, or do they enter it from without? This question has been considered by Laplace, Proctor, H. A. Newton, and others. The last named presents arguments of no little weight in favor of their origin in inter-stellar space.* To these arguments I shall attempt no reply. On the contrary, I have been disposed to accept them as, in the main, valid. For certain comets of short period, however, various facts seem to indicate an origin within the system.

(1.) According to M. Lehmann-Filhès the eccentricity of the third comet of 1884, before its last close approach to Jupiter, was only 0·2787.† This is exceeded by that of twelve known minor planets. Its period before this great perturbation was about 3619 days, and its mean distance 4·611. It was then an asteroid, too remote to be seen, even in perihelion. Its period was very nearly commensurable with that of Jupiter; six of the one being very nearly equal to five of the other. According to Hind and Krueger the great transformation of its orbit by Jupiter's influence occurred in May, 1875. Its present period is about 6½ years. It was discovered by M. Wolf at Heidelberg, September 17, 1884. Its history indicates an origin in the zone of asteroids.

(2.) *The second comet of* 1867.—This body was discovered by M. Tempel on the third of April. Its perihelion distance is 2·073; its aphelion 4·8973; so that its entire path, like those of the asteroids, is included between the orbits of Mars and Jupiter. The eccentricity of this comet at its successive returns has been as follows:

| Date of Return. | Eccentricity. |
|---|---|
| 1867 | 0·5092 |
| 1873 | 0·4625 |
| 1879 | 0·4624 |
| 1885 | 0·4051 |

The last is nearly identical with the eccentricity of Æthra, the 132d asteroid, (0·38.) The period, inclination, and longitude of the ascending node are approximately the same with those of Sylvia, the 87th minor planet.

This comet may be regarded as an asteroid whose elements have been considerably modified by perturbation.

Other comets furnish suggestive facts which bear upon the same question; but their discussion must await the development of additional data.

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* This Journ., Sept. 1878.

† Annuaire, 1886.

## ART. IX.—*The Bichromate of Soda Cell;* by SELWYN LEWIS HARDING.

IN view of the recent claims of superiority of bichromate of soda as a depolarizing agent over its companion salt, bichromate of potash, I have made a series of comparative tests of the two salts, the results of which are contained in the following paper:

The points to be examined were the relative constancy or powers of endurance, the electromotive force, and the resistance of the two batteries.

The cells, in every case, were set up in the manner known as the Bunsen battery, namely, dilute sulphuric acid and zinc outside, bichromate solution and carbon inside, the porous cup. The proportions used were those given by the chemical reactions which take place within the cells; these are:

$$Na_2Cr_2O_7+4H_2SO_4+6H=Na_2Cr_2(SO_4)_4+7H_2O \qquad (A)$$

and similarly

$$K_2Cr_2O_7+4H_2SO_4+6H=K_2Cr_2(SO_4)_4+7H_2O, \qquad (B)$$

giving, from (A)

27 parts of $Na_2Cr_2O_7$
40 parts of $H_2SO_4$
and from (B) 3 parts of $K_2Cr_2O_7$
4 parts of $H_2SO$

For every part of the bichromate of soda, seven parts of water were used, and for every part of the bichromate of potash eight parts of water.*

The liquid surrounding the zinc was a mixture of twelve parts of water to one of sulphuric acid.

*Constancy.*—To answer the question of the relative merits of the two bichromates in regard to their constancy or powers of depolarizing, I obtained a series of photographic records of cells set up with these salts. The method of obtaining these records was, in brief, the substitution of a sheet of sensitive paper—driven by clock-work and properly protected from extraneous light—for the ground-glass scale of the ordinary reflecting galvanometer; the place of the zero point on such a scale being taken by a base line traced out by the reflection from a fixed mirror.†

The records thus obtained give a history of the current strength, showing its fluctuations and gradual weakening, from

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* The result of later work indicates that a much less quantity of water would be preferable with the soda salt.

† For details, this Journal, vol. xxix, p. 374, May, 1885.

the moment of making until breaking circuit. By transferring the individual records taken under the same conditions to a sheet of coördinate paper and referring them to the same axes, their relative changes from time to time are readily noted. The accompanying diagrams show a number of these records. Fig. 1 illustrates better than many words the relative value of the two bichromate cells, at least as far as their constancy is concerned; it gives two records of each of the two classes of cells, and, for the sake of comparison, a record of a Daniell's cell. It is to be observed that in Series 1 and 2 circuit was made immediately after setting up the cells, before the liquid had time to diffuse itself through the pores of the inner cup. The increased resistance, due to this cause, and the gradual return to the normal resistance during the first hour are plainly recorded. The following table gives the length of the records or the total number of hours before the exhaustion of the depolarizer:

*Double Liquid Cells.*

| | Depolarizer. | External resist. | Hours before exhaustion. |
|---|---|---|---|
| Series 1 | Bichr. of potash | 8 ohms | $55\frac{1}{2}$ |
| Series 2 | " " " | 8 " | $56\frac{1}{3}$ |
| Series 3 | Bichr. of soda | 8 " | 78 |
| Series 4 | " " " | 8 " | $74\frac{2}{3}$ |
| Series 5 | Sulphate of copper | 8 " | |

During the first 24 to 30 hours the records show little difference in the working of the two classes of cells, both remaining comparatively constant and, therefore, giving for records nearly straight lines; though it must be understood that even in the case of the most constant cells, such, for instance, as the Daniell's cell, the curves are never absolutely straight lines but rather a series of slight but numerous fluctuations about the position of a right line. These fluctuations are far more marked during the first 10 or 15 hours than later, but at no time are they entirely absent. Both the potash and the soda cells, in the above series, showed signs of weakening after 30 hours. This weakening, however, proceeded far more rapidly, and, consequently, exhaustion was reached much sooner in the former class of cells than in the latter. As can be seen from the table, the soda cells ran on an average fully 20 hours, or more than one-third, longer than the potash cells.

The comparatively short life of the depolarizing liquids in all the above cases was due to the small resistance in circuit. As a proof that the soda cell is capable of long continued action on a larger circuit, I need only cite a record which lasted, with 35 ohms in the external circuit, over 200 hours without showing signs of exhaustion. On large circuits where

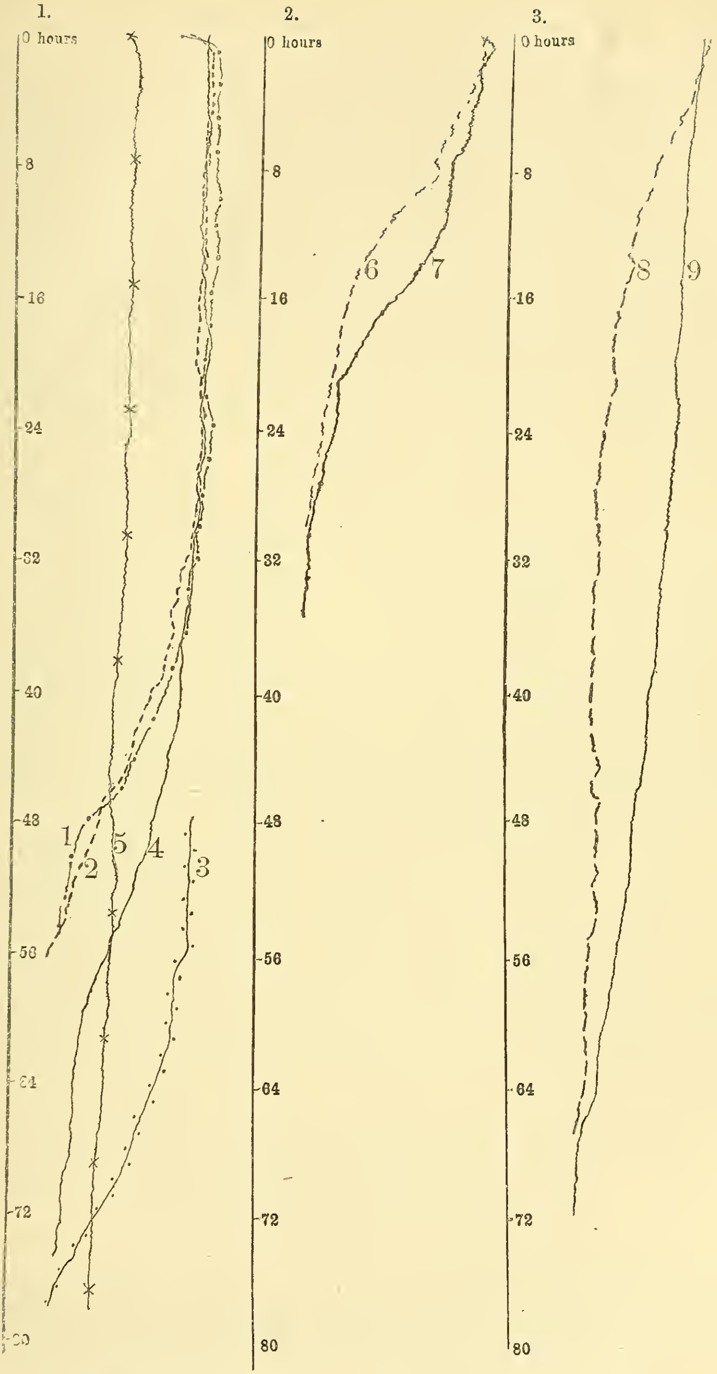

Fig. 1, Double liquid cells; 2, 3, Single liquid cells; Series 1, 2, 6, 8, bichromate of potash; 3, 4, 7, 9, bichromate of soda; 5, sulphate of copper, Daniell's.

either the expense or care of the battery is an element to be considered, the superiority of the soda cell would be especially felt.

In the case of the single liquid bichromate cells also, the superiority of the sodium salt seems to be maintained, though it is more difficult to form a correct judgment from the records of these cells, owing in part to the greater irregularity of successive records, and in part also to the fact that the greatest and most marked fall in the strength of the current occurs during the first hours of the records, while in the double liquid cells the reverse is the case, the most rapid fall occurs during the last hours and thereby indicates more accurately the close of the record. Figures 2 and 3 give several of the single liquid records, the conditions of which are contained in the following table:

*Single Liquid Cells.*

| | Depolarizer. | External resist. | Hours before exhaustion. |
|---|---|---|---|
| Series 6 | Bichr. of potash | 8 ohms | 29 |
| Series 7 | Bichr. of soda | 8 ohms | 35 |
| Series 8 | Bichr. of potash | 35 ohms | 67 |
| Series 9 | Bichr. of soda | 45 ohms | 71½ |

Though the difference in the number of hours before exhaustion in the two cells, as indicated by the above table, is not so great as in the double liquid cells, a glance at the records shows that the weakening of the current in the case of the potash cells was more sudden, and that it took place earlier than in the soda cells, so that the average strength for the whole time was greater in the latter cells.

An interesting question arises as to the cause of the greater power of the bichromate of soda. Both the bichromate batteries belong to the general class which provides oxygen to unite with the hydrogen set free at the negative electrode. The question, therefore, resolves itself into this: which salt can provide the greater amount of oxygen to unite with the hydrogen? Now our chemical reactions for the two salts are exactly similar, chromic acid being given off in both cases, as can be seen by writing out the intermediate reactions of (A) and (B). Thus:

$$\text{(A)}\quad (1)\ Na_2Cr_2O_7+H_2SO_4=Na_2SO_4+2CrO_3+H_2O$$
$$(2)\ 2CrO_3+6H=Cr_2O_3+3H_2O$$
$$(3)\ Cr_2O_3+3H_2SO_4=Cr_2(SO_4)_3+3H_2O$$
$$(4)\ Cr_2(SO_4)_3+Na_2SO_4=Na_2Cr_2(SO_4)_4$$

and a similar set for (B).

That salt, therefore, which can for a given weight of the solution furnish the most chromic acid will prove to be the superior. The solubilities of the two salts are as follows: at

15° C. 100 parts of water dissolve 12·5 parts of the bichromate of potash, and 83·16 parts of the anhydrous bichromate of soda. The available oxygen, therefore, in a given amount, for instance, a litre of the solution, is nearly five times as great for the soda salt as for the potash. This explanation, it seems to me, will go far toward accounting for the superior constancy of the soda cell.

In the appended table are contained the above results, and others computed with a view of comparing the two bichromates with other depolarizing agents of the same general class. The first column gives the per cent of oxygen in one molecule of each of the tabulated substances which is available for combination with the hydrogen set free; thus, in bichromate of potash, three atoms of oxygen, or ·1629 of the total weight, are available. The third column gives the cost of obtaining a kilogram of oxygen from each of the oxydizers. In these columns the fact that the bichromate of soda is hydrous increases the total molecular weight, and thereby lowers the per cent of available oxygen. In the last column is contained the amount of available oxygen in a saturated solution of each of the soluble depolarizers. As is seen from the table, bichromate of soda stands far ahead of the others in the last respect, giving 8·52 per cent of available oxygen from a saturated solution of the salt:

| | Per cent of available oxygen in one molecule. | Number of kilograms to produce one kilo of oxygen. | Cost of producing 1 kilo of oxygen. | Solubility: 100 parts $H_2O$ dissolve at 15° centigrade, | Per cent of available oxygen in a saturated solution. |
|---|---|---|---|---|---|
| Bichromate of potash, | ·1629 | 6·138 | $2·03 | 12·5 | .01808 |
| Bichromate of soda, | ·160 | 6·25 | 1·65 | anhydrous 83·16 | ·0852 |
| Peroxide of manganese, | ·092 | 10·87 | 1·92 | insoluble. | |
| Permanganate of potash, | ·253 | 3·95 | 3·34 | 6·25 | ·0142 |
| Nitric acid. C. P., | ·254 | 3·93 | 2·59 | | |

From this table it is seen that the bichromate of soda compares very favorably with the other depolarizers in all those respects which are essential for a good battery. The great solubility and large amount of available oxygen indicate great possibilities for this salt.

This table might be much extended, but, owing to the complicated nature of the chemical actions which take place in many batteries, our knowledge in this direction is very limited and consequently we cannot proceed far.

### *Electro-motive force.*

The electro-motive force of the soda cell I obtained by the open-circuit method of comparison, by means of an electrometer, with a standard (Daniell's siphon) battery. With one cell of this battery as the unit, the electro-motive force of the soda cells tested was as follows:

|  |  |
|---|---|
|  | 1·887 volts. |
|  | 1·884 |
|  | 1·908 |
| Average | 1·893 |

The electromotive force of the potash cell in the same way was found to be 1·852, while that of the ordinary Daniell's cell —12 parts of water to one of sulphuric acid—was 1·059 volts.

### Resistance.

Lodge's method,* a modification of Mance's method, was used in determining the resistance of the cells; a condenser, in some cases of one-third of a microfarad, and, in others, of a little over a microfarad in capacity, being used. For the soda cell, the resistance was found to be:

|  |  |
|---|---|
|  | ·494 ohms. |
|  | ·504 |
|  | ·495 |
|  | ·494 |
| Average | ·4967 |

Likewise for the potash cell, ·468 ohms was the resistance. The resistances of both cells could undoubtedly, if occasion should demand it, be reduced.

From the foregoing it is seen that the bichromate of soda cell is a most efficient cell; its effectiveness, however, could be materially increased, I believe—at least, as far as its constancy is concerned—by interchanging the positions of the electrodes with their surrounding liquids, after the fashion of the Fuller cell; that is, placing the zinc and sulphuric acid inside the porous cup, and the carbon, with a much increased quantity of the depolarizing mixture, outside the cup.

Jefferson Physical Laboratory, Harvard University, June, 1886.

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[*] See Phil. Mag. Supplement, June, 1877, p. 515.

# SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *On a new Universal chemical Spectroscope.*—A new form of spectroscope has been devised by G. KRÜSS, which is well adapted for the work of the chemical laboratory, both qualitative and quantitative.* Its fundamental form is that of the Bunsen and Kirchhoff instrument; but a variety of modifications and additions have been made, to render it available as a universal spectroscope. An upright pillar supports a table on which rests the prism, and which carries the observing, collimating and scale-telescopes. The collimating telescope has no draw-tube. It is provided with two slit-plates, one of which carries the ordinary single slit for qualitative purposes, the other the double slit of Vierordt for quantitative work. These slits are strictly parallel to the axis of the prism and are opened and closed symmetrically on the two sides of this axis, by micrometer screws, whereby the width of the slit may be determined. The knife edges of these slits are made of platinum and are so accurately worked that no horizontal lines appear in the spectrum even when the slit is open by only one or two divisions of the micrometer-head (0·002 to 0·004$^{mm}$.) Two prisms are provided; one a simple flint prism of 60° of a dispersion of 4° 18′ between A and $H_2$, the other a so-called Rutherfurd prism, having a dispersion of 8° 2′ between the same limits. By an automatic device the prism is kept at the angle of minimum deviation for the part of the spectrum under observation. The scale is fixed in its telescope so that it is in the principal focus of the object glass and so that its 100th division comes midway between the D lines. The observing telescope magnifies about seven diameters. By means of a micrometer screw with a divided head, it is moved in a horizontal plane about the vertical axis of the instrument, the amount of motion being measured by an index moving over a graduated arc upon the end of the fixed arm carrying the telescope. The value of the divisions on the micrometer head in terms of the graduations upon the arc, and the value of these in terms of the scale divisions, are easily determined. Moreover, this telescope has a micrometer eyepiece; so that spectrum measurements may be made between two colors whose wave-lengths differ by only 0·000 000 000 015 millimeter. The slide which carries the cross wires of this micrometer carries also the Vierordt slit, whose width is adjustable by the same screw that moves these cross wires. The author thinks that the results obtained by this instrument when used as a spectrophotometer, are fully equal to those obtainable with polarizing instruments.—*Ber. Berl. Chem. Ges.*, xix, 2739–2745, November, 1885. G. F. B.

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* Constructed by A. Krüss of Hamburg.

2. *On the Decomposition of Glass by Capillary water-layers containing Carbonic acid.*—Two years ago, Bunsen published the results of some experiments which he had made on the condensation of carbon dioxide gas upon the surface of glass (*Ann. Phys. Chem.*, xx, 545). His results showed that in three years 5·135 c. c. of this gas were condensed upon each square meter. Kayser subsequently repeated the experiment in a different form and obtained different results; whereupon Bunsen reëxamined the subject and showed that his glass fibers were not perfectly dry, and that a part of the observed absorption was due to this capillary water-layer. On taking the apparatus down, Bunsen analyzed the glass fibers on which the action had taken place. Under ordinary conditions carbon dioxide does not attack glass, but it is quite possible that so concentrated a solution of carbonic acid as existed in these capillary layers, might have some action. The analysis showed not only that the glass had been acted on, but that this action had been unexpectedly great. A weight of 49·543 grams of glass fiber gave to cold water sufficient sodium carbonate to yield on the addition of hydrochloric acid and evaporation, 0·8645 gram sodium chloride. From the composition of this glass, determined before the experiment, it appears that during the course of the observations—109 days—5·83 per cent of the entire weight of the glass must have been thus decomposed. The suggestion is an obvious one that possibly all the absorption, which Bunsen observed, might have been due to the formation in this way of sodium carbonate. But he shows that of the total volume of gas absorbed by the entire mass of glass, 236·9 cubic millimeters are set free again on heating. If combined as hydrosodium carbonate, the quantity of sodium found on analysis would require only 165·2 cubic millimeters, leaving 71·7 cubic millimeters to be otherwise disposed of. In view of the fact that pure water may also be expected to act on the substance of the glass, it is evident that glass is not a suitable material for experiments on capillary absorption.—*Ann. Phys. Chem.*, II, xxix, 161; *Ber. Berl. Chem. Ges.*, xix, 729, (*Ref.*) November, 1886. G. F. B.

3. *On the Properties and Constants of Germanium.*—Winkler has communicated some additional facts concerning his new metal, germanium. When obtained, either by reducing the oxide in a current of hydrogen or by gently igniting a mixture of the oxide and starch, and then fusing the gray powder under borax, the metal appears of a grayish-white color, having a brilliant metallic luster and crystallizing in well formed regular octahedrons. It melts at a somewhat lower temperature than silver, 900°, and volatilizes at a slightly higher one than this. It expands on solidifying, and crystallizes. Its specific gravity is 5·469 at 20·4°. Before the blowpipe it fuses to a globule which evolves white fumes and explodes, as does antimony. It is insoluble in hydrochloric acid, soluble in aqua regia, and is converted by nitric acid into the white oxide with evolution of nitrogen dioxide. Concentrated sulphuric acid converts it into a

sulphate soluble in water, with evolution of sulphurous oxide. It is not attacked by potassium hydrate. Its atomic weight, estimated by titering the chlorine contained in the tetrachloride, by the method of Volhard, was found to be 72·32 as a mean of four experiments. (Lecoq de Boisbaudran, it will be remembered, calculated the atomic weight from the two characteristic lines in its spectrum, $\lambda=468$ and $\lambda=422·6$, and found it to be 72·31 and 72·27, by two different methods, (*C. R.*, cii, 1291)). The position of germanium is that of the ekasilicium in Mendelejeff's table, for which he predicted an atomic weight of 72 and a specific gravity of 5·5. Its specific heat as determined by Nilson and Peterson, is at 100°, 0·0737; at 211°, 0·0772; at 301·5°, 0·0768; and at 440° 0·0757; the corresponding atomic heats being 5·33, 5·58, 5·55 and 5·47 respectively. These temperatures are the boiling points of water, nitrobenzene, diphenylamine and sulphur. The specific heat of the dioxide is 0·1293 between 0° and 100°. The vapor density of $GeCl_4$ is 7·43 and that of the iodide 20·43. Its spark spectrum shows one line in the orange, one in the yellow, four in the violet and twelve in the green and blue. Its compounds are characterized by their solubility and volatility, but they do not color the Bunsen flame. Two oxides, GeO and $GeO_2$ are described; and the corresponding sulphides and chlorides. Also $GeI_4$. The best test for germanium is the precipitation of the white sulphide $GeS_2$ upon the addition of mineral acids in excess to its solution in alkaline sulphides. This separation is so complete that it may be used quantitatively. For this purpose, the alkaline solution of germanium is mixed with ammonium sulphide, precipitated with dilute sulphuric acid in excess and saturated with hydrogen sulphide. After 12 hours standing, it is filtered off and washed, the precipitate is washed from the filter and extracted with ammonia. The ammoniacal solution, with the wash water are evaporated to dryness in a weighed porcelain dish, the main precipitate moistened with sulphuric acid added thereto and the excess of acid evaporated. After ignition the residue is treated with nitric acid, again ignited, digested with ammonia to remove the last trace of sulphuric acid, and the strongly ignited oxide weighed. To separate this metal from tin, arsenic and antimony, the author dilutes the solution to a definite volume, boils a measured portion with excess of normal sulphuric acid and determines by titering back the excess of acid required to exactly neutralize the entire solution. This amount is then added, the solution allowed to stand 12 hours, the precipitated sulphides are filtered off, the filtrate is evaporated to a considerably smaller volume, treated with ammonia and ammonium sulphide and precipitated by the addition of an excess of sulphuric acid and the passage of a current of hydrogen sulphide. This precipitates germanium sulphide pure. Argyrodite, in which this element was discovered contains Ag 74·72, Ge 6·93, S 17·13, Fe 0·66, Zn 0·22 and Hg 0·31 per cent. It is a sulpho salt of the formula $(Ag_2S)_3 GeS_2$.—*J. pr. Ch.*, II, xxxiv, 177–229; *Ber. Berl. Chem. Ges.*, xix, 652 (Ref.) Nov. 1886. G. F. B.

4. *On the distinction between spectral lines of Solar and Terrestrial origin.*—In a communication to the Physical Society, London, June 12, 1886, Professor M. A. CORNU calls attention to a method which allows one to distinguish instantly between solar lines and those due to the earth's atmosphere in the solar spectrum. This method is based upon a principle due to M. Fizeau, (Ann. de Chim. et de Phys., 4 série, t. xix, p. 211), that of the displacement of the spectral lines emitted by a source which is in absolute or relative motion. Professor Cornu shows that we shall have a variation of wave length equal to $\pm \frac{\lambda}{150{\cdot}000}$, + or − according as we take the same radiation at the eastern or western end of the solar equator, estimating the displacement in reference to the two D lines. It is found that the double displacement amounts to $\frac{1}{62{\cdot}4}$ of the distance between the two D lines. This displacement can be readily measured by the use of Thollon's prisms or Rowland's gratings. The experimental method consists in causing the image of the two extremities of the solar equator to fall alternately on the slit of the spectroscope. To effect this the beam of light passes through a condensing lens which produces in the plane of the slit a sharp image of the solar disk. A displacement of the lines of the spectrum due to the sun alone is produced by substituting one limb of the sun for the other, while the positions of the telluric lines are unaltered. Professor Cornu gives in detail the precautions which must be taken in the comparison. By causing the collecting lens to oscillate two or three times a second, the displacement becomes more evident. The distinguishing of the lines is then easily accomplished. If the line remains immovable under this shaking process it is one belonging to the earth's atmosphere, if it oscillates it is a solar line. Professor Cornu gives a map of Angström's group. He indicates the telluric nature of a certain number of lines beyond the band 8, and shows that the line 1474 of Kirchhoff is a solar one. Since it oscillates we may conclude that the vapor which absorbs the radiations of which it takes the place is carried round by the rotation of the sun, and he shows that physicists and astronomers have now a method which will enable them to tell at a glance whether a spectral line belongs to the sun or the earth. —*Phil. Mag.*, Nov. 1886, p. 458. J. T.

5. *New form of Galvanometer.*—In Wied. Ann., xxiii, p. 677, 1884, Herr Rosenthal described a very sensitive galvanometer, in which the poles of the suspended magnet were brought very near the coils. Hr. J. Kollert has constructed a similar instrument which is more sensitive than that of Rosenthal. It consists of four coils whose axes all lie in the same horizontal plane; and the coils are placed radially in this plane. The magnets are made out of very thin watch spring in the form of arcs of a circle. Two such arcs are placed at the extremity of a straight arm which is suspended horizontally from its middle point. The ends of the magnets can thus pass into the centers of the radial coils.

A current of ·000,000,001 A. gives a deflection with suitable distance of reading telescope of 0·7 of a scale division.—*Ann. der Physik und Chemie*, No. 11, 1886, p. 491. J. T.

6. *Metallic deposits formed by electrical discharges.*—Professor Wright of Yale College described in this Journal, vols. xiii and xiv, 1877, a method of obtaining very thin deposits of metals by electrical discharges in rarefied air. The subject has been taken up anew by Hr. Bernard Dessau, who investigates the interference phenomena produced by such thin layers. Generally these layers are thicker directly opposite the electrode from which the metallic particles are thrown off. Hence a cone is formed of a very small altitude. The deposits showed in reflected light colored interference rings. The dispersion in the metals platinum, iron, nickel and silver, the author calls normal, and that with gold and copper abnormal. The cross of double refraction was also noticed in reflected light.—*Ann. der Physik und Chemie*, No. 11, 1886, pp. 353–376. J. T.

7. *Electricity arising from the condensation of vapor.* — It has been maintained by Palmieri and others that the condensation of vapor results in the production of an electrical charge. Hr. S. Kalischer has renewed his investigations upon this point and believes that he has proved that no electricity results from such condensation. Atmospheric vapor was condensed upon a vessel coated with tin foil, filled with ice, carefully insulated and connected with a very sensitive electrometer. No evidence could be obtained of electricity.—*Ann. der Physik und Chemie*, No. 11, 1886, p. 407. J. T.

## II. GEOLOGY AND MINERALOGY.

1. *The Charleston Earthquake.*—The earthquake which occurred in the southeastern United States on the evening of Aug. 31, 1886, and which will doubtless always be known as the Charleston Earthquake because of the great destruction caused by it in that city, is being made the subject of careful study by the seismologists of America, and there is good hope that valuable results for the future of seismology may issue from their work. Rarely if ever has a better opportunity for study been presented. The primary shock was of sufficient intensity to destroy many buildings in Charleston and vicinity and was felt over a land area of nearly 800,000 square miles, extending from the great lakes to the gulf and from beyond the Mississippi to the Atlantic, being felt also very slightly in the Bermudas and in Cuba. This large area is covered with a network of telegraph lines whose offices were ready at once to collect and communicate the news of the shock; and the standard time is very generally in use, so that the records of time give fair promise of accuracy and are readily comparable. Our country is also supplied with active newspapers which put on record with care and in full detail the phenomena of the shock.

To these general means of information are to be added others set in operation for this special occasion. Major Powell, the Director of the United States Geological Survey, promptly took up the matter and sent W. J. McGee, a geologist of the Survey, to personally examine the ground. At the request of the Survey the United States Signal Service also sent Professor T. C. Mendenhall, of their corps, a former resident of Japan and a member of the Seismological Society there. These observers spent a week in the vicinity of Charleston, and brought back many valuable data, besides a series of photographs of injured buildings and displaced monuments. A competent person was also left on the ground to continue their observations.

A series of questions was promptly distributed through the public press and by special circular, and the personal letters received by the Geological Survey in reply already number several hundred and are still receiving additions. The Signal Service, through its observers, has a large amount of information which is also open to the Survey, while the other departments of the government, as the Hydrographic Office, the Light House Board, etc., have each contributed whatever information was in their hands.

It will be seen therefore that the mass of information in regard to the Charleston Earthquake which is accumulating in the hands of the Geological Survey, both in amount, in careful detail, in number of contributors and in area covered, is likely to far surpass that gathered in respect to any previously studied earthquake. Of course in such a mass of material, coming from all sorts of persons, much is included that has little scientific value; but there are also many careful reports from competent scientific observers, and the results should be as good as can ordinarily be obtained from non-instrumental observations. Indeed the one thing to be regretted is, that the Earthquake Commission had not yet perfected their plans for establishing a series of seismoscopes; although it is doubtful if the area selected for them would have included the southern Atlantic States even if they had been ready for use.

It will be evident, from what has been said, that much time and labor are needed to sift from such a collection what is authentic and valuable and to collate and compare the records so obtained, before any attempt can be made to formulate results. On this work the Geological Survey is now engaged, certain of its members having occupied nearly all their time for the past three months in the clerical labor involved, but it will still take months of steady labor before the final results will be ready for publication.

Meantime some things have appeared in print which deserve mention here, although their full discussion must be reserved for another time. In Science, No. 188, Sept. 10, 1886, a map of coseismals, or lines of equal times, was published as prepared by Everett Hayden of the Geological Survey, which however can only be regarded as a first rough approximation. In the U. S. Monthly Weather Review for August, 1886, issued in October, the data in the hands of the Signal Service are summarized by Professor Mendenhall in a brief report, accompanied by a map of Isoseismals, or lines of equal intensity, which show some curious deviations from uniformity. Science No. 199, Nov. 26, 1886, also contains a map of isoseismals and coseismals prepared for the Philosophical Society of Washington, by Edward Hayden, from data, mostly correspondence, in the hands of the Geological Survey up to October 23. The isoseismals of this map are considerably more irregular than those given by Mendenhall, although the two maps agree in the general form of the curves. They suggest some interesting relations with the geology of the country which it is yet too early to enlarge upon. They indicate however a focus or epicentrum lying somewhat north of Charleston. During September, Science also published copies from some of the photographs brought home by McGee.

The earthquake did not consist of a single isolated shock, but the great shock of August 31 was preceded by perceptible tremors on the 27th and 28th and has been followed by almost daily shocks, mostly of minor intensity, even up to the date of this writing, one being reported in to-day's paper. C. G. R.

Princeton, N. J., Nov. 30, 1886.

2. *Naturally Reduced Iron ;* by J. B. TYRRELL, of the Geological Survey of Canada. (Communicated to this Journal).—On the North Saskatchewan River, about seventy miles above the town of Edmonton, in the district of Alberta, in rocks of Laramie age, an almost horizontal bed of lignite may be seen cropping out at intervals in the river-bank for several miles, overlaid by dark gray clay-shales and gray and yellow soft argillaceous sandstones containing nodules of clay ironstone. Although none of the nodules from this particular locality have been analyzed, similar ones from Edmonton, obtained from beds of the same formation, were found to be essentially carbonates of iron containing 34·98 per cent of the metallic iron.

The seam of lignite has been completely burned out over a considerable area, leaving the surface covered with a bed of debris of ashes, clinkers and burnt clay, in places to a thickness of twenty feet, supporting at present a thick growth of grass and underbrush. From this mass of burnt clay and cinders pieces of metallic iron can be readily picked out, weighing, in some cases, as much as fifteen or twenty pounds, doubtless derived from the nodules of ironstone mentioned above, which had been reduced to the metallic state by the heat caused by the burning of so large a body of lignite.

Most of the pieces of iron observed were very much rusted and fell to pieces readily on being struck with the hammer, though when scratched with a file they everywhere showed a bright surface.

Ottawa, Dec. 11th, 1886.

3. *A Partial Report of the Geology of Western Texas ;* consisting of a general geological report, and a journal of geologi-

cal observations along the routes traveled by the expedition between Indianola, Texas, and the Valley of the Mimbres, New Mexico, during the years 1855 and 1856: with an appendix giving a detailed report of the geology of Grayson County, Texas; by Professor G. G. SHUMARD, Assistant State Geologist of Texas (1858–1860.) Austin, Texas: State Printing Office, 1886. Published and edited by H. P. BEE, Commissioner of Insurance, Statistics and History. 145 pages 8vo, with plates.—The scarcity of knowledge concerning the details of geological structure in the vast area embraced within the political bounds of the State of Texas is proverbial, and so inextricably is the little knowledge that we possess involved in controversy that any light upon the subject, however feeble, is always welcome at this time. The appearance at this late day of a volume giving the detail of scientific exploration that took place over twenty-five years ago in that region has a double value. In the first place it indicates a revival of interest in geological investigation by a State government, in which a once strong desire to make known its resources in a scientific manner, was almost entirely killed by the wrangling among themselves of the scientific men employed to carry out its intentions. The knowledge of large regions of hitherto unpublished territory which it brings to us is specially welcome.

The two brothers, Benjamin F. and George G. Shumard were ardent lovers of scientific exploration, and their names will always be inseparably connected with the scientific history of the southwest. The former was more inclined to descriptive paleontology, and the latter to traveling and collecting, the results of his labors often having been turned over to his brother for study and publication. He accompanied the government expeditions into and across the plains of Texas and New Mexico, and especially those conducted by Captain Randolph B. Marcey, and Lieut. Geo. B. McClellan to the head waters of the Red river, in 1852, and Captain Pope's expedition for boring artesian wells on the Staked Plains. In the year 1858 Dr. B F. Shumard was appointed State Geologist by the Governor of Texas, and he, in turn, appointed his brother to the position of Chief Assistant, and assigned him to that vast region of northern Texas adjacent to Red river. These gentlemen began their labors in a country at that time exceedingly unpropitious for successful investigation, owing to the scarcity of population, the hostility of the Comanches and allied tribes, and the absence of rail or water communication. Just as the organization was reaching a period when it was ripe for the publication of results, a State election brought into power a new political party. An ambitious subordinate poisoned its executive against the Shumards, and they were suspended, their collections taken from them, and their manuscripts lost or destroyed. The volume before us gives more of the results of the survey than any other publication made by the State of Texas. It is true that Dr. B. F. Shumard published in the Transactions of the St. Louis and Boston societies, up to the time of his death, fragments of his labors as State geologist, but never, until the present volume, in the year 1886, did the State government publish for distribution any of the results of his survey.

The volume will be of interest at the present day chiefly for purposes of compilation. The stratigraphical deductions of the Shumards are now known to have been erroneous, and their sections of the Cretaceous strata of Texas, as published by Dr. B. F. Shumard in 1860, most assuredly place the bottom of the Texas strata on top, the top in the middle, and all the other subdivisions equally out of place. Mr. Jules Marcou,* in 1861, called attention to this discrepancy, and published an approximately correct ideal section; but his then recently published erroneous opinion concerning the alleged Jurassic age of certain Texas strata prevented this criticism from carrying with it the weight it deserved.

The portion of the work entitled a "Detailed Report of the Geology of Grayson County," is especially misleading, for it leads the reader to believe that in that vicinity is to be found nearly every representative of the series from the Tertiary to the base of all the Cretaceous strata of Texas. This is not the case, however, for the writer has examined the whole region in person, and found that Dr. Shumard's Tertiary is Cretaceous, and that his "Lower Cretaceous" is really the very top of the great group of the period which once covered Texas west of that county, and which, in it, is partially covered by the southwestern prolongation of Hilgard's Mississippi series.

It is to be hoped that the State of Texas will not only publish all the results of the old Shumard survey that it can lay hands upon, but that it will some day resume the geological work which it once began with so much earnestness. R. T. HILL.

4. *The Washoe Rocks*, by G. F. BECKER. (Bull. California Acad. Sci., Nov., 1886.—The views of Mr. Becker on the Washoe Rocks, as published in 1883, are briefly presented in a notice of his paper in vol. xxvi of this Journal (p. 479). A subsequent detailed study of Mr. Becker's sections of the rocks by Messrs. Hague and Iddings, in connection with an earlier study of the region by Mr. Hague, led them to different views, as stated in vol. xxx of this Journal (p. 388), 1886, these authors making out that several of the igneous rocks, regarded by preceding authors as independent in age and mass, were of the same age and mass, although varying from scoriaceous to granitoid in texture. To the latter article Mr. Becker replies in his recent paper.

Mr. Becker states that he has new evidence of the existence, in the region, of diabase as a pre-Tertiary rock, and of the fact of two distinct out-flows of pyroxene-andesite of different periods. On the first point he mentions that six miles from the Comstock lode, in a Jura-trias sediment, diabase pebbles occur which are lithologically like the diabase of the east wall of the lode; and

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* Proc. Bost. Soc. Nat. Hist., viii, 1861.

that the two localities are in the same lithological district. He says that it is not necessary or possible to prove, that the pebbles came from the Comstock locality; and recognizes, in a following paragraph, the fact that the distinctions between the porphyritic diabase and the augite-andesite of the Comstock walls "are somewhat refined" and in many cases not distinguishable in hand specimens. Still he believes that the distinctions are sustained by his observations. Other arguments are presented in order to prove succession in periods of out-flow in the different kinds of rocks, and sustain the order:—porphyritic diabase, hornblende-andesite, pyroxene-andesite, later hornblende-andesite, pyroxene-andesite. The evidence given is partly lithological, and relates to rocks which have, as is implied, these perplexing transitions, so that it is set forth as probable rather than positive. The similarity in the rock of the two walls, claimed by Messrs. Hague and Iddings, is remarked upon adversely, but with the admission that the question is difficult to decide.

Mr. Becker states that he found the diorite at the 3,000 foot level in the Comstock lode, identical with that at the top, and concludes that the crystallization does not vary with the depth; and the same for the diabase; and in a belt at the surface about 7,500 feet above the Sutro tunnel, he failed to find a serial progress in degree of crystallization. Other points also are considered, and in general his former positions are not yielded.

On the main question, independent of Washoe, the difference between these observers appears to be small. For Mr. Becker says (p. 95) that "it has never appeared to me that a distinction between pre-Tertiary and Tertiary eruptions was a natural one," but "an artificial substitute;" yet he adds "which it would be unwise to abandon until some available principle distinguishing little eroded from deeply eroded rocks is discovered and thoroughly established." Allowing that the determination of the facts by direct observation should precede the attainment of the needed principle, and there would be agreement here also. The region is one of difficult investigation on account of the natural transitions in the rocks, transitions also from the alteration of pyroxene to hornblende, and the obscurity over the larger part of the exposed surfaces on account of the deep alteration and especially along the walls of the lode. Mr. Becker presents his arguments cautiously, making them probable rather than positive, and they indicate that he regards the question as still an open one. They appear to be insufficient, under the uncertainties, to set aside the improbability of his conclusions.

Whatever uncertainty may exist with regard to the relations of the Washoe rocks, the principles deduced from them by Messrs. Hague and Iddings appear to be placed beyond reasonable dispute by later investigations in Great Britain and Italy.

5. *Volcanic Glass changed by heat alone to Pumice.* In a paper on Marekanite, pearly glassy balls of volcanic origin (Geol. Mag., June, 1886), Professor J. W. Judd shows that the amount

of volatile matter present is large enough to convert the glass, when heated to whiteness, into cauliflower-like masses which are true pumice. The same author in a later paper "On the volcanic rocks of the Northeast of Fife, Scotland," states that a dacite-glass, when carefully dried at 110° C. and then weighed was found, on ignition, to have lost 8.90 p. c. of its weight; and when fragments were heated in a flame urged by a powerful blast they swelled up into cauliflower-like excrescences, 8 to 10 times the original bulk. The obsidian of Krakataô (a porphyritic enstatite-dacite glass) acted in the same way, yielding a dirty-white pumice, "almost undistinguishable from the natural pumice which was ejected from that volcano during the great eruption of August, 1883." The latter paper is in Q. J. G. S., Aug., 1886.

6. *North America in the Ice Period;* by J. S. Newberry. (Pop. Sci. Monthly, Nov. 1886).—Dr. Newberry reviews in this paper, the facts with regard to the general distribution of the drift in North America and illustrates the subject by two maps, one of North America, and the other of the United States east of the Rocky Mountains. He also gives the results of his personal observations, especially in Western America. His map represents glaciers as descending along the Rocky Mountains to the northern part of New Mexico, and to about the same parallel on the Sierra Nevada. The conclusions drawn from the facts are the following: that the North American ice envelope covered nearly or quite half of the continent; that the Ice period was a cold period; that it was a result of general and not of local causes, of cosmical agencies, and not of topographic or even terrestrial. With regard to the view that no lowering of the temperature in the glacier regions was necessary to explain the facts, Dr. Newberry mentions as one among many facts, that on the Cascade Mountains, Oregon, precipitation of both rain and snow is at present very copious, the snow-line falling to 7,000 feet above the sea-level, and yet there is no ice where great glaciers formerly existed; the precipitation remains; the snow-fall remains; but the glaciers are gone "because of the high annual temperature." A depression of temperature which should cause the rain-bearing winds from the Pacific to do all the year what they now do only in winter, that is, heap up snow on the highlands"—would make an annual accumulation; and thus "the slopes and valleys would soon be occupied by glaciers as they were in former times."

7. *Geological map of the United States;* by C. H. Hitchcock. —Professor Hitchcock has a paper, accompanying a colored geological map of the United States, in the Transactions of the American Institute of Mining Engineers. The map measures 18 inches by 28. It is based, as is stated, on the map published in the 5th Annual Report of the Director of the U. S. Geological Survey, prepared by Mr. W. J. McGee, and is intended "to illustrate the schemes of coloration and nomenclature recommended by the International Geological Congress." The map is handsomely printed (by J. Bien) and the effect of the arrangement of colors is excellent

Professor Hitchcock gives a brief résumé of the history of American geological maps, and the special characteristics of each, in the following order: Maclure's, 1817; James Hall's, 1843; Lyell's, 1845; Edward Hitchcock's, 1853; J. Marcou's, 1853, and again in 1855; H. D. Rogers, published at Edinburgh, in Keith Johnson's Physical Atlas, 1856; Hall & Lesley's, published in vol. i of Emory's Rep. United States and Mexican Boundary Survey, 1857; Logan & Hall's grand map, published 1866, as the Geological map of Canada—the only map hitherto published which compares in style, magnitude and detail with those of European Geological Surveys; C. H. Hitchcock and W. P. Blake's map, in the United States publications of the Ninth Census, 1872; C. H. Hitchcock's large map of 1881, published by Julius Bien; McGee's map, U. S. Geol. Survey, of 1885.

In a note, Professor Hitchcock states that Mr. J. Marcou's extensive "Mapoteca Geologica Americana," published as No. 7 of the Bulletins of the U. S. Geological Survey, has an important omission, in making no mention of the great Canada map of Logan & Hall. The paper states also the reasons of the author for disagreeing with the author of the "Mapoteca" in other respects.

8. *Tertiary Fossils: Geological Survey of Alabama*, 1886.—This volume contains a *Preliminary Report on Tertiary Fossils of Alabama and Mississippi*, by T. H. ALDRICH, and *Contributions to the Eocene Paleontology of Alabama and Mississippi*, by OTTO MEYER.—The former paper is illustrated by six lithographic plates, and the latter by three. The excellent work of Messrs. Aldrich and Meyer is doing much to remove the doubts and obscurities connected with the Gulf-border Tertiary fossils. Professor E. A. Smith, the State Geologist, opens the volume (of 60 pages) with a brief account of various stratigraphical sections of the Tertiary. In his preface he mentions that this Bulletin, No. 1, "is the first contribution toward a work, undertaken by Mr. Aldrich, illustrating the paleontology of the Tertiary formation of Alabama, and that the work, with its plates and other illustrations, is to be the *gift* from Mr. Aldrich to the State of Alabama. It will embrace figures and descriptions of all the shells found in the Tertiary deposits of the State, and include reproductions of the figures already published elsewhere." "Mr. Aldrich furnishes gratuitously not only the text of his article but also provides, at his own expense, the entire printed edition of the plates illustrating both his own and Dr. Meyer's articles."

9. *Geological Survey of Alabama*, EUGENE A. SMITH, Ph.D., State Geologist. *On the Warrior Coal Field*, by H. McCALLEY, Chemist and Assist. Geologist, Montgomery, Ala., 572 pp. 8vo, 1886.—This volume is devoted to a detailed description of the principal coal field of Alabama. The number of consecutive beds in this extensive coal field is stated to be 35; of which 15 are over 2½ feet thick and 6 of 4 feet or over. It is stated that the coal beds appear to thin toward the northwest. An estimate puts the amount of available coal in the Warrior coal region from the

seams over eighteen inches in thickness, above 108,000,000,000 tons, which is "three times that of the estimated available bituminous and semi-bituminous coals of Pennsylvania."

10. *Geological Report of New Jersey for* 1885. 228 pp. 8vo.—Speaking of the junction of the Potsdam sandstone and Archæan in New Jersey, at two localities in Sussex county, Professor Cook states that the actual plane of contact is obscured by the occurrence of so much feldspar in the sandstone as to present the appearance of a gradual transition into the older rock. Besides the general feldspathic character of the Potsdam, fragments and masses of the Archæan are imbedded in it. These facts are similar to those that have been reported from the vicinity of the junction both north and south of the Archæan, on the west side of the Hudson River. They tend to show that the Triassic was a valley or estuary formation.

A map of Sandy Hook in the report, facing the title page, gives, beside the outline for 1885, the outlines from a survey in 1685, also in 1765, and later lines from the U. S. Coast Survey. The increase in length and breadth since 1685 has given more than four times the area it then had. A map is given of Little Egg Harbor showing, since 1841, that the drifted sands have prolonged the north point of the entrance nearly 3 m. S.W. and closed the old inlet. At Holly Beach a similar change has taken place by a southward drift of the sands along the beach, which has also shortened in the north end.

11. *Freshwater Invertebrates of the N. A. Jurassic.*—Bulletin 27 of the U. S. Geological Survey is occupied with a paper by Dr. C. A. White on the freshwater invertebrates from the Jurassic rocks of Dakota, Colorado and Wyoming. The genera of shells represented are *Unio* (7 species), *Limnæa* (3), *Planorbis*, *Vorticifex*, *Valvata*, *Viviparus*, *Lioplacodes*, *Neritina;* and the *Ostracoda*, according to the best English authority, Professor T. Rupert Jones, to whom they were submitted, include *Metacypris Forbesii* Jones, besides other species of the same genus, *Darwinula leguminella* Forbes, and several yet undescribed species of *Cypris*. The memoir is illustrated by four plates.

12. *Modern Petrography*, *an account of the application of the Microscope to the study of Geology;* by George H. Williams. 35 pp. Boston, 1886 (Monographs on Education, D. C. Heath & Co.)—This is an interesting essay, telling of the methods of microscopical Petrography, and calculated to give to the reader something of the enthusiasm for the subject which is felt by the writer. Its usefulness to teachers is increased by the bibliography, suggestions as to instruments, etc., given at the end.

13. *Stromeyerite from Mexico.*—Dr. König has analyzed a specimen of stromeyerite from Zacatecas with the following results:

| S | Ag | Cu | Insol. |
|---|---|---|---|
| 15·81 | 50·18 | 33·69 | 0·26 = 99·94 |

This corresponds to the formula $(Ag, Cu)_2S$ with the ratio of silver to copper sulphide nearly 1 : 1, or exactly 47 : 53. The mineral occurs in imperfect prismatic crystals on quartz; the specific gravity was 6·230.—*Proc. Ac. Nat. Sc. Philad.*, p. 281, 1886.

14. *Stüvenite, an alum from Chili.*—Dr. Darapsky has recently described a series of Chilian alums derived from the abandoned mine Alcaparrosa near Copiapo. One of these occurred in slender acicular crystals, 2 or 3 inches in length. An analysis yielded:

| | $SO_3$ | $Al_2O_3$ | MgO | $Na_2O$ | $K_2O$ | $H_2O$ |
|---|---|---|---|---|---|---|
| ($\frac{2}{2}$) | 36·1 | 11·6 | 1·0 | 2·7 | *tr.* | 47·6 |

This corresponds to $(Na_2, Mg)SO_4 + Al_2S_3O_{12} + 24H_2O$. To this alum the name Stüvenite is given after the mining engineer Enrique Stüven. The paper from which this is taken closes with a discussion of the mutual relations of the numerous species, hydrous sulphates of alumina with potash, soda, magnesia, lime, manganese, zinc and iron.—*Verhandl. wissensch. Vereins Santiago*, p. 105, 1886.

15. *An artificial crystallized Silico-carbonate.*—RAMMELSBERG, who some years ago described crystals of gay-lussite obtained from soda lye at the chemical manufactory of Dr. Reidemeister at Schönebeck, has recently given an account of a silico-carbonate of alumina, lime and soda obtained from the same source. This is found in tabular crystals, which belong to the orthorhombic system. They yielded on analysis:

| $SiO_2$ | $CO_2$ | $Al_2O_3$ | CaO | $Na_3O$ | $H_2O$ |
|---|---|---|---|---|---|
| 22·75 | 14·99 | 7·38 | 13·28 | 22·37 | [19·23] = 100· |

This coresponds to a compound of the normal silicates and carbonates of alumina, lime and soda or simply $R(Si, C)O_3 + \frac{10}{7}$ aq. This compound is particularly interesting because related to the natural silico-carbonate cancrinite. Rammelsberg suggests that the formula of cancrinite may be written $2R_2(Si, C)O_3 + 3R_4(Si, C)O4$, assuming that $SiO_2$ and $CO_2$ play the same role, as in the artificial compound described.

## III. BOTANY AND ZOOLOGY.

1. *Bulletin of the Congress of Botany and Horticulture at St. Petersburg.*—The botanists and horticulturists held an international congress at St. Petersburg in May, 1884. The *Bulletin du Congrès*, printed in 1885, has now just reached us at the close of the year 1886. It is an imperial octavo volume of 335 pages, largely in French, partly in Russian and German, with one article in English.

The latter is "*Notes on the genus Lilium*," by H. T. Elwes, the author of the sumptuous Monograph of the Lilies (which was completed in 1880), and one of the two British delegates at the Congress. The article closes with a list of the Lilies at present known, 51 species, with principal synonyms and habitat. The only species added in these last few years are three by Brossier in the last volume of the Flora Orientalis, which may not hold good. Mr. Elwes doubts whether many more are to be expected, except from the Chino-Himalayan region. He records some interesting details respecting the cultivation and the constitutional disposition of various species; he finds it "an important point in the culture of delicate lilies, that the ground in which they are planted should be already occupied by the roots of shrubs or plants which, without overgrowing the lilies entirely, will have the effect of keeping the soil drier and more open"; he confirms what he had said "as to the extreme difficulty of raising hybrid lilies from seed," and, in view of the insufficiency of dried specimens in such plants, and the remarkable differences in the bulbs which he has pointed out, he impresses the importance of studying them in life. This he has done above all others.

Mr. Lynch, the curator of the Botanic Garden of Cambridge University, in a brief paper with some figures, explains the method of cultivating aquatic plants, such as water-lilies, which he has made so successful.

Baillon has an interesting memoir on what he terms *ovaires acropylées*, namely ovaries open at the top at the time of fecundation, and which are or may be fecundated either directly by the deposit of pollen upon the projecting or imperfectly enclosed nucleus of the ovule, as he shows in certain cases in *Rheum*, or by the growth of pollen-tubes down a pervious passage through the ovarian walls widely distant from the stigmas, as in *Passiflora*. The borders of the orifice at the apex of the ovary, between the reflexed styles, in *Passiflora cærulea*, appear to excite the growth of pollen-tubes even more readily than the stigmas themselves. For the difficulty of fecundating this species is well known; but Baillon now tells us that the French gardeners have long known how to do it, by application of the pollen to the top of the ovary between the bases of the styles! Baillon says that there are many other angiospermous plants with open ovary. Those systematists—just now in the majority—who relegate the Gymnosperms to a position far away from the other Dicotyledons, should compare all this with the structure and fecundation of *Gnetaceæ*, and reconsider.

The essay by Timarizeff on the function of chlorophyll was some time ago noticed in this Journal. So, also the paper of Maximowicz upon the vegetation of Mongolia and northern Tibet in the light of recent collections by Russian explorers.

A second communication by Mr. Lynch should not be overlooked. It is upon the tubers of *Thladiantha dubia*, which look like small potatoes, and by which this rather pretty cucurbitaceous plant propagates in the gardens freely, not to say exclusively, for the female sex is rarely seen. We took it for granted that these were true tubers, but Mr. Lynch shows that they are thickenings of roots, that they form even on the primordial root of the seedling, as well as upon secondary fibrous roots, and that the sprouts are adventitious buds. Mr. Lynch says that all the seeds he has received and raised gave rise to male plants, and that the female is unknown in England. We have had both in cultivation, but the female soon died out, while the male, thanks to these false tubers, has become a weed.

Equally interesting to pomologists and to botanists, is a communication in Russian, by a M. Wilkins, who sends from Feringha in the province of Khiva, the figures of peach-stones, filling two folio plates, with explanations,—designed to show the presumed genealogy of the varieties: it is an instructive series. Happily, Dr. Maximowicz gives an abstract of the paper in French, and appends some notes. He remarks that while in Western Asia and Europe, where the peach is prized as a fruit, it is this which has developed so many and great variations, while in China and Japan, where ripe peaches are less esteemed (being thought unwholesome), and the tree enters into ornamental cultivation, it is the flowers which are greatly varied. A. G.

2. MINOR BOTANICAL NOTES.—Mr. Maw has completed his *Monograph of the genus Crocus*, a superb royal quarto volume, with 81 hand-colored plates, maps, vignettes, &c., published by Dulau & Co., London. From Beccari we have received the second part of the third volume of *Malesia*, mainly devoted to Asiatic Palms. Part 12 of the second volume of the new (Botanical) series of the Transactions of the Linnean Society of London is occupied with a paper by Mr. Fawcett, of the British Museum, *On new species of Balanophora and Thonningia, with a note on Brugmansia Lowii;* with four fine plates.

*Jahrbuch des Königl. botanischen Gartens und des botanischen Museum zu Berlin*, Band iv, edited by Professor Eichler, Dr. Garcke, and Dr. Urban, has just appeared. The larger papers are by E. Fischer on the *Phalloideæ;* Loew, on the relations of insects to plants in the Botanic Garden (an extensive article, which we propose to give some account of); Wenzig on Old World Oaks; Urban, Miscellanea in the Botanic Garden and Museum and on Pollenisation in *Loasaceæ;* and Schumann, on Comparative Morphology of the Flowers in the cucullate *Sterculiaceæ*. We learn with great sorrow that Dr. Eichler's health is seriously impaired.

*Recent additions to Canadian Filicineæ*, by T. J. W. Burgess, forms an article of 10 pages, quarto, in the Transactions of the Royal Society of Canada, just issued.

*Additions to the Flora of Washington and vicinity* (i. e., additions to Mr. Ward's excellent catalogue), by F. H. Knowlton, make a pamphlet separately issued from the third volume of the Proceedings of the Biological Society of Washington.

*History and Biology of the Pear-blight*, by J. C. Arthur, is the thesis presented for the doctorate in science to Cornell University in June last, and now published by the author in the Proceedings of the Philadelphia Academy of Natural Sciences, 24 pages 8vo, and a plate. The whole history of this fearful blight is given in detail, the most curious fact being that it is peculiar to Atlantic North America, where it has been known for almost a hundred years. The plate gives figures of the bacterium, which, according to Professor Burrill's discovery, produces the disease; also the zooglæa grown from it in cultivation in hay and potato infusion. The name of this destructive bacterium, given by Professor Burrill, the discoverer, was *Micrococcus amylovorus*, which, "by a typographical error" was in a reprint of the author's original paper "made to read *M. amylivorus*, a mistake which has been copied into other works," says Dr. Arthur. We should say that the latter was rather the correction of an original mistake, which should have been accepted with thanks, unless indeed the bacteriologists are *super grammaticum* and prefer to write *carnovorus* and *insectovorus* and *graminovorus*, which is not likely.

I. Freyn, of Prague, has recently published several articles on *Ranunculus*, and is engaged in a complete elaboration of the European species. In furtherance of his work he solicits exchanges with American botanists.

*Acta Horti Petropolitani*, tom. ix, fasc. 2, is just received. The article which most interests us is on the plants of the Commander Islands, i. e., Bering Island and Copper Island, next to the coast of Kamtschatka, being a list of the species collected by two Russian Doctors, in 1879 and 1881. To our surprise the *Bryanthus Stelleri* is not among them. Dr. Herder gives a complete enumeration and determination of George Forster's *Icones Plantarum in itinere ad insulas maris australis collectarum*, *cum tabulis æneis et duobus pictis*, two volumes in folio, of which the Petersburg Garden possesses an unique copy. The volume also contains the younger Regel's fine *Monographia generis Eremostachys*, with ten large plates.

*Catalogus Systematicus Bibliothecæ Horti Imperialis Botanici Petropolitani*, a new edition, by Dr. Herder, forms a large 8vo volume of 510 pages, with complete indexes; a valuable volume.

Sir Joseph Hooker's Primer of Botany has been issued in a third edition, revised and considerably enlarged, especially by sections on the general nature and work of plants, on their tissues, their food, assimilation, etc. The primer now has 143 pages, about twenty more than in the second edition.

Mr. N. L. Britton, of the Torrey Herbarium, has contributed to the Bulletin of the Torrey Botanical Club, vol. xiii, no. 11, a Preliminary List of the North American species of *Cyperus*, with descriptions of new forms, a recast of the genus, with two new species, *C. Halei* and *C. Wrightii*, and several varieties. A. G.

3. *Bulletin of the American Museum of Natural History*, vol. I, No. 7, Central Park, New York.—The number for July contains the following memoirs: Description of a Squirrel, *Spermophilus tereticaudus* of Arizona, E. A. MEANS; Life history of *Amblystoma opacum*, and on *Scaphiophus Holbrooki* Col., N. PIKE; Revised list of birds of Massachusetts and on *Colinus Ridgwayi* of Arizona (with a fine colored plate), J. A. ALLEN.

## IV. ASTRONOMY AND MATHEMATICS.

1. *The Argentine General Catalogue.*—This Catalogue of Southern Stars forms volume xiv of the *Resultados del Observatorio Nacional Argentino* and contains positions of southern stars observed by Dr. Gould with the meridian circle at Cordoba. In forming the observing lists the stars needed for reducing the zones and the stars of the Uranometry were first disposed of, then those stars remaining of Lacaille and Brisbane, and the bright southern ones of Lalande. To these were then added stars from Gilliss, Yarnall, Moesta (2), Stone's Maclear, Ellery and from the Cordoba Zones. Most of the stars brighter than 8½ magnitude must have been observed, especially most of those south of the parallel 23° S. The current numbers run to 32,448, though clusters that are added will increase the total by more than a thousand stars. These figures show the magnitude of Dr. Gould's work, and the importance of the catalogue in Southern Stellar Astronomy. It is very rare that there is occasion to take note of such a remarkable contribution to the science.

2. *Theory of Magnetic Measurements with an Appendix on the Method of Least Squares;* by FRANCIS E. NIPHER. 94 pp. 8vo. New York, 1886 (D. Van Nostrand).—The experience of the author has enabled him to write a volume containing much that will aid other observers in the same field.

## V. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Precious Stones in Nature, Art and Literature*, by S. M. BURNHAM. 400 pp., large 8vo. Boston, 1886 (Bradlee Whidden).—This is a handsomely printed volume, written in an attractive style and giving much information of interest to the general public. The scientific portion of the work—a small part, indeed, is not quite as accurate as might have been desired.

2. *Transactions of the Royal Society of Canada*, Vol. III, 1886. (Dawson Bros.).—This valuable volume contains, among the papers in the sections on physical, chemical and natural science: A. Johnson, on tidal observations in Canadian waters; Dr. Hunt, on a natural system in mineralogy; Dawson, on the Mesozoic floras of the Rocky Mountain region in Canada; E. J. Chapman, on a hematite mine; G. F. Matthew, on the Fauna of the St. John's Group; R. R. Wright, on the skull and auditory organs of Hypophthalmus, and others. There are also in the other sections, many papers on archæological subjects and on historical and other topics.

3. *Journal of Morphology.*—This Journal of "Animal Morphology" is announced by Ginn & Co. of Boston as to appear early in 1887. Two numbers, of from 100 to 150 pages each and 5 to 10 double plates, will be issued a year, at $6.00. C. O. Whitman of Milwaukee, Wis., is to be the editor, with the promised coöperation of many zoologists, the list commencing with the names of Dr. J. Leidy and E. D. Cope of Philadelphia.

4. *Papers of the Berkshire Historical and Scientific Society.* 136 pp. 8vo. Pittsfield, 1886.—This first volume of the Berkshire Society contains four papers: On Berkshire Geology, by J. D. Dana; On the western boundary of Massachusetts, by F. L. Pope; the Judicial history of Berkshire, by H. W. Taft; the Early roads and settlements of Berkshire west of Stockbridge and Sheffield, by H. F. Keith.

5. *Journal and Proceedings of the Royal Society of New South Wales*, vol. xix, 1885. A. Liversidge, Editor.—This volume of the Royal Society of New South Wales contains, among its papers, the following: on Local Variations and Vibrations of the Earth's Surface, by H. C. Russell, with five diagrams; on Causes of Decay of the Australian Forests, by Rev. P. Macpherson; on the History of Floods in the Hawesbury River, by J. P. Josephson; on the Characters of the Adelong Quartz-reefs, by S. H. Cox; on the Ringal of the Northwestern Himalaya, by Dr. Brandes, besides others; preceded by the address of the President, H. C. Russell. The cause of decay in the Australian forests, after much investigation, was traced to the *Opossums.* The leaves of Eucalyptus were eaten and each margin thus deeply scolloped. This was proved to be the way with a captive opossum; and it was further proved that one opossum would devour about 200 leaves a night; and consequently shown that the 18,000 opossums killed annually in County Grant, Victoria, were sufficient to destroy upwards of 13,000 trees and lay bare a space of 700 acres, or more than a square mile.

## OBITUARY.

Isaac Lea.—Isaac Lea died at Philadelphia on the 8th of December last in his ninety-fifth year, after a life of enthusiastic devotion to science and great success in scientific work. He was born in Wilmington, Delaware, on the 4th of March. His residence in Philadelphia began when fifteen years of age; and at twenty-two, in 1814, he and his friend, Mr. Lardner Vanuxem, later Professor Vanuxem, of the Geological Survey of New York, became members of the Academy of Natural Sciences of that city. His contributions to science began and ended with the department of mineralogy. But his chief memoirs and works are devoted to the departments of modern conchology and some departments of paleontology. His investigation of the American Unios began in 1825 on receiving some specimens through Major Long, from the Ohio river; and when it closed in 1874, he had published thirteen volumes. The difficulties in discriminating species arising from varying forms in the shells he endeavored to overcome by a study of the animals, and accomplished much in this direction. His researches were extended to the fresh-water shells of other continents; and they included besides Unionidæ, also species of Melanidæ, Paludinidæ, Helicidæ, and other freshwater species. The other large field occupied by him was that of the Tertiary shells of eastern North America. His attention was called to the shells in the Claiborne bluffs in 1829. His "contributions to Geology" in 1833, in which year he published a series of papers, and included all in a volume of 226 pages, embraced discriptions and figures of 221 species of Tertiary shells, from Maryland and New Jersey as well as Alabama. Later he described fossil shells, of Oolitic age from Grenada; Unio-like species from the Carboniferous of Pennsylvania; a fossil reptile (for which he instituted the genns *Clepsysaurus*) from the Juratrias of Pennsylvania; a paper (in 1854), on large foot-marks from the Subcarboniferous red sandstone of Pottsville, of which he published a grand lithographic plate, of natural size—the discovery carrying amphibians back geologically to an earlier period than before known; and papers on some feldspars.

The establishment of this Journal in 1818 owes much to Dr. Lea, who responded with zeal to a request from Professor Silliman for his "kind countenance and favor" and for "contributions to its pages," by procuring at once and sending on (April 3, 1818) the names of more than a dozen subscribers,* the last of whom has now passed away in his own decease, after the publication of the 132nd volume.

Mr. Lea was married in 1821 to Miss Carey, daughter of the well known Philadelphia publisher, Matthew Carey; and for thirty years he was also a partner in the publishing house. Mrs. Lea, a companion of congenial tastes and an amateur in botany, especially the department of forest trees of America and Europe, died in 1873. Three children survive him, Henry Charles Lea, Matthew Carey Lea and Miss Frances Lea.

Mr. Lea became a member of the American Philosophical Society in 1828; was President of the Academy of Natural Sciences of Philadelphia from 1853 to 1858; and was elected to honorary membership in many foreign scientific societies. He received the degree of Doctor of Laws from Harvard in 1852. A complete detailed list of the publications of Dr. Lea, with a biographical sketch, is contained in number 23 of the Bulletin of the United States National Museum, prepared by N. P. SCUDDER. It speaks of Dr. Lea in his 94th year, as still "blessed with good health, his mental and physical faculties unimpaired;" and so it continued to be until ten days before his decease.

The Elements of Chemical Arithmetic with a short system of Elementary Qualitative Analysis, by J. Milnor Coit, Ph.D. 89 pp. 8vo. Boston, 1886 (D. C. Heath & Co.)

A Manual of Lithology, by EDWARD H. WILLIAMS. 135 pp. 16mo. New York, 1886 (John Wiley & Sons).

Causeries Scientifiques, Decouvertes et Moentions, Progrès de la Science et de l'Industrie, par Henri de Parvill, 25 tom année, 1885. Paris. 1887 (J. Rothschild). A popular volume telling of some of the recent advances made in scientific thought or investigation.

Lectures and Essays by the late Wm. K. Clifford, F.R.S., edited by Leslie Stephen and Frederick Pollock with an introduction by F. Pollock. Second Edition. 443 pp. 8vo. London and New York, 1886 (Macmillan & Co.).

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* A list of these subscribers, in a letter from Dr. Lea, is published in volume xxvi, 1883, of this Journal, on page 79.

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# AMERICAN JOURNAL OF SCIENCE.

## [THIRD SERIES.]

## Art. X.—*Kilauea after the Eruption of March*, 1886.* With Plates I and II.

I. *Communication to* Professor W. D. Alexander, *Surveyor General of the Hawaian Islands, by* J. S. Emerson, Assistant in the survey, dated Aug. 27, 1886: *On Observations in Kilauea made between March 24th and April* 14*th*, 1886. (With Plate I.)

. . . I reached the Volcano House soon after noon, March 24th (17½ days after the eruption) and remained three weeks, until April 14th. During much of this time the rain, drizzle and fog interfered materially with my work, but I had enough clear weather to accomplish most of what I had proposed to do.

With the kind assistance of the photographer, Mr. T. P. Severin, I measured a base line, 3532 feet in length, on the plain above the crater, near its northwest edge. With this base line I connected by triangulation the main points of my survey, filling in the details with a telemeter rod. Particular attention was paid to measuring vertical angles, from which I was enabled to compute the true height of every point located on the accompanying map, referred to the veranda floor of the Volcano house taken as datum. In addition to the information given on the map, I would add the following.

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* For the communications here published, on the condition of Kilauea since the eruption of the 6th of last March, the editors are indebted to Professor Alexander. A brief account of the eruption is contained in vol. xxxi, p. 397 (May, 1886.)

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During my stay no molten lava was anywhere visible in the entire crater. At certain points of easy access, a stick could be lighted by thrusting it down a crack so as to bring it in contact with the red hot rocks beneath. But in general there was scarcely a place from which I was prevented access on account of the heat. One of the hottest points visible at the time of my first descent into the crater, March 25th, is indicated on the map as *Severin's Furnace*, Mr. Severin having taken an excellent photograph of it. At that time, March 25th, its interior was still red with intense heat, but on my last visit to it, eighteen days later, it had so far cooled down as to excite no special interest on account of its heat. Another spot of considerable heat was a cone just to the southwest of my station at *Halema'uma'u S.* Surrounding it were a number of large cracks in the rocky floor of the crater, from which the hot air arose as from a furnace. By holding my breath as I repeatedly passed over them, I experienced no great discomfort.

*Halema'uma'u.*—On the 29th of March, in company with a tourist who had just happened along, and two native guides, from a point at the south side of Halema'uma'u, I descended into this pit, until then entered only by the Rev. E. P. Baker, of Hilo. The fragments of pahoehoe (smooth lava) over which I passed in my descent presented considerable uniformity as to size. In general they were irregular slabs, six, eight or more feet long, perhaps five or six feet wide and about a foot thick. I would remark that the greater portion of them occupied such a position that the slope of their surfaces nearly coincided with the general incline of the whole sunken floor of which they formed a part, though many were tilted up on one another in a most irregular fashion by the great fall occasioned by the removal of their liquid support on the 6th of March. I would also call attention to the fact that on this portion of the floor there was a marked absence of small fragments or gravel, which is to be contrasted with the condition of the sides of the deep central pit, soon to be described. Though our guides pointed out the danger and risk we ran of breaking a limb from the upsetting of any of these insecure slabs, we took our chances, and by carefully feeling our way with our walking sticks, passed safely down to a point near the edge of the great central pit. At the mouth of this pit the rough floor of pahoehoe slabs came abruptly to an end, leaving a nearly circular hole some 600 feet in diameter, looking almost as if punched out, from the brink of which the very regular sides sloped steeply down in the form of an inverted cone. The broken masses of pahoehoe that lay about the brink seemed to be so insecurely supported as to threaten suddenly to give way if disturbed, and precpitate themselves into the depths below. For this reason I prudently refrained from trusting myself to their support, and did not approach near enough to the sides to examine the material of which they were composed. It presented a regular, lusterless surface, quite free from projecting rocks and also without notable fissures, and bore a strong resemblance to coarse gravel or small fragments of broken lava rock. At a depth, which I estimated at about 275 feet below the upper edge of this pit, was the very bottom of Halema'uma'u, an apparently smooth surface of black pahoehoe, entirely free from fallen rocks or debris, approximately in the shape of an equilateral triangle of about twenty-five feet on a side. It was not as level as the surface of a newly cooled lake. A portion rose somewhat irregularly above the rest and gave the impression of a mass of solid rock covered over with a thin coating of fresh pahoehoe. Near the northeasterly vertex was a small fissure from which arose a slender column of faint bluish smoke. The base of this smoke column afterwards served me as a convenient substitute for a flag in my triangulation, by which I accurately determined the depth of Halema'uma'u to be 900 feet below the datum at the Volcano house. I daily watched the smoke jet above described in hopes of seeing some marked change, but I was always disappointed.

The point of greatest interest to me was within the sunken area of Halema'uma'u, 750 feet northwest of the smoke jet in the central pit and 364 feet above its level. My attention was first particularly directed to it April 5th. While engaged in the survey of New Lake I noticed at that time a continuous jet of steam arising from this point. It had burst through the broken lava rock and had already made for itself an oval-shaped aperture, perhaps five or ten feet across. I thought I had seen it from the Volcano house for a day or two before, but had not made any special note of it. I now began to watch it carefully. The next morning, on observing it with a glass from the Volcano house, there was a marked change in its appearance, and I soon saw that it was no longer a jet of pure white steam, but of pale bluish, sulphurous smoke. The continued rainy weather prevented my visiting it again until April 8th, when I observed that the size of the aperture, as well as the volume of smoke had greatly increased. After another vexatious delay of several days owing to rainy weather,—wind from the northeast, regular trades,—I made my final visit to it on the 12th of April, when through the rift in the smoke, which was now pouring out from this elongated aperture, I saw the newly formed bank of glistening sulphur on the southwest side. As I was surveying in that vicinity I had occasion to occupy the station which I had already fixed at *Halema'uma'u W.*, on the edge of the precipice overlooking the great abyss. My cautious native guide warned me that, as the station was directly to the leeward of the smoke jet, I would do well to avoid it, for fear of being suffocated by the sulphurous fumes. In spite of his warnings, I set up my instrument at this station and continued my work without regard to the smoke, which was blown by the wind directly toward me, passing a few feet over my head. I noted by my watch the length of my stay at this spot to be over thirty minutes. During that time the plumb bob of my instrument was considerably tarnished, but though at times I was obliged to stand aside for a moment to avoid the smoke, I suffered no special discomfort either then or afterward.

*New Lake and Little Beggar.*—On the 5th of April, followed by my native guide, I explored the abyss formerly occupied by the New Lake, and set up a flag at one of its lowest points marked on the map *Inferno.* Entering the $11\frac{94}{100}$ acre sunken district at a point near Central rock, I passed over a number of cracks in the inclined floor of pahoehoe from which arose a considerable volume of heated air, and paused for a moment at a still hot cone, now fallen in and rapidly cooling off. It had formerly been a most conspicuous object. To distinguish this small caldron of molten matter (once visible down its throat) from the great lakes of liquid rock, it had been dubbed the "Little Beggar." Passing over the old trail to Halema'uma'u I came to the edge of what had been called the "Bridge," between the two lakes. From this point the descent into the Little Beggar was quite abrupt, and the whole character of the rocky surface assumed a very different appearance. A large portion of the bottom of the lake was composed of huge, solid bowlders, as rounded and smoothed as if worn by some mountain torrent. They were covered about an inch in thickness with a fresh coating of black vitreous enamel, left adhering to them when the molten contents of the lake had sunk from view on the 6th of March. This enamel was very brittle, and, under the sharp blows of my walking stick, broke in pieces, exposing the solid rock beneath. The general appearance of the floor was that of a series of well-rounded hillocks and hollows, uniformly covered with the black coat already referred to. There was a marked absence of broken or angular fragments. At the base of the vertical wall, directly beneath New Lake 1, was a spot of considerable heat, much greater than that of any other place in the lake, (or what was the lake until the eruption). It was evidently the upper extremity of the shaft which had connected the boiling lava in the lake with the depths beneath. The sides of the wall above it and the vertical faces of the massive rocks on its northwestern side formed an arc, somewhat circular, of perhaps ten feet radius. They showed the peculiar glazed surface characteristic of all similar shafts in the volcanic districts of Hawaii. Its bottom, which I judged to be at about the level of the point marked *Inferno*, was closed with the fresh, shining black lava which had solidified as the retreating column had fallen to a lower level. Near the southwestern portion of the pit lay the huge hulk of the now stranded "Floating Island," a great mass of firmly cohering rock which, for more than four years previous to the sinking of the lake, had been floating like an iceberg and slowly changing its position on the molten flood. It now towered over sixty feet above its base on the bottom of the abyss and extended, I should judge, full a hundred feet in length. Piled against the southwestern base of the "Floating Island" was a mass of loose rock which had fallen from the sides above. Save at this point and at the end from which I had entered, the nearly vertical sides of the lake rose unbroken from the surface of the bottom to a height above the lowest point of 154 feet on the eastern side and 166 feet on the western side. These side walls, at least their lower portions, appeared to be of solid rock which had long been in direct contact with the intensely heated molten lava that until recently had filled the lake. The sides as well as the bottom were free from rents and cracks or any break by which the lava could have escaped. And they were everywhere coated with the black vitreous enamel which was a marked characteristic of the "New Lake." There was no direct lateral connection with Halema'uma'u to be seen. The evidence seems to point to the conclusion that the lava passed out of New Lake on the 6th of March by the same shaft at its bottom by which it had entered.

Very different was the condition of the treacherous sides of the abyss of Halema'uma'u. There, yawning fissures, with masses of rock just tottering to their fall, warned me to be very cautious in approaching the ragged edges of this still widening area of ruin. From time to time with a loud crash a portion of a cliff would fall a hundred and fifty feet or more, and dash itself to pieces on the sunken floor below, raising clouds of dust. It seems likely that this was what gave rise to the report that much smoke was rising from the lakes, for during the three weeks of my stay, there was no other smoke jet worthy of mention but the two already described.

Of steam jets in Kilauea the number was very variable, and seemed to depend greatly on the condition of the weather and the hour of the day. At times, especially in the morning, the whole crater was almost entirely free from them, while after a shower of rain, particularly in the afternoon, they were very numerous, and with the mist which often accompanied them, rendered the work of surveying impossible.

Outside of Kilauea, in addition to the large number of steam jets which are a prominent feature of the landscape about the Volcano house, there was a large rent in the earth crossing the road by which we came from Keauhou, extending in a southeasterly direction, at a point about two miles from the Volcano house. It was formed at the time of the sinking of the lakes, and when I observed it, on the 24th of March, the steam was still coming up from a considerable depth. A few days later, on a visit to "Kilauea Iki," a deep and apparently extinct crater to the east of the main crater of Kilauea, I crossed a similar rent, formed at the same time, nearer to the volcano, from which in like manner the steam was freely arising. I was also particularly interested in a line of steam jets, stretching away for miles to the southwest, arising from the steam cracks of 1868, the general direction of which, as observed by prismatic compass, was S. 44° W. On the 26th of April I examined a number of these steam jets, and found that in every case the sides about the orifice from which they arose were well covered with moss, proving that they were of an older date than the 6th of March. On the northwest side of, and running parallel with, the great steam cracks of 1868, were a number of smaller cracks in the extended plain of pumice. There were also a few on the southeast side. But in no case did I see any steam arising from them. The vertical section of some thirty feet or more in the sides of some of these fresh cracks furnished an excellent opportunity to study the arrangement of the successive layers of pumice, gravel, and fine sand which made up the mass of the great plains stretching for miles to the southwest of the crater. It was doubtless the ejecta of the volcano, which, blown thither by the wind, and accumulating for ages, must have attained considerable depth.

I was obliged to leave unsurveyed a portion of the sunken district to the southwest of the station, marked on the map *Halema'uma'u S.* It was an irregular district, of some ten acres extent, whose average subsidence I judged to be not over ten feet, save in that portion which, sloping rapidly down and connecting with the great abyss of Halema'uma'u, I found had fallen twenty feet and more. It lay nearly on the direct line from the central pit of Halema'uma'u to the steam cracks of 1868. On the 25th of March I remarked the great heat of portions of this district, and on the afternoon of the 12th of April, as I crossed it for the last time, I observed that while the crater had been decidedly cooling down as a whole, this portion had retained its heat in a marked degree, and was without doubt the hottest part of its entire area. The heated air still arose from it as from a furnace, and the steam jets from its fissures seemed unusually numerous and active.

Having now described the appearance of things as I had observed them, I will in conclusion call attention to some of the facts bearing on the cause of the great changes which had so lately taken place. On the east side of New Lake, some time ago, a small stone wall had been erected to shield those who wished to watch the lake at night from the wind and rain. The base of this wall I found to be 342 feet below the Volcano house. Mr. J. H. Maby, the manager of the Volcano house, very kindly gave me a statement of the height of the surface of the lava in the New Lake at various intervals from Dec. 1st, 1885, up to the 1st of March, 1886, as referred to the spot where this stone wall stood, and in his opinion the heights thus given would be true as well for the surface of the lava in Halema'uma'u, as there was no perceptible difference in the elevation of the molten surfaces of these two lakes. Though not claiming to be exact, these statements, coming as they do from an intelligent eye-witness thoroughly familiar with the locality, may be accepted as reliable. From them I am enabled to give the heights of the lava columns in these lakes at the various dates entered upon my map. From these figures it will be seen that the level of the lava in the lakes was rapidly rising during this time. During the fifteen days commencing Dec. 1st, 1885, it rose from 12 to 14 feet, an average of 0·87 feet per day. During the next sixteen days from Dec. 15th it rose from 18 to 21 feet, an average of 1·22 feet per day. On the 1st of January, 1886, it stood some 10 or 15 feet above the stone wall, and by the cooling and solidifying of its edges had raised the walls of the lake at that point a corresponding amount. Though the lake still continued to rise and build up its walls, it had found partial relief by a surface flow to the northeast, which eventually covered an extended tract of the desolate waste of pahoehoe which formed the floor of the crater. As it cooled it was difficult to distinguish the outline of this new flow from those which had preceded it. One of the points, which it reached a few days before it ceased, I have located by my *Pahoehoe* station on the accompanying map, from which it appears that it had flowed a mile and a half at an average grade of 1·77 feet per 100 feet. At the same time there was a smaller flow to the northwest. Halema'uma'u meantime was also overflowing and extending the rocky floor of the crater to the southeast and south, covering up the old beds of gravel in those directions. Apparently on account of the loss of matter by these flows, the rise of the lava column in the New Lake was from that time very much retarded. During the 59 days beginning with the 1st of January, 1886, it rose from 20 to 25 feet, an average of only 0·37 feet per day. On the 1st of March it stood from 30 to 40 feet above the stone wall, and at an equal height above the level of the top of Houlder's monument, while the cone which it had formed, like a little mountain, towered to a considerably greater height. The weak sides of the crater could not long resist the immense pressure of such a liquid column. As long ago as 1868, they had been badly rent, and it needed but a slight disturbance to cause them now to give way and allow the liquid free exit. The coincidence of the collapse of the lakes, following so closely upon the solar eclipse of April 5th, suggests, as Mr. C. J. Lyons, of the Government Survey, has pointed out, the possible influence of the united pull of the sun, moon and Venus upon our planet as determining the time for the sides of the overstrained caldron to give way. Be that as it may, the time had come, and the whole column sank, within a few hours, a vertical distance of from 587 to 597 feet, disappearing in the depths below. Mr. Maby observed that the fire first went out in New Lake, some little time before its final disappearance from Halema'uma'u. This would naturally be the case from its comparatively shallow depth, as the molten mass was being drained away from the two lakes into the common reservoir or duct of exit beneath.

While a portion of the escaping lava may have taken a southeasterly course, indicated by the large fissure in that direction, already alluded to, a number of indications and considerations lead to the supposition that the greater part, following the line of least resistance, found its way into the great fissures of 1868, and, from the spongy nature of the district through which its course lay, readily found all the space needed to contain its entire volume without coming to the surface or entering the sea. It has been affirmed that the steam jets along the fissures of 1868 showed greater activity immediately after the subsidence of the lakes than at any time for months before. If this be true, it becomes an indication strongly favoring the above supposition.

The numerous cracks and fissures running parallel with the great steam cracks may then possibly be explained as follows: As the subterranean lava stream forced its way through these steam cracks, it would naturally compress and force upward the spongy mass on either side of their walls. But when the swollen stream had passed along and this pressure was removed, a portion of the inelastic mass would fall back to nearly its former position, while another portion, adjusting itself to its new position, would remain separated, and a new crack would thus be formed. The escaping steam, however, would find its natural outlet through the fissures most directly over its course, instead of seeking exit by any crack removed to one side of it. I have already remarked that this was actually the case at the time of my visit. When we add to this the fact of the unsurveyed area of depression being in the line of these cracks, with the continued heat of portions of it and the number of steam jets there, the conclusion arrived at seems the more probable.

In closing, I would acknowledge my indebtedness to the Hon. S. G. Wilder for substantial courtesies extended to me during my long stay at the Volcano house; also the use I have made of the excellent map of Kilauea, made by William T. Brigham in the year 1865, from which I have extensively copied, to show the relations of my survey to the general area of the crater.

## II. *Observations of* L. L. VAN SLYKE, Professor of Chemistry and Natural Science and Government Chemistry, Honolulu, *on Kilauea, in July*, 1886.

I made my first visit to the volcano of Kilauea last July, a little over three months after Mr. J. S. Emerson's visit, and remained there from the 19th of July to the 24th. I descended twice into the crater, rainy weather preventing further observations that had been planned. The first trip down was made on July 21st, when I remained in the crater from 10 A. M. until 8 P. M.; my second visit, two days later, on July 23d, when I remained from 11 A. M. to 3 P. M.

Great changes had taken place in the pit of the crater, Halema'uma'u, since Mr. Emerson's visit. In the first place, a general upheaval had occurred in the center of Halema'uma'u; and, secondly, liquid lava had reappeared.

The steam cracks described by Mr. Emerson were in about the same condition in July as at the time of his visit. The places on the map marked "Furnace" and "Severin's Furnace" were very warm inside, but the heat was not great enough to prevent one from going within and remaining a few minutes. Only one red-hot crack was seen, and this was not far from "Central Rock," in the direction of "Halema'uma'u A."

Before speaking of the appearance and location of the places where molten lava could be seen, I will try to describe the appearance of the pit as I saw it and to indicate the changes that had occurred between April and July.

At "Halema'uma'u A," you are upon the brink of a precipice several hundred feet high, indicated by the black line on the map, extending around southward beyond "Halema'uma'u W" on one side, and eastward to "New Lake" on the other side. Just opposite this part, inside of the area bounded by this high precipice and nearly parallel to it, at a distance of perhaps from

400 to 1000 feet, there rises a very steep hill of loose rocks, perhaps 150 feet high, the base of which extends from the west wall in a rather direct line to the "Peninsula," or farther. Thus, between the wall around the pit and this hill of loose rocks, there is a deep trough-like depression. At the "Smoke Jet," near "Halema'uma'u W" the height of this hill of loose rocks suddenly drops to perhaps 30 feet, at which height the hill continues to the nearest point in the west wall. The "Smoke Jet" is located in the side of the hill just where the height drops down. This hill was found to extend on farther, being more or less clearly defined all the way around, so as to form really an immense cone with an oval or irregularly elongated base. This immense cone covers the site occupied by the deep central pit described by Mr. Emerson, as far as I can determine,—indicating that a general upheaval or rise of material had taken place in this part; for instead of a pit in the shape of an inverted cone there had appeared on its site an upright cone of lava rocks. The bottom of "New Lake" appeared to be covered with loose rocks. I did not explore this part at all carefully.

Molten lava was visible in three different places. Two of these were deep holes or wells, the other a "lake," covering perhaps five acres. I will describe these in the order in which I visited them.

Starting at a point between "Little Beggar" and "New Lake 1," I crossed the sunken "Bridge," and went, in nearly a straight line, toward the center of Halema'uma'u. For a little distance the route was down a moderate grade, but later it became very steep, when I came to the base of the cone of loose stones just described. The passage was over large slabs of pahoehoe such as Mr. Emerson describes. Ascending the cone part way, I came to the edge of a deep hole or well, of rather irregular outline, four-sided, perhaps 30 or 40 feet wide, and from 60 to 75 feet long, and not less than 100 feet deep. The mouth was surrounded by masses of loose rocks, rendering approach to the edge impossible or very dangerous, except at one point; from this point I could see the bottom of the well, and that it was covered with hardened fresh pahoehoe. At one side the liquid lava could be seen as it was puffed out of a small hole every few seconds and thrown up a few feet. The puffing noise accompanying the ejection of the lava was quite like that of a railway locomotive, though louder. The aperture through which the lava was thrown out might have been three feet long and two feet wide. Immediately beneath the point where I was standing, there seemed to be a constant and tremendous commotion, attended by a peculiar swashing noise, but I could not lean sufficiently far over with safety to see anything. Fumes of sulphur dioxide were coming up in abundance, but being on the windward side I was not greatly annoyed by them.

Leaving this place, I went back some distance toward "New Lake," and then made a detour in the direction of "Halema'uma'u S.E." From near this point I went again toward the center of Halema'uma'u over a route, probably, quite near "Emerson's descent of March 29th." This led to a second well or deep hole where molten lava was visible. This well was nearly round, with a diameter of perhaps 20 or 30 feet, and a depth of about 100 feet. At one point the edge could be safely approached, but as it was on the leeward side, the fumes of sulphur dioxide could be endured only for a few seconds at a time. Like the other well, the sides were perpendicular. At the bottom was a cone having an opening at the top perhaps 10 feet across, and inside liquid lava was boiling with intense violence, every few seconds throwing up a jet of lava, the spray of which came to the mouth of the well, almost into my face. The drops of lava thrown to the mouth of the well had cooled enough to become hardened and black when they reached the level on which I was standing. This place was quite noisy, the noise resembling that of violently swashing waters.

Besides the deep holes just described, there was, as mentioned above, a "lake" of liquid lava. It was situated immediately beneath the west wall, or that of "Halema'uma'u W" It was in the bottom of the deep trough formed by the west wall and the cone-like hill of loose rocks. It extended from the "Smoke Jet" a distance of 400 feet approximately. The best point for observing it was near "Halema'uma'u A," although this was 1,200 feet distant or farther. It was too dangerous to attempt to get a view of the lake from "Halema'uma'u W" or any portion of the wall in that neighborhood, for the edge of the precipice was mostly of loose stones and a slight giving way of the embankment would precipitate one 150 feet below into the lake. It was possible to get down to the edge of the lake, but very hazardous. The lava first appeared just under "Halema'uma'u W" and extended south along the west wall a short distance. Gradually the lava overflowed until the lake was extended to "Smoke Jet," although this latter part was a few feet below the rest. From the fact that one part of the lake is elevated above the other, the lake has been spoken of as two lakes.

On the occasion of my first visit, I took my station at "Halema'uma'u A" about noon to watch the lake. When I first saw it, the entire surface was hardened and black, the only sign of volcanic activity being little steam jets here and there. After watching about an hour, I saw some liquid lava burst through the black crust and flow a short distance, when it quickly became black and hard. These little outbreaks and flows of lava were taking place in various places on the surface of the lake during the whole afternoon. In the evening at 7:15 a very large outburst of lava came from the lake immediately below Halema'uma'u W, and, flowing in the direction of "Smoke Jet," overspread a large portion of the surface. After this the outflows were quite frequent and large during the next half hour. Little noise could be heard from our position. The "Smoke Jet" was pouring out large volumes of bluish smoke, depositing sulphur about the place of exit.

At the time of my second visit, two days later, I again took my position for watching the lake at Halema'uma'u A. There was evidently greater activity. The surface of the lake had been visibly raised by the constant outpouring and hardening of lava. At this time there was a great deal of noise, both of puffing and swashing. On the surface of the lake, at a point near the wall immediately below Halema'uma'u W, there was a place six or eight feet long and four or five feet broad, where the red-hot lava was in constant view, boiling over continuously and flowing away, and occasionally shooting up several feet into the air.

About the middle of July lava appeared in Halema'uma'u just beneath the wall at Halema'uma'u A. I saw the fresh pahoehoe at this particular place, but there was no further evidence of renewed activity at this point during my stay.

### III.—*Report to Prof. W. D. Alexander, of* Mr. Frank S. Dodge, Assistant Surveyor and Draughtsman, made Nov. 15, *on the Survey of Kilauea in the last week of September and the first of October*, 1886. With Plate II.

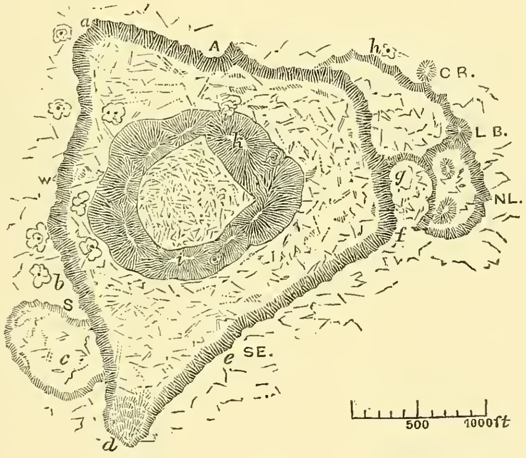
I herewith submit the following report of my visit to Kilauea, Hawaii, for the purpose of surveying the crater and vicinity, under the direction of the Bureau of Surveying. . . .

Leaving Hilo by the steamer Kinau, on the evening of Sept. 23d, '86, I landed at Keauhou early the following morning, and reached the Volcano House shortly before noon. The weather being favorable for surveying, a part of the afternoon was devoted to triangulation for the purpose of determining what changes had taken place since the last survey was made by Mr. J. S. Emerson, in March and April. From the triangulation I concluded that no material change had occurred in the general outline of the sunken district, covering the sites of Halema'uma'u and the so-called "New Lake."

At the very first opportunity I took careful observations to ascertain the height of two hills which had formed in the

Halema'uma'u pit, and later observations taken from the same station and under similar circumstances, showed that the hills were rising at the rate of nearly one foot per day. . . .

Having exhausted my supply of flags, I continued my walk along the eastern side, examining the ground carefully for proper locations for new stations, and visiting the very interesting small craters of Kilauea Iki and Keanakakoi. The former is about 3300 feet in length from east to west, and 2800 feet from north to south, with regularly sloping walls, completely covered with a dense growth of small Ohia trees, ferns, etc. In March last, at the time of the disturbance in Kilauea, a landslide occurred on the northeast side of Kilauea Iki, leaving the face of the cliff bare from top to bottom, and showing all the strata distinctly. The depth of this crater was found to be 749 feet from the point at the end of the path from the Volcano House, or 867 feet below the Volcano House veranda—which has been taken as a datum for all elevations connected with Kilauea.



Map of Halema'uma'u; from the map of Kilauea by Mr. Dodge, of which Plate II is a reduced copy. N. L., New Lake; L. B., Little Beggar; C. R., Central Rock. A, W, S, SE positions Halema'uma'u A, W, S, SE of text. Level below that of the datum mark at the Volcano House at *a*, 335·2; *b*, 350·4; *c*, 365; *d*, 344·5; *e*, 331·8; *f*, 337·4; *g*, 334; *h*, 321·3; *i*, 360; *k*, 329·5 (*i* and *k* on the cone).

Keanakakoi is 1600 feet in length and 1100 in width and approximately 400 feet in depth, with almost vertical walls, bare of vegetation, and a very smooth floor of pahoehoe.

From careful study of Mr. Emerson's map, and from observations made during five visits to the locality, I conclude that there has been no change in the "New Lake" depression, or in the "Bridge" between that and Halema'uma'u, and very little change in the main walls of the larger pit. I think a small portion of the wall near the northeast corner has fallen in quite recently, covering a part of the new floor of pahoehoe with great masses of irregularly broken rock. As far as I was able to examine it, I could discover no other change in the outline. But since the survey of March–April, there have been great and important changes going on *in* the pit of Halemau'ma'u, the present scene of activity in Kilauea. The approximate center of the sunken tract is now occupied by an irregular pit or "lake"—surrounded by a range of hills, which were carefully located, but which prevented me from obtaining the exact size of the "lake." This range of hills, or ridge, is nearly circular in form (see preceding figure), and the distance from summit to summit across the pit from northeast to southwest is 1080 feet, from east to west 1100 feet and 930 feet from northwest to southeast. I was unable to learn the condition of the central pit from close personal observation, but from the flashes of light seen over it at night, I judged that there was some action, and the native guide, who had lately visited it, informed me that there was "plenty fire."

In various places on the sides of the encircling hills, or ridge, which are formed of fine, loose material and angular blocks of stone, there were many openings which emitted dense, bluish white smoke, and steam under considerable pressure. The mouths of the openings were coated with deposits of sulphur and many of them glowed with red heat at night. The space between the base of these hills and the foot of the pali or wall, on all sides, was being filled gradually by small flows of pahoehoe from vents all over the floor of the pit. Around the base of the hills and at various points near the pali, were many small cones and "blow-holes" which sent up quantities of smoke and steam. In the extreme eastern portion of the pit were immense blocks of lava piled up in confusion; and parts of the eastern wall that had fallen in at the time of the great collapse, but the remainder of the floor was nearly level and slowly rising.

Outside the walls of the pit, in the Kilauea crater, I found only three or four localities where there were signs of any great heat below the surface. The first of these was in a small crack a few hundred feet west of Central Rock, and not far from the edge of the cliff—where the rock was red hot within two feet of the surface, and I was told that it had been so for many months. At the eastern edge of the sunken area and directly north of New Lake were large openings to a tunnel that began near the "Little Beggar," and extended several hundred feet in a general northeast direction, and considerable heat was given out from cracks in its roof; and the same was the case in a small area directly south of the peninsula, between New Lake and Halema'uma'u.

At various points on the southeast half of Kilauea, and on the face of the cliffs in that section, small jets of steam were seen at times. The steam cracks near the Volcano House, and on the sandy plain north of the crater, seemed to be in their normal condition.

Almost the entire floor of Kilauea is formed of pahoehoe, that had flowed out from the region of the lakes late in 1885, or early in the present year, covering all traces of the old Black Ledge and other features shown on earlier maps. The slope of the pahoehoe floor is quite regular in every direction, the descent from Central Rock to the foot of Lookout Hill, where the trail strikes the pahoehoe, being 163 feet—135 feet to the base of Kaniakoha, 125 feet to the foot of Kamohoalii, 105 feet to the foot of Uwekahuna pali, 75 feet to the base of Pali Iki, and approximately 80 feet to the foot of the pali* on the southeast side. Near Uwekahuna is a large patch of *Aa* (surface made of large slabs or masses of rough lavas), a few acres in extent, which I think is the only lava of that nature in the crater.

In the southern end of the crater is a long point or spit of gravel and bowlders, extending from the southeast wall about four-fifths of a mile due west, bounded on the south side by an abrupt cliff, and sloping gradually to the north and west, until it is covered up by the pahoehoe flow of this year. This same flow has also encroached upon the south bluffs and covered the older formation at the head of the bay near Holoholokolea, so that at the extreme south angle in the bluffs, a further rise of forty feet, more or less, would cause Kilauea to outflow toward the sea. At the extreme southwest corner the pali has been entirely covered by the hills of pumice which form the southern boundary.

The summits of these low, rounded hills are about 1,000 feet back from the edge of the crater, and thence they slope gently to the south and southwest, and are traversed by numerous large cracks, extending in the latter direction. At the eastern end of the aforesaid gravel point are many deep cracks parallel to the general direction of the main wall of the crater on that side, and outside the walls are many more of the same nature.

I have attempted to describe the condition of the crater of Kilauea as I found it early in October; and from observations then made, I think that in the course of time, perhaps in a few months, the great central pit will fill up and overflow, as it did prior to the 6th of March, '86, and that the center of activity will continue to be in the present locality of Halema'uma'u.

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* The word *pali* means a precipice.

## Art. XI.—*Volcanic Action;* by James D. Dana.

The new facts with regard to the recent eruption and subsequent movements at Kilauea, make this a favorable time for a review of volcanic action and phenomena; and especially so because the Hawaian volcano and its great craters illustrate more fully and simply than any others that have been particularly described the ordinary principles and methods of volcanic activity; and also because, although long since reported on, they have not yet their true place in most treatises on volcanoes. Vesuvius has been more accessible. The account of the phenomena observed by me at Kilauea in 1841, given in my Exploring Expedition Report,* needs no modification. But the conclusions after so many years of progress in science may well have a reconsideration. On the chief point, however—the essential identity in forces and laws of action between Kilauea and Vesuvius as well as other volcanoes—I find no reason for change. In my Manual of Geology (1863) I present, as the causes of eruptions:

The hydrostatic pressure of the column of lava; the pressure of vapors escaping in underground regions from the lavas, or produced by contact with them, acting either quietly or catastrophically; and the pressure of the subsiding crust of the earth, forcing upward the lavas in the conduit. I also state as sources of movements preceding an eruption: the enlarging of the mass of liquid rock in its higher portions through the vaporizable material contained in it and imbibed on the ascent; and, for aerially projectile effects, the elastic force of the vapors that escape by the forming and bursting of bubbles at the surface of the viscid lavas.

In the following pages the sufficiency or not of these causes of activity for all volcanoes, is considered.

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* Geology of the Wilkes Exploring Expedition of 1838–1842, published in 1849. 225 pages (4to) are devoted to the Hawaian and other volcanic islands of the Pacific, apart from the subject of the bordering coral reefs. The time of my visit to Hawaii and examination of the Kilauea crater was particularly opportune because of the great eruption that had so recently preceded it, and which left behind, besides features of more ordinary character, also those rarely presented. I find no facts in Capt. Dutton's report to lead me to modify my conclusions as to the mode of action in Kilauea, or as to the relations of the crater to those of other volcanoes. My tour to Kilauea commenced on the western shore at Kealakekua bay, and led me by the south side of the island and the southern slope, to Kilauea: and thence, after a study of the interior of the crater and its surroundings, eastward to the outflow of the great eruption of 1840 at Nanawale where it entered the sea.

## 1. *General.*

1. *The more prominent phenomena of volcanoes.*—In the upward movement of liquid lavas, two operations apparently distinct, are concerned: (1) the ascending movement of the liquid rock in the subterranean conduit of the volcano from the deep-seated crustal or sub-crustal region of fusion; (2) the projection of the lava aerially upward from the surface of liquid lava in the vent. Outflows accompany the upward movement whenever the height reached by the lavas is such that they have an outlet either over the walls of the crater or through an opened fissure. Each of these operations, the upthrow and outflow, involves an expulsion of material from subterranean regions; and a usual consequence (3) is a subsidence, or, *Anglicè*, a down-plunge, of the overlying rock, or the material of portions of the cone especially the more central. The upthrow, the outthrow, and the down-plunge are the three most universal and most marked of volcanic phenomena. Connected with these operations there are: (4) The escape of vapors from the crater, and (5) displacements and the opening of fissures.

2. *The ascensive action.*—The actual ascension of lavas to a height, in many volcanos, of more than 10,000 feet above the sea-level is evidence of (1) the great power of the agency concerned. In Mt. Loa, a volcanic mountain of frequent extensive summit eruptions, the height is 13,000 feet (or six miles reckoned to the sea-bottom on the east.) The observations of Mr. G. K. Gilbert on the laccoliths of the Henry mountains, proving that strata 10,000 feet thick were arched upward to a height of three to five thousand feet, by the ascending and *intrusive* lavas indicate that the ascensive force at work (2) is deep-seated as well as of great power. This inference is sustained also by the long continuance of the heat in the lava-conduit of many volcanoes, as shown by centuries of activity, in spite of the various cooling influences to which the upper part is subjected.

3. *The deep-seated ascensive action not catastrophic.*—Dr. Gilbert's valuable observations illustrate another point of much interest: the *slow* action of the force concerned, for catastrophic violence would have opened large fissures to the surface, and produced a surface discharge. A quiet mode of ascent is probably the common fact also in the larger fissure eruptions. The movement appears to be very slow in the supply conduit of a volcano. For the epochs of high level in the lavas of a crater —flood level, we might say—are separated by years, years being required for a rise in level of a few hundred feet. Three great eruptions in Kilauea were eight years apart, and, in the interval, the lift in each case was about 400 feet. The last of the three referred to occurred in 1840; and the eruptions which

have happened since illustrate the same fact. Similar testimony comes from other volcanoes. If the ascent in the upper part of the volcanic conduit is aided by some additional upthrust force, then the facts just stated make the deep-seated action by so much the slower, since in that case it is accountable only for a part of the whole rise required for an eruption.

4. *Superficial ascensive action.*—The deep-seated ascensive force in a lava-conduit should raise the contained liquid rock to a common level for all its places of discharge in a crater. It was to me a strange fact that the lava-pools over the bottom of Kilauea underwent independent changes of level—a sinking of a hundred feet or more in one, unaccompanied by a like change or any change in another. But this admits of explanation on the ground of occasional discharge by local fissures opened beneath, and on the ground of much friction along the local conduits, and a depth to the common junction as great perhaps as the space between the pools (half a mile or so in the great pit crater). It was more of a marvel that while the pools were in their usual state of ebullition, lavas should be lifted at times to a level 500 feet or more above them in a fissure intersecting the walls of the crater. Here was an effect of ascensive force, but of a force of relatively superficial origin. A similar fact is mentioned by Prof. Alexander in his notes on the summit crater Mokuaweoweo, cited on page 235 of volume xxxii (1886) of this Journal, where the lift was 800 feet above the bottom of the crater, and the eruption a large one. Some superficial agency must be concerned in such eruptions; and the same may occasion local oscillations in associated lava-vents.

5. *Surface action in the lava; Projectile effects.*—In an active volcanic vent the feeblest action possible is the quiet escape of vapors. The second stage is the aerial projection of lava in portions, masses, or fragments; which fragments may fall back as cooled cinders or as liquid lava, according to the height of projection. The latter stage may be the final one before the return to a feeble or an inactive state in the crater. But the third may follow, namely: the outflow. As long as the liquid lavas are exposed in the bottom of the crater, aerial ejections are possible and probable; and if sunk below the bottom, they may continue provided there are cavities large enough to admit of the action. This projectile force is evidently distinct in origin from the supplying force.

## 2. *Kilauea.*

6. *Character of the lavas of projectile ejections and of those flowing from the open vents.*—The lavas of projectile ejections when cooled are usually scoriaceous and often semi-glassy, and the

brittle material may be shattered in the projection, under friction and sudden cooling, into the finest dust; those of the streams flowing from the vents or pools are cellular and in part scoriaceous; over the bottom of Kilauea in 1841, they had a scoria-crust of 2 to 4 inches, easily separable from the stony part below. They were *froth-covered* streams. On the contrary, the melted rock escaping from fissures in non-volcanic regions, and those of the remoter fissures about a volcano, are generally stony, without a scoriaceous aspect in any part. Even over the bottom of Kilauea, lava that had come up through fissures distant from the lava-vents was of the more solid, stony kind "either solid stone throughout, or so excepting a *compact*, glassy exterior half an inch thick."*

The making of scoria is dependent on the kind of action characterizing the open lava vent—that is the aerially exposed extremity, or extremities, of a lava-conduit. In a fissure-ejection, some one or more places in the fissure may be broad enough to remain open as lava-vents with the usual phenomena.

7. *Abundant discharge of vapors of water.*—The exposed extremity of a lava conduit discharges vapors in great volume, the amount of which increases with the increase of activity. When at Kilauea in 1841, an immense column of heated vapors stood over the great lava lake Halema'uma'u (1,500×1,000 feet by Wilkes's measurement) and the southern half of the crater—its base some hundreds of feet above the lake, owing to the intensity of the radiated heat. It had the appearance of a threatening storm-cloud as Wilkes observes (iv, 225).† Yet this was six months after a great eruption. At times of extreme activity the pit is sometimes so densely filled with the vapors as to "obscure all the glowing fires."

Many facts show that the vapors are chiefly those of water, as is generally believed. The features of the clouds were those of ordinary clouds, and the shrubbery and ferns about the margin of the crater derived luxuriant growth from the condensed moisture.

No direct experiments were made; but we have from Mr. Emerson on page 90 of this volume, the statement that he was half an hour at his station near Halema'uma'u W exposed to the vapors that came with the wind from over the pit, and suffered nothing from the sulphurous fumes present; a fact showing that they constitute a very small part of the vapors.

While vapors are so freely discharged from the craters, the amount from fissure eruptions, even those in a volcanic region,

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* My Expl. Exped. Report, p. 180.

† Narrative Expl. Exped.

are generally small unless open active vents exist along such fissures.*

8. *Projectile action.*—In Kilauea, in 1841, the projectile action of the lava-pools, consisted in the throw of jets of lava to a height of 30 to 60 feet over the whole liquid surface—many rising and falling simultaneously. I watched the process for some time while within four or five feet of one of the smaller lakes, and, also, but necessarily from a much greater distance, the more brilliant display over the great lake of Halema'uma'u.

This lake, owing to contact with the air above had usually a red-hot surface (except when blackened at times in part by incipient cooling); but in the play of jets over its wide surface, lines of white heat, or very nearly white, opened to view between them, which a companion in the expedition, Dr. C. Pickering, well compared to a net-work of lightning flashes.

The jets were ordinarily 30 to 60 feet high; in one of the small pools about 30 feet, but 50 to 60 at intervals. At times of lull they ceased or nearly so. The diameter, if I remember rightly, was three to six inches. With a mean of 4 inches and a height of 30 feet, each would have contained about 400 pounds of lava, making the force expended equivalent to that required to raise 400 pounds 10 or 12 feet. They were in form, in rise and fall, and apparently in mode of projection, like the little jets over a surface of boiling water; and the word *ebullition* seemed to all appearance to express what was going on. On other occasions jets have been seen of 100 to 200 feet, and also of five or six feet and less. In the higher jets the lava is usually broken into parts, and the lowest of two or three feet are sometimes broad and hemispherical.

The boiling movement has been recognized by all who have visited the crater. Rev. Wm. Ellis, of Kilauea, in August, 1823, describes a lake as a flood of fire in "terrific ebullition;" and Capt. John Shepherd, R. N., there in 1839, speaks of the "violent ebullition" as "caused by the escape of elastic fluids which threw up the spray [jets] in many parts 30 to 40 feet."

In the case of "blow-holes" the boiling process goes on beneath a small aperture in the solid lavas, and the liquid rock is thrown up in masses or driblets, with swashing sounds, and volumes of vapor at each throw. Small, steep cones of lava are made around the hole; and one such, surmounted by a column consisting of adhering lava drops (each 4 to 5 inches across), the whole 40 feet high, is figured in my Report, and the

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* Prof. J. Prestwich discusses the subject of the agency of water in volcanic action at much length in a valuable memoir read before the Royal Society, in 1886. He makes no use of the facts afforded by Kilauea or of the bearing of the phenomena there observed on the great subject of volcanic action. As the views here given on the agency of water, and the special methods of its action are those of 1849, I have no occasion to make further mention of Prof. Prestwich's paper.

figure has been copied into several text-books. The hole may be what is left of a small lava pool after contraction from cooling. It varies greatly in size, from that of the open lava-pool to a diminutive hole through which drops of lava only a fourth of an inch in diameter are thrown out. One of the specimens which I obtained at the crater was a group of three slender columns, two to three inches apart, and about seven inches high, each made of lava drops of the small size mentioned—a fourth of an inch. Often the blow-hole emits intermittently only steam, whose rush out sustains the appropriateness of the name. Prof. Van Slyke describes one in action and ejecting lava, on page 96, and Mr. Dodge speaks of others, emitting steam only, on page 100.

Rev. C. S. Stewart, at his second visit, in 1829, saw, as he states, four cones from a few feet to twenty in height projecting flames [lava-jet] under a "laborious action of steam," one of which, tapering almost to a point, had "been formed by successive slight overflowings of lavas which, as it rolled down, cooled into irregular flutings ornamented with rude drops and pendants"—a good example of blow-hole action and result.

9. *Source of the vapors.*—While part of the vapors, as is well understood, are from the same deep source as the lavas or from their constituents, and some water may be here included, far the larger part have a more superficial source. The vapors from the deep-seated source of a conduit should vary little in amount except through variation in the area of liquid rock exposed; and the same would be true if the lava were a fused sedimentary rock of the depths below. But in fact, the variation between a time of quiet and of approaching eruption is often immense; the amount may increase rapidly as the height of the lava in the vent increases, proving that, as usually conceded, other more superficial sources of water-vapor exist.

The more superficial source may be either, as is generally admitted, the sea, or the fresh water of the land. Marine products like chlorides abundantly deposited about steaming fissures in the crater and outside, as at Vesuvius, have been accepted by most writers as evidence of the access of marine waters; and the absence nearly of such products at Kilauea, I regarded as evidence of the access there of terrestrial waters mainly. The latter are as likely to be concerned as the former, and the more so in most volcanic regions on account of the distance from the sea.

The very abundant rains over eastern Hawaii, the bare cavernous lavas of the mountains, arranged partly in layers or streams, and partly in vertical dikes often radiate to the crater, and the freedom from water-courses over a large part of the eastern and southern slopes of Mt. Loa, led me to regard the waters from rains as the chief supply; and Mr. Coan, who lived for years at the foot of Mt. Loa and watched the volcanic movements, was the first to suggest that seasons of abundant rain, besides multiplying steaming holes, increased activity and favored eruptions.

10. The introduction of outside waters, whether marine or fresh, into the lava conduit has often been thought an impossibility; and still it must be a fact, as this is the only means of getting the required water. The waters of the land, especially those of great rains, becoming subterranean, would descend deeply along the various vertical fissures, and the spaces by the sides of dikes, it may be to thousands of feet, since the bottom of Kilauea is between three and four thousand feet above the sea level, (and the summit of Mt. Loa over thirteen thousand); and if the copious waters filling the narrow passage ways below over a large area, anywhere reached the hot region along the conduit, they would encounter the action of the heat under great hydrostatic pressure, and be forced by the steam pressure generated into the conduit of ascending lavas as the easiest and only way of escape. Once within the conduit, they would follow the course of the hotter, more liquid, and upward-moving central portion, and expand into vapor toward the surface, there to make cellular and scoriaceous lavas, and escape as they could. The lavas from fissures that tapped the conduit below the level where the chief part of the waters were received should be feebly cellular, or not at all so; but froth-covered streams might be expected from the vents or pools of the crater; and cellular or scoriaceous from tapping near the top. The facts at Kilauea correspond precisely with this view of the operations, and give the explanation full support. The play of jets over the surface may serve to entangle some air and add to the volume of the confined vapors. But air alone has very feeble expanding power when heated, and could not make cells in the heavy liquid and much less make a scoria.*

11. *Projectile force at Kilauea.*—The vapors within the viscid lava struggling for escape are the obvious and the only possible source of the projectile results. The elastic force of the vapors would depend on the resistance to escape, and the resistance on the viscidity, as in the ordinary boiling process. The ascending spheres of vapors in the upper or more superficial part of the conduit would become bubbles at the surface; and the bubbles would continue to enlarge there until the elastic force within was sufficient to break the upper or weaker part, when a verti-

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* The facts observed by Prof. J. W. Judd with regard to the waters present (sometimes over 8 per cent.) in an obsidian, (Geol. Mag. for June, 1886), have interest here. See also the important paper by J. P. Iddings on Lithophysæ, at page 36 of this volume.

cal or nearly vertical projection of the materials of the broken bubble would follow. A partial cooling of the lavas tends to increase viscidity, and this may account for the higher jets. The mechanism exists in Kilauea for making cinder ejections; but in the case of so low jets—30 to 60 feet—the liquid material descends before it has had time to cool and the dropping masses that fall outside the lava pool plaster themselves to its sides. The only cinder cones are found on the slopes outside of the crater where greater viscidity, due to partial cooling, may have existed.*

Kilauea continues this easy, quiet throw of jets even in the covered chambers of the now-existing cone. Mr. Van Slyke speaks of the puffing up and throw of the lavas, and the swashing sounds. The work going on, producing these sounds and the throw, is the same as has been described—the breaking of bubbles of the viscid lava by the elastic vapors or gases within them.

12. *Fundamental forces at work in Kilauea.*—In review: the two chief sources of upward movements are (1) the slow-acting ascensive force carrying the lavas to the surface, where they become exposed to earth-surface agencies. (2) The elastic force of the vapors escaping in bubbles from the exposed surface of liquid lava, producing projectile effects; these vapors partly of ascensive origin, but chiefly from external waters that become subterranean and were forced into the conduit. In addition to the above: (3) Subterranean vapors in confined spaces (*α*) derived from the surface of the underground liquid lavas (those of the top of the conduit), or (*β*) made, gradually or catastrophically, from the approach or access of waters to the sides of the conduit, may, by pressure, produce:

(*a*) Disruptive effects, opening fissures within the crater and in the mountain's sides.

(*b*) Displacements or uplifts over large or small areas; and opening spaces for the intrusion of lavas.

(*c*) When acting on a surface of liquid lava, the thrusting of the lava into open spaces between layers and thus producing an elevation of the overlying bottom of the crater and of the sides of boiling lakes; or into fissures, and in the latter carrying the lavas to heights several hundred feet above the level of the active vents of a crater, as in cases above mentioned, just as mineral oil is often thrown to heights by the confined gases below.

(4) The hydrostatic pressure of the column of liquid lava in the crater is a common source, probably by itself, and cer-

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* In former periods pumice-like cinder ejections took place from Kilauea or its vicinity; but they cover a wide surface south of the crater, instead of forming cones. See my Report, p. 183.

tainly in combined action with the preceding, of extensive fractures and outflows, and sometimes in the case of both the Mt. Loa summit crater and Kilauea, of large and lofty fountain-like throws of the extended lavas.

(5) The expansion of the moisture in the liquid lava into vapors as the lava approaches the surface, thereby expanding the lava in this upper part, making it cellular and raising the level of the surface. This effect is limited by the amount of moisture present, and by the degree of pressure that prevents moisture below from taking the form of vapor.

(6) Underminings, through the discharge of lavas, leading often to subsidences and engulfments, and chiefly of the central parts of the volcano about and within the crater.

In 1840, after a time of violent activity over the whole of Kilauea, the subsided area included a large part of the floor of the crater, it being nearly two miles long and about two-thirds of a mile in mean breadth, with the depth nearly 400 feet. It left the crater over the sunken floor nearly 1,000 feet deep and elsewhere over 600 feet.

In 1886, after more local activity the subsidence was mostly confined to Halema'uma'u and its vicinity (including New Lake) the area about half a mile square; the depth of the subsidence was small, the depressions that were left being due mainly to the escape of the lava and some sinking of the walls of the two pits. Owing to the overflowings and intrusions of lavas since 1840 without equivalent subsidences, the mean depth of Kilauea after this last eruption was about 400 feet. There may be great empty chambers beneath, and after a time of general activity and great discharge, another subsidence like that of 1840 in extent may occur.

The form of Kilauea and character of the operations now going on within it show that the activity (ebullition, etc.) was at some time in the past so general over the included area that the subsidences which followed the eruption affected the whole, nearly to the present outer walls; and that under such conditions Kilauea took its form and size.* The underminings that have since occurred have from time to time caused down-plunges of portions of the walls into the emptied spaces beneath and so increased somewhat its extent just as the walls of the pits in the crater emptied by an eruption continue to fall until the pits are filled again with lavas.

### 3. *Vesuvius and other Volcanoes.*

13. *Fundamental forces in Vesuvius and other Volcanoes.*—Vesuvius and the Hawaiian volcano differ much in externals, but not in forces, or in their mode of action.

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* The plate in Ellis's Polynesian Researches represents the lower pit in 1823 (after a great eruption), as reaching at the time very nearly to the outer walls of Kilauea.

The *first* of the operations mentioned above is necessarily the same.

The *second* method of work and its consequences must also be the same; for vapors rise and escape from the crater in great abundance during periods of special activity, as attested to by many observers. For years the outside waters needed to afford the working steam gain access quietly; but at times there have been large incursions, as proved by the violence of the earthshakings, the vast amount and height of the cloud of vapors, and the lofty projection of cinders.

The recent eruption in the Tarawera Geyser district, New Zealand, affords an example in which only fresh waters were concerned, and one of much instruction. The Tarawera mountain, its height about 3,600 feet above the sea level, though made of volcanic rocks, had, previous to the eruption, as Mr. S. Percy Smith reports from observations in 1874, no distinct crater. On the morning of the 10th of last June, after some rumblings for an hour, the mountain (at 2.15 A. M.) was rent from north to south; three craters were seen to be in action; and soon after, as later observations have shown, there were seven craters in the course of 2½ miles along the top of the fissured mountain, and other small craters on what was properly an extension of the fissure six miles to the southwest. Black clouds, lighted below by the fires, rose to a height of "10,000 to 12,000 feet," and red hot scoria and cinders were shot up a thousand feet or more. The rain fell with the falling cinders in torrents, accompanied with the thunderings and shifting winds of a tornado. By daylight the village of Wairoa, five miles distant, was covered a foot deep with mud, made from the ejected cinders or volcanic ashes, and the descending waters (rain).

Three days later, the action in the mountains had mostly dwindled to steaming fissures, and on going to the region, it was found that the fissure, which was over two hundred yards wide, passed through Lake Rotomahana, 1 × ¼ m. in area; that the lake had lost its water; that the bottom was 250 feet below its former level, and in it there was a line of mud craters and geysers, one of the craters throwing the mud to a height of 600 to 800 feet. Evidence of the work of ejection and engulfment in the mountain existed in the great size of the fissure opened, and also in the depth and size of the mountain craters, one of them 900 feet deep, another 600, with five others of less depth, besides a great sunken area, 2000 feet long, 600 wide, and 250 to 800 deep in the southwestern slope of the Tarawera mountain facing Lake Rotomahana. There can be no doubt here that in this great outbreak, so sudden, so abundant in cinder ejections (but no flow of lavas), the lost waters gained access to the fires under the mountain. The waters were in so great abundance that they could not be driven back by the steam made at their approach to the fires; and they consequently entered,—the opened mountain having made upward escape for lavas and steam possible; and thence came the steam power for the grand occasion. And perhaps, the cooling action of so large a body of water may have put the surface-fires out, leaving the heat, however, in possession as before, at no great depth below.

Cinders are projected to a greater height at Vesuvius, and in most other volcanic regions, than at Kilauea; but this is proof simply of greater viscidity in the lavas; and the projected lavas fall in cooled masses or cinders because of the height of projection. Greater viscidity leads to the production of larger vapor-made bubbles before the explosion, and therefore fewer of them over a given surface of liquid lava; and, in times of moderate activity, the number may be only half a dozen or a single one at a time, while, on a like area, lavas with the Kilauea degree of viscidity would have scores. When at Naples, in May of 1834, there was at night an interval of seven to eight minutes between the explosions or the throw (some hundreds of feet in height) of fiery cinders; on the ascent, the following day, of four to five minutes; and on passing Stromboli, a fortnight later, June 16th, of fifteen to twenty minutes—the activity being less than usual, explosions every 2 or 3 minutes being common. As Spallanzani, Hofmann, and others have seen the rising bubble within Stromboli, the bursting, and, following this, the rush of vapor and the cinder projections, there is no reason to doubt that at Vesuvius, also, each throw of cinders has the same source. Mr. John Milne states that on his ascent of the Japan volcano, Oshima, in May, 1877, on approaching the top, successive explosions were heard every two seconds with occasional pauses, which explosions he found, on reaching the top, to be due to successive outbursts of steam, each projecting ashes and bombs to a height of nearly 6000 feet, that fell vertically unless wafted by the winds.*

At the eruption last June in New Zealand, above referred to, the "tremendous roar" of the craters that added to the terrors at Wairoa, five miles distant, was at Auckland, 120 miles away to the northwest, resolved into "a series of detonations, like the firing of a prolonged salute *at minute intervals*, with an occasional lull."† This fact signifies that only the heavier of the aerial vibrations reached that place. The roar heard at Wairoa was due to the simultaneous explosions in the several active craters and the storm and earthquakes; and

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* Volcanoes of Japan, Trans. Seism. Soc. Japan, ix, part 2, 1886.

† Volcanic Eruption at Tarawera with an account of the Thermal Springs district of N. Zealand, by T. W. Leys.

the "minute" guns heard at Auckland were the larger explosions; and such a periodicity in the detonations, so rapid and continuous, shows that they were those of exploding vapor-made bubbles; for nothing else in the mechanism of a volcano can produce it.

The catastrophic effects of such an action, where the jets are single or few, are small, because the break of the vapor-enclosing shell takes place at the top, and the throw is nearly vertical; the energy is wasted in the throw of the fragments. Where many jets rise together in such lavas, as in a time of violent eruption, the explosive action is great; but it is still greatest at the center of activity, which is that of greatest liquidity and easiest movement. A cone of cinders about the vent might be destroyed by being added to the projections; but the more distant walls could suffer but little from the projectile action, except in the way of fissuring, and this might be all owing to subterranean shakings and the undermining; for the force from the accumulated elastic vapors in the rising and exploding bubbles is too much confined by the limits of the area of liquidity within the crater. Hence we have reason to doubt much that has been written about explosive eruptions projecting off the tops of mountains; or at least to question it, until the piles of great rocks from such projections have been described.*

The height of the aerial projections in some volcanoes is measured by thousands of feet; but how much of this height is owing to ascending currents of air is not stated. The fineness of the dust that goes to great heights makes it of easy transport.

14. The other forces acting at Kilauea, must be alike active in all volcanic regions. The third is the one usually appealed to by writers in their explanations of eruptions, especially *3a*, *3b;* and that numbered *3c*, must have its effects also, although less easily detected where the crater is not broad and open, like Kilauea. The *fourth*, hydrostatic pressure, has, no doubt, far more common effects than has been recognized, especially in high-sloped mountains like Vesuvius. The quiet character of many of the fracturings at Vesuvius and of some of its large eruptions are strongly in favor of this conclusion. The sixth operation—subsidence or down-plunge of the undermined parts of the mountain—should be doubly more active at Vesuvius than at Kilauea, since the undermining in the latter is produced only by the outflow of lava, while at Vesuvius there is loss both by outflow and upthrow. I have alluded to

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* According to some describers of the New Zealand eruption, the Tarawera mountain had its top blown off in the making of the great southwest chasm. The place affords an opportunity to ascertain whether the piles of masses of the solid rocks which in that case should exist, are to be found to the southwestward.

this point already in this Journal (xxxi, 396, 1886) and need not repeat here.

15. In external dress the crater of highly viscid lava is very unlike that of the feebly viscid. The cone in the former often rises with slopes of 30° to 35°; that in the latter, often of but 5° to 10°. The former commonly uses cinders largely in making its cone, or else has the less fusible orthoclase lavas to deal with; the latter is chiefly lava-made, cinder-deposits being subordinate to those of lava. The crater in one is lengthened upward at top by cinders; and has cinder cones about each vent of liquid lava within the crater; that in the other, is often a broad pit, with a floor of cooled lavas over which are large and small lava-vents, and low lava-made cones. The volcano of the former kind is more liable to catastrophic eruption with noisy earth-shocks, though often quiet in some discharges; those of the latter commonly work with comparative quiet, having their large outflows at times without announcements of any kind to those dwelling a few miles away. These are differences; but they are differences in some of the results of the action going on, not in causes or methods. The first of the two kinds of volcanoes prepares for a new eruption by the gradual filling of the emptied crater, doing this by means of one or more lava-vents in the bottom, which, besides throwing up cinders, have their little outflows (as well described by Scacchi for Vesuvius), and keep at the work until the crater is filled or nearly so; and then comes the break and the greater outflows. The second kind differ only as to the cinders; and in Kilauea, as to the height of the floor of the crater before the outbreak.

16. Both from Vesuvius and Kilauea we learn that, next to the lava-vent, the crater of a volcanic mountain is its prime or most fundamental element. It encloses the extremity of a lava-conduit of greater or less breadth that reaches down to the seat of fires; and this enclosure exists because of the ejections by outflows and upthrows and the consequent down-plunges, which superficial conditions in large part determine. The growing mountain-cone cannot be rid of its crater except by the gradual disappearance and healing over of the lava-vent; and commonly, when extinction happens, the crater is still of nearly full size. If half or wholly obliterated, it may be again restored; and is likely to be, if action is ever renewed in the region by new ascensive action below. If so renewed, it may go forward through refusions and new engulfments. But the first step may be the opening of the old fissure upon which the crater was originally made; in this way the lava conduit might secure for itself at once an open way to the surface.

It may be that the course of the old fissure has been a chief cause in determining the form of a crater; and it may lead, in after history, to changes in the locus of the chief vent, or an elongation of the crater in one direction rather than another. The form of the Kilauea crater, and the existence of those steaming fissures southwest of it and others on the northeast side, suggest some such determining cause of change. The elongated form of Haleakala, the great crater at the summit of Eastern Maui, may have this explanation.

17. *Quiet after an Eruption.*—A decline to a season of quiet follows an eruption because the preceding action had opened fissures, and so the crater and the upper part of the conduit had become emptied of lava, and, as a consequence, had also become chilled down to the new surface. Further, in the inactive or weakened condition thus occasioned, the cooling of the conduit-lavas might sometimes extend to a great depth because of the still-continued intrusion of subterranean waters. The completeness of the quiet and the length of the interval would naturally vary with the greater or less extent of the discharge and of the accompanying cooling influences. An empty caldron will not overflow before its cracks are mended and the steam apparatus at work has again filled it; and it may be so badly cracked and the supply of heat so cut off as to fail of further use.

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## ART. XII.—*On the Coahuila Meteorites;* by OLIVER WHIPPLE HUNTINGTON. With Plate III.

IN the October number of this Journal, appeared a description by William Earl Hidden of an assumed new meteorite discovered by Mr. C. C. Cusick, U. S. A., near Fort Duncan, Maverick County, Texas.

On reading the article referred to, the author was at once struck by the close resemblance of the iron described by Mr. Hidden to those described by J. Lawrence Smith under the head of Coahuila Irons; and supposed to belong to one fall, but found on the opposite side of the Rio Grande River from Maverick County. The Coahuila Irons referred to are—

1. Sta. Rosa Sancha Estate, found in 1850.*
2. Butcher Iron found in 1866.†
3. San Gregorio.‡
4. Chihuahua Hacienda de Conception.*

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*This Journal, 1855, vol. xix, pp. 160–163.

† Id., vol. xlvii, pp. 383–385.

‡ Id., ii, 1871, pp. 335–338.

Mr. Hidden's reasons for thinking the Maverick County Iron does not belong to the Coahuila group are as follows (this Journal, October 1886, p. 306): "The Maverick County Meteorite was found more than one hundred miles in a due east direction from the famous Butcher Irons from Coahuila and that from the Sancha estate, Mexico, both described by Smith. But the density and composition of these last two irons show marked differences from that of Maverick County, Texas. 'The Sancha iron had a density of 7·81 and presented the figures of Widmanstätt similar to that of the Braunau iron,' (Smith). The smooth surface and regular form of this iron from Maverick County would also preclude its being a part of another fall, as it seems to be complete in itself."

That the Maverick County iron was found one hundred miles east of the Butcher iron, does not interfere with its belonging to the same fall; since the Santa Rosa and Butcher irons were eighty-five miles apart, the Butcher and San Gregorio about three hundred, and the San Gregorio and Conception about ninety miles apart. Moreover, J. Lawrence Smith writes (this Journal ii, 1871, pp. 335–338) that these were probably products of the fall of one meteoric mass, moving from the northeast to the southwest, the smaller fragments falling first. The meteorite described by Mr. Hidden is small in comparison with the others, and thus would naturally be found farther to the east.

The Santa Rosa iron weighed 252 lbs. The Butcher irons weighed respectively 290, 430, 438, 550, 580 and 654 lbs. The San Gregorio was calculated to weigh about five tons, and the Hacienda or Conception about 3[illegible]53 lbs. And then there is still a fifth mass said to be larger than any of the others.

Mr. Hidden states in his paper that the density and composition of the Santa Rosa and Butcher meteorites "show marked differences from that of the Maverick County, Texas;" but he mentions the density only of the first. It is worthy of note in this connection that the densities of the Santa Rosa and the Butcher irons differ from each other, according to Smith's determination, nearly as much as the Maverick County iron differs from the Butcher iron, and yet the two former are accepted as portions of one fall.

In order to see how far we can rely upon specific gravity for distinguishing these irons, ten determinations were made with different fragments of the same specimen of the Butcher iron, and these have been compared below with similar determinations of the other Coahuila irons.

| | Butcher. | Sta. Rosa. | San Gregorio. | Hacienda. |
|---|---|---|---|---|
| | 7·616 | 7·925 | 7·740 | 7·953 |
| | 7·751 | 7·953 | 7·477 | |
| | 7.836 | 7·826 | 7·555 | |
| | 7·204 | 7·631 | 7·734 | |
| | 7·758 | 7·632 | 7·487 | |
| | 7·831 | | | |
| | 7·867 | | | |
| | 7·858 | | | |
| | 7·405 | | | |
| | 7.727 | | | |
| Smith | 7·692 | 7·810 | 7·84 | |
| Maverick County | | 7·522 | | |

Comparing Smith's analyses of Santa Rosa and the Butcher irons with the Maverick County as given by Hidden, it will be seen at once that, if Smith could conclude from the similarity in composition of the Santa Rosa and Butcher irons that they belonged to one fall, there appears no reason for considering that the Maverick County has a new composition, as it agrees more closely with the Coahuila analyses than they do with each other.

| | Butcher. | Sta. Rosa. | Maverick Co. |
|---|---|---|---|
| Iron | 92·95 | 95·82 | 94·90 |
| Nickel | 6·62 | 3·18 | By difference. 4·87 |
| Cobalt | ·48 | ·35 | |
| Phosphorus | ·02 | ·24 | ·23 |
| | 100·07 | 99·59 | 100·00 |

Furthermore, Mr. Hidden speaks of Smith's having compared the etched surface of the Coahuila iron with that of the Braunau. This comparison was made because the Braunau was the nearest iron at that time to compare it with, though differing widely from the Coahuila. Mr. Hidden's description of the etched surface of the Maverick County iron applies most perfectly to that of the Coahuila iron, particularly the appearance of two sets of fine parallel lines, which become obliterated by the continued action of the acid. That these lines crossed at angles of 70° and 110° of course means nothing when the surface was cut at random. (This Journal, Oct. 1886, p. 284–303.) The accompanying plate printed directly from a specimen of the Butcher iron will be seen to be wonderfully like fig. 3 in Mr. Hidden's paper, already referred to, and this appearance is utterly different from any other known iron.

Then he further speaks of the smooth surface and regular form of the Maverick County iron precluding its being part of the Coahuila fall; but his diagrams of the Maverick County iron might be taken for almost any one of the many Coahuila specimens, each one of which, like the Maverick County, is complete in itself, and in Smith's description of the Sta. Rosa iron,* which is one of the most irregular of the group, he speaks of it as being "rather smooth with only here and there thin coatings of rust."

Still another point of resemblance is the softness of the iron, which, in the case of the Maverick County, Mr. Hidden says could be easily cut with a knife, while Smith states several times in his descriptions of the various Coahuila irons that they were soft, so that they could easily be cut with a saw.

With the attention which is now being given to the study of meteorites, and the numbers of new specimens which are coming daily into our cabinets, it is important that different names should not be given to different individuals of the same fall, as it confuses the science. A very marked incident of such a confusion of names is shown by the Sevier and Cocke County meteorites, which are of so striking a character that no one could possibly examine specimens of these two irons without unhesitatingly concluding that they were products of one and the same fall.

This meteorite must evidently have been a very large one, passing through West Virginia and the eastern counties of Kentucky and Tennessee, and it is probable that several masses fell during its flight, and were subsequently distributed quite widely, as described by Prof. C. U. Shepard, in this Journal, second series, vol. iv, p. 83. Fragments are constantly being offered for sale as specimens of silver ore, owing to the whiteness of the iron.

Through the kindness of Mr. George F. Kunz we were able to examine a specimen of the iron described by him in this Journal, third series, vol. xxxi, p. 145, which evidently belongs to the same fall.

Three years ago we received, through the kindness of Prof. N. S. Shaler, a specimen, said to have come from near Lebanon, Wilson County, Tennessee, with the same loose character and white color of the Sevier County iron, having also large nodules of graphite, and thin laminæ of very magnetic elastic foil, easily separable from the mass, so characteristic of that iron. This specimen we did not describe, because it so obviously belonged to the same fall.

Prof. Shaler further informs us that he has heard frequent reports of other specimens throughout that region.

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* This Journal, 1855, vol. xix, pp. 160.

## Art. XIII.—*A new Rhizostomatous Medusa from New England;* by J. Walter Fewkes. With Plate IV.

A small number of Acraspedote Medusæ have been taken in shallow waters along the shores of New England. The genera thus far recorded are *Aurelia*, *Cyanea*, *Dactylometra* and *Callinema*. Other genera are known to make their way or to be carried along in the Gulf Stream into our latitudes, and may sometimes be washed on our coast. Among these may be mentioned *Pelagia*, *Periphylla*, *Linerges* and others.* Some of these have already been taken on George's Bank and off Martha's Vineyard, but none have been recorded from the shallow waters along the coast line.

Through the kindness of Professor A. E. Verrill I am able to add to the above list of Medusæ found in shallow water near the coast, a fifth genus, a large Acraspedote jelly-fish, not only new to New England, but also one which is unlike any yet captured on the Atlantic coast of North America. This Medusa, the only non-tentaculated Acraspedote, so far as we now know, which ventures into our waters, is allied to a common species found on the western shores of Europe, *Pilema* (*Rhizostoma*, auth.) *octopus* Hæck., and to the *P. pulmo* of the Mediterranean Sea. It has no nearer relatives in the waters of the United States, so far as known, than the well-known *Cassiopea frondosa* and *Stomolophus Meleagris* Ag. of Florida, the Carolinas, and the Gulf Stream.

The single specimen of this new medusa from which my description and figure were made was captured in September, 1886, in New Haven harbor.† It was more or less mutilated when it came into my hands for examination, but owing to the exceptional toughness of the umbrella and oral arms, it was possible to study the more important organs and to write a description of them before the external form of the specimen had greatly changed.

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* A list of Acraspeda found in the Gulf Stream by the U. S. Fish Com. Str. Albatross will be found elsewhere. There is no reason now known why any of these genera should not straggle at times into our southern bays and sounds.

† It was taken alive near the Yale Boat House at the mouth of the Quinnipiac River, near the extreme upper end of the harbor, where the water is somewhat brackish, perhaps four miles from Long Island Sound. It was caught by Mr. Arthur J. M. Andrus and preserved by Mr. George E. Verrill, during my absence from New Haven. When living, the diameter was about 18 inches. When first seen by me, after it had been in alcohol about a week, the oral cylinder and frills, and the radial tubes of the umbrella were of a rich deep brown; the distal oral filaments were whitish; the disk or "umbrella" was uniform translucent bluish white. My son told me that the color had changed but little from what it was in life. A. E. Verrill.

### NECTOPILEMA, gen. nov.

### *Nectopilema Verrilli*, sp. nov.

*Umbrella.*—The form of the bell and the relation of the height to the diameter could not be made out from the broken fragments.* From what is known of certain related genera, it is supposed that the diameter is about double the height.† Exumbrella smooth. Gelatinous substance of the bell tough, thick at center, thinning out near the margin. There are eight sense organs, each of which lies in a broad deep incision in the bell-margin and is protected by a slightly developed hood. Each sense body probably lies in the radius of an oral arm.

The lappets of the bell-margin are of two kinds, known as the occular and velar marginal lappets. The velar lappets are divided into two kinds, those formed by shallow and those formed by deep marginal incisions. The eight pairs of lappets which lie one on each side of each marginal sense body will be known as the occular lappets. The velar lappets‡ with shallow incisions may be called the small velar lappets, and those with deep incisions, the large velar lappets.

The occular lappets are short, stumpy and rounded, projecting but slightly beyond the sense body, never extending to the periphery of the bell formed by the distal marginal tips of the velar lappets. The sense body has no marked conical pit or external "*Riechgrübchen*."

The smaller velar lappets are formed by a slight incision in the compound lappets, which lie on each side of the occular lappets. When taken together they are much broader than the so-called large lappets, and singly their breadth is not much less than the large velar lappets. The incision, however, which separates them from each other is less than that which separates them from the large velar lappets or the large velar lappets from each other. They are called the small velar lappets from the fact that the incision is so slight as compared with the incisions of the greater lappets. The compound base formed by the consolidation of two small lappets may be regarded as a single compound lappet. Each small velar lappet is triangular, pointed, thin, and flexible.

The large velar lappets are two in number between each

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* The quadrant of the bell-margin represented in the figure is probably increased in size from the broken and therefore expanded condition.

† See *Crambessa Tagi* Hæck., Grenacher and Noll, Beiträge zur Anatomie und Systematik der Rhizostomeen, and *Pilema* (Rhizostoma, auct.) Hæckel, System der Acraspeden. In *Stomolophus* the relative height is more than one-half the diameter, and in *Lychnorhiza* it is less.

‡ The *velar lappets* are the marginal lappets between two pairs of *occular lappets.* An octant of the bell is therefore made up of two occular lappets, four small velar lappets and two large velar lappets.

pair of compound lappets* and are separated by incisions in the bell-margin equal to that in the radii of the sense bodies. Each large velar lappet is pointed at its free rim, thin and flexible. All velar lappets are penetrated by an anastomosing network of vessels, and are destitute of a marginal vessel skirting its rim. There are no tentacles.

Deep grooves in the exumbral walls of the bell, extending radially from the incisions, both occular and velar, are supposed to be in part characteristic of the live animal and in part due to the state of preservation. These are indicated by indistinct lines in our figure. They may be wholly a result of contraction of the bell margin.†

The distance between two sense bodies on the margin of the extended bell of a fragment is $105^{mm}$. The thickness of the umbrella increase very greatly at the junction of the marginal lappets.

The lower surface of the umbrella (subumbrella) is divided into two regions, a central from which hangs the oral appendages and a peripheral. The peripheral region is occupied by sections of muscular fibers forming together a strong circular compound muscle. There are sixteen sectors in this compound muscle. The radii passing to the sense bodies and those to the incision which separates the two larger velar lappets of each octant of the bell-margin also indicate the line of separation of the compound muscle. Each sector of muscle is composed of a number of parallel folds extending from the radii mentioned and from a line near the union of the oral arms to a line connecting the occular and large median velar incision. The breadth‡ of the sector of muscle is $80^{mm}$. In alcohol the muscle has a brown color; along the occular radii and that which passes through the large velar incision this color is absent.

The size and arrangement of these muscles recall that of the subumbral muscle of *Stomolophus*, and somewhat more distantly the same in *Crambessa Tagi*, as figured by Grenacher and Noll (*op. cit.* pl. iv, fig. vii, *m*), where, however, in the latter case the number of sectors appears greater. The prominence of the muscle on the under floor or subumbrella of *Nectopilema* is apparently very different from *Rhizostoma luteum* of the last mentioned authors, if pl. viii, fig. xvii (*op. cit.*), correctly represents the subumbrella of *R. luteum* Gren. and Noll.

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* My nomenclature "*compound lappets*" will lead to no confusion if the reader remembers that two small lappets (*velar*) unite to form the compound axial region at the base of these lappets. The compound lappets adjoin the occular lappets (see figure).

† These furrows recall the radial furrows of the umbrella border of *Polyrhiza* Hæck.

‡ Distance from axial to abaxial border. Measurements of specimens of medusæ preserved in alcohol, are more or less deceptive.

*Oral arms.*—From the central region of the umbrella there hangs a complicated oral apparatus known as the Mundscheibe. The general form of this region is pyramidal or more like the frustrum of a cone.

The oral region of the medusa consists of a consolidated portion, oral cylinder, next the subumbrella, by which it is joined to the bell, and a more distal part composed of eight separate oral arms. It was impossible for me to study the structure of the basal region, or oral cylinder of the Mundscheibe for the reason that it was broken from its attachment so that the union could not be observed. At the same time it was for the same reason impossible for me to observe the character of the genital cavities and the central gastral cavity, structures which present most important characters in the study of the *Rhizostomidæ*. The wall in the region of the mouth opening was also ruptured so that it was impossible for me to observe whether it really exists. Portions of the genital glands were found clinging to the basal region of the Mundscheibe, but their true form and relation to other organs could not be determined. The distal region of the mouth-apparatus is the best preserved of all the fragments which were studied. These are markedly peculiar and different from the same structures in other medusæ which have been figured.

Two different sets of appendages to the oral cylinder make up the distal extremities of the oral apparatus. The longest of these, eight in number, are direct continuations of the oral cylinder, and will be known as the oral arms. The second set of appendages are shorter than the former and are sixteen in number. These will be described as the scapulettes. The oral arms are gelatinous, more or less angular appendages, arising from small supports, and gradually broadening and enlarging towards their free distal ends. Near their free extremity they subdivide in fleshy, gelatinous lobes, along the edges of which are sucker-like structures, which will be described as sucker-frills. The outer or abaxial region of the oral arms is smooth, rounded, angular, the gelatinous wall being rather thick. On the axial side the gelatinous substance of the oral arms thins out, and along the margin the lobes bear sucker-frills. Each oral arm is generally irregular, trifid, and in some cases we find a large number of gelatinous lobes at the distal end of the arm. When the arm has three lobes, two of these lobes were observed pointing abaxially and one axially. Along the free edges of these lobes there extends a thin, membranous structure with small papillæ or pigmented projections. These membranous folds are mouths, and from their form are called the sucker-frills. Those frills on the two outer lobes are known as dorsal frills; those on the axial, the ventral frills.

The ventral frills extend along the axial edge of each of the oral arms to the junction of the oral cylinder, while the dorsal are simply turned outward and do not extend along the outer sides of the arms, which are smooth and destitute of appendages. In addition to the three lobes mentioned—two dorsal and one ventral—there are others also bearing sucker-frills, so that in some instances it is impossible to recognize three separate lobes.

The lobes bear terminally long, gelatinous, filamentary appendages called "*Kolbenförmige Gallertknöpfe.* These bodies, always gelatinous and colorless in alcohol, are of varying sizes and lengths, sometimes slender, often inflated, short, band-shaped. These appendages are numerous.* The smaller appendages to the oral cylinder are sixteen in number and are known as the scapulettes† or upper leaf-like appendages. They arise one on each side of the base of the oral arms a short distance above the separation, and hang down parallel with the oral arms. Two surfaces may be distinguished in each scapulette—an abaxial convex, and an axial concave side. The concave side is smooth, gelatinous, thick, rounded or angular. The convex side is more irregular, and lobed, skirted by sucker-frills resembling those of the ventral lobes and the axial side of the oral arms. The color of the sucker-frills of the scapulettes in alcohol recalls that of the sucker-frills of the oral lobes.

The relative position of the scapulettes as compared with the oral arms may be seen in my figure. Whether, however, these bodies are hidden by the margin of the umbrella when in contraction cannot now be determined. The reader is reminded that in my specimen the oral cylinder is broken from the bell, and so far as this goes, our figure is a restoration intended to show the bell-margin and the scapulettes, not the relation of one to the other.

*Affinities.—Nectopilema* is thought to be a member of the family of Acraspeda called by Hæckel the *Pilemidæ.* The family *Pilemidæ* Hæck. includes Rhizostomatous Acraspeda with four separate subgenital cavities,‡ and with dorsal as well as ventral sucker-frills on the eight mouth-arms. No tentacles and no central mouth opening, and numerous sucking-frills extending along the oral arms perform the functions of the

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* The number and character of these appendages recall what has been described in a *Rhopilema* from the China Sea. They resemble the "*Peitschen Filamenten*" of *Polyrhiza* and others.

† This term here used to designate these bodies is the modified "*Scapuletten*" of Hæckel's description. It seems to me a better designation for these bodies than the term "leaflike appendages" sometimes used in descriptions.

‡ From the mutliated condition of my specimen the structure of the genital cavities could not be made out.

mouth. Eight sense bodies on the bell-margin. Eight to sixteen or more narrow radial canals, branched, and forming by anastomosis a network of vessels in the subumbrella. Generally with a ring canal.* Four internemral sexual glands in the aboral wall of the four separate gastral subgenital cavities.

The *Pilemidæ* are divided into three sub-families; I. The LYCHNORHIZIDÆ. II. The EUPILEMIDÆ. III. The STOMOLOPHIDÆ.

The *Lychnorhizidæ*, among other characteristic features, differ from the other sub-families in the absence of scapulettes.

The *Eupilemidæ* and *Stomolophidæ* have eight pairs of scapulettes, but in the former sub-family the eight oral arms are three-winged,† free from each other, and not grown together. In the *Stomolophidæ* the oral arms are dichotomously branched, and more or less grown together. *Nectopilema* is thought to belong to the sub-family of *Eupilemidæ*, and to be allied to *Pilema* and *Rhopilema*. The presence of "Scapuletten" removes it from the *Lychnorhizidæ*, *Toreumidæ*, and *Crambessidæ* as defined by Hæckel. It differs from the *Stomolophidæ* Hæck. in that the oral arms are not consolidated as in *Stomolophus*, nor dichotomously branched at their free extremities as in *Brachiolophus*, the only two genera of this sub-family. It is more closely allied to *Brachiolophus* than to *Stomolophus*.

The close allies of *Nectopilema* among the *Eupilemidæ* are the two genera *Pilema* and *Rhopilema*. From the former it differs in several particulars, the most striking of which is the possession of numerous "Gallertknöpfe" appended to the lobes of the oral arms. Whether this feature is enough to separate *Rhopilema* from *Pilema* cannot be discussed here. It is noteworthy that Hæckel found a specimen of the common *P. octopus* (*Rhizostoma octopus* auct.), regarded by him as abnormal, in which there were numerous appendages to the oral arms, as in *Rhopilema*.

Of the different species of *Pilema* all except *P. clavigera* Hæck. have a larger number of marginal lappets in the umbrella margin than *Nectopilema*, which has forty-eight velar lappets (six in each octant) and sixteen occular, while *P. clavigera* has thirty-two velar and sixteen occular lappets. *Nectopilema* has numerous filamentous appendages to the oral arms, while, as far as known, *P. clavigera* Hæck. has but one.

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* *Nectopilema* has no marginal ring canal.

† Both the Lychnorhizidæ and the Eupilemidæ, according to Hæckel, have the eight oral arms "*dreikantig*" or "*dreiflügelig*," while the Stomolophidæ have oral arms dichotomously branched, more or less grown together. The lobes of *Nectopilema* are more than three to each oral arm, but the arms are not branched nor grown together. This fact adds a new argument to support my supposition that *Nectopilema* stands on the border line between *Brachiolophus*, *Pilema*, and *Rhopilema*.

*Rhopilema* has sixteen small velar and two occular lappets in each octant, which is thought to be a sufficiently marked difference to separate it from *Nectopilema*, which has six velar and two marginal lappets in each octant.* Moreover, Grenacher and Noll's figure of *Rhizostoma luteum* Gren. & Noll, to which, according to Hæckel, *P. clavigera* is related, differs from that of my *Nectopilema* so widely that I cannot think that my genus is the same as his *P. clavigera.*

There remains to be mentioned the relationship of *Nectopilema* to the genus *Polyrhiza*, a genus belonging, according to Hæckel, not to the *Pilemidœ* but to the *Toreumidœ.* Of all the *Toreumidœ*, *Polyrhiza* is the most closely allied to the *Pilemidœ* and to the sub-family *Stomolophidœ.* It certainly is not known, so well as might be wished, what is the structure of certain organs of *Polyrhiza*, nor what its true affinities are. Hæckel has placed it in the family of *Toreumidœ*, while *Brachiolophus* and *Rhopilema* are placed with the *Pilemidœ.* There are resemblances between *Rhopilema*† and *Polyrhiza* which imply their close relationship. As *Nectopilema* has strong resemblances to *Rhopilema*, it also has affinities with *Polyrhiza* Ag. I cannot, however, place it in this genus as at present defined.

The following characters when combined are thought to distinguish *Nectopilema* from other *Pilemidœ:* Six velar lappets in each octant; no tentacles; sixteen scapulettes; eight oral arms with numerous gelatinous filiform appendages, "*Gallertknöpfe.*" The genus is believed to belong to the Pilemidæ, connecting the Stomolophidæ and the Eupilemidæ.

## EXLPANATION OF THE PLATE.

This Plate represents a side view of *Nectopilema*, showing the oral arms and a portion (quadrant) of the umbrella margin. As the bell was in fragments it was not possible to give its form, and therefore the relative extension of the oral appendages beyond the bell-margin may not be accurately represented.

In the medial line on the bell-margin a sense body is represented. On either side we have octants of the bell-margin with occular and velar lappets.

The bodies seen behind the bell-margin are sexual bodies. Their extension is more or less conjectural. as they were more or less ruptured. The leaf-like appendages to the sides of the oral apparatus below the bell-margin are the scapulettes. The lower part of the oral appendages or oral arms bear filamentous appendages or "*Kolbenförmige Gallertknöpfe.*"

The figure was drawn from nature by Mr J. Henry Blake. It is one-half natural size of the alcoholic specimen.

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* The marginal lappets correspond closely with those of *Cramborhiza flagellata* or *macronema* (both specific names given by Hæckel in the same work, *op. cit.*). This genus (Cramborhiza), according to Hæckel, is allied to Lychnorhiza, which has no scapulettes.

† It is probable that the numerous "*Kolbenförmige Gallertknöpfe*" of *Rhopilema* and the "*Peitschen Filamenten*" of *Polyrhiza* are homologous.

Cambridge, Mass., Dec., 1886.

## ART. XIV.—*A short Study upon the Atmosphere of β Lyræ;*
by ORRAY T. SHERMAN.

A COMPARISON of the observations upon the spectra of those stars admitted to possess a spectrum comprising bright lines leads to the conclusion that, while persistent in place, the bright line is not persistent in intensity. That this is the case in the solar chromosphere, β Lyræ, γ Cassiopeiæ, R. Geminorum, γ and η Argus, the Wolf and Rayet stars, and through the courtesy of Dr. Konkoly we add η Ceti, may not be doubted. In the others also it seems probable. This peculiarity, now presented as a characteristic of the bright line in stellar spectra, affords a distinction between bright line light, bright background space, and any accidental disturbance the spectrum light may suffer.

Under its guidance the observation was extended to noting the relative places of every persistent or at times outflashing break in the spectrum light, and the single observation was replaced by a series as frequently as opportunity allowed. For greater intensity of bright line light, the sharply focussed star was made to replace the slit, the jaws being symmetrically opened, so that, while allowing the full disc to pass, any displacement soon caused a diminution of the stellar light. For reference spectra the jaws were reclosed. The cylindrical lens was removed. The observing telescope was of low power. For least intensity of background light, the highest dispersions practicable were employed. No foreign light was permitted, the telescope being set during the day so as to be swept upon the star. The record was automatically made. The routine of observation is as follows: For some time previous the observer's eye is kept in the dark. Seated at his telescope, he has then before him a faint, barely traceable line of light, beading or imbedded in which are a number of bright monochromatic stellar images. These points are brought so as to be bisected by the edge of the thick cross-bar which it is desirable to employ. The position is recorded and the observer proceeds to the next dot. In this way he has usually passed through the first, second and a portion of the third spectrum. At the end of the observation the position of the bright lines afforded by a salted alcohol flame or Plücker's tube are added. The slip is withdrawn. The relative position of the punctures are measured and the wave-length reduced by a proper formula. The record of the three spectra combined in one is then recorded as the result of the day's observation. The spectra in which the especial line has been observed forms a measure of its intensity. In combining one day's work with the others, those lines which lay nearest together have been referred to the same line. No line has been admitted unless circumstances rendered its admission necessary. The mean of each horizontal line has then been taken as the approximate wave-length. Throughout the observation the observer has absolutely no definite knowledge of the identity of any especial dot. Nor is it possible for him, while at the telescope, to connect one day's work with another. Nor in tabulating is there any great chance for judgment.

These appearances seem worthy to be classed as bright lines, for (1) they are seen as well with prism as with grating; (2) their number increases as the dispersion increases; (3) they occur for periods together, and are absent for periods together; (4) they remain constant in position but vary in intensity; at times they are dazzling bright, and at times they are faded, scarcely noticeable; at times they remain a steady glare, at other times they sparkle in and out, are caught only in instants; (5) these variations are not dominated by the weather, they may be bright or dull under the most favorable circumstances, and dull or bright under the most unfavorable.

Our final list contains over a hundred and fifty positions; some appear so few times that independently they could not be claimed as bright lines. Although probably correct to within two in the fourth figure, yet they are useless for purposes of identification. The number of observations, however, places a means of discriminating at our disposal. If those lines, which are capable of being referred to a single substance, varied together, we may fairly consider that they belong to the same substance.

In this way we have identified *hydrogen*, presenting in addition to the four ordinary excitation lines to which we are accustomed, a large number, perhaps ninety, due to its low excitation spectra.

*Oxygen* presents eleven lines of its high excitation spectrum, and in addition the *glow of the negative pole* represented by sixteen lines.

*Nitrogen* presents probably eighteen lines of its high excitation spectrum, and in addition the *glow of the negative pole* represented by five lines.

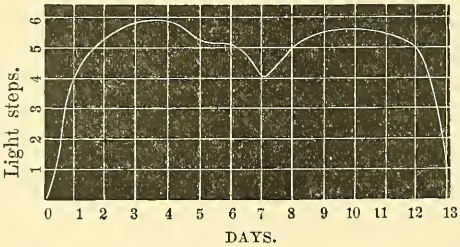
*Carbon* presents five lines, generally occurring together.

Compounds of carbon and hydrogen present seven lines, generally occurring together. Oxygen and carbon in combination present eight lines generally occurring together. Nitrogen and carbon in combination are probably represented by the most intense line of the cyanogen spectrum, but from the scantiness of the data we are unable to speak with certainty.

*Magnesium* is represented by five lines generally occurring together, and yet the traces of magnesium burning in hydrogen are very faint.

The whole of this evidence, the low temperature of the hydrogen spectrum, the apparent ease with which the hydrocarbon* compound forms, the fact that during its formation there is an increase in the star's variable light without accompanying evidence of combustion and the spectra of the negative glow, presents us with the fact of an electric discharge in which hydrogen plays the part of the positive pole, and oxygen and nitrogen the parts of the negative pole. From evidence presented by the bright line† stars, noting that, roughly speaking, the high erexcitation hydrogen belongs to the brighter, the lower to the fainter stars, we are inclined to think this charge the residual of that produced by chemical action, perhaps simply dissociation taking place in the interior. We will not stop here to recall to the student of terrestrial and cosmical physics the evidence presented by comets, by the magnetic needle, by certain bands of the solar spectrum, by sun spots, by the zodiacal light perhaps, and many similar phenomena, not only of an electric charge upon the sun, but also of a cold atmosphere between it and our earth.

We have studied these spectra with regard to their appearance in time, and find evidence of a force especially evident in the nitrogen negative glow, in the magnesium and in the hydrogen, whose laws our short series does not permit us to determine, but which is probably the cause effecting the disappearance of the hydrogen lines in 1874,‡ and their reappearance in 1883, and is perhaps similar to that causing the sun spots.



Light curve of β Lyræ. Observation by Sawyer.

We have also studied the spectra with regard to the variation of the star's light, a single period of which derived from observations by Sawyer is represented in the adjoining cut. And we find in the spectra of hydrogen, oxygen and their carbon compounds a simultaneous variation. To any one acquainted with Berthelot's§ work, upon the action of mixtures of these gases under an electric spark, this will appear quite natural. The rise in the curve from primary minimum to primary maximum corresponds to a period of increasing oxygen,

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* Ann. Chim. et Phys., III, lxvii, 67, 1863. † The Astron. Jour., No. 4, vol. vii.
‡ Astronomische Nachrichten, No. 2581. § Comptes Rendus, t. lxviii, 1869.

of increasing hydro-carbon, and of an almost entire absence of carbonic acid. The downward slope to secondary minimum corresponds to a period abundant in carbonic acid, almost wanting in oxygen with variable evidences of hydro-carbon. The remaining portion of the curve corresponds to a period in which the evidences of hydro-carbon, oxygen, and carbonic acid are irregularly variable; as would be the case if the light waxed and waned by a series of undulations similar to those which Chandler* tells us are actually observed. The final slope corresponds to a period of decreasing carbonic acid, increasing hydro-carbon, increasing oxygen, preparing as it were for a conflagration at primary minimum, and such apparently takes place. It is of interest to remark that hydro-carbon probably formed a part of the spectra of both Nova Cygni and the star near $\chi_{\prime}$ Orionis, but was only traceable near the star's maximum.

Recalling Lockyer's result in the study of the solar atmosphere, agreeing as it does with certain observations which we have quoted above, we may picture to ourselves the condition of the stellar atmosphere, and the action therein somewhat as follows: An outer layer of hydrogen positively electrified, an inner layer of oxygen negatively electrified, and between them a layer of carbon mingling on its edge with hydrogen. The electric spark passing through the mixture forms the hydrocarbon compound, whose molecular weight carries it into the oxygen region where combustion ensues with the formation of carbonic acid and aqueous vapor, both of which descending under the influence of their molecular weight are again dissociated by internal heat, and return to their original positions. Under the insight which this result gives we have found the spectrum of the nebulæ† referable to low excitation hydrogen, the spectra of the bright line stars referable to high excitations oxygen and hydrogen of higher or lower excitation according as the central star is of a high or low magnitude, and as far as the accuracy of the observations permits, τ Coronæ, Nova Andromedæ, Nova Cygni and the star near $\chi_{\prime}$ Orionis itself a variable, likewise referable to the same spectra similarly conditioned. There is also reason for thinking that a similar atmosphere in similar physical conditions, lies between us and the sun, and it seems as if we might consider that from the faintest nebula to the most highly finished star we have but progressive stages of the phenomenon here presented. To observe, to differentiate, to classify, to interpret, presents a vast field of deep interest and high promise. This line of investigation, however, will appreciate both new work in the laboratory and new methods with the telescope. To prepare these is now our charge; later we hope, under some clearer sky, to reënter the field.

* Chandler. Astronomical Journal, vol. vii, No. 1. † Ibid., vol. vii, No. 6.

## ART. XV.—*Phenacite from Colorado;* by SAMUEL L. PENFIELD. *With notes on the locality of Topaz Butte;* by WALTER B. SMITH.

THE occurrence of phenacite in the United States was first mentioned by Messrs. Cross and Hillebrand,[*] who published a short description and figure of a crystal occurring with microcline (amazon stone) from the Pike's Peak region, El Paso Co., Colorado; later these same authors[†] gave a more detailed description of more complicated crystals from Florissant, in El Paso Co. At about the same time Mr. W. E. Hidden[‡] mentioned the occurrence of phenacite from Florissant; a second note by him, recently[§] published, contains some crystallographic notes and two figures by Prof. Des Cloizeaux, of Paris. Some additional facts regarding the crystallization of this remarkable mineral with some new figures may not be without interest to those who are especially interested in American minerals. In addition to the crystals from the above mentioned locality, I have also, through the kindness of Mr. Whitman Cross, been provided with crystals from an entirely different locality, and with different associations and crystalline habits, which are especially worthy of description.

The lenticular crystals which have already been described are from Topaz Butte, near Florissant, and about sixteen miles from Pike's Peak. In studying them, the first point noticed is their great similarity in habit to those described and figured by N. v. Kokscharow,[‖] from the Ilmengebirge, Urals, where they occur with the same associations on amazon stone. All of the forms mentioned by Kokscharow occur on the crystals from Topaz Butte, and besides them I have found no others. His figures also represent very closely the habit of the crystals. The specimens which I have examined include those in the collection of Prof. Geo. J. Brush, the Yale College cabinet, and two loose crystals from the collection of Mr. C. S. Bement, of Philadelphia. The forms which have been identified are as follows: they are of especial interest because belonging to the rhombohedral-tetartohedral division of the hexagonal system.[¶]

| Rhombohedrons 1st order. | Rhomb. 2d order. | Rhomb. 3d order. | Prisms. |
|---|---|---|---|
| $r$, $10\bar{1}1$, $+1$ | $p$, $11\bar{2}3$, $r\,\frac{2}{3}\text{-}2$, | $x$, $\bar{1}3\bar{2}2$, $-r\,\frac{2}{3}\text{-}\frac{3}{2}$ | $a$, $11\bar{2}0$, $i\text{-}2$ |
| $z$, $01\bar{1}1$, $-1$ | $p_{,}$, $2\bar{1}\bar{1}3$, $l\,\frac{2}{3}\text{-}2$, | $x_{,}$, $12\bar{3}2$, $-l\,\frac{3}{2}\text{-}\frac{3}{2}$ | $m$, $10\bar{1}0$, $I$ |
| $d$, $01\bar{1}2$, $-\frac{1}{2}$ | $o$, $4\bar{2}\bar{2}3$, $l\,\frac{4}{3}\text{-}2$, | $s$, $21\bar{3}1$, $+r\,3\text{-}\frac{3}{2}$ | |
| $\mu$, $02\bar{2}1$, $-2$ | | | |

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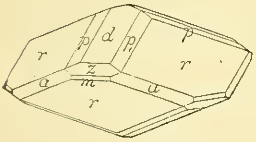
[*] This Journal, III, xxiv, 282.
[†] Bulletin No. 20 of U. S. Geological Survey.
[‡] This Journal, III, xxix, 249.
[§] This Journal, III, xxxii, 210.
[‖] Materialien zur Mineralogie Russlands, ii, 322.
[¶] As these forms are tetartrohedral, $\frac{1}{4}$ should be understood before each of the Dana symbols.

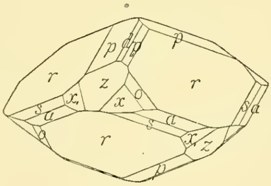
In addition to the above, Des Cloizeaux identified a third prism *k*, $41\bar{5}0$, *i*-$\frac{5}{4}$, and a new plane which he lettered *z*, $13\bar{4}4$, $-l$ 1-$\frac{4}{3}$ which were not identified on the crystals which I have examined. In lettering the forms I have followed Kokscharow, with only a few deviations, *r*, *z*, *μ* and *m* above equal *R*, *r*, *m* and *g* respectively of other authors.

All of the crystals which I have seen occurring on the feldspar are lenticular in shape, resulting from the slight development of prismatic and predominance of rhombohedral forms. Fig. 1 represents the form of crystals which occur with topaz on a brownish, lamellar albite. This specimen is in Prof. Brush's collection, labeled only Pike's Peak; the crystals are a trifle simpler than those occurring on the amazon stone from Florissant, and it may be that they are from some other special locality in the Pike's Peak region. Here the rhombohedron *r* predominates, *d* is large, and the two forms *p* and $p_{,}$ are, as is usually the case, about equally developed; the other forms *z*, *a* and *m* are at times wanting, and scarcely ever more developed than shown in the figure. The crystals occurring on the amazon stone are usually more highly modified. Fig. 2 represents the forms which were observed on a crystal from Mr. C. S. Bement's collection, while fig. 3 is a basal projection of the same with the position of the lower faces dotted in, which is well suited to show the tetartohedral character of the crystal.

1.



2.



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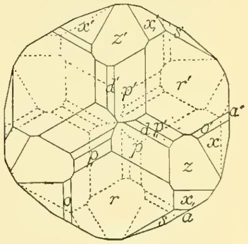

All of the forms mentioned in the above list are shown in these figures except *μ* and *m*; *μ* was not observed on this crystal, and *m* only as a very narrow face. While the usual custom has been followed of drawing these crystals so that an edge of the positive rhombohedron above runs toward the observer, the basal projection has been so turned that the positive rhombohedron above is in front, so that the indices in the above list of forms can be better understood. The relative size and position of the rhombohedrons of the first order can readily be understood from the figures. Of rhombohedrons of the second order there is a decided predominance in size of *p* to the right of $r$, over $p_{\prime}$ to the left; unfortunately the crystal had been so attached that the relative size and position of these faces on the lower side could not be observed; on the top of the crystal, however, the three alternating faces were large, the other three small, as shown in the figure: $o$ occurs only to the left of $r$, being present three times above and three below. Of rhombohedrons of the third order, $x$ and $x_{\prime}$ occur under the negative rhombohedron, $z$, both to the right and left, and are about equally developed, while $s$ occurs under the positive rhombohedron $r$ to the right only. These forms have not only the same symbols, but also the same position with reference to the positive rhombohedron on the Colorado as on the Russian phenacites, as shown by a comparison with the figure of Kokscharow.

The remaining crystals, which are to be described, are from an entirely new locality, Mt. Antero, in Chaffee Co., about one hundred miles southwest of Denver, fifty-five miles from Topaz Butte, and sixty-five miles a little to the south of west from Pike's Peak. Mt. Antero is over 14,000 ft. high, and the phenacites were found by a prospector (whose name I do not know) at one spot on the surface, in a streak up and down the steep slope of the mountain and above the timber line, probably at an altitude of 12,000 feet. The crystals were given by the discoverer to the Rev. R. T. Cross,* of Denver. So far as known the country rock is granite, and the associations are beryl, quartz and feldspar. The suite of specimens in the author's possession consists of eight specimens of pale, bluish green aquamarine, upon three of which the crystals of phenacite are implanted. The crystals are prismatic, and the largest, about $7^{\mathrm{mm}}$ in length, is implanted in an inclined position upon the basal plane of the beryl, while others are scattered irregularly over the prismatic face. The specimens were probably not found in place, as the edges of the crystals are more or less rounded and nicked, as if they had rolled around in contact with other hard minerals. The beryl crystals are deeply striated parallel to the vertical axis and eaten out, having perhaps furnished the material for the formation of the phenacite. The habit of the phenacite crystals is remarkable, and is shown in fig. 4 in ordinary projection, and in fig. 5 in basal projection, the figures being placed in the same relative position as those above. In the prismatic zone the prism of the second order $a$ prevails, while $m$ is always small, in some cases wholly wanting. The crystals are terminated mainly by the rhombohedron of the third order $x$, $\bar{1}3\bar{2}2$, $-r\,\frac{3}{2}\text{-}\frac{3}{2}$: The unit rhombohedron $r$ is small and in a zone between it and the prism $a$ is the rhombo-

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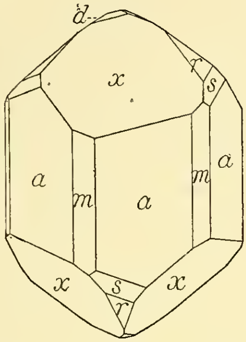
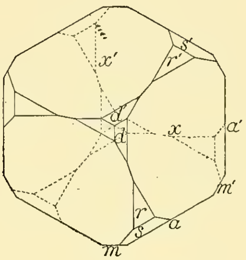
* Some notes upon this locality by the Rev. R. T. Cross will be found on a later page of this Journal.

hedron of the third order *s*. At the top of the crystal are the three small faces of the minus rhombohedron *d*. The prismatic faces are striated not only vertically, especially that part of the prism farthest away from the *s* face, but also near each *s* face parallel to the intersection between *s* and *a*. These two sets of striations do not cross but meet along a line running in an inclined direction across the *a* face; the *s* and *r* faces, especially the former, are also striated parallel to the intersection between *s* and *a*. These striations point to vicinal faces, prisms and rhombohedrons of the third order, but no definite indices could be assigned to them. The *x* faces are not smooth and polished, but covered with little prominences with curved unsymmetrical contours. Crystals with exactly this habit have previously been described by Prof. M. Websky,* of Berlin, from an unknown locality in Switzerland, and they are the only crystals, so far described, which are terminated mainly by rhombohedrons of the third order. It is interesting also to note that, while in the Russian localities the crystals of phenacite occurring on amazon stone are lenticular, as is the case also in Colorado, the crystals from the emerald mines of Katharinenburg are prismatic, terminated however not by rhombohedrons of the third, but by those of the first and second order.

4.



5.



In the following table the angles are given which were measured for the identification of the above mentioned forms and also the corresponding angles calculated from the fundamental angle of Kokscharow, $r \wedge r'$, $10\bar{1}1 \wedge \bar{1}101 = 63° 24'$, $c = 0{\cdot}66106$. In measuring those faces which are deeply striated, and where there were a number of reflections of the signal the most prominent reflection was chosen.

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* Jahrb. f. Min., 1882, i, 207.

| | | Lenticular crystal from Topaz Butte. | Prysmatic crystal. Mt. Antero. | Calculated, Kokscharow. |
|---|---|---|---|---|
| $r \wedge r$ | $10\bar{1}1 \wedge \bar{1}011$ | 63° 14′ | 63° 24′ | 63° 24′ |
| $r \wedge d$ | $10\bar{1}1 \wedge 01\bar{1}2$ | 31° 40′ | 31° 30′ | 31° 42′ |
| $r \wedge p$ | $10\bar{1}1 \wedge 11\bar{2}3$ | 20° 4′ | | 20° 4′ |
| $r \wedge o$ | $10\bar{1}1 \wedge 4\bar{2}\bar{2}3$ | 19° 19′ | | 19° 18′ |
| $r \wedge x_{,}$ | $10\bar{1}1 \wedge 12\bar{3}2$ | 27° 42′ | | 27° 43′ |
| $r \wedge s$ | $10\bar{1}1 \wedge 21\bar{3}1$ | 29° 59′ | | 29° 57′ |
| $r \wedge a$ | $10\bar{1}1 \wedge 11\bar{2}0$ | 58° 17′ | 58° 13′ | 58° 18′ |
| $d \wedge z$ | $01\bar{1}2 \wedge 01\bar{1}1$ | 16° 26′ | | 16° 28′ |
| $z \wedge \mu$ | $01\bar{1}1 \wedge 02\bar{2}1$ | 19° 25′ | | 19° 28′ |
| $s \wedge a$ | $21\bar{3}1 \wedge 11\bar{2}0$ | | 28° 52′ | 28° 21′ |
| $x \wedge x'$ | $\bar{1}3\bar{2}2 \wedge \bar{2}\bar{1}32$ | | 75° 48′ | 75° 57′ |

In closing, I wish to express my obligations especially to Mr. Whitman Cross, of the U. S. Geological Survey, for the information concerning the localities and associations of the Colorado phenacites, and to Rev. R. T. Cross, Prof. Geo. J. Brush and Mr. C. S. Bement for the material which they have placed at my disposal.

Mineralogical Laboratory, Sheffield Scientific School, Nov. 19th, 1886.

## *Notes on the Crystal Beds* of Topaz Butte*; by WALTER B. SMITH.

The "crystal beds," from which by far the greater number of the specimens labeled *Pike's Peak* have actually come, are situated about 20 miles northwest of that point. This locality has been known and worked for about 20 years. Topaz Butte, a sharp point five miles due north from Florissant, marks the southern limit of the "crystal beds." It is the highest of a chain of similar, bare granitic points extending several miles to the north and known as the Crystal Peaks. A rectangle, beginning at Topaz Butte and running six miles north along the above ridge, and extending three miles eastward, will include most of the pockets from which the beautiful amazon stone and smoky quartz crystals have been taken.

On the west side of the Crystal Peaks, pockets have been found scattered over an area equal perhaps to that on the eastern slope, but they are fewer by far in number. Phenacite and topaz have been found in three of these pockets, while neither mineral has been observed on the eastern side, though the formation, conditions and associations are apparently similar.

A pocket found in 1884, on a debris-covered slope about one and a half miles northwest of Topaz Butte, yielded the first phenacites and topazes that were found in this region, which have been described by Cross and by W. E. Hidden. The

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* Extract from a paper read Oct. 3, before Colorado Scientific Society, to be published in vol. ii, part 2.

minerals associated with phenacite in this pocket are topaz, microcline, quartz (smoky and white), albite, fluorite, limonite (pseudomorph after siderite), columbite (very rare), and biotite. At this pocket the writer found fragments of topaz, albite, quartz, and microcline with phenacite attached. On one piece of albite were fourteen distinct crystals of phenacite on a surface about three-quarters of an inch square.

The largest phenacite ever found in this locality is a rough lenticular crystal about 15$^{mm}$ in diameter. Most crystals are colorless, but those that have been entirely imbedded in gangue are generally of a faint wine color; one was observed having a smoky bluish tinge. All phenacites attached to microcline, here, as well as at the Specimen Rock locality, have been on the green or amazon stone variety. A few phenacite crystals have been observed in the interior of smoky quartz and of amazon stone crystals, these minerals showing no evidence of a secondary growth. Phenacites have also been found half in quartz and half in microcline when the two minerals are in contact. Other crystals seem to be of a later generation than the original minerals of the cavity, as they occur slightly attached to amazon stone, to albite coating microcline, and entirely imbedded in the limonite crust on some feldspars.

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## ART. XVI.—*The Norites of the "Cortlandt Series" on the Hudson River near Peekskill, N. Y.;* by GEO. H. WILLIAMS.

IN a former paper on the "Peridotites of the Cortlandt Series,"* the writer has described the most basic members of that extremely varied and interesting group of massive rocks which occupy the northwestern corner of Westchester County, N. Y. These peridotites are characterized by the presence of the mineral olivine and the almost complete absence of feldspar. They are most abundantly developed on the western edge of the area occupied by the Cortlandt rocks (Stony Point, on the west bank of the Hudson River, and in the southern part of Montrose Point) but are also met with at several localities in its southeastern portion. Quantitatively they make up but a small proportion of the whole series.

By far the larger majority of the Cortlandt rocks contain, as their most important constituent, a triclinic feldspar. Quartz and orthoclase also occur in some of them, although these minerals are comparatively rare. Other characteristic components are hypersthene, augite, hornblende and mica. Magnetite

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* This Journal, Jan., 1886, p. 26.

and apatite are always present, though in varying quantities, and garnet is not uncommon, especially around the edge of the area.

The predominating rock-type within the Cortlandt area is particularly characterized by the presence of hypersthene. Throughout nearly the entire township east of the New York Central and Hudson River Railroad and also, to a considerable extent west of this, rocks of this class prevail; and still examples of the pure norite type, composed wholly of plagioclase and hypersthene, appear to be exceptional. In nearly all specimens biotite, hornblende and augite, either singly or together, accompany the hypersthene in every conceivable proportion and thus form gradual transitions into mica-diorite, hornblende-diorite and gabbro. These rocks are developed in considerable purity in the western portion of the township; and yet, throughout the entire Cortlandt region, intermediate and transitional forms are everywhere more abundant than well defined extremes. The naming and classification of particular specimens becomes a matter of great difficulty; and when it is remembered that to the mineralogical variety a great structural diversity is added, some idea may be formed of the number of different types which may be collected within this very limited district.

The constant occurrence of such transitional forms and the want of any regularity in the distribution of the pure types, makes it impossible to regard these rocks as anything but local modifications or special facies of one and the same mass. However great their mineralogical variety may be, they together form but a single geological unit.

As already stated there seems to be a peripheral distribution of those rock-types which, like diorite and gabbro, differ most widely from the prevailing norite. A possible connection between this fact and the proximity to these rocks of the mica-schists and limestones which surround or are enclosed in the massive area, the writer hopes to discuss, in connection with some chemical analyses, in a later paper.

At present only a petrographical description of the massive rocks themselves will be attempted. For this purpose the pure types will be treated in succession and about each will be grouped such varietal or transitional forms as are produced by the various admixtures of accessory constituents. Each class will be designated according to its prevailing non-feldspathic mineral as follows:

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|---|---|---|
| Class II, | hypersthene, | NORITE. |
| " III, | augite, | GABBRO. |
| " IV, | hornblende, | DIORITE. |
| " V, | biotite, | MICA-DIORITE. |

### NON-CHRYSOLITIC ROCKS.

### Class II. *Norite.* (Esmark).

The application of the microscope and accurate optical methods have been instrumental in showing that many rocks formerly supposed to contain orthorhombic pyroxene are in reality devoid of this mineral. Many of the so-called "hypersthenites" of the older petrographers contain only a glistening, bronzy diallage (the "*diallage metalloide*" of Hauy). This peculiar luster is found to be in no way connected with an orthorhombic crystallization, and yet the microscopic studies of rocks have by no means tended to show that hypersthene is a less widely distributed mineral than was formerly supposed. On the contrary, orthorhombic pyroxene is constantly being found to be a more and more important rock constituent. Not only is it discovered to have an unsuspectedly wide spread occurrence in the younger volcanic lavas, but in the more basic of the older granular rocks true hypersthene is by no means a rare constituent. The localities for hypersthene-gabbro or hyperite are constantly increasing, wherever the older rocks are being studied.

Hypersthene rocks have long been known to be developed on an enormous scale in the Laurentian formation of Canada and northern New York, where they are called anorthosite or norite. True hypersthene is also known to have a wide distribution in the dark, fine grained gabbros of Maryland,* Delaware† and Pennsylvania. These rocks are members of the Archæan formation and resemble traps, although they are wholly different from the mesozoic diabase of the Atlantic border.

The occurrence of a considerable area of massive rocks in which hypersthene is the prevailing bisilicate, on the southern flank of the Archæan Highlands of New York, is very interesting in connection with the distribution of this mineral in the rocks of the Appalachian belt to the north and south of it.

The earliest identification of hypersthene in the Cortlandt rocks is, as far as I have been able to ascertain, that of Hermann Credner in 1865.‡ These rocks are described by Mather, in

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*See Bull. U. S. Geol. Survey, No. 28, p. 18.

†F. D. Chester: Proc. Acad. Nat. Sci. Philadelphia, Oct. 14, 1884. Dr. Geo. W. Hawes also found hypersthene-gabbros abundant in the White Mts., N. H.

‡It may be of interest to quote here a few sentences from Credner's description of these rocks, given in an article entitled "Geognostische Skizze der Umgegend von New York." He says: "Noch einige Meilen (von New York) nördlich wird der Gneiss sehr reich an Hornblende. bis diese den Glimmer noch und noch verdrängt, wodurch ein ausgezeichneter Hornblendeschiefer entsteht. welcher allmählig sein schiefriges Gefüge verliert und zu einem porphyrartigen Syenit wird, in dessen weisser Grundmasse grosse blättrige Hornblendeindividuen ausgeschieden liegen. Von diesem Gestein sollen wiederum Uebergangsstufen nach dem Hypersthenfels

his report on the geology of the first district of New York, as "syenite" and "hornblende rock."* The next notice of the occurrence of hypersthene in the rocks near Peekskill was given by Prof. Jas. D. Dana, who identified and described it in connection with his studies of the rocks of Westchester County.†

The comparative rarity of pure rock types in the Cortlandt Series above alluded to render various subdivisions under the hypersthene rocks necessary. I shall consider in succession:

1. Norite proper.
2. Hornblende Norite.
3. Mica Norite.
4. Hyperite or Augite Norite.
5. Pyroxenite.

### 1. *Norite proper.*

As already stated, hypersthene rocks which are entirely devoid of mica, hornblende and augite are extremely rare within the Cortlandt region. Indeed it may be doubted if any specimen of the absolutely pure norite type could be found; and yet such are occasionally met with as contain these minerals in very small quantities. These specimens are regarded as representing the norite proper.

Two thin-sections in Professor Dana's collection, prepared from specimens collected at the iron mine three-fourths mile N. 15° W. of Cruger's station, show the norite type in greater purity than any others which have come under the writer's notice. They are almost wholly free from the non-essential minerals, only occasional plates of a very dark biotite being observable. The ground-mass is here a rather coarse-grained mosaic of plagioclase. The hypersthene is present in well-defined individuals with a more or less rounded outline. This mineral is freer from inclusions and has a much lighter color than is usual in the Cortlandt norites.

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nachzuweisen sein, welcher das hügelige aus steilen Bergkuppen bestehende Plateau bildet, das sich am linken Ufer des Hudson in östlicher Richtung von Peekskill, einer etwa 40 Miles von New York gelegenen Stadt, ausdehnt. Ich war verhindert diese Uebergänge genau zu verfolgen, habe aber ein feinkörnig-syenitisches Gestein beobachtet, welches grosse Partieen von grüner Hornblende umfasste, in welcher kupfer-glänzende, scharf-begrenzte Hypersthen-Individuen lagen. Diese Gesteinsart scheint die Mitte der Uebergangstufen zwischen Hypersthenit und Syenit einzunehmen. . . . . Nördlich von Peekskill geht der Hypersthenfels wieder in Syenit über. Das zwischen beiden liegende Gestein, welches Hornblende und Hypersthen zugleich enthält, habe ich auch hier beobachtet."—Zeitschrift der deutschen geologischen Gesellschaft.—Bd. xvii, 1865, p. 390. The gradual transition of the hypersthene rock into syenite and hornblende-schist does not in reality appear to exist.

* Geology of New York—Part I, Geology of the First District by Wm. W. Mather, 1843, p. 528.

† On the geological relations of the limestone belts of Westchester County, New York. This Journal, III, xx, p. 197, Sept. 1880.

Slide No. 118 of the Johns Hopkins University collection, is of a rock from the same locality as the two just mentioned. It is essentially the same as the preceding but contains as additional constituents pleonaste and garnet. The relation of the first of these minerals to the norite is very interesting and will be more fully described beyond. The garnet here forms narrow borders around the iron minerals. Here again the hypersthene and feldspar are unusually light colored and free from inclusions, a fact which may indicate that nearly all the iron present in the magma crystallized in the ores.

No. 43, from Shaw's blacksmith shop near the railroad crossing at Centerville on the road to Peekskill, exhibits a very interesting variety of the typical norite containing large porphyritic crystals of *orthoclase.* At first glance this rock in the hand-specimen appears like a medium grained aggregate of reddish brown feldspar and glistening bronzy hypersthene, but a closer examination reveals the presence of long, narrow cleavage surfaces of feldspar. Some of these measure as much as $10\times 60^{mm}$! The crystals are elongated in the direction of the clinodiagonal axis, as may be seen from the direction of the cleavages. The highly reflecting surfaces are everywhere sprinkled with dull spots which the microscope shows to be inclusions of the other constituents in grains of the usual size. Here, therefore, we have another example of the structure which the writer has distinguished as *pœcilitic** in describing the hornblende of the Cortlandt peridotites.

A careful examination of this feldspar leaves little doubt as to its being a true orthoclase. Its specific gravity, determined by the Thoulet solution and a Mohr's balance, is 2·615. The powder, which was completely isolated from the other constituents, gave a strong potassium reaction. A series of measurements on the reflecting goniometer gave, for the angle between the two cleavage planes, values varying from 89° 35′ to 90° 44′, a slight uncertainty being occasioned by the somewhat undulatory character of the cleavage surfaces. Stauroscopic determinations of the extinction angles, made on carefully detached cleavage pieces, yielded values averaging 5½° for $\infty P \grave{\infty}$ (010) and 0° for 0P (001).

This feldspar also differs in several other particulars from the small reddish brown plagioclase crystals which, as usual, make up the greater part of the Cortlandt norite. Twinning lamellæ are altogether wanting in it, and its color is white, owing to the absence of the reddish dust which is always present in the plagioclase. Its appearance in the hand-specimen is fresh and glassy, while under the microscope it possesses to a high

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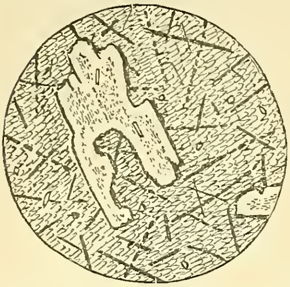
* This Journal, Jan. 1886, p. 30. The word is here changed to the accepted form.

degree the peculiar "shagreen" surface, so characteristic of certain minerals such as olivine (fig. 1). This appears to be due to a vast number of very minute oval indentations which completely cover the surface wherever it is exposed.

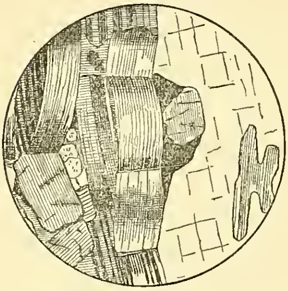
1.



This occurrence of orthoclase in norite is very interesting and is quite in accord with determinations formerly made of the feldspars in these rocks by Prof. Dana and the late Dr. G. W. Hawes.*

The plagioclase, which composes most of the groundmass of this rock and also occurs occasionally as inclusions in the orthoclase, is shown by its specific gravity and extinction angles to be *Andesine.* The former, as determined by the Thoulet solution, is 2·674. The extinction angles are 4°–5° on 0P (001) and 10°–12° on $\infty P \breve{\infty}$ (010). In the groundmass of the rock these plagioclase individuals are crowded thickly together and are often bent or broken. In such cases they show most beautifully the increase in the number of twinning lamellæ where the strain has been greatest (fig. 2.)

2



Section No. 43. Bent and broken plagioclase crystals showing secondary twinning lamellæ. On the left and near the center hypersthene. On the right orthoclase enclosing an irregular plagioclase crystal. Plagioclase is represented between crossed Nicols in order to bring out its twinning structure.

Such a mechanical origin of twinning lamellæ in feldspar has been figured and described by van Werveeke† and Judd,‡ but it would be difficult to conceive of finer examples of it than are to be found in this rock. In the groundmass these plagioclase crystals are well developed and have their characteristic lath-shaped form, but where they are imbedded in the orthoclase they show exceedingly irregular shapes as though they had been partially dissolved (fig. 1).

*The hypersthene* is generally arranged in groups of three or more crystals. These are intensely colored owing to the large amount of iron which they contain and show their characteristic trichroism ($\breve{a} = \mathfrak{a} =$ red; $\bar{b} = \mathfrak{b} =$ yellow: $\acute{c} = \mathfrak{c} =$ green) very vividly. In spite of their deep color, these hypersthene crystals are unusually full of the

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* This Journal, Sept. 1880, p. 197.

† Neues Jahrbuch für Mineralogie, etc., 1883, ii, p. 97.

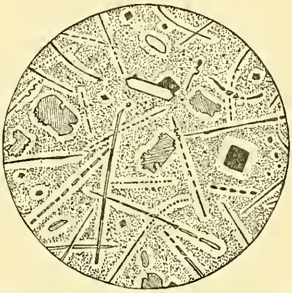
‡ Quarterly Journal of the Geological Society, Aug. 1885, p. 365.

red inclusions so characteristic of this species, a fact which would speak against their having been secondarily formed by "*schillerization,*" which Professor Judd states is attended by a bleaching of the original mineral substance. The extinction of the mineral is in all sections parallel to the crystallographic axes. In sections parallel to the basal- or macropinacoids, the bisectrix may be seen to stand perpendicular to the face and the optical angle to be smaller in the latter case than in the former. This fact, taken in connection with the deep colors exhibited by the mineral, is sufficient to place its nature as true hypersthene beyond a doubt.

The only other constituents observed in this rock are biotite, irregularly dispersed in small quantities, and a considerable amount of apatite and magnetite or ilmenite.

All the feldspar of this norite, both orthoclase and andesine, is filled with inclusions of such great beauty and delicacy that they seem to merit a description, especially on account of their bearing upon the former remarks of the writer regarding Professor Judd's theory of Schillerization.* These inclusions, which are represented in fig. 3 as magnified about 350 diameters, consists of plates, rods and minute dots.

3.



1. *The plates.*—The color of these is either red, grading as they become thinner into shades of orange and yellow; or greenish-gray. They are sometimes hexagonal, sometimes rectangular and sometimes irregular in shape. Almost always they are finely serrated for a portion of their edge. The largest measure about 0·04 × 0·01 mm. From this size they grade down to the minutest dots, always, however, transparent, homogeneous and very sharply outlined. These plates do not exercise any influence upon polarized light. This is, however, on account of their extreme thinness as compared with the mineral in which they are imbedded. These plates very strongly resemble extremely thin crystals of hematite (micaceous iron, eisenglimmer) and the writer is inclined to regard them as composed of this substance.

2. *Rods.*—When very minute, the above described plates are frequently arranged in parallel rows, which grade insensibly, into long, hair-like rods. These are sometimes discontinuous, a mere series of dots, through a part or the whole of their length; sometimes they are thickened in certain places. Often these rods may be seen to be continuous with the plates, and, like them, they are always transparent with a brown color except

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* This Journal, January, 1886, p. 33.

when of the extremest thinness. These rods are often curved and closely resemble the trichites seen in certain volcanic glasses. *There is no parallelism whatever in the arrangement of these bodies*, a fact which has an important bearing on their mode of origin.

3. *The dots.*—These are extremely minute, opaque, globulitic bodies, which may be regarded either as very small plates or as the elements of which the rods are composed. They vary somewhat in size, the smallest forming the fine reddish-brown dust, which imparts the characteristic color to the andesine and which no power of the microscope can resolve. These dots resemble the globulites in certain obsidians in the same way in which the rods resemble trichites.

The mutual arrangement of these three classes of inclusions throws considerable light on their nature and origin. As above remarked, there seems to be no regularity in their direction, as would be required by the "solution planes" of Judd; and yet there is a very decided regularity in their arrangement in zones in the enclosing crystal. As a rule, the center of the plagioclase individuals is occupied by an indiscriminate mass of rods and plates, which is surrounded by a zone filled only with reddish dust. Outside of this there is almost always an exterior zone quite free from inclusions of any kind. This arrangement is essentially the same as that recently described by the writer in the bytownite of the Baltimore gabbros.*

The dust-like globulites are also present in the space between the rods and plates near the center of the crystal. Then, however, there is always a perfectly clear space around each larger inclusion and *the width of this clear zone depends upon the size of the inclusion which it surrounds.* It is widest about certain occasional octahedral crystals of magnetite (see fig. 3). The bearing of this phenomenon upon the mode of origin of the inclusions is too apparent to need further elucidation.

The fact that the arrangement of these inclusions is altogether independent of the numerous bendings and cracks, mentioned above as so common in this feldspar, also speaks strongly against their secondary origin.

A careful and prolonged study of the form, size and arrangement of these inclusions has convinced the writer that they are original and represent the form in which the iron first separated from the magma. This was probably simultaneous with the crystallization of the feldspar, as is indicated by the uniformity of their zonal arrangement.

Such red globulitic dust is well known to be the coloring matter of the feldspar in many of the quartz porphyries. The sunstone of Tvedestrand owes its peculiar luster to plates of

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* Bulletin of the U. S. Geological Survey, No. 28, p. 21, 1886.

hematite, similar to those found in the well known perthite, or even in some crystals of carnallite.

Although such inclusions are almost always present in the older rocks which have originated at great depths, they are by no means unknown in certain minerals of volcanic rocks which have cooled at the earth's surface. Those above described in the plagioclase of the Cortlandt norite are almost identical in both form and disposition with the ones which Prof. Hermann Vogelsang so admirably figured in 1874 from the nosean of Rieden.[*] Mierisch has also very recently described and figured similar bodies in the sodalite and apatite found in druses of the limestone blocks ejected from Monte Somma.[†] [‡]

Although the norite is the prevailing type of massive rock throughout Cortlandt township, still the pure aggregate of plagioclase and hypersthene is comparatively rare. In almost every case either biotite or hornblende or monoclinic pyroxene is present, and often two or all three of these together in accessory quantities, forming transitions to the mica-diorite and gabbro which are common modifications of the same continuous mass, especially around its periphery. The writer has therefore designated all rocks in which one-half or more of the nonfeldspathic constituents was hypersthene as norite, and named varieties of this after the prevailing accesssory component.

[*] Ueber die natürlichen Ultramarinverbindungen. Bonn, Taf. I.

[†] Tschermak's Min. und Petrog. Mitth., viii, pp. 166 and 183.

[‡] The writer does not wish to imply by the above observations any direct opposition to Professor Judd's theory of schillerization. Through the kindness and liberality of this gentleman he has been enabled to study a suite of sections of the Scottish rocks upon which this theory was based, and can express himself as convinced of the correctness of Prof. Judd's conclusions as far as these rocks are concerned. The idea of schillerization, which Prof. Judd has so admirably developed, is to be welcomed as a new and most valuable addition to what microscopical petrography has accomplished. It is doubtless capable of a wide application and will serve to clear away many difficulties. The writer desires only to call attention to the fact that it is unsafe to ascribe *all* the inclusions occurring in the old granular rocks to the effects of what Professor Judd calls schillerization, even when these apparently resemble such as have been undoubtedly produced in this way. How often is it observed that nature employs diverse means to accomplish approximately the same result! Two investigators, commencing with the study of effects which may with certainty be attributed to very different causes, often succeed in tracing these by insensible transitions to a common ground, where the phenomena observed may be ascribed with almost equal right to the one cause or the other. Here two opposing views may be defended with excellent reasons, which depend largely upon the direction from which the subject was approached. Both may be right and yet particular cases may arise where it is impossible to decide between them.

Thus it would appear that both original and secondary inclusions may occur in the constituents of the granular, deep-seated rocks and that the similarity between them may be so great as to occasion difficulty in referring certain cases to the one class or the other.

### 2. *Hornblende Norite.*

No. 117, from the same iron mine north of Cruger's Station as 118, is like this except that it contains an abundance of compact, dark green hornblende. This is present in good-sized individuals without crystal outline. The color is greenish-brown, with a trichroism: $\mathfrak{a}$=light yellow; $\mathfrak{b}$=dark greenish brown; $\mathfrak{c}$ nearly like $\mathfrak{b}$. Absorption, $\mathfrak{a}<\mathfrak{b}<\mathfrak{c}$. Around frequent magnetite inclusions the color is generally bleached out to a clear, light green.

No. 119, from Montrose station, south of Peekskill, is quite like the foregoing except that its hornblende is in larger areas, often enclosing the other constituents. Its color is brown and in its inclusions, pleochroism and general character, it appears to be wholly identical with the hornblende described at length as occurring in the Cortlandt peridotites. (See this Journal, Jan., 1886, p 31.

No. 125 was collected on the road leading S.E. from Peekskill, directly east of Blue Mountain and just about in the middle of Cortlandt Township. In the hand specimen well formed, glistening black hornblende crystals are seen to be thickly scattered through a grayish groundmass of feldspar and hypersthene. These hornblende crystals vary in size, the largest being 12–15 mm. in length. Other representatives of the hornblende norites are specimens Nos. 50*a* and 50*b* from the "Butler Section," on the road from Montrose Station to Montrose Point, to be described beyond. The amount of hornblende is so great in these rocks that they might perhaps be better classed as diorites, and yet so much hypersthene is present that it was thought better to place them here. They are very fresh and coarse-grained aggregates. The hornblende is of the greenish kind described in section No. 117. The hypersthene is in much smaller individuals imbedded in the hornblende.

All of these rocks contain a greater or less quantity of biotite and so grade into the next variety.

(To be concluded.)

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## ART. XVII.—*A method for subjecting living Protoplasm to the action of different liquids;* by GEORGE L. GOODALE.

IN the studies of Loew and Pokorny, and of Pfeffer, on the action of very dilute solutions on living vegetable protoplasm, the objects under examination were generally exposed to large quantities of the solutions and thence transferred to the field of the microscope. It is indispensable in such investigations that the living object should be exposed to the action of a large quantity of the liquid.

To obviate the necessity of transferring the specimen from the litre-flask to the stage of the microscope, I have recently made use of an apparatus by which all handling of the specimen is avoided, and yet by which the object can be placed under the action of as large a quantity of liquid as may be desirable.

Reduced to its simplest terms, the apparatus consists of a small number of ordinary "chlorid of calcium jars" (i. e. tall slender jars provided with an opening near the base), which are connected by means of "three way" tubes, with a common tube of small size. The latter tube is inserted into the side of a microscopic-cell of simple construction. The best cells for the purpose are made of soft rubber, firmly cemented to the slide, and provided with an inflow and an outflow. The object to be examined is held without injurious pressure on the under side of the thin glass cover, either by delicate floats of glass, or better, by threads of glass fastened by wax. As soon as the object has been put in place, and the observer is convinced that it has suffered no injury by manipulation, the flow of liquid is allowed to begin by slightly opening one of the cocks or clamps connected with one of the three-way tubes. The object becomes at once bathed in the liquid, and may be subjected to its action either under a continuous slow or rapid flow, or to the action of another liquid. which may be substituted by shutting off one and turning on another current. In my repetition of Pfeffer's interesting experiments, I was enabled in this manner to wash the object with pure water after every exposure, without removing it from the stage of the microscope.

It should be further said that the same apparatus also serves for the study of differential staining of tissues by various coloring matters.

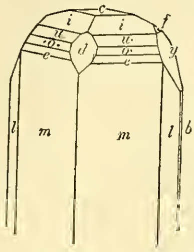
By a slight modification, it may be applied also to the examination of the effect of different liquids with regard to their plasmolytic power (de Vries's experiments in Plasmolysis).

The application of this apparatus to the cultivation of organisms under different conditions of nutriment and the like, is obvious. Fresh solutions in any amount and number can be brought into contact with the submerged parts without even momentary exposure of the parts to the air.

And lastly, by a slight modification of the apparatus, it is possible to examine without disturbance of the growing plants the character of the acid given off by the extremities of roots during growth.

By due attention to temperature and to the height of the column of liquid in the jars, all the necessary physical conditions for studies of this character can be kept well under control.

## ART. XVIII.—*On the Topaz from the Thomas Range, Utah;**
by A. N. ALLING.



THE topaz crystals under examination were selected out of a considerable number in the cabinet of Professor Brush, from the locality in Utah in the Thomas Range, forty miles north of Sevier Lake, where they occur in rhyolite.† They vary from $3^{\mathrm{mm}}$ to $10^{\mathrm{mm}}$ in length, and are perfectly clear and colorless. The planes for the most part are very highly polished, though vicinal planes appear in a number of cases to disturb the accuracy of measurements. The habit to which most of the crystals conform is shown in the figure. The observed planes are:

Pinacoids $b$ (010, $i$-$\breve{\imath}$), $c$ (001, $O$); prisms $m$ (110, $I$), $l$ (120, $i$-$\breve{2}$); macrodome $d$ (201, 2-$\bar{\imath}$); brachydomes $f$ (021, 2-$\breve{\imath}$), $y$ (041, 4-$\breve{\imath}$); pyramids $i$ (223, $\frac{2}{3}$), $u$ (111, 1), $o$ (221, 2), $e$ (441, 4).

The following angles, each representing the mean of a number of careful measurements with a Fuess compound goniometer, were taken as fundamental:

$$y \wedge y' \quad 041 \wedge 0\bar{4}1 = 124^\circ\ 41'\ 45''$$
$$u \wedge u' \quad 111 \wedge \bar{1}11 = \ \ 91^\circ\ 12'\ \ 0''.$$

From these angles the axial ratio was calculated, viz:

$$\breve{a} : \bar{b} : \overset{|}{c} = 0{\cdot}5285 : 1 : 0{\cdot}47715.$$

It is interesting to note that these values approximate very closely to those obtained by von Kokscharow,‡ upon the Siberian crystals; he gives:

$$\breve{a} : \bar{b} : \overset{|}{c} = 0{\cdot}52854 : 1 : 0{\cdot}47698.$$

On the other hand, the axial ratios for crystals from Ehrenfriedersdorf, Altenberg, Schneckenstein and Brazil, vary from both more or less widely (compare Grünhut, Zeitsch. Kryst., ix, 113). Some of the calculated and measured angles on the Utah crystals, in addition to those given above, are as follows:

| | | Calculated. | Measured. |
|---|---|---|---|
| $c \wedge f$ | $001 \wedge 021 =$ | $43^\circ\ 39'$ | $43^\circ\ 39'$. |
| $c \wedge i$ | $001 \wedge 223 =$ | $34^\circ\ 15'$ | $34^\circ\ 15'$. |
| $c \wedge o$ | $001 \wedge 221 =$ | $63^\circ\ 58'$ | $63^\circ\ 57'$. |
| $c \wedge e$ | $001 \wedge 441 =$ | $76^\circ\ 14\frac{1}{2}'$ | $76^\circ\ 12'$. |
| $u \wedge u'''$ | $111 \wedge 1\bar{1}1 =$ | $39^\circ\ 0'$ | $39^\circ\ 1'$. |
| $o \wedge o'''$ | $221 \wedge 2\bar{2}1 =$ | $49^\circ\ 39'$ | $49^\circ\ 39'$. |
| $y \wedge e$ | $041 \wedge 441 =$ | $59^\circ\ 11'$ | $59^\circ\ 9'$. |
| $m \wedge m'''$ | $110 \wedge 1\bar{1}0 =$ | $55^\circ\ 43'$ | $55^\circ\ 44'$. |

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* Abstract of a college thesis written June, 1886.

† Compare W. Cross, this Journal, xxxi, 437, June, 1886.

‡ With v. Kokscharow the vertical axis has double the length taken here.

Advantage was taken of a natural prism to measure the indices of refraction $\beta$ and $\gamma$. Further, the optic axial angle was also obtained from a cleavage section. The values obtained are as follows:

$\beta = 1{\cdot}6104$ for yellow (sodium) $= 1{\cdot}6075$ for red (lithium).
$\gamma = 1{\cdot}6176$ " " $= 1{\cdot}6148$ " "
$2E = 126° 24'$ for yellow.
Also $2V = 67° 18'$ and $\alpha = 1{\cdot}6072$ calculated.

## Art. XIX.—*On a Simple and Convenient form of Water Battery;*
by Henry A. Rowland.

For some time I have had in use in my laboratory a most simple, convenient and cheap form of water battery whose design has been in one of my note-books for at least fifteen years. It has proved so useful that I give below a description for the use of other physicists.

Strips of zinc and copper, each two inches wide, are soldered together along their edges so as to make a combined strip of a little less than four inches wide, allowing for the overlapping. It is then cut by shears into pieces about one-fourth of an inch wide, each composed of half zinc and half copper.

A plate of glass, very thick and a foot or less square, is heated and coated with shellac about an eighth of an inch thick. The strips of copper and zinc are bent into the shape of the letter U, with the branches about one-fourth of an inch apart, and are heated and stuck to the shellac in rows, the soldered portion being fixed in the shellac, and the two branches standing up in the air, so that the zinc of one piece comes within one-sixteenth of an inch of the copper of the next one. A row of ten inches long will thus contain about thirty elements. The rows can be about one-eighth of an inch apart and therefore in a space ten inches square nearly 800 elements can be placed. The plate is then warmed carefully so as not to crack and a mixture of beeswax and resin, which melts more easily than shellac, is then poured on the plate to a depth of half an inch to hold the elements in place. A frame of wood is made around the back of the plate with a ring screwed to the center so that the whole can be hung up with the zinc and copper elements below.

When required for use, lower so as to dip the tips of the elements into a pan of water and hang up again. The space between the elements being $\frac{1}{16}$ inch, will hold a drop of water which will not evaporate for possibly an hour. Thus the battery is in operation in a minute and is perfectly insulated by the glass and cement.

This is the form I have used, but the strips might better be soldered face to face along one edge, cut up and then opened.

# SCIENTIFIC INTELLIGENCE.

## I. Chemistry and Physics.

1. *On Isopycnic curves.*—Von Wroblewsky proposes to represent graphically the relations between the liquid and the gaseous states of matter by a system of equal density curves, which he calls isopycnic lines. Hitherto these relations have been graphically represented by curves of uniform temperature (isothermals) in which the pressure and the volume are the variables. In the new method the temperatures are laid down as abscissas and the pressures as ordinates. In the memoir the application of the method is shown for carbon dioxide, one of the substances for which the observed data are the most complete. An inspection of the curve shows distinctly that our knowledge of changes of state such as these is, especially in the vicinity of the liquefying point, very incomplete and in part incorrect. Moreover the author concludes that, even above the so-called critical temperature, there is a distinct difference between the liquid and the gaseous states, although this difference is very small.—*Wien. Monatsb. f. Chem.*, vii, 383; *Ber. Berl. Chem. Ges.* xix, 728, (*Ref.*) Nov. 1886. G. F. B.

2. *The Vapor-pressure of Hydrated Salts.*—Müller Erzbach has continued his researches upon the constitution of hydrated salts as determined from the pressure exerted by the vapor of the water they contain, measured at ordinary temperatures. This he experimentally determines from the loss of weight which two identical tubes, one of which contains the hydrated salt in question, the other water, simultaneously suffer, when placed in an atmosphere dried by means of sulphuric acid. The ratio of this loss of weight in the two cases the author regards as rigorously equal to the ratio of the elastic forces of the water vapor in the two tubes. Measured in this way, he finds that the evaporation from hydrated salts in completely dry air gives constant dissociation-pressures. The present paper gives the results obtained with nitrates and hydrates. Calcium nitrate for example, $CaN_2O_6.(H_2O)_4$ loses its water under a dissociation-pressure of 0·06 to 0·07. A white crystalline mass, left after evaporating an aqueous solution of the nitrate over sulphuric acid in rarefied air, contained only three molecules of water, of which one was given up at a pressure of 0·10 to 0·11, while the two others were evolved at the lower pressure of 0·04. Hence the author represents the constitution of this salt as $\frac{Ca\,N_2O_6+(H_2O)_2}{H_2O}$. If a fourth molecule of water be added, about one-half of this water is evolved under the pretty constant pressure of 0·27 to 0·36; the pressure then falls to 0·08 to 0·07, and before this water is entirely given up, the pressure reaches 0·04, as above. Strontium nitrate,

$SrN_2O_6.(H_2O)_4$ gives up all its water under the moderate pressure of 0·61 at 12·4°; and hence its water molecules cannot be separated in the formula. Zinc nitrate $ZnN_2O_6.(H_2O)_6$ showed for two of the water molecules a pressure of 0·18 at 16·1°, which fell rapidly during the evaporation of the third molecule to 0·025 and then became insensible. Hence its formula is $\frac{ZnN_2O_6.(H_2O)_3}{H_2O}+(H_2O)_2$. By heating this salt to 100°, Graham found that three molecules of water were driven off and the residue $ZnN_2O_6.(H_2O)_3$ left. Barium hydrate $BaH_2O_2.(H_2O)_8$ loses the eighth molecule of water under the relatively high pressure of 0·88 to 0·92, then five molecules at the pressure of 0·18 to 0·22, then two molecules at 0·10 to 0·12 and retains one molecule; so that the formula of composition of this hydrate is $\frac{\frac{BaH_2O_2.H_2O}{H_2O}+(H_2O)_5}{H_2O}$. Strontium hydrate $SrH_2O_2.(H_2O)_8$ loses one water molecule at 0·73 at 17·6° and six molecules at the pressure 0·27 at 18·5°, while the last molecule remains with the hydrate. Hence this salt has the formula $\frac{SrH_2O_2.(H_2O)}{(H_2O)_6}+H_2O$.—*Ber. Berl. Chem. Ges.*, xix, 2874–2876, November, 1886. G. F. B.

3. *On the solidification of Hydrogen fluoride, phosphide and antimonide.*—Hydrogen fluoride, according to Olszewsky, prepared by heating dry hydro-potassium fluoride and condensing the product in a platinum receiver cooled by ice and salt, solidifies at −102·5° as a transparent crystalline mass fusing at −92·3°. In the absence of water the liquid does not attack glass. Hydrogen phosphide boils in the vicinity of −86° and solidifies as a crystalline semi-transparent mass at −133·5°, beginning to fuse again at −132·5°. Hydrogen antimonide, evolved by the action of dilute sulphuric acid upon an alloy of two parts antimony and three parts of zinc, crystallizes at −102·5° as a snow-white mass, fusing at −91·5° to a colorless liquid, which even at the low temperature of −56° to −66° partially decomposes with separation of antimony. It boils at −18°.—*Wien. Monatsb. f. Chem.*, vii, 371–374; *Ber. Berl. Chem. Ges.*, xix, 739 (*Ref.*), Nov., 1866.

G. F. B.

4. *On the Fluorescence of certain Metallic Oxides, when exposed to an Electric discharge in a high vacuum.*—Lecoq de Boisbaudran has examined several of the metallic oxides by the method of Crookes, with a view to determine the character and intensity of their fluorescence under these conditions, either alone or mixed with other substances. Of these oxides that of manganese is remarkable for the variety of the colors it gives, and for the characteristic band in its fluorescent spectrum. Neither manganese sulphate nor manganese peroxide perceptibly fluoresces after calcination, when alone. But mixed with calcined calcium sul-

phate (which alone gives only a weak continuous spectrum) even in the proportion of only one per cent, the mixture fluoresces with a magnificent green color, reaching its maximum brilliancy when five per cent of the oxide is present. Calcium carbonate, which does not fluoresce when not previously heated, and which fluoresces violet-blue after calcination, gives, on adding a trace of manganese, a magnificent orange-yellow color. Magnesium sulphate alone, after heating to redness, fluoresces feebly greenish-white; but a trace of manganese causes it to fluoresce of a superb red color. Zinc sulphate, calcined, fluoresces feebly pale rose color; but with manganese, it gives a splendid orange-red color. Cadmium sulphate, which alone gives a feeble greenish-yellow, gives with manganese a brilliant greenish-yellow color. Strontium sulphate, however, which fluoresces of a pale lilac color alone, has its color or intensity scarcely changed by the addition of manganese. Lead sulphate when alone gives a violet-blue feebly, which is changed by manganese to a beautiful yellow. Glucinum sulphate has the color of its fluorescence changed from green to yellowish-green. In all these cases the spectrum is a broad band reaching from wave-length 672–619 to 480–456, having a maximum at 600 to 550.

Bismuth sulphate, which alone does not fluoresce after calcination, gives to calcium sulphate, even in very small proportion, the property of emitting a beautiful red-orange fluorescence. To strontium sulphate it gives a still more brilliant fluorescence, of a tint somewhat less red. To barium sulphate, which alone does not fluoresce, a trace of bismuth oxide gives a fine orange-red fluorescence. To magnesium sulphate, bismuth oxide gives a red fluorescence, still less orange. No result was obtained with zinc, with cadmium or with lead sulphate. The spectrum bands extend over a considerable range in the spectrum and are characteristic.

Purified yttrium sulphate, which alone gives only traces of the yellow band $Z\alpha$ yields, when containing two per cent manganous sulphate, a fine yellow-green fluorescence whose spectrum consists of a wide band beginning nebulously at wave-length 650, reaching a maximum at about 564, having an appreciable intensity at 509–504, and ending vaguely at 489–484. A similar mixture with bismuth sulphate gives a beautiful red fluorescence, resolved by the spectroscope into a band beginning nebulously at 684, reaching a maximum at 642–640 and ending vaguely at 579–577. On treating calcium sulphate with manganous and with bismuth sulphates, with both of which it is active, the fluorescence was yellow at the center and pale green farther from the electrodes. The red-orange band was brighter than the green; but on heating the tube it almost disappeared. When cadmium sulphate was mixed with manganous and with bismuth sulphates, with the former of which only it fluoresces, the yellow-green light gave a spectrum somewhat more extended and less brilliant than that produced by manganese alone. When both zinc and calcium sulphates were mixed with manganous sulphate, in various proportions, the green fluorescence of the calcium salt predominated when the weights of the two sulphates (zinc and calcium) were equal; while with equivalent weights the red of the zinc salt was slightly the stronger. This result increased with the proportion of the zinc sulphate until it became 98 per cent, the fluorescence being orange-red. On interrupting the current, the orange fluorescence quickly disappears, while the green of the calcium sulphate remains for a considerable time.

The author has also ascertained that calcined alumina does not give a trace of fluorescence when submitted to the electric discharge in vacuo. The characteristic fluorescence of this substance as described by Becquerel, who has figured its spectrum, is most brilliant when the alumina contains one per cent or even one-tenth of one per cent of chromic oxide. A very perceptible rose color is given by one hundred thousandth of chromic oxide. One per cent of manganous oxide yields a beautiful green, and the same quantity of bismuth oxide a lilac when cold and a blue on heating. Magnesia with one per cent of chromic oxide gives a fine red color; while lime does not appear to be affected by this oxide. The red fluorescence of alumina seems then to depend upon the presence of chromium; the analogy being complete between its action and that of manganese, bismuth, $Z\alpha$, $Z\beta$ and samarium.—*C. R.*, ciii, 468–471 (Sept.); 629–631 (Oct.); 1064–1067 (Nov.); 1107 (Dec.), 1886. G. F. B.

5. *On the Refractive index of Carbon dioxide and of Cyanogen.*—Chappuis and Rivière have deduced from their researches upon carbon dioxide at 21° and under pressures up to 19 atmospheres, and upon cyanogen at temperatures from 0° to 35° and pressures from 1 to 3 meters of mercury, formulas for calculating their refractive indices. They find for carbon dioxide at 0° and 0·76 meter, the value 1·000448, and for cyanogen under the same conditions 1·000825.—*C. R.*, ciii, 37–39, July, 1886. G. F. B.

6. *The Spectrum of Germanium.* — This spectrum has been mapped by H. Gustaf Kobb. It was formed by passing sparks from a large induction coil from an electrode of germanium to one of platinum. The lines of the latter could be readily identified and separated. The germanium lines are given in the following table:

| λ | Observations. | > | |
|---|---|---|---|
| 6336 | | 5131 | Broadly diffused. |
| 6020 | Very strong. | 4813 | " " |
| 5892 | " | 4742 | " " |
| 5255·5 | | 4684·5 | Sharp, weak. |
| 5228·5 | | 4291 | Diffused weak. |
| 5209 | | 4260·5 | " " |
| 5177·5 | Broadly diffused. | 4225·5 | |
| 5134 | | 4178 | " " |

*Ann. der Physik und Chemie*, No. 12, 1886, p. 670. J. T.

7. *A new Quicksilver Pump.*—The three different systems of quicksilver pumps—the Geissler, the Töpler and the Sprengel—have their peculiar advantages and disadvantages. The Geissler

requires a large number of cocks; the Töpler is very fragile on account of the convolutions of its parts; and the Sprengel is suited only to certain kinds of work. Messrs. Greiner and Friedrichs describe a new pump which has a wide range of usefulness, with the possibility of obtaining a good vacuum. The chief peculiarity of the pump resides in a three-way cock, which is fully described in the author's paper. The use of but one cock gives the pump a great practical advantage.—*Ann. der Physik und Chemie*, No. 12, 1886, p. 672. J. T.

8. *Relation of the Electrostatic and Electromagnetic Units.*—The earlier determinations of this ratio by different investigators differ by as much as four per cent, and the later determinations of Exner ($v=29,20.10^9$), Klemencic ($v=30,18.10^9$) and J. J. Thomson ($v=29,63.10^9$), leave much to be desired. H. Hinstedt has made a new determination, and obtains the result $v=30,07.10^9$. The method employed by Hinstedt required only the determination of the capacity of a condenser, Q, and a resistance, W, together with a ratio of resistances. The observations were independent of the electromotive force of the battery employed.—*Ann. der Physik und Chemie*, No. 12, 1886, pp. 560–579. J. T.

## II. GEOLOGY AND MINERALOGY.

1. *Notes on the Geology of Northern California*; by J. S. DILLER. (Abstract of paper, from the Proceedings of the Phil. Soc. of Washington, Jan. 16, 1886.)—Under the direction of Captain Dutton I have spent the last three summers studying the geology of northern California and the adjacent portion of Oregon. The conclusions of a general nature referring to that region may be briefly summarized as follows:

In the northern end of the Sierra Nevada and the central portion of the Coast range, among the highly plicated, more or less metamorphosed strata which are older than those of the Chico group, there appears to be but one horizon of limestone, and that is of Carboniferous age.

The northern end of the Sierra Nevada is made up of three tilted orographic blocks which are separated from each other by great faults. The westernmost of these blocks, stretching far to the southeast, appears to form the greater portion of the range. As in the Great Basin region, the depressed side of each block was occupied by a body of water of considerable size. The deposits formed in these lakes gave rise to the fertile soils of American and Indian valleys.

The *plication* of the strata in the Sierra Nevada range took place, at least in great part, about the close of the Jurassic or beginning of the Cretaceous period; but the faulting which really gave birth to the Sierra as a separate and distinct range by differentiating it from the great platform stretching eastward into the Great Basin region, did not take place until toward the close of the Tertiary or the beginning of the Quaternary. Although the faulting may have commenced earlier, the greater portion of the displacement has taken place since the deposition of a large part of the auriferous gravels and the beginning of the great volcanic outbursts in the vicinity of Lassen's Peak. If we may accept numerous small earthquake shocks as evidence, the faulting still continues. The distribution of the rocks of the Chico group indicates that the western coast of the continent at that time lay along the western base of the Sierra, extending around the northern end of the range in the vicinity of Lassen's Peak and stretching far northeasterly into Oregon. Off the coast lay a large island which now forms northwestern California and the adjacent portion of Oregon. This island extended as far southeast as the Pit river region where it was separated from the main land by a wide strait. All of the ridges developed out of the Cretacean island belong to the Coast range.

The volcanic ridge of Lassen's Peak lies between the northern end of the Sierra Nevada and the Coast range. The great volcanic field of Oregon and Washington Territory, to which Lassen's Peak and the Cascade range belong, appears in a general way to be outlined by the depression between the Cretacean island and the main land. A general account of the facts from which these conclusions are drawn will appear in Bulletin of the U. S. Geological Survey No. 33.

2. *The Taconic System.*—In a paper read before the Philosophical Society of Washington, January 15th, 1887, entitled "Geologic Age of the Lowest Formations of Emmons's Taconic System," Mr. CHAS. D. WALCOTT considered: 1st. That he had found the fauna of the lowest formation of the original Taconic (the Granular Quartz) to belong to the Middle Cambrian or Georgia fauna. 2d. That the fauna of the typical "Upper" Taconic rocks in Washington County, N. Y., is a part of the same fauna. 3d. That the granular quartz and the Upper Taconic are the same geologic formation; the quartz rock being the shore deposit, and the shales, sandstones and limestones of the Upper Taconic being the synchronous deposit off shore, in deeper water. 4th, The hydromica shales beneath the limestone on the west side of the Taconic range are the equivalent of the Potsdam sandstone; the lower part of the limestone, or, in places, the hydromica shales between the quartz rock and limestone representing the Potsdam on the east side. 5th. Professor Dana was correct in considering the Stockbridge and sparry limestones and the overlying hydromica schists as of Lower Silurian (Ordovician) age; the latter representing the Hudson River formation. 6th. Of the strata referred to the Taconic system in the Taconic region, the granular quartz and the Upper Taconic still remain in it as pre-Potsdam formations, and the Stockbridge and sparry limestones and the superior hydromica schists are referred to the Lower Silurian (Ordovician) system.

Reference was made to the bearing of these generalizations on the use of the names Taconic and Cambrian; the former being applicable to American strata carrying the first or primordial fauna unless Cambrian has a clear priority of usage.

Maps were exhibited to show the distribution of the formations under discussion in Vermont, Massachusetts and New York; and a section, crossing Washington County, N. Y., and into southern Vermont, gave the position of the formations in relation to each other. A hypothetical section, showing the formations as originally deposited, aided materially in the elucidation of the subject.

Specimens Hyolithes and Olenellus were shown from the "granular quartz" and the interbedded limestones of the Upper Taconic. C. D. W.

3. *Remarks on the Revision of the Palæocrinoidea of Wachsmuth and Springer;* by C. A. White.—It has rarely happened that a more important paleontological work than this has been published; and it is still more rare that a difficult subject has been more philosophically treated. The work has been published in parts by the Philadelphia Academy of Natural Science, ending with the second section of Part III. Part I, embracing the families Ichthyocrinidæ and Cyathocrinidæ, was published in 1879. Part II, containing the Platycrinidæ, Actinocrinidæ and Rhodocrinidæ appeared in 1881. Part III, of which the second and concluding section has just been issued, gives the conclusion of the family and generic descriptions, a general review in which are suggested some modifications of the work of preceding parts, and an extended discussion of the classification and relations of the Brachiate Crinoids.

The authors have evidently aimed to bring into systematic order all existing knowledge of the paleozoic crinoids; and their work is therefore systematic rather than descriptive. The few new species which they have described are presented as illustrative of the general questions which they discuss.

They have from the beginning recognized the fact that the only way to arrive at a correct understanding of the fossil crinoids is by a comparative study of their living representatives. Therefore, the discussion of the morphological relations of the ancient and recent crinoids forms a conspicuous feature of their work. This method of treatment of the subject presents important zoological as well as paleontological results.

Even in the earlier part of the work these authors recognized two comprehensive types among crinoids, for which they established the orders Palæocrinoidea and Stomatocrinoidea; but for the latter they afterwards adopted the name Neocrinoidea, as subsequently proposed by Dr. P. H. Carpenter. The principal distinction between the two orders is found in the condition of the mouth and food grooves. In the Palæocrinoidea, these organs are more or less subtegminal, the food grooves along the disc taking the form of tubular passages, hidden beneath a vault; while in the Neocrinoidea the mouth and food grooves are open and exposed to view.

In their broader generalizations they recognize the stalked echinoderms as constituting a class, for which they adopt Leuckart's appropriate name, Pelmatozoa, thus distinguishing them from Ophiurans, star-fishes and sea-urchins, which are characterized by locomotion and the downward position of the mouth. The Pelmatozoa are divided into two well-marked sub-classes, namely, the Crinoidea of Miller, embracing all brachiate crinoids, with the orders Neocrinoidea and Palæocrinoidea; and the Anthodiata, or armless forms, including the orders Blastoidea and Cystidea.

Three sub-orders are proposed, to include all the known forms of the Palæocrinoidea. (1) The Camarata, which are the typical Palæocrinoids, having the plates of the test solidly united by suture and having the lower armplates incorporated into the calyx by means of interradial plates. Actinocrinus is a typical form of this sub-order. (2) The Articulata, which are characterized by an articulate structure of the calcareous skeleton, which renders it more or less pliable, as in Ichthyocrinus. (3) The Inadunata, which have the arms free from the first radials upward, as in Cyathocrinus. These three groups are found to be also respectively characterized by differences in the construction of the summit, which the authors consider to be subordinate to and consequent upon the fundamental modifications in the plan of structure above mentioned.

The authors subdivide the Inadunata into two groups, namely, the Larviformia and the Fistulata. The former group includes such embryonic, or permanent larval, forms as Haplocrinus and Symbathocrinus. The latter group embraces forms which have the ventral portions of the body expanded or elevated into a porous ventral sac, of variable size, of which Cœliocrinus presents an extreme example.

The several groups are separated into many families, some of which are sharply defined, while others shade into each other by perplexing transitional forms. The generic relations of the Palæocrinoidea are minutely discussed, and a detailed diagnosis of each genus is given, which is followed by a list of all the species which the authors consider to be properly referable to the genus. The synonymy and references to the literature of each species is also given in full. At the end of the work is a complete catalogue of species, which serves both for an index and a synonymic list. This very valuable feature of works of this kind is too often entirely neglected by authors.

The morphological discussions in Part III deal with interesting questions in relation to homologies between different parts of the widely divergent types of recent and fossil crinoids. In the early larva of the living crinoids the abactinal side, so far as at present known, consists of only five basals, forming a cup. The actinal side consists of a closed pyramid of five plates; the latter covering the mouth. Subsequently the radials, and afterward the arms, appear. The appearance of the basals and orals at the same time, the one occupying the oral and the other the aboral side, led Professor Goette and Mr. Wachsmuth independently to the conclusion that there exists a morphological resemblance between them. This view has since been accepted by Dr. Carpenter, and he, as well as Wachsmuth and Springer, base thereon the different views which they respectively entertain concerning the summit plates of the Palæocrinoidea.

The orals in most of the recent crinoids are confined to their larval state, but whether they are persistent through life, or are resorbed in the adult, the mouth and food grooves become exposed to view before the animal reaches maturity. In the Palæocrinoidea these organs are permanently closed by series of plates which collectively occupy the place of the orals in the Neocrinoid larva. The authors of the revision agree with Dr. Carpenter upon this point; but they differ from him as to which of the various summit plates in the Palæocrinoidea individually represent the orals.

The authors have ascertained that the summit and other vault plates, which were generally ignored by the earlier writers, have a high classificatory value. They find them to be arranged upon a well-defined general plan which, to a considerable extent, should be regarded as a counterpart of that which is shown by the plates of the calyx. The plan consists of a central piece, which occupies the oral pole and covers the mouth, six proximal plates surrounding this central one, but they are not always in contact with it, and frequently radial dome plates, corresponding with the calyx radials. The authors conclude that the central piece of the dome, which they think primitively consisted of five pieces, is the homologue of the basals, and that it represents morphologically the closed pyramid of five oral plates in the Neocrinoid larva, the proximals representing the calyx interradials. Contrary to this Dr. Carpenter believes that the orals are represented by the six proximals surrounding the central piece, the two smaller posterior ones being regarded by him as one plate divided by anal structures. This view was formerly held by Wachsmuth and Springer, but they have since abandoned it. Dr. Carpenter regards the central piece as representing the dorso-central or terminal plate of the column. Both parties support their opinion by extended arguments based on the latest researches upon both recent and fossil crinoids, with an earnestness which shows their full conviction of the correctness of their respective opinions.

An important discovery is announced as to the relations of the parts on the dorsal side of the paleozoic crinoids which seems to be of much importance in their practical study; and a statement of it will serve to illustrate the minute care with which these authors have prosecuted their work. They consider the first ring of plates below the radials as the true basals in all cases. In those crinoids which have a dicyclic base the lower ring of plates are called the underbasals. These are often very minute, concealed within the basal concavity, or hidden from external view by the column, so as to be difficult, and in many cases impossible, to distinguish.

By cutting, grinding and breaking many specimens, Wachsmuth and Springer have discovered that there is a regular alternation in the arrangement of the successive parts below the radials. The basals are interradial in position and all underbasals are radial. The exterior angles of the column, if it be angular, alternate with the ring of plates next above it; and if the central canal in the column be angular, its angles alternate with those of the column. So, if in relation to the calyx plates above, the exterior angles of the column are found to be radial in position, the ring of plates next above, being alternately arranged, will be basals, and consequently underbasals are wanting. If, on the contrary, those angles are interradial, the next plates in succession above will be radial, and hence underbasals. If the column be round, and the axial canal angular, the angles of the latter may be consulted; if radial, underbasals are present; if interradial, they are absent. Similar results are given by the cyrri when they exist; and by the segments of the column, when divided longitudinally, as sometimes happens.

It thus becomes possible to distinguish between underbasals and the top segment of the column, which has hitherto been often attended with difficulty. The authors assert that this rule is applicable without an exception to the paleozoic crinoids.

An appendix to the work contains two articles. In the first the authors place the genus Stephanocrinus among the Palæocrinoidea, assigning it to the Larviformia. Roemer and J. Muller had previously referred this genus to the Cystidea; and later, Etheridge and Carpenter referred it to the Blastoidea. The latter authors seem to have regarded the evidence adduced by Wachsmuth and Springer as conclusive, for in their lately-published catalogue of the Blastoidea they omit Stephanocrinus.

In the second article they apply the rules which they have found to govern the structure of dicyclic and monocyclic Palæocrinoidea, to the later crinoids; and they come to the conclusion that the Apiocrinoidæ and Comatulæ are constructed upon the plan of dicyclic crinoids; and that in their larval state they probably had rudimentary underbasals. If hereafter those plates should be discovered their existence will have been predicted upon paleontological evidence, and as the result of comparative studies.

The second section of Part III completes the work as the authors originally planned it; but they have begun the preparation of a monograph of the Paleozoic Crinoids of North America, which they intend to make the most extensive illustrated work on crinoids ever produced. Paleontologists will await the results of their newly self-imposed task with great interest. C. A. W.

4. *A card to American Geologists.*—A meeting of the American Committee of the International Congress of Geologists, will be held in Albany from April 6 to April 9, 1887.

The object of the meeting is to perfect a scheme embodying the thoughts of American geologists on the questions of classification, nomenclature, coloration, etc., entering into the system of unification of geological science which is the object of the International Congress. In order that the Committee may represent the views of all American geologists it invites from all their individual opinions on any subjects likely to arise in the Congress. Those who will meet the American Committee in Albany, are requested to send to the undersigned a note of the topic or topics they propose to treat, and the time which they will require. In cases where it is not convenient for them to go to Albany, they are requested to forward a statement of their views in writing to the undersigned before April 1, for presentation to the Committee. For information as to the kinds of questions to be discussed, attention is called to the report of the American Committee published last Spring, in which the debates of the 3d session of the International Congress are reported. The following are the sub-committees of the American Committee:

*Archæan*, Hunt, Hitchcock, Winchell; *Lower Paleozoic*, Hall, Winchell, Lesley; *Upper Paleozoic*, Hall, Lesley, Newberry, Stevenson, Williams; *Mesozoic*, Newberry, Cook, Cope, Powell; *Cœnozoic* (Marine,) Smith, Newberry; *Cœnozoic* (Interior), Cope; *Quaternary*, *Recent Archæology*, Powell, Winchell, Cook.

PERSIFOR FRAZER, *Secretary.*

5. *The "Mountain limestone" in Pennsylvania a little over 1100 feet below the Pittsburg Coal.*—The Pennsylvania Geological Report for the year 1885, contains, on pages 222 to 226, a brief report, by Professor A. Linn and E. Linton, on the discovery of the Mountain limestone in connection with the Washington County gas well. The limestone is nearly pure for 120 feet or so, and has below it 60 feet of arenaceous limestone. The latter contains quartz sand, and even pebbles in places, with some grains of feldspar. This bed is regarded as the equivalent of that described by Professor Lesley and Dr. Stevenson as occurring in the gaps of Laurel Hill and Chestnut Ridge.

6. *Fossil Trunk of a tree in hydromica or sericitic gneiss.*—Dr. E. de Fellenburg announced to the Helvetic Society of Natural Sciences in Geneva, Aug. 1886, the discovery of a fossil trunk of a tree in the gneiss of the valley of Oberhasle (Haslithal)—the length 1·45 meter, and breadth 0·12 to 0·17. It is not quite cylindrical, and has a series of annular furrows, in several places a brown coating, with fine longitudinal striations and what appears to be a series of joints. Another smaller specimen accompanied this; some characters suggested that it was a Calamites, but no decisive opinion is expressed. Professor Baltzer stated further that the sericitic gneiss is associated with phyllite, and also with bands of granite; and he expressed his confidence that the specimen was a true fossil, and the gneiss a paleozoic gneiss.—*Arch. Sci. Phys. et Nat. Geneva*, Sept.–Oct., 1886.

7. *Second Contribution to the Studies of the Cambrian*

*Faunas of North America;* by C. D. WALCOTT. 369 pp. 8vo, with 33 plates. Washington, 1886. Bulletin No. 30, U. S. Geol. Survey. A very large and elaborate contribution to Cambrian Paleontology, with numerous excellent illustrations on the 33 plates.

8. *The Geological and Natural History Survey of Minnesota for* 1885. N. H. WINCHELL, State Geologist.—This volume contains reports on the Aphididæ of the State by O. W. Œstlund, on Cheiocrinus and Calceocrinus and some new genera of Crinoids by E. O. Ulrich; Report on the Museum; bibliography in the department of Foraminifera; new fossils by N. H. Winchell; on copper alloyed with silver from the L. Superior region (less than one-tenth per cent in assays given), and on the Cambrian of Minnesota, by the same.

9. *Annuaire Géologique universel et Guide du Géologue autour de la Terre, etc.*, publié par le Dr. Agincourt avec le concours de nombreux Géologues, E. Chelot Secrétaire. Tome II, 1$^{e}$ partie, 362 pp.; 2$^{e}$, Appendice, 27 pp.; 3$^{e}$, Index bibl. 1885, 79 pp. Paris, 1886.—This second edition of the Geological Annual by Dr. Agincourt is an important advance upon the volume of last year both as regards amount of matter and accuracy. It includes a long list of the Geologists of different countries, with their addresses; of the prominent museums; geological charts and other kindred matter.

10. *Notes on Minerals from North Carolina;* by G. VOM RATH.—In a recent copy of his "Vorträge und Mittheilungen," containing the communications made to the Scientific Society at Bonn between the dates January 11 and July 7, 1886, Professor vom Rath gives, together with other interesting matter, the results of his study of some North Carolina minerals. The specimens in hand were received from Mr. W. E. Hidden, having been found by the latter in his explorations in the neighborhood of Stony Point, Alexander County. The following abstract includes the points of most interest.

BERYL.—A highly modified crystal 12$^{mm}$ in length by 10$^{mm}$ in width, and of nearly ideal symmetry, was found to be a combination of the following forms:

$O\,(0001)$, $I\,(10\bar{1}0)$, $i\text{-}2\,(11\bar{2}0)$, $1\,(10\bar{1}1)$, $2\,(20\bar{2}1)$, $2\text{-}2\,(11\bar{2}1)$, $3\text{-}\frac{3}{2}\,(21\bar{3}1)$, $4\text{-}\frac{4}{3}\,(31\bar{4}1)$, $2\text{-}\frac{3}{2}\,(42\bar{6}3)$, $6\text{-}\frac{3}{2}\,(42\bar{6}1)$, $\frac{9}{4}\text{-}\frac{9}{5}\,(54\bar{9}4)$? $\frac{3}{2}\text{-}\frac{3}{2}\,(21\bar{3}2)$.

The figure accompanying the description shows all these planes except the last two. The form $4\text{-}\frac{4}{3}$ is spoken of as new to the species, which, however, is hardly true, as it was noted by Hessenberg in 1863 on an Elba crystal. The results of careful measurements agreed very closely with the angles given by Kokscharow as seen in the following list; the double angles indicate the extreme values for the different edges measured.

| | Vom Rath. | Kokscharow. |
|---|---|---|
| $O \wedge 2\text{-}2$ | $=135° 2'$ to $135° 4'$ | $135° 3' 55''$ |
| $2\text{-}2 \wedge 2\text{-}2$ | $=138° 37'$ to $138° 38\frac{1}{2}'$ | $138° 38' 23''$ |
| $O \wedge 1$ | $=150° 1'$ to $150° 3'$ | $150° 3' 24''$ |
| $1 \wedge 1$ | $=151° 4'$ to $151° 6\frac{1}{2}'$ | $151° 5' 45''$ |

It was observed that the fine emerald color characteristic of the crystal under examination belonged to a border $\frac{1}{2}$ to $\frac{3}{4}^{mm}$ in thickness; furthermore, narrow canals hexagonal in form and made by planes of the unit prism, were noted running through the crystal parallel to the vertical axis.

MONAZITE.—The crystals examined were remarkable for their size and perfection of form, and especially interesting as being penetration-twins cruciform in shape, with the orthopinacoid as the twinning plane. The chief points in regard to these crystals are contained in the note by Mr. Hidden in this Journal for September last, p. 207. In addition to the planes given by Hidden, vom Rath notes 1-2 ($\bar{2}12$). As fundamental angles were taken $001 \wedge 1\text{-}\grave{\imath} = 138° \ 7'$, $010 \wedge 110 = 133° \ 8'$, also the twinning angle $1\text{-}\grave{\imath} \wedge 1\text{-}\grave{\imath} = 160° \ 4'$; from these the axes were calculated

$$\grave{a} : b : \overset{\mid}{c} = 0{\cdot}96092 : 1 : 0{\cdot}90807 ; \ \beta = 103° \ 26\tfrac{1}{2}'.$$

The faces did not allow, in most cases, of very accurate measurements, though on the whole the agreement with the calculated angles was tolerably satisfactory. A minute comparison is made with the crystals from other localities both as to occurring planes and angles. Some of the measured and calculated angles are :

| | Measured. | Calculated. | Measured. | Calculated. |
|---|---|---|---|---|
| $i\text{-}\breve{\imath} \wedge O$ | 103° 29′ | 103° 26½′ | $1\text{-}\grave{\imath} \wedge 2\text{-}\grave{\imath} = 160° \ 1'$ | 160° 25¾′ |
| $i\text{-}i \wedge 1\text{-}\grave{\imath}$ | 100° 23′ | 99° 58′ | $1\text{-}\grave{\imath} \wedge 1\text{-}i \wedge 119° \ 26'$ | 118° 48½′ |
| $i\text{-}\grave{\imath} \wedge 1\text{-}\grave{\imath}$ | 131° 53′<br>132° 5′ | 131° 53′ | $I \wedge 2\text{-}\grave{\imath} = 133° \ 4'$ | 132° 54¾′ |
| | 130° 40′ | | $i\text{-}\grave{\imath} \wedge 2\text{-}\grave{\imath} = 150° \ 40'$ | 151° 27¼′ |

APATITE.—Some delicate prismatic crystals ($25^{mm}$ in length) showed the planes $O(0001)$, $\frac{1}{2}(10\bar{1}2)$, $1(10\bar{1}1)$, $2(20\bar{2}1)$, $1\text{-}2(11\bar{2}2)$, $2\text{-}2(11\bar{2}1)$, $3\text{-}\frac{3}{2}(21\bar{3}1)$. The angles measured agreed within a minute or two with those of Kokscharow.

SPODUMENE.—Some crystals, $20^{mm}$ in size, and fully developed at both ends except a single point of attachment, proved to be very different in habit from the hiddenite previously described. The identification of the planes was a matter of some difficulty, as the faces were dull and only to be measured by means of attached glass plates. The planes observed are given in the following list; of these, $z$, $f$, $t$, $d$, and $\varphi$ are new.

$b\,(010, i\text{-}\breve{\imath})$; $I\,(110)$, $m\,(120, i\text{-}\grave{2})$, $n\,(130, i\text{-}\grave{3})$, $z\,(150, i\text{-}\grave{5})$; $f\,(011, 1\text{-}\grave{\imath})$; $\phi\,(312, \frac{3}{2}\text{-}3)$, $d\,(\bar{4}21, 4\text{-}2)$, $\varepsilon\,(\bar{2}41, 4\text{-}\grave{2})$, $t\,(\bar{4}81, 8\text{-}\grave{2})$.

As fundamental angles were taken:

$$I \wedge I' = 86° \ 48', \ I \wedge \varepsilon = 147° \ 30', \ b \wedge \varepsilon = 152° \ 45',$$

and the axial ratio calculated is

$$\grave{a} = \bar{b} : \overset{\mid}{c} = 1{\cdot}1283 : 1 : 0{\cdot}62345, \ \beta = 110° \ 27\tfrac{1}{2}'.$$

These results agree very well with the axial ratio given by J. D. Dana for the Norwich crystals. The crystals showed $f$ and $\varphi$ large and striated parallel to the edge of $I$ and $f$; $I$, $b$, $t$ were also well developed, while the other planes were quite small.

Another spodumene crystal, prismatic in habit and $18^{mm}$ long, resembled in aspect crystals of certain varieties of pyroxene. The crystal was altered and the faces consequently were dull and gave poor measurements. The planes finally identified were

$a\,(100,\ i\text{-}\bar{\imath})$, $b\,(010,\ i\text{-}\breve{\imath})$, $I(110)$, $m\,(120,\ i\text{-}\breve{2})$, $k\,(230,\ i\text{-}\breve{\tfrac{3}{2}})$, $h\,(021,\ 2\text{-}\breve{\imath})$, $e\,(241,\ -4\text{-}\breve{2})$, $\xi\,(131,\ -3\text{-}\breve{3})$, $x\,(\bar{2}31,\ 3\text{-}\breve{\tfrac{3}{2}})$, $w\,(\bar{3}21,\ 3\text{-}\breve{\tfrac{3}{2}})$, $v\,(\bar{3}41,\ 4\text{-}\breve{\tfrac{4}{3}})$.

Of these, $k$, $\xi$, $w$ and $v$ were new to the species.

RUTILE.—The beauty and brilliancy of the black rutiles is strongly emphasized by vom Rath. The most remarkable crystal was a combination of the planes: $i\text{-}i(100)$, $I(110)$, $i\text{-}\frac{5}{3}(530)$, $i\text{-}\frac{9}{4}(940)$, $i\text{-}4(410)$, $1\text{-}i(101)$, $1(111)$, $321(3\text{-}\frac{3}{2})$; of these the prism $i\text{-}\frac{9}{4}$ is new. The crystal was a twin of the rare type figured by Miller in his Mineralogy, the twinning-plane being $3\text{-}i$.

TOURMALINE.—Three crystals examined were 14 to $16^{mm}$ in length and 7 to $10^{mm}$ through the prism. They showed the two prisms, and the terminating planes $R(10\bar{1}1)$, $-\frac{1}{2}R(01\bar{1}2)$, $-2R(01\bar{1}2)$, $-2R(02\bar{2}1)$, in one crystal the form $-\frac{1}{2}R$ was prominent; the planes $\frac{2}{3}\text{-}2(11\bar{2}3)$ were also identified.

XENOTIME.—A few remarks are made in regard to some crystals already described more fully by Mr. Hidden. The terminal angle of the pyramid was found to be 124° 28′ and 124° 30′.

11. *Notes on Aquamarine from Mount Antero, Colorado;* by Rev. R. T. CROSS. (Communicated.)—The aqua-marines forming the subject of this note were obtained two or three years ago on Mt. Antero, in Chaffee County, Colorado, by Mr. N. D. Wanamaker. He states that they were found in the decomposed granite of the Sawatch Range, Continental Divide, above timber line, and most of them near together in one pocket. I have deferred writing this note in the hope of being able to visit the locality myself, but in this I have been disappointed.

The color of the aqua-marines is bluish green. The two largest crystals found were three inches long and about half an inch in thickness. Of those now in my possession eight crystals have terminations, and a dozen others are tolerably clear but not terminated. The longest crystal is one and three-eighths inches in length and three-eighths of an inch in diameter. The lower third is translucent, the remainder transparent, with some flaws. This crystal, like the others, is finely striated on the prism, but the basal plane is very smooth and brilliant. The next crystal is very nearly the same size, is clear through its whole length, but has only an imperfect termination. Another is three-fourths of an inch long, and on its termination shows the planes 2-2 quite large, and the planes 1 and 2 very small. The terminal edges of the prism of a number of the crystals are rounded; and some of them exhibit what appear to be slender longitudinal cavities running parallel to the prism, and probably due to striations on the original crystal now forming the core. This central part, or core, is often very distinct; it is transparent, while the outside layer, looked at lengthwise, is opaque. Sometimes the core projects at the broken end of the crystal in a globular form, similar to certain tourmalines described by Hamlin.

On examining the crystals closely I found a few which had attached to them what seemed to be small quartz crystals. The angles, however, did not appear to agree with those of quartz, and knowing that phenacite was often mistaken for quartz, as its name suggests, I thought that they might be phenacites. Mr. W. Cross confirmed my supposition, and he placed the crystals in the hands of Mr. Penfield of the Sheffield Scientific School, who has fully described them (see page 130 of this number).

## III. BOTANY AND ZOOLOGY.

1. *Beobachtungen über den Blumenbesuch von Insecten und Frielandpflanzen des Botanischen Gartens zu Berlin.* von Dr. E. LOEW, Oberlehrer am K. Realgymnasium zu Berlin, 1885. Also *Weitere Beobachtungen*, etc., 1886.—These two papers, published one in the third, the other in the fourth volume of the *Jahrbuch* of the Berlin Botanic Gardens, together make a treatise of 180 pages, intended to supplement and to extend the well-known investigations of the late Hermann Müller upon the reciprocal relations of showy flowers and insects. Müller investigated these relations in a natural flora, that of Germany, in which these relations were normally established. Dr. Loew studies them in an artificial assemblage of plants recently brought together in a large botanical garden. Müller undertook, by counting the visitors to each kind of flower, to determine what kinds and species of insects were especially active in its fertilization, and how the insect had become adapted to the particular blossom, as well as the blossom to the insect, in the long process of natural selection. Dr. Loew's object was to ascertain what selections each species or group of insects will make among the flowers of all the principal natural orders brought together for cultivation in our own days from various parts of the world. To keep the inquiry within definite and manageable limits, it was restricted to three geographical groups of plants: 1, those of the European and N. Asiatic forest zone; 2, those of the Mediterranean and the Orient; 3, N. American and E. Asiatic plants.

Müller assumed that wherever the flower and its fertilizing insects harmonize perfectly in their adaptations, it must be that the visiting insects have remained the same since the blossom, under the influence of the fertilizers, acquired its special adaptations; and that, wherever the adjustment is incomplete a considerable change has occurred; either the plant is an immigrant from some other locality, or foreign insects have come into its locality, or its proper cross-fertilizers have disappeared. And the conclusions gathered from Müller's statistics were: 1. That the more exposed the nectar in a flower, the larger the proportion of insects with short proboscis visiting it, also, of the kinds; while in proportion as the nectar is removed from direct access, the proportion of visitors with long proboscis increases, bees, flies and butterflies; 2. Conversely it is found that the shorter the proboscis of an insect the more it visits flowers with free or little concealed nectar; the longer the proboscis the more it prefers flowers with deep-seated nectaries. And insects specially adapted to flowers of a particular form mainly visit these flowers only. 3. Short-lipped insects prefer light-colored blossoms (white and yellow); those with long proboscis, not in need of much food, prefer deep colors (red, blue, violet); but those which require more nourishment are not so particular as to color.

The question which Loew asked was, whether these conclusions hold good of foreign plants placed before the insects of a certain locality. On the whole, they were corroborated by his very extensive observations in the Berlin Garden. But the selection of foreign plants by the bee tribe was often different from that of indigenous plants. For example, among the fitting S. European and Oriental flowers presented to them in the garden, bees and humble bees greatly preferred deep-colored flowers; while among the American plants the lighter-colored Compositæ were preferred, probably because the number of the yellow-flowered Compositæ was so greatly in excess of the proper bee-adapted flowers. Moreover, some nearly related genera of the bee-tribe, and with probosces of the same length, differed greatly in their selection of flowers; indeed, in most *Apidæ* the selection of flowers was evidently much influenced and even determined by some other factor than the mere length of the proboscis. From such facts Loew is led to believe that Müller's theory of the origination of long-beaked *Apidæ* from the short-beaked, in a direct line through natural selection *pari passu* with corresponding change in flowers, is not borne out. Müller had concluded that Compositæ-flowers were a sort of common feeding-ground of various classes of insects; and the way in which bees and other indigenous insects shifted their preferences to foreign *Compositæ* in the Berlin garden confirmed this. Finally, Loew proposes a more simple classification than Müller's of the stages or adaptation of insects to flowers, based upon morphological and biological characters, quite irrespective of theories of descent, rightly keeping the latter in abeyance until the facts are determined by direct observations. A. G.

2. MINOR BOTANICAL NOTES. — Under the patronage of the Bentham Trustees, volumes xvi and xvii, of *Hooker's Icones Plantarum*, have been simultaneously in press during the past year. The two parts of the sixteenth volume, wholly phanerogamous, have already been noticed. Of vol. xvii, which is wholly devoted to Ferns under the editorship of Mr. Baker, three parts have appeared. One of them gives a figure of a new North American Fern, the *Asplenium Glenniei* of Baker (*Athyrium gracile* of Fournier), a Mexican species, which Mr. and Mrs. Lemmon collected in the mountains of S. Arizona.

Baron von Müller, Government Botanist for Victoria, Australia, has just brought out, under official auspices, his *Descrip-*

*tion and Illustrations of the Myoporineous Plants of Australia*, i. e. the lithograms, seventy-four plates, in a beautiful large quarto volume. The letter press is to come "somewhat later." But that, as the author intimates, can wait, because the species here so admirably illustrated are all described either in the monumental *Flora Australiensis* (which owes its value no less to Müller's labors than to Bentham's), or in the *Fragmenta Phytogr. Australiæ*, a part of the special and multitudinous work of the present author. There was a natural wish to give colored plates, which would have cost very much more, but would have been not much better for truly botanical purposes. The drawings are all by R. Graff, and are his first effort in this line. They are truly good, and the lithography does credit to the Government printing office at Melbourne, and to the Colony.

*The Report on the Primula Conference held at South Kensington*, April 20, 21, 1886, and on the *Orchid Nomenclature Conference held at Liverpool*, on June 30, 1886, makes up vol. vii, no. 2, of the *Journal of the Royal Horticultural Society*, London. The most permanently interesting matter is the part relating to the origin and history of the cultivated Auricula, and next Dr. Masters' paper on the root-structure and mode of growth of Primulas, with copious illustrations. As to Orchid Nomenclature for the mass of varieties and forms in cultivation, the upshot of the conference seems to be, that the botanists should give scientific names to the more distinct forms, and the cultivators should not imitate those, but give fancy names—vernacular or other, but never Latin—to their own productions and to indicate those differences which the grower may value, but the botanist takes no account of.

Professor Macoun's *Catalogue of Canadian Plants*, part iii, *Apetalæ*, has just appeared, although the preface is dated April, 1886, since which, we presume, it was printed. It is one of the publications of the Geological and Natural History Survey of Canada. This completes the first volume, carrying it on from p. 305 to p. 623, including an elaborate appendix to the first and second parts, and a complete index to the volume. This volume embodies a vast amount of work, both in field and in herbaria, and is full of valuable observations. Our attention is particularly arrested by the observations on trees, especially the coniferous trees, which naturally are most important as well as interesting. A. G.

3. Botanical Necrology for 1886.—The following are European:

**Eduard Morren**, Professor of Botany and Director of the Botanical Institute at Liège, Belgium, son of a distinguished botanist, himself more distinguished, died at Liège, February 28, at the age of 53 years.

**Rev. Wm. W. Newbould**, a most acute and critical British botanist, died at Kew, April 16, at the age of 67.

**Dr. Wm. Hillebrand**, who lived and botanized for several years in the Sandwich Islands, had published not a little upon their botany, and was engaged upon a Flora Hawaiensis, died, at Heidelberg, July 13. He is commemorated by the Begoniaceous genus *Hillebrandia* of Oliver.

DR. HENRY FLETCHER HANCE, English Consul at Whampoa, an acute and most indefatigable systematic botanist, unequalled for his knowledge of Chinese botany, died at Hongkong, June 22, at the age of 59. Mr. Francis B. Forbes, equally a devotee to Chinese botany, contributes to the Journal of Botany, British and Foreign, for January, 1886, an appreciative memoir of his associate and friend.

T. G. ORPHANIDES, Emeritus Professor of Botany in the University of Athens, and who in former years did much to make the botany of Greece better known by excellent *Exsiccatæ*, died August 17, at the age of 69.

PROF. J. W. ALBERT WIGAND, of the University of Marburg, after a long illness, died at Marburg, October 22, in the 66th year of his age.

The notable loss from our ranks in this country is that of our eminent Lichenologist,

EDWARD TUCKERMAN, who died on the 15th of March last, in the 69th year of his age. His biography is given in this Journal, vol. xxxii, and in the Proceedings of the American Academy of Arts and Sciences, vol. xxi, 1886. A. G.

4. *Bulletin of the Museum of Comparative Zoology*, Harvard College.—No. 6, vol. xii, on the Deep Sea Mollusca, (Brachiopoda and Pelecypoda,) by W. H. DALL, from dredgings of the steamer "Blake." No. 1, vol. xiii, on the Holothurioidea, ibid., by H. THÉEL.

5. *Elementary Course in Practical Zoology;* by BUEL P. COLTON. 186 pp. 12mo. Boston, 1886 (D. C. Heath & Co.)—This small manual for practical zoology covers the whole animal kingdom in a concise manner, and will be found a convenient work for the student.

## IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Ice Period in the Altai Mountains.*—Mr. E. MICHAELIS, in *Nature* of December 16 (p. 149) states that in the southern part of the Altai, where there are now some large glaciers, there are evidences of "a mighty spreading of ancient glaciers." The evidences occur to the south on the ranges of Tarbagatay and Savor, the southern limits of the basin of the Irtysch, where there are now no glaciers. There are great bowlder and cobblestone deposits on the northern slopes, extending for ten miles from south to north. The Savor chain is a post-Tertiary elevation; the Altai is of remote age, and must have formed dry land since the Cretaceous period at least.

2. *Signal Service Bureau.*—The death of the head of this bureau, General Hazen, opens the question as to the best successor. The work of the bureau is scientific in the collection of

facts and the preparation of daily reports on the observations, as well as in the discussion of the series of results brought in from over the country and world with reference to a knowledge of meteorological principles, and a broad basis for prognostications. All considerations sustain the decision that the head of the department should be a man of meteorological and physical science, accustomed to scientific work, and, at the same time, one of large executive experience and success.

G. F. Matthew. Fauna of the St. John Group, No. 3, Trans. Roy. Soc. Can., 1885.

Bulletin of the Washburn College Laboratory, Topeka, Kansas, vol i, No. 7. Contains descriptions of fresh-water molluska by R. E. Call and notes on fishes by C. H. Gilbert.

Bulletin of the Buffalo Soc. Nat. Sci., vol. v, No. 2. Contains papers on the fossil fishes of the Genesee, Portage and Black Shales, by H. U. Williams; and on the fishes of the Corniferous, by the same and F. K. Mixer, and other papers.

Catalogue of Fossil Mammalia of the British Museum, Part 3, by R. Lyddekker. Contains catalogue with notes of the Ungulate, suborders Perissodactyla, Taxodontia, Condylarthra and Amblypoda, with some figures.

The Geology of Long Island, by F. J. H. Merrill, 24 pp. 8vo, with 2 plates (Ann. N. Y. Acad. Sci., iii, Nos. 11, 12, 1886). A valuable contribution to American geology.

*Fossil Insects.*—Bulletin No. 31 of the U. S. Geological Survey contains a systematic review of our present knowledge of Fossil Insects, including Myriapoda and Arachnids, by Mr. S. H. Scudder.

## OBITUARY.

Professor E. L. YOUMANS, of New York, died on the eighteenth of January, in his 67th year. He had long been active and successful in the work of extending a knowledge of scientific truths and principles among the general public. His published works include a Class Book of Chemistry (1852); Alcohol and the Constitution of Man (1853); Chemical Atlas (1855); Hand-book of Household Science (1857); and some others. He planned the well known International Scientific Series, begun in 1871 and of which fifty-seven volumes have now been issued. He also established the Popular Science Monthly in 1872, of which he remained the chief editor. A compilation of essays on the Conservation of Energy and the Correlation of Forces, to which he added an Introduction, was prepared by him in 1864. He was also instrumental in extending a knowledge of the writings of Spencer, Tyndall and Huxley in this country, and as the scientific adviser of the Messrs. Appleton, and in other ways, his influence was felt in the advancement of science.

SELWYN L. HARDING, the young author of a valuable paper in the first number of this volume died early in January after five days illness. The past summer he received from Harvard his degree of A.B., *summa cum laude*, with honors in physics; and at the time of his death he was studying Electrical and Mechanical Engineering in the Massachusetts School of Technology.

THEODOR VON OPPOLZER, the eminent astronomer, died at Vienna on the 26th of December in his 46th year.

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Chas. D. Walcott,
U. S. Geological Survey.

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## Art. XX.—*On the Absolute Wave-length of Light;* By Louis Bell, Fellow in Physics in Johns Hopkins University.

Up to the present time, Ångström's map of the solar spectrum and with it his determination of absolute wave length, has remained the final standard of reference in all spectroscopic matters. But since Ångström's work was published, optical science, particularly that part of it which deals with the manufacture and use of diffraction gratings, has made enormous progress. It is now possible with the concave grating to measure relative wave-lengths with an accuracy far greater than can be claimed for any one of the absolute determinations. The numbers given by Ångström are now known to be too small by as much as one part in seven or eight thousand, as has been shown by Thalén in his monograph "Sur le spectre du Fer," and since Ångström's work but one careful determination has been made. This is by Mr. C. S. Peirce and was undertaken some eight years since for the U. S. Coast and Geodetic Survey. No full report of this work has as yet been published, though it is evidently very careful and has already consumed several years. Certain results were communicated to Prof. Rowland of this University to serve as a standard of reference for his great map of the solar spectrum now nearly completed, and it was to serve as a check on these results and to furnish a value of the absolute wave length as nearly as possible commensurate in accuracy with the micrometrical observations, that the experiments detailed in the present paper were undertaken. Only the work with glass gratings has been as yet completed, but since the relative wave lengths, which are intrinsically of far greater importance, are now ready for publication and have been reduced by the value herein given, the result is published, leaving for further work with speculum metal gratings, its final confirmation or correction.

This portion of the determination is delayed awaiting better facilities for carrying it out, but the writer intends undertaking it at the earliest possible moment and hence leaves for a future paper the complete discussion of the problem.

The writer desires here to express his deep obligations to Prof. Rowland, under whose guidance the work has been carried on and to whom a very important correction is due, and to Profs. W. A. Rogers and C. S. Peirce for information given and courtesies extended.

## EXPERIMENTAL.

The determination of absolute wave-length involves two quite distinct problems—first, the exact measurement of the angle of deviation of the ray investigated, and second, the measurement of the absolute length of the gratings used. Each portion of the work involves its own set of corrections, frequently quite complicated and difficult, but it is the latter part that is peculiarly liable to errors, which will be treated in detail further on. As to the former part, several important questions arise at the very outset. First is the choice between transmission and reflection gratings. The principal work heretofore has been done with the former, but metallic gratings possess certain advantages, notably from the ease with which their temperature can be accurately measured, and the fact that they can easily be made of a size much larger than glass gratings, and consequently a small inaccuracy in measuring them involves much less error in the result.

On the other hand the coefficient of expansion of speculum metal is more than twice as great as that of glass, and being a good conductor it is far more sensitive to small changes of temperature. And this property increases the liability to irregularities in the ruling, particularly in large gratings which require several days for completion. In ruling on glass change of temperature is less serious but this advantage is more than offset by the faults caused by the wearing away of the diamond point, which breaks down so rapidly that it is enormously difficult to produce a glass grating free from flaws and at all comparable in optical excellence with those upon speculum metal. The determination of absolute wave-length should rest on measurements made with both classes, and with sufficiently exact instruments and very careful experimentation, the better results can probably be obtained from the metallic gratings. For the reasons previously stated, this paper is confined to the results from glass ones.

Now there are two quite distinct ways of using transmission gratings—first, perpendicular, or nearly so, to collimating or observing telescope; and second, in the position of minimum deviation. The method in the first case is familiar—the properties of the second are as follows:

The general relation between the incident and the diffracted ray is:

$$\sin i + \sin (\delta - i) = \frac{m\lambda}{a}.$$

When $i = o°$, this gives the ordinary formula for normal incidence. Putting it in the form—

$$\lambda = \frac{2(a)}{m} \sin \frac{\delta}{2} \cos \left(i - \frac{\delta}{2}\right),$$

the deviation represented by the angular term will evidently be a minimum when $i = \frac{\delta}{2}$ and the wave-length will then be given by the formula

$$\lambda = \frac{2(a)}{m} \sin \frac{\delta}{2}.$$

It is not easy to say which method of procedure is preferable, but on the whole the ordinary plan of normal incidence offers fewer experimental difficulties and therefore was adopted, particularly as the spectrometer used was specially well suited to that method. It is quite certain that either method will with proper care give the angular deviation with a degree of exactness far surpassing that attainable in the measurement of the gratings.

## The Spectrometer.

This was a large and solid instrument by Meyerstein with a circle on silver $32^{cm}$ in diameter divided to tenths of a degree. This is read by two micrometer microscopes 180° apart. The pitch of the micrometer screws is such that one turn equals about $2'$, and as the head is divided into sixty parts each of these represents $2''$. The micrometer can, however, be set with certainty to less than half this amount. The collimating and observing telescopes are of $4^{cm}$ clear aperture and $35^{cm}$ focal length and the lenses are well corrected. The collimator is fixed to the massive arms which carry the reading microscopes while the observing telescope is attached to a collar on the axis of the main circle and moves freely upon it or can be firmly clamped so as to move with the circle. The grating is carried on an adjustable platform with a circle $12{\cdot}5^{cm}$ in diameter, divided to 30′ by verniers to 1′ and moving either upon or with the large circle.

This arrangement of parts does not admit of fixing the grating rigidly normal to the collimator, so in all the experiments it was placed normal to the observing telescope, a position which was particularly advantageous in the matter of adjustment. The instrument was set up in a southern room in the physcial laboratory and throughout the experiments the collimator pointed about south-southeast. With the eyepiece used the observing telescope had a power of very nearly sixteen diameters.

## GRATINGS.

Very few glass gratings have ever been ruled on Prof. Rowland's engine, since for most purposes they are much inferior to the metallic ones, and are very much more difficult to rule, as they run great risk of being spoiled by the breaking down of the diamond point. A very few, however, were ruled in 1884 with special reference to wave-length determination, and of these the two best were available for these experiments. They are both ruled upon plane sextant mirrors, and are of very nearly the same size—thirty millimeters long, with lines of about nineteen millimeters. Each hundredth line is longer, and each fiftieth line shorter than the rest, so that the gratings are very easy to examine in detail. The ruling of both is smooth and firm, without breaks or accidental irregularities and almost without flaws. They were ruled at different temperatures and on different parts of the screw, and while one was ruled with the ordinary arrangement of the engine, the other was ruled to a very different space by means of a tangent screw. This great diversity of conditions in the two gratings is far from favoring a close agreement in the results, but tends to eliminate constant errors due to the dividing engine, and hence to increase the value of the average result. It must be remembered that two gratings ruled on the same part of the screw are in most respects little better than one. The grating designated I in this paper contains 12,100 spaces, at the rate of very nearly 400 to the millimeter, and was ruled (by tangent screw) at a temperature of 6°·7 C. in January, 1884. It gives excellent definition with almost exactly the same focus for the spectra on either side, and is quite free from ghosts or other similar defects.

The grating designated II has 8,600 spaces, at the rate of about 7,200 to the inch, and was ruled in November, 1884, at 11°·6 C. Its definition and focussing are very nearly as good as in I and like it, it shows no trace of ghosts or false lines; they are both exquisite specimens of the work which Prof. Rowland's engine is capable of doing, though as the event showed, I is decidedly the better grating, in the matter of regularity of ruling.

## ANGULAR MEASUREMENTS.

At the beginning of the work a serious question of adjustment arose. There are two ways of using a grating perpendicular to one of the telescopes. In the first place it may be placed and kept accurately in that position, and secondly it may be placed nearly in the position for normal incidence, and the error measured and corrected for. Ångström used the latter method, which involved a measurement on the direct image of the slit as well as on the lines observed. Using Ångström's notation—let $\alpha$ and $\alpha'$ be the readings on the spectra, and M that on the slit. Let, also,

$$\frac{\alpha+\alpha'}{2}-\mathrm{M}=\Delta \quad \text{and} \quad \frac{\alpha-\alpha'}{2}=\varphi.$$

Then if $\gamma$ is the angle made by the incident ray with the normal to the grating, and N the order of spectrum,

$$\frac{\mathrm{N}\lambda}{\varepsilon}=\cos\,(\gamma+\Delta)\,\sin\,\varphi;$$

also $$\sin\,\gamma=\sin\,(\gamma+\Delta)\,\cos\,\varphi,$$

and $$\tan\,\gamma=\frac{\cos\,\varphi}{1-\cos\,\varphi}\,\Delta.$$ But from the second of the above equations,

$$\sin\,(\gamma+\Delta)=\frac{\sin\,\gamma}{\cos\,\varphi}.$$

Now it was found that with the collimating eyepiece belonging to the spectrometer, $\gamma$ would never exceed and seldom reach 10″, while the angles of deviation observed were about 45°. Substituting these values in the last equation, it at once appeared that the cosine of $(\gamma+\Delta)$ was a quantity differing from unity by considerably less than one part in a million, and hence entirely negligible. Further, it was found that the grating once set could be trusted to remain perpendicular through a series of measurements, and though at the end of each series the grating was adjusted to a new part of the circle, and a close watch was kept for its slipping out of adjustment, it was never found necessary to reject a series from that cause.

The grating was centered and adjusted with reference to the circles and their axes by the ordinary methods. Throughout the experiments the light was concentrated on the slit by an achromatic lens of about half a meter focus, which was placed behind a sheet of deep yellow glass, which served to cut off the overlapping blue rays which might otherwise have proved troublesome. A heliostat enabled the sun's image to be kept centrally upon the slit.

The method of observation was as follows: When instrument and grating were in exact adjustment, readings were taken on $D_1$ in the spectra on either side of the slit, and the angle measured from three to six times in rapid succession, the last reading being of course on the same side as the first.

Then the grating was rotated about ten degrees, readjusted, and the process repeated.

The angles observed in one series were combined to eliminate errors of setting, while the use of all portions of the circle served to correct errors of subdivision, since the number of independent series of observations was quite large.

To eliminate any errors which might be due to imperfections of figure in the gratings they were used in all the four possible positions. No such error, however, became apparent either from critical examination of the gratings themselves, or from the results obtained in the different positions.

Observations with grating I were begun late in October, 1885, and occupied the clear days for a month. Forty-eight series of measurements were made, and the agreement between them was very satisfactory. After correcting for temperature, thirty-six of the number fell within a range of three seconds and the rest were clustered closely about them. Observations on the various days were as follows:

| | Date. | Number of Series. | Angle. |
|---|---|---|---|
| Oct. | 19 | 1 | 45° 1′ 47″·2 |
| | 20 | 1 | 45° 1′ 48″·4 |
| | 22 | 2 | 45° 1′ 48″·2 |
| | 23 | 1 | 45° 1′ 49″·8 |
| | 26 | 4 | 45° 1′ 49″·3 |
| | 27 | 3 | 45° 1′ 48″·2 |
| | 31 | 1 | 45° 1′ 50″·1 |
| Nov. | 3 | 1 | 45° 1′ 48″.6 |
| | 4 | 3 | 45° 1′ 47″·4 |
| | 5 | 2 | 45° 1′ 47″·9 |
| | 10 | 4 | 45° 1′ 47″·8 |
| | 11 | 6 | 45° 1′ 49″·7 |
| | 16 | 8 | 45° 1′ 48″·2 |
| | 17 | 5 | 45° 1′ 47″·5 |
| | 20 | 6 | 45° 1′ 47″·5 |

All the above were in the third spectrum to which measurements were in the main confined as in it the definition was particularly good, and it being the highest order which could be conveniently observed, an error in the angle would produce the minimum effect. The spectra on both sides of the slit were about equal in brilliancy and definition.

The observations were weighted as nearly as possible according to the favorable or unfavorable conditions under which they were made, and when finally combined gave as the value of the angle of deviation for grating I,

$$\varphi=45^\circ\ 1'\ 48''{\cdot}24\pm0''{\cdot}11.$$

The above probable error is equivalent to a little less than one part in a million and can introduce no sensible error into the resulting wave length.

Other work intervened and the measurements with grating II were not taken up until early in the succeeding March. Precisely the same method of observation was employed and the results were nearly as consistent and satisfactory.

The observations by days were as follows:

| Date, 1886. | Number of Series. | Angle. |
|---|---|---|
| March 6 | 2 | 42° 5′ 1″·2 |
| 10 | 1 | 42° 4′ 58″·6 |
| 11 | 7 | 42° 5′ 1″·4 |
| 15 | 1 | 42° 5′ 4″·0 |
| 16 | 6 | 42° 4′ 57″·8 |
| 17 | 6 | 42° 4′ 58″·5 |
| 18 | 7 | 42° 4′ 59″·1 |
| 23 | 6 | 42° 4′ 58″·3 |

When collected thus by days the observations do not appear to agree nearly as well as those made with grating I, particularly since a solitary wild reading, that of March 15, is retained. The distribution of the various readings, however, is such that after weighing and combining the final result is by no means deficient in accuracy. It is,

$$\varphi = 42^\circ\ 4'\ 59''{\cdot}28 \pm 0''{\cdot}2$$

The above probable error amounts to about one part in six hundred thousand. The observations with grating II were uniformly in the fourth order of spectrum.

Throughout the measurements with both gratings the temperature was kept within a few degrees. 20° C. had been selected as the standard temperature and the variation was rarely more than two or three degrees on either side of that figure. The question of temperature determination is a serious one in case of glass gratings, for it is very hard to tell what heating effect the incident beam has on the grating, and equally hard to measure that effect. It is hardly safe without extraordinary precautions to assume that the grating has the same temperature as the air near, and it is such a bad conductor that it would not easily assume the temperature of the apparatus. In these experiments a sort of compromise was effected. A small thermometer was attached to the thin metallic slip that held the edge of the grating, and shielded by cotton from air currents which of course would affect it much more than they would the grating. The thermometer was a small Fahrenheit graduated to quarter degrees and quite sensitive. It was carefully compared, throughout the range of temperatures employed, with thermometer Baudin 7312, which served as a standard in all the measurements regular and linear, and during part of the time was placed directly over the grating to give a check on the attached thermometer. This expedient was finally abandoned as unlikely to help the matter much.

The corrections for temperature were deduced from the assumed coefficient of expansion of glass, which was taken as 0·0000085. This was reduced to angular correction for the approximate value of $\varphi$ and applied directly to the observed angles. Since the temperatures at which observations were made varied little from 20° C. and were quite equally distributed on both sides of that figure any error in the assumed coefficient would hardly affect the average result, but would appear, if at all, as a slight increase in the probable error.

760$^{\text{mm}}$ (reduced) was taken as standard pressure and the values for the days of observation were taken from the U. S. Signal Service observations for the hours of 11 A. M. and 3 P. M. on those days. The average for the measurements made with grating I was 761$^{\text{mm}}$, and for those with grating II 760$^{\text{mm}}$, so that corrections for pressure were uncalled for.

The effect of the velocity of the apparatus through space is a subject concerning which there has been much discussion. Ångström deduced a correction, but van der Willigen in quite a lengthy discussion of the whole matter came to the conclusion that there was no error due to the above cause. Since that period the question has been raised from time to time, but no decisive investigations on the subject have yet been published. At present however it seems to be tolerably well settled that no correction is needed, as the error, if there be any, is of an order of magnitude entirely negligible, and in the present paper none has been applied.

The angular measurements, after all corrections were applied, may thus be regarded as determined with a high degree of accuracy—most probably to less than one part in half a million.

## MEASUREMENT OF THE GRATINGS.

The exact determination of the grating space is by far the most difficult portion of a research on absolute wave length, and has been uniformly the most fruitful source of errors.

Besides the experimental difficulties of the task, it is far from an easy matter to secure proper standards of length. The standards used in various former investigations have proved to be in error, sometimes by a very considerable amount, and indeed very few of the older standards are above suspicion. As Peirce has very justly remarked in connection with this subject, "All exact measures of length made now must wait for their final correction until the establishment of the new metric prototype." Short standards of length are in some respects peculiarly liable to error, since they must be compared with the subdivisions (often not sufficiently well determined) of secondary standards, and small sources of uncertainty such as poor defining lines, slight changes in the apparatus and the like, of course are much more serious as the length is less.

Fortunately there were available for the measurement of the gratings two standard double decimeters which have been determined with almost unprecedented care by Professor W. A. Rogers. They are upon speculum metal; were graduated and determined by Professor Rogers early in 1885 and were purchased by the university late in the same year. They are designated respectively $S_1^a$ and $S_2^a$ and are discussed at length in the Proceedings of the American Society of Microscopists for 1885.

The bar $S_1$ is $23^{cm}$ in length. Near one edge is the double decimeter $S_1^a$ divided to centimeters, the $5^{cm}$ lines being triple. $S_2$ is $27^{cm}$ in length and graduated in the same way. The defining lines in both are fine and sharp and the surfaces are accurately plane. They are standard at $16°{\cdot}67$ C. and from an elaborate series of comparisons with four different standards the coefficient of expansion was found to be,

$$17{\cdot}946\ \mu \text{ per meter per degree C.}$$

$S_1^a$ and $S_2^a$ depend for their accuracy on a long series of independent comparisons with Professor Rogers' bronze yard and meter $R_2$ and steel standards whose relation to $R_2$ was very exactly known. $R_2$ has been determined by elaborate comparisons with various standard meters and yards, and is described and discussed at length in the Proceedings of the American Academy, vol. xviii. The length of the meter was determined both directly and through the yard, by comparison with the following standards:

I. The meter designated T, copper with platinum plugs, traced and standardized by Tresca in 1880 from the Conservatoire line metre No. 19, which bears a very exactly known relation to the Metre des Archives.

II. The yard and meter designated C. S., brass with silver plugs, belonging to the Stevens Institute. The yard was compared with the Imperial Yard in 1880 so that it is directly and exactly known. It was afterwards sent to Breteuil and the meter was determined with great exactness by elaborate comparisons with type I of the International Bureau of Weights and Measures.

III. "Bronze 11" a primary copy of the Imperial Yard presented to the United States in 1856. It was taken to England in 1878 and finally determined by direct comparison with the Imperial Yard, Bronze Yard No. 6, and Cast Iron Yards B No. 62 and C No. 63.

The subdivisions of $R_2$ have been determined with very great care, and thus $S_1^a$ and $S_2^a$, whose lengths relative to $R_2$ are accurately known, may finally be referred to the ultimate standard Type I of the International Bureau.

Only the $5^{\text{cm}}$ spaces of $S_1^a$ and $S_2^a$ were investigated by Prof. Rogers, but these were determined by various methods under widely different conditions, and their relations to the standards with which they were compared may be regarded as definitely known. From a combination of all results the subdivisions of $S_1^a$ have the following lengths at the standard temperature.

$$\begin{aligned}
\text{Standard } S_1^a &= 199{\cdot}99918^{\text{mm}}\\
{}^{\text{dm}}{}_1 S_1^a &= 99{\cdot}99995\\
{}^{\text{dm}}{}_2 S_1^a &= 99{\cdot}99923\\
5^{\text{cm}}{}_1 S_1^a &= 50{\cdot}00010\\
5^{\text{cm}}{}_2 S_1^a &= 49{\cdot}99985\\
5^{\text{cm}}{}_3 S_1^a &= 49{\cdot}99901\\
5^{\text{cm}}{}_4 S_1^a &= 50{\cdot}00022
\end{aligned}$$

Similarly the following values were derived for $S_2^a$.

$$\begin{aligned}
\text{Standard } S_2^a &= 199{\cdot}99968^{\text{mm}}\\
{}^{\text{dm}}{}_1 S_2^a &= 100{\cdot}00001\\
{}^{\text{dm}}{}_2 S_2^a &= 99{\cdot}99967\\
5^{\text{cm}}{}_1 S_2^a &= 50{\cdot}00020\\
5^{\text{cm}}{}_2 S_2^a &= 49{\cdot}99981\\
5^{\text{cm}}{}_3 S_2^a &= 49{\cdot}99931\\
5^{\text{cm}}{}_4 S_2^a &= 50{\cdot}00042
\end{aligned}$$

As to the degree of accuracy attained in determining $S_1^a$ and, $S_2^a$, Prof. Rogers says that including all sources of uncertainty either standard may have an error of $\pm 0{\cdot}3\mu$, but the mean of the two, since the determinations were independent ought to be even more reliable. Taking all things into consideration it seems very improbable that the mean value of $S_1^a$ and $S_2^a$ can be in error by as much as one part in half a million.

So much for the standards of length. The comparator used in the measurements was a very efficient instrument, particularly suited for the purpose. It consisted essentially of a long carriage ($\frac{1}{2}$ meter) running on V-shaped ways and carrying the microscope. This carriage slides against adjustable stops, and is pressed against them with perfect uniformity by means of weights. An adjustable platform below carries the standards and objects to be measured. The ways of both carriage and platform had been ground till they were perfectly uniform and true and the working of the instrument left little to be desired in the way of accuracy. Throughout a long series of measurements the stops would not be displaced by so much as 0·1$\mu$ if proper care were used in moving the carriage. The microscope was attached so firmly as to avoid all shaking, and was armed with a half-inch objective and an excellent eyepiece micrometer. The objective was made specially for micrometric work and was fitted with a Tolles' opaque illuminator. Measurements were made as follows: The standard bar, and the grating mounted on a polished block of speculum metal, were placed side by side,—or sometimes end to end,—on the platform and very accurately leveled. The stops were set very nearly three centimeters apart, one end of the grating brought under the microscope resting against one of the stops, and the micrometer set on the terminal line. Then the carriage was brought against the other stop and the micrometer again set. The same process was then gone through with on three centimeters of the standard, and then going back to the grating it was compared in the same manner with succeeding triple centimeters till the fifteen centimeter line was reached, thus eliminating the errors of the single centimeters and making the determination rest only on the fifteen centimeter line. The temperature was given by a thermometer placed against the standard bar or the block that carried the grating. In this manner each grating was repeatedly compared with the first 15 centimeters of each bar, at or near 20°, the temperature at which the gratings had been used. The micrometer constant was determined by measuring tenths of millimeters ruled on Prof. Rowland's engine, but in practice the stops were so adjusted that it was almost eliminated. Each division of the micrometer head equalled 0·28$\mu$ and the probable error of setting was less than half that amount.

All measurements were reduced to 20° C. as in case of the angular determinations. The line along which the linear measures were made was that formed by the terminations of the rulings. It therefore was necessary to know very exactly the angle between this line and the direction of the individual rulings, in other words the angle between the line of motion of the grating and the direction of the diamond stroke in the dividing engine. This was ascertained by means of two test plates each some twelve cm. long ruled in cms. and then superimposed line for line. By measuring the minute distances between each end of a pair of superimposed lines, the length of the lines and the amount by which their ends overlapped at each end of the test plate, the required angle could be deduced with great exactness. It differed so little from 90° however, that the correction produced, barely one part in a million, was entirely negligible.

After all reductions and corrections, the following series of values were obtained for the grating spaces of gratings I and II.

| Series. | Grating I. | Standard. |
|---|---|---|
| 1 | 0·00250023$^{\text{mm}}$ | $S^a_2$ |
| 2 | 0·00250016 | “ |
| 3 | 0·00250013 | “ |
| 4 | 0·00250015 | “ |
| 5 | 0·00250018 | “ |
| 6 | 0·00250021 | $S^a_1$ |
| 7 | 0·00250023 | “ |
| 8 | 0·00250023 | “ |
| 9 | 0·00250023 | “ |

Mean value adopted after weighting and combining the above observations was:

0·002500194$^{\text{mm}}$±10

The probable error thus appears to be not far from one part in two hundred and fifty thousand. The difference in the results obtained from the two standards seems to be purely accidental as appears from the measurements on grating II.

| Series. | Grating II. | Standard. |
|---|---|---|
| 1 | 0·00351888$^{\text{mm}}$ | $S^a_1$ |
| 2 | 0·00351883 | “ |
| 3 | 0·00351885 | “ |
| 4 | 0·00351886 | “ |
| 5 | 0·00351883 | “ |
| 6 | 0·00351893 | $S^a_2$ |
| 7 | 0·00351888 | “ |
| 8 | 0·00351888 | “ |
| 9 | 0·00351888 | “ |

Mean adopted, 0·003518870±10

The probable error appears to be rather less than in the measurements of grating I. As however the angular determinations made with I are the better, so far as probable errors of observation are concerned the result from the two gratings are about equal in value.

Computing now the wave-length corresponding to the given values of $\varphi$ and $\delta$ for each grating, we have finally for the wave-length of $D_1$ at 20° C. and 760$^{\text{mm}}$ pressure:

From Grating I uncorrected, 5896·11 tenth meters.
From Grating II “ 5895·95 “

The difference in the above results is by no means large compared with the results obtained from different gratings by other investigators, but it certainly is enormously great compared with the experimental errors alone.

As nearly as can be judged these ought not in either grating to exceed one part in two hundred thousand, while the above discrepancy is about one part in thirty-five thousand.

Its cause must be sought in the individual peculiarities of the gratings, rather than in the method of using them.

All gratings are subject to irregularities of ruling, and the effects of these is various, according to the nature and magnitude of the defects. Linear or periodic errors in ruling, unless very small, will make themselves apparent by changing the focus of the spectra or producing ghosts, respectively; and if such errors are large, render the grating totally unfit for exact measurement. Accidental errors, such as a flaw or break in the ruling, are also serious, but are easily detected and may be approximately corrected, as was done by Ångström in the case of one of his gratings. Any marked and extensive irregularities of spacing will produce bad definition or false lines, and in most cases both. If, then, a grating on microscopical examinations is free from flaws and on the spectrometer gives sharply defined spectra, alike in focus and free from ghosts, it is safe to conclude that it is tolerably free from the errors above mentioned, but unfortunately there is one fault that does not at once become visible, while it introduces a very serious error in the measurements. This is a rather sudden change in the grating space through a portion of the grating, usually at one end. Such an error is usually due to abnormal running of the screw when the dividing engine is first started, and may in this case be avoided by letting the engine run for some time before beginning to rule. Thus Grating I, ruled with this precaution, is nearly free from this error. Sometimes, however, it is the terminal or an intermediate portion of the grating that is thus affected in which case the error may be due to a change of temperature or to a fault in the screw. If an error of this kind is extensive, it will produce the effect of two contiguous gratings of different grating space, injuring the definition and widening or reduplicating the lines. When, however, the abnormal spacing is confined to a few hundred lines it produces no visible effect when the whole grating is used, but simply diffuses a small portion of the light and increases or decreases the average grating space. For it is evident that such a portion of the grating must possess little brilliancy and less resolving power, and the more its spacing differs from that of the rest of the grating, the less chance of visible effect and the greater error introduced. Such a fault is compatible with the sharpest definition, but can be detected by cutting down the aperture of the grating till the spectrum from the abnormal portion is relatively bright and distinct enough to be seen. The effective grating space, producing the spectra on which measurements are made is, of course, that of the normal portion only. Both the gratings used in these experiments were affected by the above error, No. I, very slightly, No. II, somewhat more seriously. Not only the discrepancies between different gratings, but those between different orders of spectra in the same grating are due to this cause. For while in one order, where the effect due to the abnormal portion is imperceptible, the spectrum as measured is produced by the effective grating space alone, in another order there may be produced a slight shading off of the lines so that their apparent centers may correspond approximately to the average grating space. In any case, it is quite clear that a combination of the results from different orders of spectra will not eliminate the error.

The remedy lies either in stopping out the imperfect portion of the grating, or measuring it and introducing a correction. As the work of angular measurements was nearly finished before the study of the gratings was begun owing to a delay in getting apparatus, the latter course was adopted in these experiments. Each grating was examined in detail, and the relation of the grating spaces in the various portions of it carefully determined. From these data a simple graphical method gave the correction to be applied to the wave length. In each grating the fault was confined to a small portion, and as the order of spectrum employed in each was selected on account of its good definition and freedom from anything like haziness or shading of the lines, it seems safe to assume that the abnormal portion produced no visible effect and that consequently the correction above mentioned counteracts the error quite effectually. In grating I the correction was one part in 300,000, and in grating II one part in 60,000. Applying these to the wave lengths we have for grating I,

| | |
|---|---|
| Wave length | 5896·11 |
| Correction | —·02 |
| Corrected w. l. | 5896·09 |

And for grating II,

| | |
|---|---|
| Wave length | 5895·95 |
| Correction | +·10 |
| Corrected w. l. | 5896·05 |

Combining these and giving to Grating I the greater weight on account of its very small error of ruling, we have finally for the wave length of $D_1$ at 20° C. and $760^{mm}$ pressure,

| | | |
|---|---|---|
| 5896·08 | or *in vacuo*, | 5897·71 |

It is no easy matter to give any well founded estimate of the probable error of the above result. So far as experimental errors are concerned the result with either grating should be correct to one part in two hundred and fifty thousand, but the error in the gratings introduces a complication by no means easy to estimate. As nearly as the writer can judge, however, it seems probable that the error of the final result does not exceed one part in two hundred thousand. For comparison, the values deduced from the work of Peirce and of Ångström are subjoined.

| | |
|---|---|
| Micrometer measure by Rowland, from Peirce's preliminary result | 5896·22 |
| Thalen's correction of Ångström | 5895·89 |

both being in air at ordinary temperature and $760^{mm}$.

As neither result was corrected for errors in the gratings the cause of the discrepancy is obvious.

Two determinations of absolute wave length have been published since this work was undertaken by the writer. One is a very elaborate one by Müller and Kempf, who employed four gratings by Wanschaff and used the method of minimum deviation. Their results were as follows:

| Grating | (2151) | (5001) | (8001) | (80014) |
|---|---|---|---|---|
| Wave length | 5896·46 | 5896·14 | 5895·97 | 5896·33 |

By a correction founded on the unwarrantable assumption that the mean value was correct the above results are brought into apparent agreement. Nothing, however, short of a study in detail of each grating can furnish data for obtaining anything like an accurate result from the above figures. It would seem that (5001), which had the smallest probable error, should show but a trifling error of ruling, while one would expect to find a portion or portions of (2151), in which the grating space is abnormally large. Corresponding errors of ruling should appear in (8001) and (80014). A similar study of the gratings used by Ångström would be of no little interest.

The other determination alluded to is one by M. de Lépinay, using a quartz plate and Talbot's bands. Without discussing the method it is sufficient to say that the result obtained depends on the relation of the liter to the decimeter, a ratio not at present exactly determined.

The results detailed in this paper are in a certain sense preliminary. The writer hopes that in the near future, experiments with metallic gratings will enable him to lessen the probable error very materially and therefore defers, for the present, further discussion of the problem.

Through the courtesy of Mr. Peirce the writer has been enabled to test the legitimacy of the above correction and at the same time check his own results. Mr. Peirce kindly forwarded his gratings and standard of length for examination and comparison, and the results were decidedly instructive.

Grating "H," with which a large part of the work was done, showed, as was suspected, a local error, equivalent to a correction of one part in 55000 in the resulting wave length. Tested in the spectrometer, the portion including the error showed a grating space distinctly greater than that of the grating taken as a whole, showing thus both the necessity and the algebraic sign of the correction. The other gratings showed similar errors varying in amount, but the same in sign, the correction requiring in every case a reduction in the wave length. The abnormal portion was invariably at one end or the other of the grating concerned, never in the middle.

The standard of length used by Mr. Peirce—"No. 3" a glass decimeter—was compared with $S_1^a$ and $S_2^a$ and the preliminary results show that the length assigned to it was too great by very nearly $2\mu$, 1 part in 50000. Now the wave length of $D_1$ as deduced from grating H was,

| | |
|---|---|
| | 5896·26 |
| Less error of ruling-- | —·10 |
| Less error of "No. 3" | —·12 |
| Corrected value----- | 5896·04 in air at 30 in. pressure and 70° F; |

which shows a tolerably close correspondence with the results obtained by the writer. A more complete discussion of Peirce's results is reserved until the relation between "No. 3" and $S_1^a$ and $S_2^a$ shall be more exactly known. The latter standards would appear to be the more trustworthy, since they are based on various independent determinations, while "No. 3" is based on an indirect comparison with meter "No. 49," a standard concerning the exact length of which there seems to be some little doubt.

## ART. XXI.—*On the Relative Wave-length of the Lines of the Solar Spectrum;* by HENRY A. ROWLAND.

FOR several years past I have been engaged in making a photographic map of the solar spectrum to replace the ordinary engraved maps and I have now finished the map from the extreme ultra violet, wave length 3200, down to wave length 5790. In order to place the scale correctly on this map, I have found it necessary to measure the relative wave lengths of the spectrum and to reduce it to absolute wave lengths by some more modern determination. I have not yet entirely finished the work, but as my map of the spectrum is now being published and as all observers so far seem to accept the measures of Ångström, I have decided that a table of my results would be of value. For as they stand now they have at least ten times the accuracy of any other determination. This great accuracy arises from the use of the concave grating which reduces the problem of relative wave lengths to the measure of the coincidences of the lines in the different spectra by a micrometer.

The instrument which I have employed has concave gratings 5 or 6 in. diameter, having either 7200 or 14,400 lines to the inch and a radius of 21 ft. 6 in. By my method of mounting, the spectrum is normal where measured, and thus it is possible to use a micrometer with a range of 5 inches. The spectrum keeps in focus everywhere and the constant of the micrometer remains unchanged except for slight variations due to imperfections in the workmanship. The micrometer has no errors of run or period exceeding the $\frac{1}{20000}$ inch. The probable error of a single setting on a good clear line is about $\frac{1}{2000000}$ of the wave length. 1″ of arc is about ·0012 inch. The D line in the second spectrum is ·17 inch or 4·4$^{\text{mm}}$ wide. Determinations of relative wave length of good lines seldom differ 1 in 500,000 from each other and never exceed 1 in 100,000, even with different gratings. This is, of course, for the principal standard lines, and the chance of error is greater at the extremities of the spectrum. The interpolation of lines was made by running the micrometer over the whole spectrum, 5 inches at a time, and adding the readings together so as to include any distance, even the whole spectrum. The wave length is calculated for a fixed micrometer constant and then corrected so as to coincide everywhere very nearly with the standards. I suppose the probable error of the relative determinations with the weight 1 in my table to be not far from 1 in 500,000. Ångström thinks his standard lines have an accuracy of about 1 in 50,000 and ordinary lines much less.

As to the absolute measure, it is now well determined that Ångström's figures are too small by about 1 part in 6000. This rests: 1st, on the determination of Peirce made for the U. S. Coast Survey with Rutherford's gratings and not yet completely published; 2nd, on an error made by Tresca in the length of the standard meter used by Ångström* which increases his value by about 1 in 7700; 3d, on a result obtained

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* Thalen, Sur Spectre du Fer Sociéte Royale des Sciences d'Upsal, September, 1884, p. 25.

in my laboratory with two of my gratings by Mr. Bell, which is published with this paper. Mr. C. S. Peirce has kindly placed his grating at our disposal and we have detected an error of ruling which affects his result and makes it nearly coincide with our own. The wave length of the mean of the two E lines is

| | |
|---|---|
| Ångström (atlas) | 5269·12 ± ·05 |
| “ (Corrected by Thalen) | 5269·80[*] |
| Peirce | 5270·16 |
| “ (Corrected by Rowland and Bell) | 5270·00[†] |
| Bell | 5270·04 |

These results are for air at ordinary pressures and temperatures. The last is reduced to 20° C. and $760^{mm}$ pressure. To reduce to a vacuum, multiply by the following:

| Fraunhofer line | A | C | E | G | H |
|---|---|---|---|---|---|
| Correct'n factor | 1·000291 | 1·000292 | 1·000294 | 1·000297 | 1·000298 |

The relation between my wave lengths and those of Ångström are given by the following, Ångström's value being from p. 31 of his memoir.

| | A (edge) | B (edge) | | C | |
|---|---|---|---|---|---|
| Ångström | 7597.5 | 6867·10 | 6717·16 | 6562·10 | 6264·31 |
| Rowland | 7593·97 | 6867·38 | 6717·83 | 6562·96 | 6265·27 |
| Difference | – 3·5 | ·28 | ·67 | ·86 | ·96 |

| | $D_2$ | $D_1$ | | Peirce's line | |
|---|---|---|---|---|---|
| Ångström | 5895·13 | 5889·12 | 5708·45 | 5623·36 | 5454·84 |
| Rowland | 5896·08 | 5890·12 | 5709·56 | 5624·70 | 5455·68 |
| Difference | ·95 | 1·00 | 1·11 | 1·34 | ·84 |

| | E | E | $b_1$ | | F |
|---|---|---|---|---|---|
| Ångström | 5269·59 | 5268·67 | 5183·10 | 5138·78 | 4860·74 |
| Rowland | 5270·43 | 5269·65 | 5183·73 | 5139·47 | 4861·43 |
| Difference | ·84 | ·98 | ·63 | ·69 | ·69 |

| | | G |
|---|---|---|
| Ångström | 4702·44 | 4307·25 |
| Rowland | 4703·11 | 4307·96 |
| Difference | ·67 | ·71 |

The greatest variation in these differences is evidently due to the poor definition of Ångström's grating by which the numbers refer to groups of lines rather than to single ones. Selecting the best figures, we find that Ångström's wave

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[*] Thalen, Sur Spectre du Fer, Sociéte Royale des Sciences d'Upsal, September, 1884, p. 25.

[†] From one grating only.

lengths must be multiplied by 1·00016 to agree with Bell, while the correction for Ångström's error of scale would be 1·000110.

It is impossible for me to give at present all the data on which my determinations rest, but I have given in Table I many of the coincidences as observed with several gratings, the number of single readings being given in the parenthesis over each set.

Table II gives the wave lengths as interpolated by the micrometer. It is scarcely possible that any error will be found (except accidental errors) of more than ·02, and from the agreement of the observations, I scarcely expect to make any changes in the final table of more than ·01, except in the extremities of the spectrum, where it may amount to ·03 in the region of the A and H lines. The wave lengths of weight greater than 1 will probably be found more exact than this. The lines can be identified on my new photograph of the spectrum down to 5790. Below this there is little trouble in finding the right ones. All maps of the spectrum, especially above F, are so imperfect that it is almost impossible to identify my lines upon them. The lines can only be properly identified by a power sufficient to clearly divide $b_3$ and $b_4$. Some of them are double and most of these have been marked, but as the table has been made for my own use, I have not been very careful to examine each line. This will, however, be finally done. Micrometric measures have now been made of nearly all the lines below *b* with a view of making a map of this region.

Table I gives the coincidences of the different orders of the spectra as observed with several concave gratings on both sides of the normal, the numbers in the brackets indicating the number of observations. The observations have been reduced as nearly as possible to what I consider the true wave length, the small difference from the numbers given in table II, being the variation of the observations from the mean value. The true way of reducing these observations would be to form a linear equation for each series and reduce by the method of least squares. A simpler way was, however, used and the relative wave length of the standard lines, marked S in table II, was obtained; however, some other observations were also included.

Table II gives the wave lengths reduced to Bell's value for the absolute wave length of the D line. These were obtained by micrometric measurement from the standards as described before. The weights are given in the first column and some of the lines, which were measured double, have also been marked. But the series has not yet been carefully examined for doubles.

The method is so much more accurate than by means of angular measurement that the latter has little or no weight in comparison.

This table is to be used in connection with my photographic map of the normal spectrum to determine the error of the latter at any point. The map was made by placing the photograph in contact with the scale, which was the same for each order of spectrum, and enlarging the two together. In this way the map has no local irregularities, although the scale may be displaced slightly from its true position, and may be a little too long or short, although as far as I have tested it, it seems to have very little error of the latter sort. The scale was meant in all cases, except the ultra violet, to apply to Peirce's absolute value and so the correction is generally negative, as follows:

*Approximate correction to the photographic map of the normal spectrum to reduce to latest absolute value.*

| | | | |
|---|---|---|---|
| Strip | 3200 to 3330 | Correction | —.05 |
| “ | 3275 to 3530 | “ | —·05 |
| “ | 3475 to 3730 | “ | —·02 |
| “ | 3675 to 3930 | “ | —·10 |
| “ | 3875 to 4130 | “ | —·16 |
| “ | 4075 to 4330 | “ | —·04 |
| “ | 4275 to 4530 | “ | —·08 |
| “ | 4480 to 4735 | “ | —·10 |
| “ | 4685 to 4940 | “ | —·18 |
| “ | 4875 to 5130 | “ | —·14 |
| “ | 5075 to 5330 | “ | —·15 |
| “ | 5215 to 5595 | “ | about —·05 |
| “ | 5415 to 5795 | “ | about —·04 |
| “ | 3710 to 3910 | “ | —·20 |
| “ | 3810 to 4000 | “ | —·14 |

It is to be noted that the third spectrum of the map runs into the second, so that it must not be used beyond wave length 3200, as it is mixed with the second in that region.

TABLE I.

*Coincidences.*

(2)
7039·969
7027·658
7023·676
5269·656
5270·448

(6)
7039·963
4222·336
7027·627
5270·429
5269·647
4215·627
7023·632

(8)
4691·516
4690·260
5624·696
5624·184

(6)
4508·402
4501·387
5624·696
5624·181
4496·990
4494·677

(18)
6430·993
6439·222
4293·181

(9)
6439·222
4293·181

(2)
4824·240
4823·640
7184·701

(4)
7247·569
4824·249
4823·630

(4)
7240·868
4824·243
4823·636
7234·854
7233·063

(6)
4501·377
6750·332

(4)
4691·517
7035 056
6027·665
7015·641

7015·256
(4)
4691·517
7027·675
(10)
4501·377
6759·308
(8)
4508·381
4504·921
4502·791
6752·830
4501·377
6750·306
(4)
6013·682
4508·407
6003·173
4501·377
4496·982
4494·652
(10)
4215 613
6322·820
(4)
6562·960
6564·341
4376·052
(4)
4222·309
4215·613
6322·817
6318·165
6278·255
6252·698
6246·451
(6)
6562·960
4376·041
(3)
4691·517
7023·706
(2)
4691·517
7027·655
(1) Phot.
5624·691
3754·63
3747·09
(1) Phot.
5914·32
3942·72
(1) Phot.
5914·32
3942·70
(1) Phot.
5890·12
5896·10
3926·12

(4)
6883·994
4590·051
4588·306
(2)
4823·638
4824·261
7233·103
7240·902
(2)
5288·632
6609·215
6593·992
6593·038
5270·419
5269·651
6567·645
6564·313
4376·050
5250·751
5250·329
6562·970
6569·353
6546·393
6495·119
6493·931
6462·760
5162·492
5159·171
6439·215
6430·984
6421·513
6420·090
5133·805
6411·776
5110·506
5109·754
5068·878
5060·191
5049·932
6322·833
6318·150
6265·256
6261·221
(1) Phot.
6024·2
6016·8
5948·7
3953·9
3950·4
5916·4
5914·3
3916·8
5862·5
5859·8
3897·5
5791·1
5788·1
(1) Phot.
4789·7
4789·4

4788·8
4754·1
3564·6
3549·9
4772·5
3545·2
3540·2
4691·5
4690·3
(14)
5162·394
6883·995
(6)
6594·016
6593·072
5270 427
5269 647
6569·348
6562·970
5250·325
5250·752
4376·032
(4)
6569·370
4924·889
4924·045
6562·965
6546·409
4903 419
4859·866
4861·428
6462·744
4824·255
4823·631
(6)
5914 323
5896·084
5890·125
4691·517
4690·266
5862·522
5859·751
4683·691
(6)
4376·039
5269·632
5270·420
(4)
4222·301
4215 613
5270·435
5269·654
(12)
5914·314
4222·325
4924·889
4924·052
4215·613
5896·083
5890·125
4903·411

(4)
4508·397
4501·380
5624·696
5624·180
4496·979
4494·647
(10)
4508·396
5405·901
4501·377
6750·299
4496·977
4494·660
(15)
4215·613
6322·848
(6)
5896·091
5890·124
4703·112
4691·517
4690·272
4683·694
(6)
5791·124
4824·255
4823·632
5788·064
(4)
5914·314
5896·086
5890·121
5862·514
5859·753
5857·613
(6)
6564·330
5270·430
5269·647
(8)
5068·880
6335·486
4222·330
5064·779
4215·613
5060·194
6322·842
6318·168
(4)
7027·671
5624·696
7035·107
7039·980
(6)
4891·523
5624·696
5624·184
4686·345
4678·971

(4)
5896·080
4691·517
5862·506

( )
7039·975
4691·532

5624·696
5624·198
7027·657
7023·686

(4)
5270·431
6322·825

4508·417
4501·393

(24)
6322·825
5270·431

(16)
4222·328
5624·696
5624·194
4215·612

### TABLE II.

*Wave Lengths of Standard Lines.*

| Wt. | W. L. | Wt. | W. L. | Wt. | W. L. |
|---|---|---|---|---|---|
| 1 | 3169·4 | S | 4376·039 | 4 | 4978·712 |
| 1 | 3261·6 | 2 | 4391·089 | 2 | 4980·292 |
| 1 | 3347·9 | 2 | 4407·797 | 2 | 4981·836 |
| 1 | 3329·50 | 2 | 4447·848 | 2 | 4994·251 |
| 1 | 3406·50 | S | 4494·667 | 2 | 4999·626 |
| 1 | 3540·24 | S*d*(?) | 4496·984 | 2 | 5005·838 |
| 1 | 3545·31 | 1 | 4499·022 | 2 | 5006·239 |
| 1 | 3549·97 | 1 | 4499·267 | 3 | 5007·370 |
| 1 | 3564·64 | S | 4501·384 | 2 | 5014·350 |
| 1 | 3747·09 | S | 4508·400 | 3 | 5020·139 |
| 1 | 3754·63 | 2 | 4554·154 | 2 | 5036·029 |
| 1 | 3897·54 | 2 | 4571·214 | 3 | 5049·944 |
| 1 | 3916·82 | 2 | 4572·092 | S | 5060·188 |
| 1 | 3924·70 | 2 | 4578·663 | S | 5064·773 |
| 1 | 3925·38 | 4 | 4588·320 | S | 5068·879 |
| 1 | 3925·81 | 4 | 4590·055 | 2 | 5083·460 |
| 1 | 3926·15 | 2 | 4602·107 | 2 | 5090·897 |
| 2 | 3942·54 | 2 | 4611·376 | 2 | 5097·071 |
| 1 | 3950·45 | 2 | 4629·445 | 3 | 5105·663 |
| 1 | 3953·93 | 2 | 4630·218 | 4 | 5109·760 |
| 1 | 3984·08 | 2 | 4643·580 | 4 | 5110·502 |
| 1 | 3985·54 | 2 | 4668·230 | 2 | 5115·495 |
| 1 | 3987 000 | S | 4678·970 | 2 | 5121·730 |
| 1 | 4005·261 | 5 | 4683·683 | 2 | 5126·309 |
| 1 | 4035·764 | S | 4686·344 | 2 | 5127·468 |
| 2 | 4048·821 | S | 4690·262 | 4 | 5133·812 |
| 2 | 4055·626 | S | 4691·520 | 3*d* | 5139·472 |
| 2 | 4073·837 | 4 | 4703·110 | 2 | 5141·845 |
| 3*d* | 4083·748 | 2 | 4703·910 | 2*d* | 5142·986 |
| 3 | 4107·578 | 2 | 4727·565 | 3 | 5146·612 |
| 3 | 4114·530 | 2 | 4754·159 | 3 | 5150·957 |
| 2 | 4157·893 | 2 | 4805·186 | 2 | 5154·157 |
| 2 | 4184·992 | S | 4823·630 | 2 | 5155·864 |
| 2 | 4199·190 | S | 4824·256 | 3 | 5159·171 |
| S | 4215·613 | S | 4859·864 | 6 | 5162·486 |
| S | 4222·323 | S | 4861·428† | 2 | 5165·518 |
| 3 | 4254·452 | 2 | 4890·885 | 2*d* | 5167·499‡ |
| 1 | 4267·974 | 1 | 4900·039 | 2*d* | 5169·094§ |
| 4 | 4293·201 | 1 | 4900·237 | 3 | 5171·714 |
| 2*d* | 4307·961* | S | 4903·409 | 2 | 5172·795‖ |
| 2 | 4318·782 | 1 | 4907·869 | 3 | 5173·838 |
| 4*d* | 4325·924 | 2 | 4919·111 | 3 | 5183·735¶ |
| 2 | 4337·143 | 3 | 4920·632 | 2*d* | 5188·892 |
| 2 | 4343·304 | S | 4924·050 | 2 | 5193·071 |
| 3*d* | 4352·865 | S | 4924·887 | 2 | 5198·819 |
| 2*d*(?) | 4359·715 | 2 | 4934·181 | 3 | 5202·422 |
| 2 | 4369·887 | 4 | 4973·294 | 2 | 5204·646 |

* Fraunhofer's G. † Fraunhofer's F. ‡ Fraunhofer's $b_4$.
§ Fraunhofer's $b_3$ ‖ Fraunhofer's $b_2$. ¶ Fraunhofer's $b$.

| Wt. | W. L. | Wt. | W. L. | Wt. | W. L. |
|---|---|---|---|---|---|
| 4 | 5210·492 | 3 | 5544·073 | 2 | 5919·795 |
| 2 | 5215·277 | 3 | 5555·035 | 3 | 5930·339 |
| 2 | 5217·488 | 2 | 5569·772 | 2 | 5934·809 |
| 2 | 5225·617 | 1 | 5576·222 | 2 | 5946·130 |
| 2 | 5229·950 | 2 | 5582·120 | 4 | 5948·685 |
| 2 | 5233·047 | 2 | 5588·910 | 2 | 5951·710 |
| 2 | 5241·599 | 2*d* | 5603·019 | 2 | 5955·106 |
| S | 5250·334 | 2 | 5615·451 | 2 | 5956·853 |
| S | 5250·759 | 2 | 5615·809 | 2 | 5975·508 |
| 2 | 5253·558 | S | 5624·181 | 3 | 5976·934 |
| 2 | 5261·815 | S | 5624·696‡ | 2 | 5984·977 |
| S | 5269·649* | 2 | 5641·595 | 3 | 5987·214 |
| S*d* | 5270·429* | 2 | 5645.751 | S | 6003·173 |
| 2*d* | 5273·379 | 2 | 5655·645 | 2 | 6008·700 |
| 2 | 5276·138 | 3 | 5658·019 | S | 6013·682 |
| 2 | 5281·908 | 2 | 5662·679 | 4 | 6016·776 |
| 2 | 5283·747 | 2 | 5675·593 | 2*d* | 6020·278 |
| 3 | 5288·640 | 2 | 5679·184 | 2 | 6021·948 |
| 3 | 5296·798 | 4 | 5682·894 | 4 | 6024·207 |
| 2 | 5300·843 | 2 | 5688·370 | 4 | 6042·241 |
| 2 | 5307·478 | 2 | 5701·708 | 3 | 6056·153 |
| 3*d* | 5316·803† | 2 | 5709·565 | 6 | 6065·635 |
| 2 | 5324·311 | 2 | 5709·700 | 6 | 6078·635 |
| 2 | 5333·038 | 3 | 5715·244 | 4 | 6079·146 |
| 3 | 5353·530 | 4 | 5731·909 | 3 | 6102·864 |
| 2 | 5361·752 | 2 | 5741·994 | 1 | 6103·346 |
| 1 | 5362·970 | 3 | 5752·188 | 2 | 6108·262 |
| 2 | 5367·600 | 3 | 5753·278 | 2 | 6111·206 |
| 2 | 5370·093 | 2 | 5754·819 | 2 | 6116·345 |
| 2 | 5371·622 | 3 | 5763·153 | 5 | 6122·357 |
| 2 | 5379·704 | 2 | 5772·299 | 2 | 6136·760 |
| 4 | 5383·497 | 3 | 5775·235 | 3 | 6141·882 |
| 2 | 5389·611 | 2 | 5782·285 | 4 | 6162·319 |
| 2 | 5393·298 | 2 | 5784·015 | 2 | 6169·699 |
| 2 | 5397·268 | S | 5788·075 | 2 | 6173·477 |
| S | 5405·914 | S | 5791·137 | 2 | 6176·943 |
| 2 | 5415·341 | 2 | 5798·330 | 2 | 6180·337 |
| 2 | 5424·203 | 2 | 5809·357 | 3 | 6191·324 |
| 2 | 5434·656 | 2 | 5816·504 | 4 | 6191·695 |
| 2 | 5447·046 | 3 | 5853·838 | 5 | 6200·455 |
| 3*d* | 5455·682 | 4 | 5857·606 | 3 | 6213·569 |
| 2 | 5462·666 | 6 | 5859·741 | 4 | 6219·420 |
| 2 | 5463·090 | 7 | 5862·511 | 4 | 6230·876 |
| 3 | 5463·408 | 2 | 5883·971 | 2 | 6237·452 |
| 3 | 5466·521 | 3 | 5889·804 | 3 | 6246·460 |
| 2 | 5477·040 | S | 5890·125 $D_2$ | 3 | 6252·706 |
| 3 | 5497·660 | 3 | 5893·026 | 2 | 6256·500 |
| 2 | 5501·609 | S | 5896·080 $D_1$ | 3 | 6261·234 |
| 2 | 5506·920 | 2 | 5898·327 | 5 | 6265·271 |
| 2 | 5513·122 | 2 | 5901·630 | 6 | 6270·370 |
| 3 | 5528·560 | 3 | 5905·820 | 5 | 6278·225 |
| 2 | 5534·990 | S*d* | 5914·319 | 4 | 6281·315 |
| 2 | 5543·339 | 3 | 5916·409 | 1 | 6289·542 |

* Fraunhofer's E. † Kirchhoff's 1474.

‡ Peirce's standard, given by him 5624·825 (Amer. Jour. of Science) later corrected by him to 5624·86 and finally corrected by Rowland & Bell for error of ruling of grating and of standard to 5624·66. The latter can be considered as very near to what the final corrected value of Peirce will be, though it may be even so high as 5624·76.

| Wt. | W. L. | Wt. | W. L. | Wt. | W. L. |
|---|---|---|---|---|---|
| 2 | 6293·077 | 4 | 6722·005 | 1 | 7090·612 |
| 2 | 6296·066 | 3 | 6726·835 | 1 | 7122·431 |
| 2 | 6314·798 | S | 6750·325 | 1 | 7147·893 |
| S | 6318·160 | 4 | 6752·876 | 1 | 7148·276 |
| S | 6322·830 | 5 | 6767·945 | 1 | 7168·134 |
| 8 | 6335·479 | 5 | 6772·479 | 2 | 7176·279 |
| 8 | 6336·968 | 2 | 6787·051 | 1 | 7184·401 |
| 2 | 6344·297 | 2 | 6807·007 | 4 | 7184·705 |
| 5 | 6355·184 | 4 | 6810·432 | 2 | 7186·470 |
| 4 | 6358·834 | 4 | 6828·770 | 1 | 7194·805 |
| 2 | 6380·889 | 2 | 6841·518 | 1 | 7199·689 |
| 5 | 6393·751 | 3 | 6855 348 | 1 | 7200·673 |
| 2 | 6400·453 | 3 | 6867.382† | 1 | 7216·693 |
| 5 | 6408·163 | 3 | 6867·717 | 1 | 7219·282 |
| 6 | 6411·793 | 2 | 6870·123 | 2 | 7223·830 |
| 4 | 6420·103 | 4 | 6875·742 | 1 | 7227·686 |
| 7 | 6421·498 | 2 | 6876·879 | 1 | 7232·419 |
| 6 | 6430·993 | 2 | 6877·797 | S | 7233·092 |
| 5 | 6439·224 | 6 | 6879·212 | S | 7234·868 |
| 2 | 6449·951 | 6 | 6880·102 | S | 7240·879 |
| 7*d* | 6462·762 | 10 | 6883·992‡ | 2 | 7243·800 |
| 2 | 6471·805 | 6 | 6885·925 | S | 7247·590 |
| 2 | 6480·198 | 6 | 6886·898 | 1 | 7264·770 |
| 4 | 6482·031 | 1 | 6896·211 | 1 | 7265·750 |
| 5 | 6493·921 | 2 | 6897·103 | 2 | 7273·133 |
| 5 | 6495·127 | 2 | 6901·032 | 1 | 7287·590 |
| 4 | 6499·896 | 2 | 6909·597 | 1 | 7289·844 |
| 2 | 6516·226 | 4 | 6919·160 | 1 | 7290·621 |
| 3 | 6518·514 | 1 | 6923·488 | 2 | 7299·993 |
| 4 | 6532·496 | 4 | 6924·340 | 2 | 7304·382 |
| 4 | 6534·090 | 2*d* | 6929·687 | 2 | 7318·678 |
| 5 | 6546·400 | 4 | 6947·685 | 1 | 7331·101 |
| 2 | 6552·758 | 4 | 6956·609 | 2 | 7335.532 |
| S | 6562·965* | 4 | 6959·634 | 1 | 7442·574 |
| S | 6564·338 | 5 | 6961·437 | 2 | 7445.941 |
| 7 | 6569 360 | 2 | 6978·586 | 2 | 7495.248 |
| 2 | 6572·245 | 6 | 6986·755 | 1 | 7511.188 |
| 2*d* | 6575·090 | 2 | 6989·172 | 2 | 7545·817 |
| 2 | 6592·725 | 3 | 6999·104 | 2 | 7593·975§ |
| 6 | 6593·068 | 2 | 7006·069 | 2 | 7621·183‖ |
| 8 | 6594·016 | 2 | 7011·481 | 2 | 7623·425 |
| 5 | 6609·253 | 3 | 7015·253 | 2 | 7624·737 |
| 2 | 6633·898 | 3 | 7015·639 | 1 | 7627·259 |
| 6 | 6643·787 | 4 | 7016·616 | 1 | 7628·605 |
| 2 | 6663·601 | S | 7023·675 | 1 | 7659·550 |
| 6 | 6678·141 | S | 7027·659 | 1 | 7660·679 |
| 5 | 6703·719 | S | 7035·083 | 1*d* | 7665·683 |
| 5 | 6705·262 | 2 | 7038·398 | 1*d* | 7671.412 |
| 4 | 6717·833 | S | 7039·968 | | |

* Fraunhofer's C.

† First line in what may be called the head of Fraunhofer's B.

‡ Single line between what may be called the head and tail of B.

§ Edge of what may be called the head of A.

‖ Single line between the head and tail of A.

## ART. XXII.—*The Norites of the "Cortlandt Series" on the Hudson River near Peekskill, N.Y.;* by G. H. WILLIAMS.

[Continued from page 144.]

### 3. *Mica Norite.*

The purest types of this rock are to be found in the eastern part of Cortlandt Township, along the road leading from Montrose Station (Munger's Corners) to Montrose Point on the river. Nos. 40, 41, 49, 51 and 52 and a slide marked Mt. 9 in Prof. Dana's collection were obtained along the section described in detail in Prof. Dana's paper and adduced by him as evidence of the metamorphic origin of the rocks from sedimentary deposits.* The microscopic study of these slides is therefore important with reference to the light which it may throw upon this question.

This section, which occurs just at the residence of Mr. Butler (1883), has been called by the writer the "Butler Section" (see above). Professor Dana gives a profile of it and says (p. 218): "*It consists mainly of noryte and augite-noryte, but with some hornblendyte and noryte-gneiss and has distinct planes of bedding in several places, all of which are conformable to one another.* . . . . This ledge, although made up of massive noryte and augite-noryte, bears thus positive evidence of its having once had bedding throughout, and affords thereby a demonstration that its noryte is of metamorphic origin and that the associated beds comprised also the limestone of the region."†

The specimens 41 (*c*), 47 (*g*), 49 (*e*), 51 (*c*)‡ and 52 are identical in structure and composition, except in so far as they contain different proportions of biotite. They consist of aggregates of magnetite, hypersthene and biotite which are curiously bent and twisted around larger areas of feldspar, so as to form a pronounced "microflaser" structure. The feldspar too shows to a remarkable degree both mechanical and optical deformation. Its crystals are bent or broken; secondary twinning lamellæ have been abundantly produced by strain, and the extinction is very uneven. Moreover portions of the areas are frequently seen to be broken up into the peculiar mosaic which both Lehmann§ and Lossen‖ have shown to be a characteristic result of pressure. Then again garnet, a mineral well known to be the product of dislocation metamorphism in rocks, is here abundant in some of the most schistose bands, notably Nos. 51 and 52.

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* This Journal, September, 1880, xx, p. 218.

† The italics are those of Professor Dana.

‡ These letters in parentheses are those used by Professor Dana to designate particular beds in his section.

§ Ueber die Entstehung der altkrystallinen Schiefergesteine. Bonn, 1884.

‖ Jahrbuch der kön. preuss. geolog. Landesanstalt für 1883. Berlin, 1884.

The writer has already described another rock from this section* (a peridotite, No. 54), occurring in the bed marked by Professor Dana "*a*," as showing in a marked degree the effects of pressure, while No. 48, from his band "*f*," is still more remarkable in this respect. This rock was once a gabbro, like that to be described in the sequel as occurring at Munger's Corners (No. 42). At present it is highly altered both structurally and mineralogically. The diallage is largely changed to hornblende and is drawn out into long lenticular patches. The feldspar is mostly broken up into a mosaic which bends around the pyroxene, producing a fine gneissic structure. In fact this rock is almost identical with some of the more altered "Flaser gabbros" of Saxony, which Professor Lehmann† has so conclusively shown to have resulted from the action of pressure upon massive rocks.

The hornblende norites (Nos. 50*a* and 50*b*) from this section mentioned above are wholly massive and show no internal evidence of having been subjected to pressure.

A careful study of the rocks of this interesting section, both in the field and with the microscope, has convinced the writer that they offer an unusually plain and instructive instance of the *metamorphism of eruptive rocks by pressure. The evidence of bedding*, seen in the cleavage and parallel arrangement of the constituents, *instead of being an indication of original sedimentation, is a secondary feature.* The action of the pressure was here so slight that original structure is not wholly changed, as is more usually the case; but the alteration has only taken place along certain planes which allow the tracing of transitions into the original, unaltered and still prevailing form of the rock.

No. 6*a* from near Cruger's Station, is a remarkable variety of mica-norite, in which the hypersthene is segregated into irregular patches. Outside of these the rock is a typical mica-diorite composed of plagioclase, biotite, magnetite and apatite, together with a considerable amount of garnet which is a secondary crystallization. Within the segregated areas the space is almost wholly occupied by hypersthene, which exhibits in a striking manner its alteration to secondary fibrous hornblende.

### 4. *Augite Norite or Hyperite.*

Professor Dana has communicated the following analyses, by Mr. M. D. Munn, of a specimen of augite-bearing norite from the northern part of Montrose Point on the Hudson River.‡

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* This Journal, Jan., 1886, xxxi, p. 39.

† l. c., p. 190.

‡ This Journal, Aug., 1881, xxxii, p. 104.

| | I. | II. | Mean. |
|---|---|---|---|
| $SiO_2$ | 55·28 | 55·40 | 55·34 |
| $Al_2O_3$ | 16·31 | 16·44 | 16·37 |
| $Fe_2O_3$ | 0·69 | 0·85 | 0·77 |
| FeO | 7·57 | 7·51 | 7·54 |
| MnO | 0·40 | 0·39 | 0·40 |
| MgO | 5·05 | 5·05 | 5·05 |
| CaO | 7·52 | 7·49 | 7·51 |
| $Na_2O$ | 4·10 | 4·03 | 4·06 |
| $K_2O$ | 2·05 | 2·00 | 2·03 |
| $H_2O$ | 0·58 | 0·58 | 0·58 |
| | 99·55 | 99·73 | 99·65 |

Professor Dana describes this rock as an augite-norite containing about equal proportions of hypersthene and augite. A thin section in his collection marked (Mt. 20) the writer supposes to be the one alluded to in his description as it is the only one from this locality. This is, however, almost a typical norite with a large proportion of the usual reddish-brown feldspar, very typical hypersthene, and only occasional individuals of a green fibrous diallage and dark brown biotite. The percentage of lime in the analysis, after deducting what is necessary for the feldspar also indicates but a small proportion of augite. This section also shows considerable unstriated feldspar, which, from the analogy of No. 43 and the percentage of potash found in the analysis, may safely be assigned to orthoclase. A study of this section indicates that this analysis is very representative of the average norite of the Cortlandt Series.

A more typical augite-norite or hyperite is to be found in specimen No. 69, of the Johns Hopkins University collection, which was collected from the same locality as the above. Here the proportion of both augite and biotite is considerably greater than in Professor Dana's section. This slide is especially interesting from the fact that it exhibits, in both the hypersthene and augite, inclusions which the writer would without hesitation consider as secondary and identical as those in the Scottish rocks which Professor Judd rightly ascribes to schillerization. Side by side with these, however, are other inclusions in the feldspar which, like those above described, are original.

No. 105 in the University collection from the road from Centerville to Verplanck, and a section, marked J, in Professor Dana's collection from Craig's place, one mile S.E. of Peekskill are also admirable examples of the augite-norite. Both contain nearly as much augite as hypersthene. The former mineral is distinguished from the latter by its green color, the entire absence of pleochroism, its highly inclined extinction-angle, the frequency with which it forms twins, and its comparative freedom from inclusions. These are not altogether wanting, but consist almost wholly of small plates of biotite or grains of magnetite, presenting, both in their number and irregular arrangement, a contrast to the characteristic red plates of the hypersthene. Both of these slides contain considerable biotite in addition to the augite. This mineral, as well as the feldspar, exhibits in a beautiful manner the effects of pressure.

### 5. *Pyroxenite.*

Very interesting and comparatively coarse-grained rocks composed wholly of hypersthene and diallage or augite may be regarded as a modification of the type last described, due to the disappearance of the feldspar. They are quite abundant in the eastern part of the township near the emery mines and are represented by Nos. 127, 129, 131 and 132 in the Johns Hopkins University collection. Such rocks also occur on the northern half of Montrose Point, but here they carry more or less brown hornblende and are intimately related to the hornblendites which are the prevailing rock in that locality and which will be described later.

Diallage-hypersthene aggregates have recently been found by the writer, associated with the hypersthene-gabbros of Baltimore and Harford Counties, Md., which are quite analogous to those occurring in the Cortlandt Series.*

### *The Iron ore and Emery in the Cortlandt Norite.*

The deposits of magnetic iron ore and emery mentioned in Professor Dana's paper† as occurring in the massive rocks of the Cortlandt Series, although of but little practical importance, possess considerable scientific interest. The veins, which appear to be segregations in the norite, have been opened north and northeast of Cruger's Station only for iron ore, while quite similar deposits in the southeastern part of the township, are still worked to some extent for emery.‡ The ore is heavy and black, but does not turn out as rich as would be expected from its appearance. A microscopic examination of it shows that it is largely composed of a dark green mineral in which octahedral crystals of magnetite are imbedded. Professor Dana considered this mineral to be chlorite, but a more careful examination shows it to be the iron-magnesian spinel, *pleonaste.* The action of chlorite upon polarized light, as is well known, is extremely feeble and so it was not unnatural to mistake for it

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* Bulletin of the U. S. Geol. Surv., No. 28, p. 55.

† This Journal, September, 1880, xx, p. 199–200.

‡ The emery mill at Peekskill owes its origin to the discovery of these deposits, although at present it procures its raw material almost exclusively from Asia Minor.

an isotropic mineral, like spinel. In the massive ore this mineral forms an aggregate of interlocking grains, but in the adjoining rock it is disseminated in small octahedral crystals as in section No. *6a* described above. It was isolated from a specimen of iron ore collected near Cruger's Station and analyzed by Mr. W. S. Bayley.*

In the eastern and southeastern parts of the norite region similar deposits of pleonaste occur in great number, and frequently contain more or less corundum and fibrolite.

The Westchester Co. pleonaste is remarkable for its small proportion of magnesia. The eight analyses of this mineral given in Dana's System of Mineralogy (p. 148) have from 13 to 26 per cent MgO. The specimen which comes nearest in composition to the Cortlandt mineral is one from Tunaberg in Sweden, in which Erdmann found $Al_2O_3$ 62·95, FeO 23·46, MgO 13·03.† Still even here the amount of magnesia is considerably greater than in the mineral analyzed by Mr. Bayley. In this respect the Cortlandt pleonaste approaches the pure iron spinel ($FeO,Al_2O_3$) which Zippe, in 1839, named Hercynite.‡ This was analyzed in 1845 by B. Quadrat, who found that it contained

$Al_2O_3$ 61·17, FeO 35·67, MgO 2·92.§

This mineral occurs in black masses near the villages of Natschetin and Hoslau, nor far distant from the town of Ronsperg, at the eastern edge of the Bohemian Forest. (Lat. "*Silvia Hercynia*," Pliny, whence Zippe's name). Quadrat states that it is only found in loose blocks in the soil, but von Hochstetter says that it occurs in position, as "a member of the Archæan Series, between amphibolite and amphibole-schist."‖ The Bohemian hercynite was first microscopically studied by H. Fischer, who discovered in the spinel aggregate what he considered to be magnetite, quartz and hematite.¶ E. Kalkowsky, subsequently showed the supposed quartz to be corundum, and the hematite, iron-hydroxide.** Certain very thin, dark gray plates which are frequently interpolated in the hercynite are referred by Kalkowsky to ilmenite. A microscopic section of the Ronsperg hercynite in the possession of the writer, contains

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* The exact results of this analysis were unfortunately lost, but it is definitely remembered that the mineral was found to contain only alumina, ferrous iron and magnesia; and that the latter constituted slightly over 9 per cent of the whole.

† Ak. H. Stockh., 1848.

‡ Verh. der Gesellsch. des Vaterländ. Museums, 1839.

§ Annalen der Ch. und Ph., lv, p. 357. 1845.

‖ Geog. Studien aus dem Böhmerwald. Jahrbuch der k.k. geologischen Reichsanstalt, 1856, p. 785.

¶ Kritisch micromineralogische Studien, Freiburg, 1869, p. 18, II. Fortsetzung, 1873, p. 88.

** Zeitschrift der deutschen geologischen Gesellschaft, 1881, p. 536.

magnetite, limonite, ilmenite, considerable light brown biotite and a colorless mineral which may once have been corundum, but which now shows only a very fine aggregate polarization.

The Cortlandt ore, when examined under the microscope, exactly resembles the Bohemian hercynite. In the purest specimens, there is only the aggregate of bright green grains mixed with more or less magnetite. These grains are always of a much lighter color in contact with the magnetite. They contain no ilmenite plates, like the Bohemian mineral, but are full of irregular shreds and dots of magnetite. (Nos. 134, 143 and 144 from the eastern part of the township.) Other specimens (No. 133 from Wm. Haight's farm and I of Prof. Dana's collection, from 1 mile northeast of Colabaugh Pond) contain more or less corundum scattered through them.* Sometimes this mineral is associated with fibrolite; and, in the section of Prof. Dana's collection marked Cb4, from the Iron Mine south of the road south of Summer Hill, only fibrolite occurs with the pleonaste. This is interesting in connection with the intimate association discovered by Kalkowsky between the hercynite and fibrolite in the Saxon granulites.†

The spinel at the Cruger iron mines is quite like that in the eastern part of the township except that it is less pure. It occurs as veins in a typical norite into which it passes by gradual transitions. Even the most compact specimens of the ore contain the norite minerals, hypersthene, feldspar, biotite, and garnet, mixed with it in greater or less quantity. At this locality no corundum or sillimanite was observed.

Quadrat remarked in 1845 that on account of its great hardness (7·5–8), the Ronsperg hercynite was employed, in the region near where it was found, as an abrasive agent.‡ The admixture of true corundum, of course, very much increases its value for such purposes, and it is this which accounts for the opening of numerous emery mines in the eastern portion of Cortlandt township.

According to the late Dr. J. Lawrence Smith, large deposits of corundum or true emery occur either associated with magnetite on the contact between crystalline limestone and mica-schist (as in Asia Minor) or in connection with serpentine (as in North Carolina).§ Its association with spinel in massive rocks, where it is probably a product of contact metamorphism

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* The writer is under obligations to Professor A. H. Chester of Hamilton College for several interesting specimens of corundum altered to hercynite. They came from India and have been described by Genth, Proc. Am. Phil. Soc. Philadelphia, Sept., 1873.

† Zeitschrift der deutschen geologischen Gesellschaft, 1881, p. 537.

‡ l. c., p. 357.

§ Memoir on Emery, this Journal, 1850, p. 354. Annales des Mines, 1850, p. 259. Original Researches, 1884, p. 75.

like the fibrolite, is exceptional, but by no means unprecedented, as may be seen from the above description of the Ronsperg hercynite. In the Cortlandt deposits the distribution of the corundum is so irregular as to seriously interfere with its practical value. Specimens in which it is comparatively abundant are not to be distinguished, except under the microscope, from those which are entirely free from it. How far this is true may be judged from the fact that the purest specimens of pleonaste which the writer obtained anywhere in Cortlandt township were taken from the pile of "emery ore" in the yard of the Peekskill emery mill. This so reduces the grade of the Cortland product as to practically rule it out of the market.

The following seven analyses of the Cortlandt ore were made in 1880, for the New York Emery Co., of Peekskill, by Prof. Th. Egleston of the Columbia College School of Mines. They are here published for the first time with the permission of their author.

| | I. | II. | III. | IV. | V. | VI. | VII. |
|---|---|---|---|---|---|---|---|
| $Al_2O_3$ | 31·93 | 40·77 | 37·78 | 37·43 | 36·49 | 41·66 | 46·53 |
| $Fe_2O_3$ | 18·19 | 18·37 | 24·35 | 21·17 | 21·36 | 23·71 | 32·31 |
| MgO | 7·41 | 6·73 | 7·92 | 7·20 | 8·39 | 7·91 | 9·43 |
| Magnetic iron | 34·20 | 32·01 | 17·37 | 19·81 | 22·77 | 14·76 | 8·98 |
| Siliceous residue | 6·42 | 1·04 | 11·19 | 13·14 | 10·08 | 11·48 | 2·42 |
| $TiO_2$ | 1·12 | 1·08 | 0·62 | 0·65 | 0·67 | 0·54 | 0·51 |
| Sulphur | 0·04 | 0·04 | 0·02 | 0·02 | 0·02 | 0·01 | 0·01 |
| Phosphorus | trace | trace | trace | trace | trace | trace | trace |
| Total | 99·31 | 100·04 | 99·25 | 99·42 | 99·78 | 100·07 | 100·19 |

If from these analyses all the components except the alumina, magnesia and iron be deducted, and if these be calculated in proportions of 100 after the ferric iron has been reduced to its equivalent per cent of ferrous iron, we shall have:

| | I. | II. | III. | IV. | V. | VI. | VII. | Mean. |
|---|---|---|---|---|---|---|---|---|
| $Al_2O_3$ | 53·63 | 60.00 | 51·94 | 54·92 | 53·18 | 54·88 | 50·65 | 54·17 |
| FeO | 33·92 | 30·05 | 37·18 | 34·52 | 34·59 | 34·70 | 39·08 | 34·87 |
| MgO | 12·45 | 9·95 | 10·88 | 10·56 | 12·23 | 10·42 | 10·28 | 10·96 |
| Total | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 |

A glance at these analyses is sufficient to show that a very large proportion, if not all, of the samples consisted of pleonaste. Still, the microscope discloses the presence of true corundum in many specimens, although its amount is very variable.

Section H of Prof. Dana's collection from 1 mile northeast of Colabaugh Pond, consists of magnetite and pleonaste mixed with about an equal quantity of colorless corundum. This is in good sized grains ($\frac{1}{2}$-$\frac{2}{3}^{mm}$ in diameter) with a high refractive index and often shows a sharp hexagonal section. These exhibit between crossed nicols, very brilliant interference colors. Frequently, however, they appear to be somewhat altered and then exhibit a gray tone with aggregate polarization. These corundum crystals contain inclusions in great quantity. These appear to be either magnetite in small rods or dots or reddish translucent plates of iron oxide. They are always massed together in the center of the crystal, frequently in such abundance as to render this portion quite opaque.

No. 126, from near Travers' farm in the eastern part of Cortlandt township, is quite like the preceding, except that the corundum is much more abundant and present in individuals of much smaller size ($\frac{1}{6}$–$\frac{1}{8}^{mm}$ in diameter.) The distribution of the inclusions is quite like that in the specimen last described.

In some of the sections, the corundum is seen to have a deep blue color, and then to exhibit its characteristic dichroism. This is most notably the case in specimens taken from the Lombard mine, just north of Colabaugh Pond. This locality is represented by Nos. 136 and 137 of the University collection and by section A, belonging to Prof. Dana. These are seen under the microscope to be composed of an aggregation of the three minerals, fibrolite, corundum and magnetite. The first is present in long, colorless needles, showing the characteristic cleavage, transverse parting, parallel extinction, and brilliant interference colors of this species. They have their longest axes approximately parallel thus producing a somewhat schistose structure. The corundum is present in rather stout crystals, with a sharp hexagonal outline in cross-section. Such sections have in every position a uniform deep blue color, while those nearly parallel to the vertical axis have this color when their lateral axis is parallel to the principal section of the polarizer and a light greenish yellow tinge when brought into a position at right angles to this. The pleochroism is therefore:

$$\begin{cases} \text{E} = \text{light greenish yellow} \\ \text{O} = \text{dark blue} \end{cases}$$

and the absorption $O > E$. The hexagonal sections, when examined in converged polarized light, show a uniaxial interference figure and negative double refraction. All of these characters agree fully with corundum; and the examinations, for comparison, of sections of typical emery, from Samos, Naxos, Smyrna and Gumuch-dagh in Asia Minor and from Chester, Mass., leaves little doubt of the identity of these with the Cortlandt mineral.

The results of the optical examination are fully in accord with a series of chemical tests which Dr. C. Pigot, assistant in the Chemical Laboratory of the Johns Hopkins University, kindly made for me. The powder of the mineral, which had been separated from the fibrolite by the boro-tungstate of cadmium solution and from the magnetite by boiling it in hydrochloric acid, was found not to be attacked by any acids. It is very difficultly fusible with sodium carbonate but fuses readily with acid potassium sulphate or acid sodium sulphate. In the solution thus obtained the presence of nothing except alumina and iron could be detected. The only unusual property of this corundum is a lower specific gravity than was expected. This is probably due to incipient alteration, which can be easily seen under the microscope, and is another cause that would tend to materially diminish the value of the Westchester Co. emery.

In a succeeding paper the writer hopes to describe the remaining members of the Cortlandt Series (gabbros and diorites) and to point out the metamorphosing effect which the massive rocks have exercised upon the surrounding schists and limestones, as well as other proofs of their undoubted eruptive character.

Petrographical Laboratory of the Johns Hopkins University,
Baltimore, December, 1886.

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## ART. XXIII.—*Natural solutions of Cinnabar, Gold and associated sulphides*; by GEORGE F. BECKER.

IN the course of investigations on the geology of the quicksilver deposits of the Pacific slope I have taken up the question of the state of combination in which quicksilver is dissolved in natural waters. Pyrite or marcasite almost invariably accompanies cinnabar, gold is known to be associated with cinnabar in a considerable number of cases, copper sulphides or sulphosalts are also not infrequent in quicksilver mines, and sulphides of arsenic and antimony are known to occur in a similar association. Zincblende too has been found with cinnabar. The solubility of these substances has been incidentally examined. In performing the experiments I had the assistance of Dr. W. H. Melville, who also made all the quantitative analyses involved. The results obtained seem interesting enough to justify their publication, in an abbreviated form, in advance of the monograph of which they will form a part. They also possess some value from a purely chemical point of view, and may interest readers of this Journal who are not geologists.

The waters of Steamboat Springs are now depositing gold, probably in the metallic state; sulphides of arsenic, antimony and mercury; sulphides or sulpho-salts of silver, lead, copper and zinc; iron oxide and possibly also iron sulphides; manganese, nickel and cobalt compounds, with a variety of earthy minerals. The sulphides which are most abundant in the deposits are found in solution in the water itself, while the remaining metallic compounds occur in deposits from springs now active, or which have been active within a few years. These springs are thus actually adding to the ore deposit of the locality, which has been worked for quicksilver in former years and would again be exploited were the price of this metal to return to the figure at which it stood a few years since. At Sulphur Bank also there is reason to suppose that ore deposition is still in progress, though the opportunities for determining this point are greatly inferior to those presented at Steamboat Springs. The waters of the two localities are closely analogous. Both contain sodium carbonate, sodium chloride, sulphur in one or more forms and borax as principal constituents, and both are extremely hot, those at Steamboat Springs in some cases reaching the boiling point. In attempting to determine in what forms the ores enumerated can be held in solution in such waters, it is manifestly expedient to begin by studying the simplest possible solutions of the sulphides and particularly of cinnabar.*

*Solubility of* HgS *in mixtures of* $Na^2S$ *and* NaOH.—A series of experiments were made in my laboratory with a view of testing

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* *Previous investigation.*—The solubility of mercuric sulphide in alkaline compounds containing sulphur has long been recognized by experimental and industrial chemists. This fact is the foundation of the methods of preparation of vermilion in the wet way, first described by G. S. C. Kirchoff in 1799 (Scheerer's Allgem. Journ. der Chem., vol. ii, p. 290). In 1829, C. Brunner (Pogg. Ann., vol. xv, p. 593) discovered the double soluble salt $HgS, K^2S, + 5H^2O$. Later Dr. Rheinhardt Weber (Pogg. Ann., 1856, vol. xcvii, p. 76), reëxamined the properties and formation of this salt, which he found could exist only in the presence of free caustic alkali. In opposition to Prof. Stein, Dr. Weber is extremely positive in his statements that mercuric sulphide is entirely insoluble either in the simple sulphides of sodium and potassium, or in the sulphydrates of these metals, excepting in the presence of free hydrates. Dr. Weber's solvent was not, as he evidently supposes, a mixture of hydrate and sulphydrate but of simple sulphide and sulphydrate.

In 1864, Mr. C. T. Barfoed (Journ. für prakt. Chemie, 1864, vol. xciii, p. 230) investigated the behavior of mercuric sulphide to sodium sulphides. He, like Dr. Weber, found the metallic sulphide wholly insoluble in the sulphydrate, but soluble in the simple sulphide, and in mixtures of the latter either with the sulphydrate or with the hydrate. He insists that the necessary and sufficient condition for the solubility of mercuric sulphide is the presence of sodic monosulphide.

The assertion is frequently made in chemical writings (for example Graham-Otto, 5th Ed., part 3, vol. ii, p. 1119) in spite of the result obtained by Weber and by Barfoed that mercuric sulphide is soluble in sodic sulphydrate. In 1876, Mr. M. C. Méhu (Russian Journ. of Pharm., reported in Jahresbericht der Chemie, 1876, p. 282), examined the soluble crystalline mercury-sodium salt corresponding to Brunthe relative effect of the quantity of sodium sulphide and sodium hydrate on the quantity of mercuric sulphide which a given mixture of the solvents would take up. It is almost impossible to make experiments of this kind with the same accuracy which can easily be attained in precipitations because, if one or more drops of either fluid reagent is added to a mass consisting of mercuric sulphide partially dissolved in the menstruum, it is not practicable to say how long a time will elapse before the additional drop will have become saturated. Approximate results are however readily obtained, and these appear in the present case to be sufficient.

It was found that, provided a small quantity of free hydrate exists in the mixture, the solubility of HgS depends solely upon the quantity of $Na^2S$ in the solution. The average of fourteen experiments made with varying proporsitions of sodic hydrate gives 1HgS to 2·03 $Na^2S$. From the nature of the experiments a slight excess in the quantity of solvent employed is to be expected. One experiment was made by mixing mercuric sulphide and sodic sulphide in the proportion of two molecules of the latter to one of the former, and adding a few drops of caustic soda. A mere trace of mercuric sulphide remained undissolved, and this completely disappeared on the addition of a single drop of a solution of sodic sulphide, so that less than one drop completed the solution.

Chemists of course regard cases of solution such as that under discussion as due to the genesis of soluble double salts, which are formed according to ordinary laws of composition. The

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ner's potassium compound. He found mercuric sulphide insoluble in sodic hydrate or in the simple sulphide of sodium, but highly soluble in mixtures.

Alkaline pentasulphides convert amorphous quicksilver sulphide digested with them into cinnabar (Gmelin-Kraut, Handbuch der Chemie, vol. iii, p. 756, where many references may be found), and this process implies a certain degree of solubility. Mr. Barfoed, however, found mercuric sulphide insoluble at ordinary pressures in sodium sulphydrate to which sulphur had been added, and the solubility, in the pentasulphide is probably slight. The conversion of the black sulphide into the red, does not appear to imply more than a mere trace of solubility, for Messrs. H. Sainte-Claire Deville and Debray produced rhombic crystals of cinnabar by heating precipitated sulphide with chlorhydric acid to 100° C. in a closed tube (Fouqué and Michael-Lévy, Synthése des Min. et des Roches, p. 313). No statement is made in the account of this experiment of any means being employed to produce any great pressure. Mr. S. B. Christy (this Journal, vol. xvii, 1879, p. 453) found that at pressures of from 150 to 500 pounds per square inch and temperatures of from 180° to 250° various liquids heated with precipitated mercuric sulphide convert it into vermilion. He experimented with polysulphides of potassium, potassic sulphydrate, acid sodic carbonate charged with sulphydric acid, and a spring water containing acid sodic carbonate which he charged with sulphydric acid. He reached no conclusion as to the state of combination of the mercury in solution. The fact that glass is greatly attacked at high pressures and temperatures by alkaline solutions of course leaves many possibilities open. Prof. R. Wagner (Journal für prakt. Chemie, vol. xcviii, 1866, p. 23), has shown that mercuric sulphide is soluble in barium sulphide, and Prof. Roth (Allgem. u. chem. Geol., vol. i, p. 264) thinks it probable that calcium sulphide possesses a similar power.

above experiments show that this soluble double salt can be represented only in the formula $HgS, 2Na^2S$. The soluble mixture given by Méhu answers to $HgS + 2{\cdot}07\ Na^2S$ and is thus, so far as it goes, confirmatory of the above experiments.

*Solubility of* $HgS$ *in* $Na^2S$.—The most carefully prepared solutions of sodium sulphide dissolve mercuric sulphide freely. This statement is directly contrary to that which some of the chemists referred to have made, and it would be a rash one if the evidence to be adduced for it depended simply upon bringing solutions of sodic sulphide into contact with mercuric sulphide; for it is impossible to make certain that there is no trace of free caustic alkali or of sulphydrate in a solution of sodic sulphide, however closely its analysis may correspond to its theoretical composition. If, however, a solution of sodic sulphide containing sodic hydrate is treated with hydrogen sulphide, it is gradually converted into sodic sulphydrate and passes through a point at which the only compound present is the monosulphide. If mercuric sulphide is dissolved in a mixture of sodic sulphide and caustic soda, and the clear filtrate is treated with hydrogen sulphide, the mercuric sulphide begins to be precipitated when very little free caustic alkali is left, and is continuously precipitated until the entire amount of sodium present is converted into sulphydrate. The purest preparations of $Na^2S$ which we have been able to make, dissolve mercuric sulphide less freely than mixtures of sodic sulphide and sulphydrate. Different preparations, however, shown by most careful analysis to correspond very accurately to the formula $Na^2S$, give somewhat different results, possibly indicating a minute variation from absolute purity. It does not seem *a priori* improbable, that the soluble salt when the sodic sulphide is absolutely pure is $HgS, 3Na^2S$; and one of our preparations gave almost exactly this result. It may also be that mixtures of $HgS, 2Na^2S$, and $HgS, 4Na^2S$ are formed in proportions varying with other conditions than the purity of the sodium sulphide, such as temperature and concentration.

*Insolubility of* $HgS$ *in cold* $NaHS$.—Repeated experiments and analyses undertaken during this investigation have shown that mercuric sulphide is totally insoluble in sodium sulphydrate at ordinary temperatures, and that any preparation of this compound which will dissolve a trace of mercuric sulphide can be shown by analysis to fall short of complete saturation. A long time and an enormous quantity of hydrogen sulphide are required to completely saturate even a small amount of caustic soda with sulphur. As already mentioned, both Weber and Barfoed were aware of the insolubility of mercuric sulphide in sodium sulphydrate at ordinary temperatures. It will be seen later that the behavior of these compounds varies with the temperature. If mercuric sulphide is left in contact with cold sodic sulphydrate for twenty four hours, just a trace of mercury goes into solution. This is due to the spontaneous loss of hydrogen sulphide which the sulphydrate is well known to undergo.

The absolute want of power of a preparation of sodic sulphydrate to dissolve a trace of mercuric sulphide is perhaps the best known test of its freedom from the alkaline monosulphide. This test does not show the absence of polysulphides, however, for we have frequently found mercuric sulphide totally insoluble in solutions of sodic sulphydrate, which possessed a yellow color, and which were proved by analysis to contain an excess of sulphur. This corresponds to Barfoed's observation. The occurrence of alkaline polysulphides in nature, excepting near the surface of the earth, seems so improbable, that I have undertaken no investigations of the conditions under which they dissolve mercuric sulphide.

*Solubility of* HgS *in mixtures of* $Na^2S$ *and* NaHS.—For the purpose of determining the character of solutions of mercuric sulphide in mixtures of sodium sulphide and sulphydrate, clear solutions of mercuric sulphide in sodium sulphide and sodium hydrate were made, all the reagents being carefully prepared for the purpose, and sulphuretted hydrogen was passed through the solution until a large permanent precipitate of mercuric sulphide formed. The mass was then filtered, and of course the filtrate represented an absolutely saturated solution of mercuric sulphide in a mixture of sodic sulphide and sulphydrate. A portion of this solution was analyzed. The remainder was treated further with hydrogen sulphide, the precipitation being arrested before the separation of mercuric sulphide was completed, and the second filtrate, representing a second saturated solution of the metallic sulphide in a mixture of alkaline sulphide and sulphydrates, but one containing much less mercuric sulphide, was also analyzed.

These analyses, which formed the conclusion of a tedious series of experiments, show beyond any reasonable doubt that there is a compound HgS, $4Na^2S$ which is soluble in the presence of $Na^2S$, $H^2S$ and which is decomposed by hydrogen sulphide in the presence of the sulphydrate by the reaction,

$$HgS,\ 4Na^2S + 4H^2S = HgS + 4Na^2S,\ H^2S.$$

*Conclusion from the experiments.*—It appears from the above that there are at least three double salts of the form HgS, $nNa^2S$, where $n$ may be either 1, 2 or 4 and, judging from the analogy of the potassium compounds, there is probably also a compound of this group where $n$ is $\frac{1}{2}$. The possibility of a case where $n$ is 3 has also been adverted to. Thus mercuric sulphide readily enters into combination with sodic sulphide in various proportions, while all the best known soluble compounds of mercuric sulphide and sodium have the same general formula. The presence of carbonates of the alkalies is also known, especially from Méhu's results, to be compatible with the existence of these compounds. The question therefore arises whether such double sulphides may not exist in natural waters.

*Possible existence of* $Na^2S$ *in natural waters.*—This question resolves itself into two. It is to be considered whether $Na^2S$ may exist in natural waters as such. In that case such waters must dissolve mercuric sulphide. It is also possible that alkaline monosulphides cannot exist as such in these waters, but that the affinity of sodic sulphide and mercuric sulphide is sufficient to overcome the obstacles to the formation of sodic sulphide, and that this compound will form when mercuric sulphide is present. The latter possibility is the more important one, but the former is manifestly one of interest to chemical geology.

A train of thermochemical reasoning, upon which it is not necessary to enter here, makes it extremely probable that, at temperatures exceeding 80°, a certain amount of sodic sulphide may form by the decomposition of neutral sodium carbonate and sodium sulphydrate in the presence of acid sodium carbonate. The behavior of such mixtures to mercuric sulphide at the temperature indicated is also such as it would be if the sodic sulphide actually formed; but a full and sufficient proof of the reaction which theory indicates as probable seems very difficult and has not yet been accomplished. It is certain, however, that a tendency exists to the formation of sodium sulphide under these conditions. When in addition to this tendency, the affinity of mercuric sulphide for sodic sulphide is brought into play, it can be proved experimentally that sodic sulphide is formed. We found that at a temperature of about 90° a mixture of the two carbonates and the sulphydrate dissolves mercuric sulphide freely without a sensible evolution of gas. If the solvent does not contain sodic sulphide, it must contain the sulphydrate. Hence it becomes important to ascertain the behavior of mercuric sulphide to sodic sulphydrate at moderately elevated temperatures.

While sodic sulphydrate will not dissolve a trace of mercuric sulphide at ordinary temperatures, if mercuric sulphide is added to a solution of sodium sulphydrate which stands upon the water-bath, hydrogen sulphide is evolved and mercuric sulphide goes into solution. The fact that hydrogen sulphide is evolved demonstrates that sodic sulphide must be formed. Cooling does not reprecipitate the mercuric sulphide, and the compound dissolved is therefore of the form $HgS$, $nNa_2S$. Though the solubility of mercuric sulphide in warm solutions of the alkaline sulphydrates at ordinary pressures has, so far as I know, never been explicitly stated, I have no doubt that chemists have observed it and that, in consequence of this observation, the general statement of the solubility of mercuric sulphide in alkaline sulphydrates has remained in chemical literature in spite of the observation of Weber and Barfoed. The preparation in which I originally observed this important reaction was one from which mercury had already been removed by precipitation with hydrosulphuric acid. The experiment was afterwards repeated by Dr. Melville with several preparations of sulphydrate which had been accurately analyzed and had been tested in numerous ways. Now in a mixture of the carbonates and sulphides of sodium at the temperature of the water-bath, either sodic sulphide or sodic sulphydrate is present, or, more probably, both coexist. If, then, mercuric sulphide is added to such a solution, either sodic sulphide combines directly with mercuric sulphide, or sodic sulphydrate is decomposed by mercuric sulphide setting free hydrogen sulphide, which must be immediately absorbed by neutral sodic carbonate. Hence in any case the salt dissolved in the mixture must be of the form $HgS, nNa^2S$.

*Effects of dilution*—Laboratory experiments are usually made with solutions which are much more concentrated than those found in nature. Hence the effect of dilution on solutions of $HgS, nNa^2S$ are important. Whether mercuric sulphide is dissolved in a mixture of sodium monosulphide and sodium hydrate, or of the former and sulphydrate, dilution with cold water precipitates mercuric sulphide.

The cause of this precipitation. which is attended by some curious phenomena to be described hereafter, is clear. It is known through the investigations of Messrs. Kolbe, Thomsen and others, that while in moderately concentrated solutions

$$NaHS + NaHO = Na^2S + H^2O,$$

this reaction is partially reversed on dilution ; or that, in the presence of much water, sodic sulphide is decomposed by water, the proportion of the sulphide undergoing this decomposition increasing gradually with the dilution. It is evident that the decomposition of $HgS, nNa_2S$ is effected in the same way, more and more of the monosulphide being converted into the sulphydrate as the dilution increases, probably without any limit. Since mercuric sulphide decomposes hot sodic sulphydrate, the effect of dilution in hot solvents will evidently be less than in cold ones.

Brunner* found that dilution of solutions of his salt precipitated a black mass in which, on examination with the

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* Loc. cit.

lens, minute globules of mercury were visible. The quantity of mercury was extremely small, so that the precipitate on analysis corresponded very closely indeed to the composition expressed by the formula HgS. Gmelin-Kraut* appear to have some independent confirmatory evidence on this point. If metallic mercury is precipitated in diluted solutions, of course sulphur is liberated; and, as shown above, sodium hydrate must also be present. Now when these two substances are brought in contact, sodic hyposulphite forms. Accordingly Brunner found hyposulphite in the solution forty years before the decomposition of sodic sulphide in dilute solution had been elucidated.

As Brunner experimented with HgS, $Na^2S$, I thought it best to compare the action of HgS, $4Na^2S$. A very concentrated perfectly clear solution of freshly prepared mercuric sulphide in a mixture of sodic sulphydrate and caustic soda, containing very little of the latter, was suddenly diluted with cold water to 200 times its volume and rapidly filtered. Minute globules of mercury could be seen with the black sulphide on the filter. On digestion (after thorough washing) with very dilute nitric acid, a solution was obtained from which sulphydric acid precipitated black sulphide. The decomposition thus appears to be the same in each of the compounds, HgS, $Na^2S$ and HgS, $4Na^2S$.

*Influence of foreign substances.*—The fact that sodium carbonates do not prevent the solution of HgS in $Na^2S$ is evident both from Méhu's result and from our own. Experiments show that borax solutions precipitate a portion of the mercury from solution, but not the whole. The precipitation does not appear to be progressive, like that accompanying dilution, but to reach a sharp limit beyond which further additions produce no effect. A large amount of borax added to a concentrated solution of $Na^2S$ and NaHS does not rob it of the power to dissolve HgS. It is easy to imagine reactions by which borax may precipitate a portion of the mercuric sulphide. But the behavior of solutions of borax to sulphydric acid and to alkaline sulphides is very peculiar and, so far as I am aware, has not been thoroughly investigated.† Very concentrated solutions of sodium chloride do not precipitate mercuric sulphide from strong solutions in mixtures of sodic sulphydrate, and they even appear to delay but not to prevent, precipitation by dilution

*Solubility of* $Fe^2S$.—The sulphide which is most frequently associated with that of mercury is pyrite or marcasite, indeed these minerals in greater or smaller quantities are to be found in nearly every hand specimen of ore, and occur very abundantly in most quicksilver mines. On making the experiment

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* L. c., vol. iii, p. 851.

† Gmelin-Kraut, l. c., vol. ii, p. 160.

I found that pyrite, marcasite or precipitated ferrous sulphide when warmed with a solution of sodic sulphide diminished in quantity, while the solution changed color. The filtrates gave strong reactions for iron.

Pyrite dissolves in cold solutions of sodium sulphide without any evolution of gas. The solvent power seems to increase with the temperature. Pyrite like cinnabar appears totally insoluble in cold sodium sulphydrate, and, like cinnabar, pyrite dissolves to some extent in hot solutions of the sulphydrate. Pyrite is also soluble in solutions of sodium carbonate partially saturated with sulphydric acid, both hot and cold. Quantitative determinations have been made, but are omitted here for the sake of brevity.

Marcasite is more easily soluble than pyrite, and the simple precipitated sulphide goes into solution most readily of all. I think there can be no doubt that pyrite and marcasite form double salts with sodium sulphide entirely analogous to the soluble compounds of mercuric sulphide. Marcasite is more easily attacked than pyrite, just as metacinnabarite is more susceptible to the action of reagents than cinnabar.

*Solubility of gold.*—The association of gold and pyrite is world wide. According to Gahn* there is no pyrite which does not yield traces of gold when carefully tested. This indeed does not accord with my experience, for extremely careful tests of some pyrite in my laboratory have failed to reveal any indication of gold. Gold is associated with quicksilver, however, at Steamboat Springs, at some points on the gold belt of California, at the Manzanita mine, at the Reddington mine, and some other localities both in California and in foreign countries. From these facts I concluded that gold should be soluble in sodic sulphide. On warming chemically pure, precipitated gold-dust with a solution of sodic sulphide, the glittering scales of gold gradually disappeared. The filtrate after proper manipulation yielded a purple precipitate with phosphorous acid.

A solution containing 843 parts of $Na^2S$ (by weight) dissolves one part of gold at the ordinary temperature of the atmosphere. Gold also dissolves at ordinary temperatures in sodic sulphydrate, and in solutions of sodic carbonate partially saturated with sulphydric acid. The solubility appears to be increased and facilitated by heat.

*Solubility of other sulphides.*—Cupric sulphide dissolves less readily than pyrite in sodic sulphide and in mixtures of the sodic carbonates and sodic sulphydrate. Unlike pyrite, it also dissolves in thoroughly saturated sodic sulphydrate. Zinc sulphide is also soluble and behaves much as pyrite does. Quantitative determinations of the solubility of these substan-

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* Bischof's Chem. Geol., vol. iii, p. 939.

ces have also been made. The solubility of the sulphides of arsenic and antimony in sodic sulphide and in the sulphydrate is of course well known. In the presence of neutral sodic carbonate sulphides of arsenic and antimony dissolve in sodic sulphydrate without the evolution of gas, because the sulphydric acid set free reacts upon the carbonate.

*Natural solutions and precipitations.*—The foregoing experiments show that there is a series of compounds of mercury of the form HgS, $n\mathrm{Na}^2\mathrm{S}$ one or the other of which is soluble in aqueous solutions of caustic soda, sodic sulphydrate or sodic sulphide, and apparently also in pure water, at various temperatures. These solutions subsist, or subsist to some extent in the presence of sodic carbonates, borates and chlorides. There is the strongest evidence that the waters of Steamboat Springs contain mercury in this form, and that the waters of Sulphur Bank have contained mercury in the same form, if indeed they do not still carry it in solution. Bisulphide of iron, gold and zincblende form double sulphides with sodium, which appear to be analogous to those of mercury. Copper also forms a soluble double sulphide, but combines more readily with sodic sulphydrate than with the simple sulphide. All of these soluble sulphosalts may exist in the presence of sodic carbonates.

Mercuric sulphide is readily precipitated from these solutions. Any substance is more soluble in hot solutions than in cold ones, provided that increase of temperature does not resolve the fluid molecules into others which are less soluble; as happens with sodium chloride, neutral sodium carbonate, etc. Diminishing temperature is thus a cause of precipitation, and diminishing pressure appears to act in a similar way. There are also other methods of precipitation which may be carried out under natural conditions. If a natural solution of mercury comes in contact with strong solutions of borax, or with sulphydric acid, or any stronger acid, it will lose a portion of the mercuric sulphide in solution. At Steamboat Springs and Sulphur Bank large quantities of sulphuric acid are formed near the surface and, percolating downward, must precipitate mercury in some form. The acid waters penetrate to a depth of at least 20 or 30 feet and this explains the fact that the waters reaching the surface carry so little quicksilver. These same causes must also produce precipitation of the other ores and of gold from solutions.

Another method by which mercuric sulphide may be precipitated, as has been seen, is mere dilution. Now, ascending solutions of quicksilver must sometimes meet with springs; and when they do so, metacinnabarite, or black sulphide will be precipitated, and with it also a small amount of quicksilver. In nearly all mines a small quantity of "virgin" quicksilver is found and in most it constitutes a very small proportion of the entire ore.* Accompanying this precipitation is the formation of hyposulphite, which actually occurs in the waters of Steamboat Springs. Dilution of solutions of quicksilver with extraneous spring waters thus explains the occurrence of metacinnabarite, found in at least four of the mines of California, and in New Zealand, and of native quicksilver. Native quicksilver however occurs in many mines in which no metacinnabarite has ever been seen. This does not preclude the supposition that the metal has been isolated by dilution; for black sulphides in the presence of solutions of mercury might readily be converted into the allotropic modification, and I know of no reason for denying that much of the cinnabar of the ore deposits may have been deposited in the amorphous state. Cinnabar and metacinnabarite are sometimes found mixed, as if the conversion to the red form were incomplete; and there is other evidence from observation that mercuric sulphide is slightly soluble in the waters of some of the cold mines.

While dilution will produce metallic mercury and a *causa vera* of its existence is thus detected, there may be other ways besides this in which it is produced in nature. Thus sulphydric acid precipitates a mixture of quicksilver and mercuric sulphide from mercurous salts. Whether soluble mercurous salts can occur in nature, excepting near the earth's surface, is another question. But even light is well known to decompose this feeble sulphide, and it is not impossible that the decomposition of organic matter, which is associated in most cases with cinnabar deposits, and seems to be specially abundant in the mines in which metallic mercury most prevails, may yield ammonium sulphide and metallic mercury.

*Conclusions.*—The conditions of the solution and precipitation of ores traced in this paper appear beyond doubt those mainly instrumental in forming the deposits of Steamboat Springs and Sulphur Bank. Most of the other quicksilver mines in California show ores and gangue minerals of similar composition to these, and many of them are accompanied more or less closely by warm springs containing much the same salts in solution. Some of the gold veins also appear to bear so considerable a resemblance in many particulars to these deposits as to lead to the belief that they too were formed by precipitation from solutions of soluble double sulphides.

That pyrite, gold and other ores are sometimes produced in nature by other methods is absolutely certain; for some auriferous pyrite is known to have resulted from the reduction

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* It is a very curious fact that from ancient times to the beginning of the last century virgin quicksilver was supposed to possess qualities superior to that of the metal reduced from cinnabar. Brückmann, Magn. dei in loc. subt.

of iron sulphate by organic matter. This particular process is probably confined to short distances from the surface; for I know of no indication of the formation of iron sulphate far from the oxidizing influence of the atmosphere. But there may be other solvents yet for these and other minerals which can form at great depths and, if such there be, I am convinced they are cases in which they, and not those which it has been my good fortune to trace in the foregoing pages, have been instrumental in the segregation of ores.

U. S. Geological Survey, Dec., 1886.

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## Art. XXIV.—*Fluviatile Swamps of New England*; by N. S. Shaler.

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In examining the fresh water swamps of New England I have found it necessary to consider in a careful manner the geographical distribution of one class of these deposits, viz: The swamps formed along the banks of rivers. This work has been done with the intention of presenting the matter in a report on the inundated lands of the United States, but a part of the results seem to have an important bearing on the question of recent changes in the altitude of the continent in relation to the sea and are therefore stated in the following pages in order that they may be at the service of students who are interested in this problem.

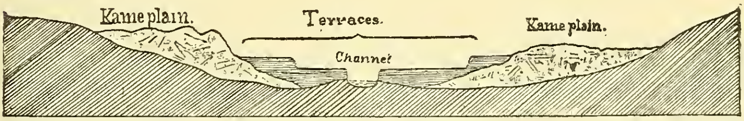
Let us first note the fact that the greater part of the New England streams flow from north to south or with slight deviations from this direction. Except at the head-waters of these southward flowing streams, where the brooks have too little volume to clear their beds of the glacial waste which encumbers them, the valleys of this group contain no swamps. There are, it is true, occasional small areas of marshy ground upon the bordering terraces of these rivers; these, in all the cases I have examined, are evidently "moats" or the cut-off portions of the old stream beds which have been abandoned by the rivers in their changes of channel.

All these southward flowing streams show that they have, for a considerable time, been cutting their beds downward through a deep layer of detrital material which was evidently deposited in their channels while the ice sheet was disappearing from the district on which they lie. This is indicated by the fact that, above the alluvial plain, at present overflowed in the times o flood, there is usually one, occasionally several, terraces which bear the mark of river action and to which the stream never attains.

It is a fact, one that so far as I am aware has not been noticed, that the uppermost of these terraces in the Merrimac and Connecticut, as well as some other rivers, generally exhibits features not reconcilable with the supposition that it was formed by river action. Its surface is frequently cast into the peculiar forms characteristic of the deposits which were made at the front of the ice-sheet when the base of the glacier lay below the level of the sea. It is my belief that these kame-bearing terraces were formed while the valleys in which they lie were depressed. Mr. Warren Upham in his essay on the New Hampshire drift, repeatedly refers to the fact that these plains differ essentially from those forming at present, still he conceives them as formed by river action.

Although we must exclude the upper terraces, those having kame ridges and the crater-like hollows which accompany kame deposits, from the category of terraces formed by the action of rivers, there remain enough of the elevated benches, distinctly marked by the action of fluviatile forces, to make it clear that, in the valleys of the rivers flowing from north to south, the conditions have been such that the streams have had no difficulty in constantly cutting deeper and deeper into the detrital deposits which hindered their flow at the close of the Glacial period. The accompanying diagram (figure 1) represents the general condition of the terraces in the valleys of the Merrimac, Connecticut, and other New England rivers of considerable size, which flow from north to south. It is intended to give the typical form of these terraces and not to show the actual conditions at any one point, though those who are familiar with the aspect of the Merrimac or the Connecticut will recall many sections which it closely resembles.

1.



Type of river valleys in New England when the streams flow from north to south.

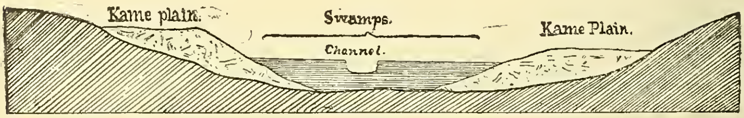
It is evident that in a valley characterized by the presence of the terrace debris the conditions are extremely unfavorable for the formation of swamps, for even the lowest of the alluvial plains is drained, except in times of flood.

Turning now to the streams which flow from south to north we find conditions in marked contrast to those which are found in the rivers flowing in the opposite direction. The number of these northward flowing streams is small and none of them have drainage areas to be compared with those of the greater

New England rivers. So far I have been able to examine the valleys of but few of this group, viz: The Nashua, the Concord, the Charles, and the Neponset, all situated in eastern Massachusetts. Although these streams are not large they all carry, in times of flood, large bodies of water.

The general conditions of their drainage basins, as far as can be shown by a cross section, are exhibited in diagram No. 2. It will be seen from a comparison of this with the preceding diagram (figure 1) that the most important difference in the cross section is as follows, viz: Along the streams which flow from south to north there are no river terraces except those which are covered by the ordinary floods and are at times swampy; while in the rivers which flow in the opposite direction there are normally several of these elevated fluviatile benches and even the lowest of them is well drained in the dry season. The only benches are of the kame terrace character before adverted to and these are very conspicuous features in some of these valleys; in that of the Concord River they are particularly extensive and characteristic. At first sight these kame plains are likely to deceive the unwary observer into the belief that he has ordinary fluviatile terraces before him. Even when he has a considerable acquaintance with such terraces as abound in the region south of the glaciated area of this continent he may fall into this error. Seen from the level of the streams the faces of the kame terraces where they have been scarfed away by the stream are almost exactly like those of ordinary fluviatile benches. Observing them closely their escarpments are seen to be slightly more irregular than on the terraces formed by a stream in its down cutting, but occurring, as they do, in a somewhat fragmentary way, these peculiarities are readily overlooked.

2.



Type of river valleys in New England when the streams flow from south to north.

When, however, the student ascends upon the surface of these plains, he at once remarks that they are essentially unlike the true fluviatile terraces as we may call those benches which have in earlier times been overflowed by the stream. In place of the level or slightly rolling surface characteristic of these old flood plains we find these kame terraces, though generally nearly level, to be here and there deeply indented by the peculiar pits termed 'kettles' so characteristic of the kame plains of New England. Here and there also we find low but sharp kame ridges which are equally characteristic of this class of deposits. These contours are of themselves sufficient to prove that these areas have never been the flood plains of any river. Other evidence is found in the fact that these kame bearings terraces have bowlders scattered over them; usually these erratics are of small size, but occasionally they have a mass of twenty cubic feet or more. The materials which form the kame plains consist in the main of sand and pebbles deposited in an irregular, cross-bedded way quite different from the structure of fluviatile terraces. Again the kame plains may be traced completely beyond the valleys into positions where it is evident that they have no relation to river action.

Below the level of this kame terrace the valleys of the rivers which flow from south to north show no other benches until we descend to the level of the present flood plain. This is always, as is shown in the diagram, in direct communication with the present margin of the river so that a very slight flood sends the water over the whole of its level. Even in the times of ordinary low water the river extends through sedgy flats for some distance from the margin of the flowing stream. The whole of this alluvial plain is swampy; so far as I have seen none of it is exempt from floods, and there is, at no point, any indication of down-cutting on the part of the stream bed. This absence of a distinct lowering of the drainage level in these basins may possibly be accounted for in part by the fact that they are all more or less obstructed by mill-dams. Still making all allowance for these obstructions and considering only the conditions which remain when the water is drawn away from the pools, it is clear that there has been in these channels an entire absence of that swift down-cutting which is so marked a feature in the rivers which flow from north to south.

It is moreover clear that the reverse process is now rapidly in action; none of these northward flowing streams have, at the present time, sufficient currents to clear their beds of the detritus brought into them by floods from their tributaries. Even in the time of floods they discharge no coarse detrital matter; only the small amount which is held in suspension by a slight current is carried to the sea. The result of this failure of the streams to exercise any general erosive effect is that the process of deposition is constantly going on not only on the bottoms of their channels but upon a wide field on either side of the waterways. The deposition of coarse sediment is taking place not only along the bottoms of the streams but in the form of small deltas where the brooks from the higher ground are arrested in their speed at the margins of the swamp lands. These deltas are inconspicuous; in part because the greater number of the

New England streams do not bear a large amount of coarse sediment, but also because the continued rise of the swamp deposits causes the deltas to be masked by the growth of plants and the accumulation of peaty matter. It seems evident that we have not yet come to a point where the conditions have attained their equilibrium though it may well be that the present condition of these basins is affected by the artificial dams which have recently been constructed across their main channels. I believe that, if these dams were removed, the accumulation of detritus would continue.

The general character of the swamps which border the northward flowing rivers, merits some consideration. In the first place we note the fact that they do not belong to the group of sphagnum deposits, for the reason that the alternations of water level are too great to permit the extensive development of these mosses. These fluviatile swamps are divisible into three classes. There are those which are formed in areas so frequently subjected to overflow and so constantly penetrated with water that they cannot afford a site for any of our perennial shrubs to maintain a place upon them. These areas are occupied in their lower part by rushes and in the higher by the ordinary marsh grasses of this country. Above this level we have a belt of ground, generally narrow, in which the grasses give place to various bushy but low growing plants of which the alders are the most common. Above this we have in certain places a wide field of swamps which are really only very wet woods, water-covered in the times of the greater floods, say once or twice a year, but generally two or three feet above the level of ordinary inundations.

These wide inundated plains demand explanation; this I am not yet able to give. It seems to me, however, from their aspects and the trifling sections I have been able to secure, none of which extend more than three feet below the surface, that they may be true terrace plains formed perhaps during a time when the channel of the river was at a lower level than it is at present. These plains may have been converted into swamps by the same changes in the drainage conditions which have so embarrassed the flow of the stream.

The foregoing statement will make it clear that there is a great difference in the drainage conditions of the streams which flow from and toward the north in the belt of country included in eastern New England. A little further consideration of the facts will make it also clear that this difference is probably not one of the original nature but has recently been brought about. We note in the first place that the valleys of the rivers, which flow from south to north, show evidences of an erosive power which the rivers no longer possess. As is indicated in the diagram (see figure 2) we often find on either side of the present stream bed the remains of a terrace-like mass of sand and gravel which is the product of peculiar conditions of the Glacial period. In some rare cases these masses of tabular drift are found as fragments of an old table-land left in the middle of the valley. These lateral and central masses of terraced sands have in all cases steep escarpments which by their slope indicate the erosive action of the stream. It is often evident that these drift plains at the close of the Glacial period extended across the valleys in which they lie.

In some cases the mass excavated is very great; on the average it seems to me as great as that which has been removed by some of the larger streams of the valleys which flow from north to south. The excavation in the valleys of the rivers which flow from south to north is entirely beyond the power of their streams to accomplish with their present slopes. In similar streams flowing in the reverse direction the process of erosion of their drift plains is still going on. In the Merrimac, for instance, the river is rapidly wearing away its banks at many points. On the western side of the elevated plateau of kame plains, which lies on the east side of the river near Concord, N. H., the process of erosion keeps a fresh face on a cliff nearly one hundred feet high and several hundred yards in length. This escarpment is wearing away at the rate of somewhere near one foot per annum. The same is the case with many other bluffs on this stream. This activity of erosion by the rivers is seen in many other streams of this class in this part of New England, but in the valleys which slope to the south the streams no longer attack their banks in this manner though it is evident that they at one time were capable of such work.

I have at present no data sufficient to determine the depth to which the valleys have been encumbered by the swamp accumulations which have been formed in them or how much their beds have been raised from their original level. It seems to me likely that they originally possessed alluvial plains such as those which now characterize the Merrimac and other normal valleys. This would seem almost necessarily the case from the extensive erosion of the drift terraces, for the reason that this erosion by the stream would necessarily lead to the oscillation of the channel from side to side, which would bring about the production of fluviatile plains. If such plains existed the filling up of the valleys has evidently been sufficiently great to suppose their surface beneath the existing swamp deposits. As before remarked I am disposed to believe that the great area of wet-woods on the banks of the Concord river in Bedford, Mass., is in its nature a supposed fluviatile terrace.

It thus appears probable that after the streams which flow to the northward had in good part done their work of excavating their drift-encumbered channels, bringing them into essentially the condition of those occupied by the rivers flowing from north to south, a change came over them which led to a lowering of their slopes and a consequent diminution of their fall. It is evident that the only change which could produce this would arise from a tilting of the land area in which they lie. This tilting might be accomplished by a positive down sinking of their head waters or by a positive elevation of the lands about their mouths; either of these movements might be local in their nature or they might be a part of a general movement of the continent.

It is perhaps too soon to interpret the movements which have led to these peculiarities in the drainage of the two classes of our New England rivers, but in order to secure a basis for the further study of the facts I venture to give the succession of events which my observations appear to indicate.

First as to the origin of the kame terraces which are by far the most conspicuous as well as the most inexplicable features of our river valleys. I have already incidentally given the principal reasons why they are not to be considered as in any way the result of river action. I have stated that the character of their surfaces as well as the order of stratification of their materials excludes them from the class of fluviatile deposits. A further study of their features shows us that there are other reasons why they cannot be regarded as the product of river action. Deposits of essentially similar nature are found along the shore line at many points between Portland and New York, especially on Cape Cod and the islands of Nantucket and Martha's Vineyard where the supposition of river action is quite out of the question. Again they are found in the valleys of our smaller lakes in positions where they could never have been exposed to river currents. Still further they are, when found in the river valleys, in no very definite relation to the plane of the stream, they lie at all heights above its level and only for short distances and accidentally correspond in slope with the surface of true fluviatile plains. I am, therefore, driven to the opinion that these kame terraces were formed beneath the level of the sea during the submergence which attended and followed the stage of the Glacial period when this surface was deeply covered with ice. During the period of submergence which endured for a time after the disappearance of the ice the surface of the sea floor was swept by strong currents which tended to move the detrital matter from the elevations and accumulate it in the hollows of the bottom. The currents which bore the materials to the sea and arranged them on its floor were in the main produced by the sub-glacial streams which emerged from beneath the ice while its base lay in the sea. As the sub-glacial streams normally had their points of discharge at the lowest parts of the ice front, the greater part of the kame gravels were deposited in the depressions of the sea floor which have since become river valleys. But a share of this debris found its way to the higher lying districts and occasionally occupied positions on the divides between adjacent valleys.*

When the surface of this district rose above the level of the sea the movement took place suddenly as is shown by the preservation of the delicate features of the kames, especially along the sea shore as well as by the absence of old benches of levels above the plane of the present shore. The elevation probably brought the level of the land to a position considerably above its present altitude, as is shown by the submerged forests along the shore of Massachusetts Bay and on Nantucket, where there has been a down sinking of ten to twenty feet in depth since the post-glacial elevation.

During this period of post-glacial elevation, when this part of the continent was somewhat higher than at present, the valleys of all the streams were, to a greater or less extent, cleared of their incumbrance of drift. It is during this period that the valleys of the rivers which flow from south to north were exposed to the measure of erosion which we find indicated in them. This condition of the surface must have endured for some thousands of years in order to have permitted the removal of such extensive masses of debris as have been cleared from these valleys. As before remarked, the erosion of these valleys as far as it is measured by the abrasion of the original drift deposits, the kame terraces and other glacial materials, is nearly if not quite as extensive in the valleys whose streams flow to the northward as in those that decline to the south. It is evident that the elevated condition of the continent endured long enough to permit the complete re-establishment of the drainage in the drift-encumbered valleys of this region, a process which could not have taken place with the present declivity of the streams. When the change in the position of the land came about it led to the relative lowering of the southern part of New England and a corresponding relative increase in the height of the northern part of this section of the shore. It is not perfectly clear whether the movement actually lifted the northern districts above their previous level or no, but it seems likely there was a positive sinking of the southern section.

It is probable that the submerged forests and swamps of southern New England before and after, referred to, were depressed beneath the sea level at the time of this movement.

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* Compare on the Origin of Kames, by N. S. Shaler, Proceedings Boston Soc. Nat. Hist., vol. xxiii, pp. 30–44.

The amount of downward movement indicated by these remains of submerged land plants cannot well be less than fifteen feet. It may have much exceeded this amount. It is impossible to determine by the scanty remains of these submerged forests and swamps, which are disclosed along the shore line, just how high above the water the surface which they occupy stood before they were lowered beneath the sea. Therefore, although a certain amount of subsidence of the region appears to be indicated by these submerged plants, the amount of the movement can only be determined by a careful examination of the valleys themselves. Fortunately the data obtainable in this manner seem to make an approximate determination of the point in question. The evidences of former erosion which these valleys afford shows us that at one time their rivers had a rate of flow comparable in a general way to that of the rivers which flow from north to south. The question is, how great a tilting of these basins would be required in order to bring the streams to their present condition of relative stagnation and permit the development of the swamps which now characterize their basins. After the careful study of these valleys, comparing them with those in other districts, I am of the opinion that the tilting need not have exceeded two feet to the mile to have effected the change, and that it might have been effected with a somewhat less amount of alteration in the inclination of the stream beds. The least amount which would satisfy the conditions would be a lowering of the inclination of the river beds by one foot to the mile. The greatest submergence which I have been able to prove from the evidence of buried forests is in the region about Boston harbor, where it appears to have been somewhere about twenty feet, rather less than more. This evidence is derived from some roots of a species of spruce obtained in Cambridgeport at a depth of about seventeen feet below high water, and some traces of roots of trees in their natural position below the level of low tide mark in the portion of Massachusetts Bay near Lynn. Now, from the sources of the Concord river to its outlet into the Merrimac, is a distance of about thirty miles in a direct line, and by the sinuosities of the stream is about forty miles. We see, therefore, that the proved subsidence, since the close of the Glacial period, is hardly sufficient to account for the change in the condition of the river, though it represents at least half the amount necessary to bring about that alteration.

The moderate amount of the subsidence which has led to the swampy condition of these valleys is furthermore indicated by the fact that when the tributaries of the embarrassed streams, themselves flowing from south to north, are so placed that their original descents were steep, they have not had their basins made swampy by the change of inclination.

It is clear that the precise amount of this dislocation cannot be determined from a study of the streams themselves; we can only set it in general terms as equivalent to a diminution in the rate of descent to the amount of from one to two feet to the mile. It is, however, clear from the evidence afforded by the valleys that the change was in effect a downward tilting of their southern ends. This is shown by the fact that the encumbering by marshes often extends to the head-waters of the streams. If the subsidence had consisted in an even lowering of the whole shore the result would have been the checking of the current of the rivers in the lower part of their course alone. As it is, it has affected the movement of some of their tributary streams up to a height of one hundred feet above the sea. There is a chance that the amount of the dislocation may be determined in the manner pursued by Gilbert in his admirable work on the lake basins of the central and western portions of the continent, viz: by tracing the elevated shore lines of shrunken fresh water areas. In the essays which I have made towards the use of this method I have as yet attained no success, for the reason that over New England elevated shore-lines are rare and extremely indistinct in their outlines. It is likely, however, that a careful study of the numerous lakes of New England which have been partially drained since the Glacial period will afford some data for the accurate determination of this question.

An inspection of the best accessible maps seems to show that this encumbering of the valleys of the streams which flow from south to north, becomes less evident as we recede from the shore. It is but slightly shown in the hill districts of southern New Hampshire, or of central Massachusetts, as well as in the Berkshire hills. It will not do, however, to conclude that this tilting action did not take place in those districts. The only streams which in that region have a course from south to north are of small size, and rapidly descend from considerable heights. If, as seems likely, the amount of down sinking of the level to the south did not exceed two or three feet to the mile, the original slope of the stream beds may not have been so far overcome as to lead to the formation of swamps in their valleys.

It need hardly be said that this tilting movement was most likely a change which involved a large part, if not the whole, of the glaciated district of the continent. The occurrence of such a movement is sufficiently proved by the position of the post-glacial beds containing marine fossils along the shore from northern New England to Greenland, as well as by the evidence obtained by Gilbert from the old shores of Lake Ontario. These observations above recounted on the northward-flowing streams come, therefore, as a corroboration of an hypothesis which has perhaps sufficient verification from other evidence. The chief interest of the facts indicated by the valleys we have been discussing is that they give an approximate measure of the amount of dislocation of the continent on the southern part of New England, and that they apparently show that the down-tilting took place in relatively recent times, and after a period of elevation during which the streams had steeper slopes than they at present exhibit.

I venture to suggest that the uplifting probably took place during the period of retreat of the New England glacial sheet, and before the ice had passed away from the northern part of the continent, and that the down tilting occurred when the ice had been in good part, if not completely, removed from the northern regions. It seems to me not improbable that the upward movement which followed the retreat of the ice was due to the removal of its weight from the surface of the continental arch. Assuming this to have been the case then we can easily imagine that in the region which was at a certain distance to the south of the retreating glacial escarpment would be temporarily elevated by the counter thrust arising from the weight of the neighboring ice. We may aid ourselves in forming this conception by the somewhat similar case in which the surface of a peat bog rises above its original level around the part which is weighted down by the filling of a roadway. It is easy to see that if we should remove the weight which produces the counter-thrust the elevated surface would tend to resume its original level.

We may thus conceive the succession of movements which have led to the present condition of our streams flowing from north to south, as follows, viz: 1st. The subsidence of the land surface under the weight of the ice to a depth below the level of the sea. 2d. With the retreat of the ice, a reëlevation, in a sudden manner, to a height much above the level of the sea. 3d. With the disappearance of the ice from the continent a readjustment of its position and a consequent lowering of the southern portion of the glaciated area. It is not likely that in the readjusted condition of the continent all parts are equally elevated or equally lowered. The present levels of the several divisions of the continental area would probably be determined by complicated equations of thrusts, and it is probable that in this way we may explain the fact that certain of the lesser valleys of New England show little effect from the tilting movement which in immediately contiguous areas has had a great influence in the flow of the streams. I have observed the fact that in the hills of Mt. Desert we have evidence which goes to show a rising of the shorelands from the sea by a succession of uplifts, each separated from the others by a period in which the land remained in the same relative position to the sea for a period of time sufficiently long to permit the waves to excavate a strongly marked bench while in the intermediate sections the elevation took place so rapidly that the drift coating was not swept away from the rocks. It seems at present likely that these benches on Mt. Desert do not correspond with any similar coast lines in the southern part of New England. If this is proved to be the case then we have evidence that the rate and manner of upward movement were very diverse in regions which are close together.

Although in this paper I propose to limit the matter of inquiry in the main to the post-glacial changes which have come upon the valleys of the northward-flowing streams it may be noticed that the facts above referred to throw much light upon the preglacial attitude of the continent. These river-valleys retain the general form which they had before the last glacial ice began to act upon them, they pursue their present courses because their flow is mainly determined by the existence of the pre-glacial river valleys in which they lie. It is clear that these valleys could not have been excavated by streams of their present slope, it seems, therefore, necessary to assume that the descent of the northward flowing rivers must have been more rapid in the pre-glacial times than it is at present, or, in other words, this part of the continent was at that time relatively less elevated in its northern parts than it is at present.

## ART. XXV.—*On the Mazapil Meteoric-iron, which fell November 27th, 1885*;[*] by WILLIAM EARL HIDDEN.

AMONG the large number of meteoric irons which have been described, only eight[†] are recorded as having been seen to fall. It is my privilege to be able to add a ninth fall to this short list, and one which may prove to be of exceptional scientific importance. This mass of meteoric iron I received in August last as a gift from my friend, Professor José A. y Bonilla, Director of the Astronomical Observatory at Zacatecas, Mexico. He stated that it was *seen to fall* at about 9 P. M. on the 27th of November, 1885, during the periodical star-shower of the "Bielids." Such is the great interest of this meteorite,

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[*] This meteorite was first announced on Jan. 17, 1887, before the New York Academy of Sciences, at a regular meeting.

[†] Agram, Croatia, May 26, 1751: Charlotte, Dickson Co., Tenn., Aug. 1, 1835; Braunau, Bohemia, July 14, 1847; Tabarz, Saxony, Oct. 18, 1854; Victoria-West, Africa, in 1862; Nejed, Arabia, spring of 1865; Nedagolla, India, Jan. 23, 1870; Rowton, Shropshire, England, April 20, 1876. See the catalogue of the meteorites in the Mineral Department of the British Museum, by L. Fletcher, p. 42.

as shown by its history, that I have delayed announcing it until the evidence of its fall had been substantiated as thoroughly as possible.

The general freshness of surface, which shows very perfectly the flow of the melted crust; the presence of unusually large nodules of a very compact graphite; the very slight superficial oxidation, and its dissimilarity to other meteorites of the region, are all interesting features of this iron, and serve to confirm the statement of its recent fall. When received it weighed about 3950 grams. Its present weight is 3864 grams, or ten pounds four and one-quarter ounces, troy. Its greatest length is 175 millimeters, as measured diagonally across the mass. In its thickest part it measures about 60 millimeters. It could be described as a flat irregular mass, covered with deep depressions, having a smooth surface. (See figure 1.)

The evidence of the fall is set forth in the following communication from Professor Bonilla.

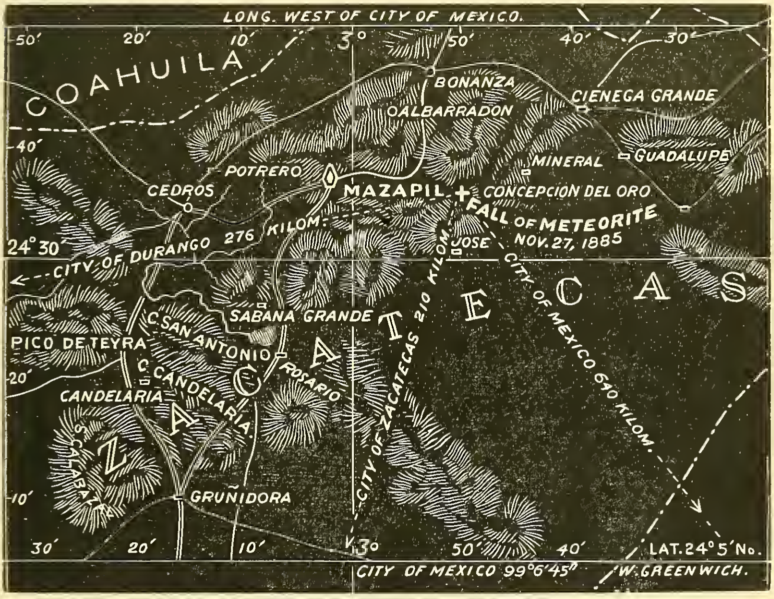
(Translation).—"It is with great pleasure that I send to you the Uranolite which fell near Mazapil, during the night of the 27th of November, 1885. That you may the better appreciate the great scientific interest which this uranolite possesses, I will state that everything points to the belief that it belongs to a fragment of the comet of Biela-Gambart, lost since 1852. I here give you the history of this celestial wanderer. On the second day of December (1885) I received, to my great delight, from Eulogio Mijares, who lives on the Conception Ranch, 13 kilometers to the east of the town of Mazapil, a uranolite, which he saw fall from the heavens, at nine o'clock on the evening of the 27th of Nov., 1885. The fall, simply related, he tells as follows, in his own words:—

"'It was about nine in the evening when I went to the corral to feed certain horses, when suddenly I heard a loud sizzing noise, exactly as though something red-hot was being plunged into cold water, and almost instantly there followed a somewhat loud thud. At once the corral was covered with a phosphorescent light and suspended in the air were small luminous sparks as though from a rocket. I had not recovered from my surprise when I saw this luminous air disappear and there remained on the ground only such a light as is made when a match is rubbed. A number of people from the neighboring houses came running toward me and they assisted me to quiet the horses which had become very much excited. We all asked each other what could be the matter, and we were afraid to walk in the corral for fear of getting burned. When, in a few moments, we had recovered from our surprise, we saw the phosphorescent light disappear, little by little, and when we had brought lights to look for the cause, we found a hole in the ground and in it *a ball of light.** We retired to a distance, fearing it would explode and harm us.

"* *Una bola de lumbre.*"

Looking up to the sky we saw from time to time exhalations or stars, which soon went out, but without noise. We returned after a little and found in the hole a hot stone, which we could barely handle, which on the next day looked like a piece of iron; all night it rained stars but we saw none fall to the ground as they seemed to be extinguished while still very high up.'

"The above is the simple recital of the ranchman, and the uranolite which fell is the one I send to you. From the numerous questions I have asked Sr. Mijares, I am convinced that there was no explosion or breaking up on falling. Others who saw the phosphorescence, etc., were Luz Sifuentes, Pascual Saenz, Miguel Martinez, Justo Lopez and some whose names I have not obtained.



Map of Mazapil, Mexico, and vicinity.

"Upon visiting the place of the fall (see accompanying map of the northern section of Mazapil in the State of Zacatecas) I was particular to examine the earth in and around the hole, and by careful search and washing the earth I found a few small bits of iron, which must have become detached from the uranolite when it penetrated the earth.

"The hole was thirty centimeters deep. Probably the light which was seen came from the volatilization of the surface of the celestial body due to the high temperature acquired by friction with the atmosphere, and of this volatilized matter falling to the earth as an incandescent powder."

The above communication was followed by an account* of

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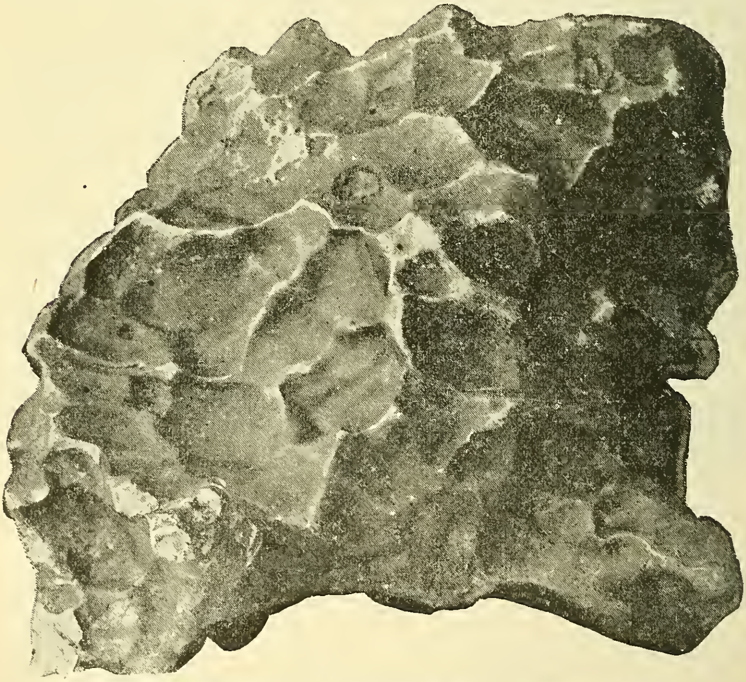
* For full text of which, see Annals of N. Y. Acad. Sci., for 1887 (now in press).

the observation of the Biela meteors at Zacatecas by Professor Bonilla and his assistants.

The locality of the fall is situated in latitude 24° 35′ North and in longitude 101° 56′ 45″ West of Greenwich.

That no explosion was heard when this iron fell, is paralleled by the account of the fall of the fifty-six pound aerolite near Wold Cottage, Yorkshire, England, on Dec. 13th, 1795. "This stone fell within ten yards of where a laborer was at work. No thunder, lightning, or luminous meteor accompanied the fall; but in two of the adjacent villages, the sounds were so distinct of something passing through the air towards Wold Cottage that several people went to see if anything extraordinary had happened to the house or the grounds." (L. Fletcher, An Introduction to the study of Meteorites, 1886, p. 22). Concerning the aerolites which fell at 11.50 A. M., on June 28, 1876, at Ställdalen, in Sweden, "it is remarkable that no meteor was visible at the place where the stones fell, though it was seen over nearly all Sweden."

1.



Mazapil Meteoric Iron. Wt. 10 lbs. 4¼ oz. troy (¾ natural size.)

The surface of the Mazapil iron is of great interest. The deeply hollowed depressions entirely cover the mass (see figure 1). A thin black crust coats the surface, and exhibits well the striæ of flow, as seen on meteorites whose fall has been observed. In eleven places nodules of graphite are noticed extruding from the surface (the engraving shows some of these), one of them is nearly an inch in diameter. The graphite is very hard and apparently amorphous; troilite and schreibersite were noticed on a section cut off for analysis and for the development of the figures of Widmanstätten. The crystalline structure (fig. 2) is well shown in the engraving (Ives' process) which is of natural size. The lines are somewhat similar to those of the Rowton iron, in their width and distribution, and are very unlike the known Mexican irons from Toluca, Durango, Coahuila, etc.

2.

Section of Mazapil Meteoric Iron
(natural size.)

In its surface and general flatness, the mass bears a remarkable resemblance to the Hraschina, Agram iron* which fell May 26th, 1751. In its weight it is nearly like the Irons of Rowton (7¾ lbs.), Charlotte (9½ lbs.), Victoria-west (6 lbs. 6 oz.), and Nedagolla (9¾ lbs.), which were all seen to fall.

Mr. J. B. Mackintosh has kindly analyzed a small fragment with the following results, which, for comparison with other irons, seen to fall, I have placed in tabular form :—

| | Mazapil.<br>Mackintosh. | Rowton.<br>Flight. | Charlotte.<br>Smith. | Estherville.†<br>Smith. |
|---|---|---|---|---|
| Iron | 91·26 | 91·25 | 91·15 | 92·00 |
| Nickel | 7·845 | 8·582 | 8·05 | 7·10 |
| Cobalt | 0·653 | 0·371 | 0·72 | 0·69 |
| Phosphorus | 0·30 | ---- | 0·06 | 0·112 |
| | 100·058 | 100·203 | 99·98 | 99·902 |

Carbon is distributed all through the iron between the crystalline plates, and it is noteworthy that this element was observed with the spectroscope as present in the "Bielids" of Nov. 27th, 1885. Chlorine is also present and shows itself by a slight superficial deliquescence. Of this latter I will state that most of the surface oxidation of the ferrous chloride has occurred since August last. As yet no tests have been made to ascertain the amount of occluded gases, or to analyze the graphite nodules, and it is probable that such analyses give only results

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* See Beyträge zur Geschichte und Kenntniss meteorischer Stein- und Metalmassen, by Dr. Carl von Schreibers, Wien, 1820, plate VIII.

† Fell May 10, 1879 and contains embedded nodules of nickeliferous iron surrounded by silicates.

similar to those already obtained. Over the mass, where the crust has been accidentally removed, the lines of crystallization (Widmanstätten figures) can readily be traced without etching the surface. The abrasion due to impact was very slight.

In conclusion, we cannot, from the very circumstantial account of the fall, which in several paticulars contains heretofore unrecorded observances, and the corroborative evidence of the iron itself, decline to receive this meteorite as the ninth recorded fall of an iron mass to the earth; and perhaps at another period of the November "Bielids," this fall will be confirmed in all its interesting details. The interest connected with this meteorite, because of its beautifully marked and fresh surface, is enhanced by the concurrence of the time of its fall with the shower of the Biela meteors.

I wish to express here my deep obligation to Professor Bonilla for the interesting data concerning this meteorite, and for the gift of the meteorite itself, and to Mr. Mackintosh also, for his kind interest in making the chemical analysis.

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## ART. XXVI.—*On Observations of the Eclipse of* 1887, *Aug.* 18, *in connection with the Electric Telegraph;* by Professor DAVID P. TODD, M.A., Director Amherst College Observatory.

IN the proceedings of the American Academy of Arts and Sciences for 1881, at page 359, I suggested the use of the electric telegraph during total solar eclipses, and showed the applicability of the proposed scheme of observation to the eclipse of 1882, May 16. Had this suggestion been adopted, it is easy to see how the unique discovery of a comet by the Egyptian observers might have been verified, and important data obtained regarding the orbit of an object now lost. Interesting as such data would have been, however, they have slender importance in comparison with the results in solar research possibly attainable through the adoption of the proposed method of telegraphic transmission of important observations eastward along the path of central eclipse. In the same paper, I alluded to the eclipse of the coming summer as affording the most auspicious opportunity of the present century for the application of the telegraphic method, and it may be hoped that an attempt will be made toward getting something out of the suggestion on this occasion, as I learn, in a late letter from Dr. S. von Glasenapp, Professor of Astronomy in the Imperial University of St. Petersburg, that the Russian telegraph service may be expected to give the use of its lines at this time for astronomical purposes. Accompanying his letter, Dr. Glasenapp sends also the subjoined list of possible observing stations where telegraphic communication is at hand. By plotting these upon a map, anyone may see the remarkably close coincidence of the path of totality with the extended lines of the Russian overland telegraph.

*List of towns and places with Telegraphic Stations (longitudes from Greenwich) where the central eclipse of Aug. 18, 1887, may be seen.*

(The places marked with an asterisk * lie very near the central line.)

| Place. | N. lat. | E. long. |
|---|---|---|
| 1. Velikije Louki | 56°21′ | 30°30′ |
| 2. Toropetz, | 56 29 | 30 38 |
| *3. Beloi, | 55 53 | 30 55 |
| 4. Sytchefka, | 55 50 | 34 17 |
| *5. Rjew, | 56 16 | 34 20 |
| *6. Zoubzoff, | 56 10 | 34 35 |
| *7. Stariza, | 56 31 | 34 56 |
| 8. Kjatsk, | 55 33 | 35 0 |
| 9. Torjok,† | 57 2 | 34 57 |
| 10. Twer, | 56 22 | 35 55 |
| 11. Volokolamsk, | 56 2 | 35 57 |
| 12. Mojaisk, | 55 31 | 36 11 |
| 13. Rousa, | 54 42 | 36 12 |
| 14. Klinn, | 56 20 | 36 44 |
| 15. Kortcheva, | 56 47 | 36 51 |
| 16. Dmitroff, | 56 21 | 37 31 |
| 17. Kashinn, | 57 22 | 37 37 |
| 18. Kaliasinn, | 57 15 | 37 53 |
| 19. Alexandroff, | 56 24 | 38 44 |
| *20. Pereiaslawl-Salesky, | 56 43 | 38 49 |
| 21. Kirjatch, | 56 10 | 38 52 |
| *22. Petrowsk, | 57 1 | 39 16 |
| 23. Rostoff, | 57 11 | 39 25 |
| 24. Turieff-Podolsky, | 56 21 | 39 41 |
| 25. Taroslawl, | 57 37 | 39 54 |
| 26. Gawrilowsky Possad, | 56 30 | 40 41 |
| 27. Souzdal, | 56 25 | 40 27 |
| 28. Piszowo, | 57 11 | 40 30 |
| 29. Nerehta, | 57 28 | 40 34 |
| 30. Lejneff, | 56 44 | 41 18 |
| 31. Kostroma, | 57 46 | 40 56 |
| *32. Tsanoff-Vosnesensk, | 56 50 | 41 24 |
| 33. Kowroff, | 56 23 | 41 18 |
| 34. Shouia, | 56 51 | 41 23 |
| 35. Pless, | 57 27 | 41 33 |
| 36. Soudislaff, | 57 53 | 41 42 |
| *37. Kineshma,‡ | 57 28 | 42 10 |
| *38. Turiewetz-Podolsky, | 57 19 | 43 8 |
| 39. Poutcheg, | 56 59 | 43 11 |
| 40. Katounki, | 56 50 | 43 15 |
| 41. Gorodez, | 56 39 | 43 29 |
| 42. Makarieff na Oungé, | 57 53 | 43 49 |
| 43. Semenoff, | 56 47 | 44 29 |
| 44. Baki, | 57 10 | 45 0 |
| *45. Varnawinn, | 57 23 | 45 3 |
| 46. Voskresenskoe, | 56°53′ | 45°22′ |
| *47. Vetlouga, | 57 51 | 45 48 |
| 48. Taransk, | 57 18 | 47 53 |
| 49. Kotelnitch, | 58 18 | 48 22 |
| 50. Orloff, | 58 32 | 48 55 |
| 51. Viatka | 58 36 | 49 41 |
| 52. Nolinsk, | 57 33 | 49 56 |
| 53. Slobodskoi, | 58 44 | 50 12 |
| 54. Omoutninsky Zavod, | 58 40 | 52 33 |
| *55. Glasoff, | 58 8 | 52 41 |
| 56. Debessy, | 57 38 | 54 0 |
| 57. Ohansk, | 57 43 | 55 23 |
| 58. Perm, | 58 1 | 56 16 |
| 59. Koongoor, | 57 26 | 56 58 |
| *60. Choossowaia, | 58 1 | 57 30 |
| *61. Cooshwinsky Zavod, | 58 1 | 59 12 |
| *62. Verhne-Toorinsky Zavod, | 58 30 | 59 30 |
| *63. Nijne-Toorinsky Zavod, | 58 40 | 59 45 |
| 64. Nijne-TagilskyZavod, | 58 3 | 60 19 |
| 65. Verhotoorie, | 58 51 | 60 48 |
| 66. Trbit, | 57 30 | 63 0 |
| 67. Toorinsk, | 58 3 | 63 40 |
| *68. Tobolsk, | 58 12 | 68 13 |
| 69. Tomsk, | 56 30 | 84 56 |
| 70. Kolgonskaia, | 56 25 | 86 10 |
| 71. Mariinsk, | 56 18 | 87 44 |
| *72. Atchinsk, | 56 16 | 90 30 |
| *73. Krasnoiarsk, | 55 1 | 92 50 |
| *74. Ooiarskaia. | 54 50 | 94 20 |
| 75. Kansk, | 56 12 | 95 39 |
| 76. Birusinskaia, | 54 50 | 97 5 |
| 77. Nijne-sodinsk, | 54 55 | 99 2 |
| 78. Tooloonowskoe, | 54 40 | 99 52 |
| 79. Kimilteiskoe, | 54 10 | 100 30 |
| 80. Cheremhowskoe, | 53 10 | 102 15 |
| 81. Trkootsk, | 52 16 | 104 16 |
| 82. Mansoorskaia, | 53 45 | 106 0 |
| 83. Cabanskoe, | 52 2 | 106 15 |
| 84. Verhneoodinsk, | 51 50 | 107 35 |
| 85. Coolskaia, | 52 12 | 109 47 |
| 86. Possiet, | 42 55 | 120 40 |
| 87. Nowgorodskaia, | 42 50 | 120 50 |

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† 12 kilometers from Torjok is the private observatory of General Majeffsky.

‡ 2 kilometers from Kineshma is the private observatory of Professor Bredichin.

To this already very long and favorable list of places, we might add several stations in Japan, at which telegraphic connection might, by suitable prearrangement, be without doubt secured.

As Dr. Glasenapp remarks, the coming eclipse will afford a good occasion for astronomers to observe the phenomena in coöperation, and this coöperation may become very extended, if the telegraph is used in the manner proposed.

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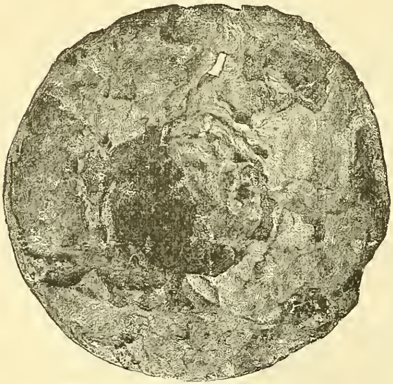
## ART. XXVII.—*On two new Meteorites from Carroll County, Kentucky, and Catorze, Mexico*; by GEORGE F. KUNZ.

TWO meteorites have recently come to me for description, which are of more than ordinary interest, both on account of their peculiar composition and structure, and also because of their ethnological relations. The mass from Carroll County, Kentucky, is especially interesting because of its probable connection with the meteoric iron found in the Turner mounds.

1. *Carroll County, Kentucky, Meteorite.*—In the spring of 1883, Professor F. W. Putnam found on the altar of mound No. 3 of the Turner group of mounds in the Little Miami Valley, Ohio, several ear ornaments made (see fig. 1)* of iron and several others overlaid with iron. With these were also found a number of separate pieces that were thought to be of iron. They were covered with cinders, charcoal, pearls (two bushels were found in this group of mounds), and other material cemented by an oxide of iron, showing that the pieces had been subjected to a high temperature. On removing the scale Dr. Kennicutt found they were made of iron of meteoric origin.† One of the pieces weighed 28 and another 52 grams.

1.



Earring made of Meteoric Iron.

In the autumn of 1883, another mass was found on the altar of mound No. 4 of this same group, which weighed 767·5 grams (27¼ ozs.). Dr. Kennicutt suggests that these were all parts of some larger meteoric mass. The results of the inves-

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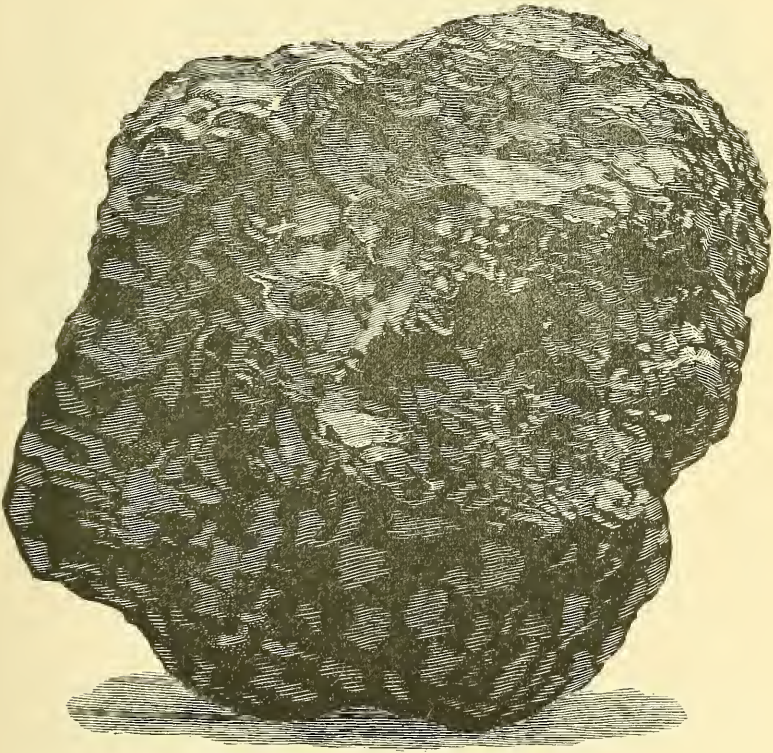
[*] I am indebted to Professor Putnam for the cuts from which figures 1 and 5 are printed, as also for the information he has kindly furnished me.

[†] 16–17 Report of Peabody Museum of Archæology, p. 382.

tigation were published in connection with the description of the Atacama meteorites, because in structure they approached more closely to the latter than to those of any other occurrence. In the Liberty group of mounds in the same valley, Professor Putnam found a celt five inches long, and in another of the Turner mounds, an ornament five inches long and three inches wide, made also of this same meteoric iron.

It was not until after the above masses had been found that the Carroll County meteorite was brought to my notice; after a careful comparison I have reached the conclusion that the irons from the Ohio mounds and the Carroll County meteorite probably belong to one and the same meteoric fall. Either the former was broken from the main mass by the mound-builders or they were all fragments of the same fall scattered as were the Estherville meteorites, or as suggested by Dr. J. Lawrence Smith, those of Coahuila, and further, by Huntington,[*] the Sevier, Cocke County, and Jenny's Creek irons.

2.



Carroll County Meteorite, upper side, $\frac{1}{3}$ natural size.

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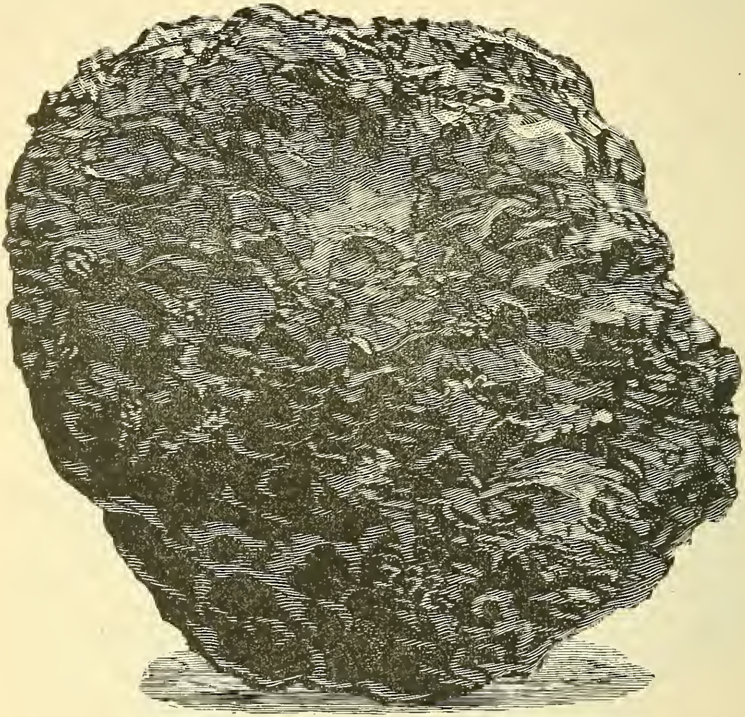
[*] This Journal, III, xxxiii, p. 115.

The Carroll County meteorite was found in 1880, about $\frac{3}{4}$ of a mile from Eagle Station, Carroll County, Kentucky, ten miles from the mouth of the Kentucky River and about seven miles in a direct line from both the Kentucky and the Ohio Rivers. The distance to the Turner mounds, where Professor Putnam found the meteoric iron and the ornaments made of it, is about 60 miles. The mass, which weighs about 80 lbs. or 36·5 kilos (figs. 2 and 3), is almost square, measuring 19$^{cm}$ ($7\frac{1}{2}$ inches) in thickness, 22$^{cm}$ (10 inches) in width and 29$^{cm}$ (12 inches) by 29$^{cm}$, 12 inches in length. The surface is rusted in some places to a depth of 10 to 12$^{mm}$, and deep pits, some 2$^{cm}$ across, are observed in spots where grains of olivine have probably dropped out. All of the original crust has disappeared. The mass is largely made up of fine yellow, transparent olivine, resembling closely that of the famous Pallas iron. This meteorite belongs to the siderolites or "syssidères" of Daubrée, and the Pallasite group.

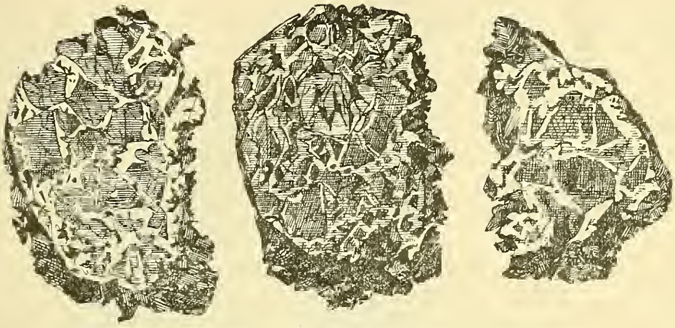
3.



Carroll County Meteorite, lower side, $\frac{1}{3}$ natural size.

Figure 4 shows three sections of the Carroll County mass, the

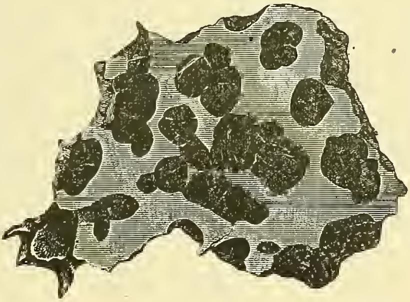
4.



Sections of the Carroll County Meteorite. Natural size.

light portions representing the iron and the dark portions the olivine. Figure 5 shows a similar section made by Dr. L. Kennicutt, of the Turner Mound mass. The specific gravities of the three sections figured are given below, with those of the Atacama and Turner's Mound meteorites.

5.



Section of the iron from the Turner Mounds.

| No. | Carroll County. | | Turner's Mound. | Atacama. |
|---|---|---|---|---|
| 1 | 4·21 | mean 4·41 | 4·72 | 4·35 |
| 2 | 4·379 | | | |
| 3 | 4·66 | | | |

Taking the specific gravity of the iron at 7·6, and that of the olivine at 3·3, we find that all of these meteorites consist of about three parts of olivine to one part of iron. The iron in the Carroll County meteorite is scarcely more than sufficient to hold the mass together securely, as the olivine is in so much larger crystals than in the Atacama meteorite. On etching, small, fine Widmanstätten markings are produced. By reflected light minute crystals of bronzite can easily be recognized, and analysis showed the presence of chromite in fine grains and a very small quantity of schreibersite. The analyses of the olivine and iron were kindly furnished by Mr. James B. Mackintosh of Lehigh University. The sample of the iron taken was selected, as he states, as carefully as possible, to ensure purity, but it was found impossible to free it entirely from earthy matter. The sample of olivine was also somewhat contaminated with foreign matter.

| Olivine, | 1. | 1a. G.=3·47. | | 2. Metallic Portion. | | | |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 37·90 | 39·36 | Fe | 73·44 | or | Fe | 71·73 |
| MgO | 41·65 | [41·83]* | Ni | 14·27 | | Ni | 14·27 |
| FeO | 19·66 | 18·81 | Co | 0·95 | | Co | 0·95 |
| MnO, CoO | 0·42 | ---- | P | 0·05 | | P | 0·05 |
| | | | $SiO_2$ | 4·23 | | Olivine | 11·12 |
| | 99·63 | 100·00 | MgO | 4·69 | | Chromite | 0·90 |
| | | | Chromite | 0·90 | | | |
| | | | | | | | 99·02 |
| | | | | 98·53 | | | |

* By difference.

The balance in the last analysis is oxygen in the form of iron oxide, and undetermined constituents. For the pure metallic portion we obtain then A below, or B on the assumption that the deficiency in the analysis is chiefly oxygen combined with iron as magnetic oxide.

| | A. | B. |
|---|---|---|
| Fe | 82·45 | 81·92 |
| Ni | 16·40 | 16·90 |
| Co | 1·09 | 1·12 |
| P | 0·05 | 0·06 |
| | 100·00 | 100·00 |

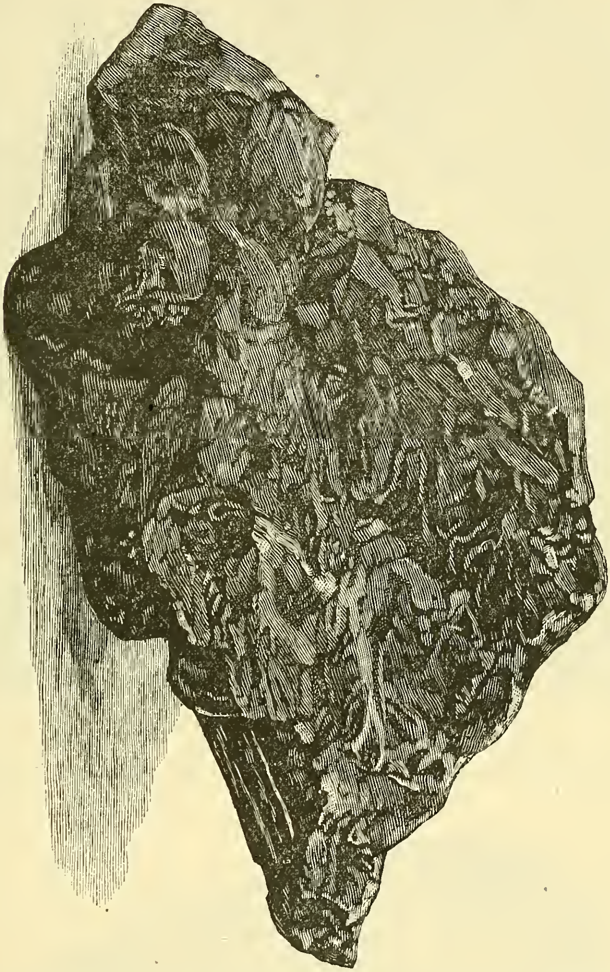
For comparison, analyses of the olivine and iron from the Turner mound and Atacama meteorites are added.

| Olivine. | | | | Iron. | | |
|---|---|---|---|---|---|---|
| Turner Mound.* G.=3·336. | | Atacama.† G.=3·33. | | | Turner Mound.* | Atacama.‡ |
| SiO | 40·02 | ---- | 36·92 | Fe | 89·00 | 88·01 |
| FeO | 14·06 | $Fe_2O_3$ | 17·21 | Ni | 10·65 | 10·25 |
| MnO | 0·10 | $Mn_2O_3$ | 1·89 | Co | 0·45 | 0·70 |
| MgO | 45·60 | ---- | 43·90 | Cu | tr. | ---- |
| | | | | P | ---- | 0·33 |
| | | | | Na | ---- | 0·21 |
| | | | | K | ---- | 0·15 |

* Kennicutt, loc. cit. † Schmid, Pogg. Ann., lxxxiv, 501.
‡ Buchner, Die Meteoriten, Giessen, p. 195, 1859.

2. *Catorze meteorite.*—The Catorze mass (fig. 6), weighing 92 lbs., was found by a miner near Catorze, San Luis Potosi, Mexico, in 1885. It is $31{\cdot}5^{cm}$ (12½ inches) long, $34{\cdot}5^{cm}$ (13¾ inches) wide, and $20^{cm}$ (8 inches) thick. It shows beautiful raised octahedral markings. On one side an opening $9^{cm}$ (3½ inches) long has been made, and a piece of a chisel of native copper left wedged in it (fig. 7). This piece, which is partially covered with oxide of copper, is $22^{mm}$ (⅞ inch) long on one side, $33^{mm}$ (1¼ inch) on the other, and $14^{mm}$ wide.

6.



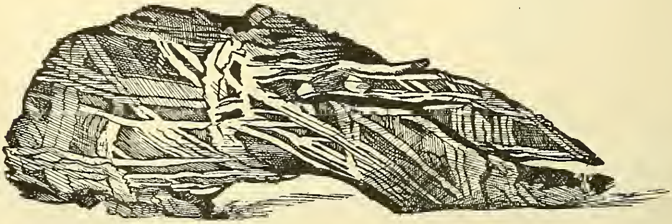
Catorze Meteorite; ⅛ natural size.

7.

Catorze Meteorite, showing copper chisel (*c*); natural size.

This iron is one of the Caillite group of Stanilas Meunier and shows the Widmanstätten lines very finely (see fig. 8),

8.



Catorze Meteorite, Widmanstätten Figures; natural size.

It resembles the irons of Augusta County, Virginia, of Glorieta Mountain, and others of this group. No troilite was observed, the mass having been cut very little, and schreibersite is only sparingly present.

The specific gravity of the piece was found to be 7·509, the analysis by James B. Mackintosh, E.M., of Lehigh University, is given below. To this are added analyses of masses found nearest to Catorze, since G. V. Bogulawski suggests that perhaps the Charcas, Zacatecas and Durango irons were all parts of one fall.*

| | Catorze. Mackintosh. | | Toluca. Wöhler.[1] | Toluca. Wöhler.[1] | Charcas. Stan. Meunier.[2] |
|---|---|---|---|---|---|
| Fe | 90·09 | | 90·43 | 87·894 | 93·01 |
| Ni | 9·07 | | 7·62 | 9·056 | 4·32 |
| Co | | | 0·72 | 1·070 | |
| P | 0·24 | | 0·15 | 0·620 | ---- |
| Scale insoluble in $HNO_3$ | 0·60 | Insoluble in HCl. | 0·34 | 0·224 | 0·70 |
| Schreibersite | ---- | | 0·56 | 0·344 | ---- |
| S | ---- | | 0·03 | ---- | ---- |
| CuSn | ---- | | 0·03 | ---- | ---- |
| Mn | ---- | | ---- | 0·201 | ---- |
| | 100·00 | | 99·88 | 99·409 | 98·03 |
| Sp. gr. | 7·509 | | | | |

[1] Wöhler Sitzber. K. Akad. Wiss., xx, 217. [2] Meunier, Encycl. Chim., ii, 118.

Del Rio† mentions that two of his pupils found above the Aqua Blanca Estate, native iron in a conglomerate rock in a vein from one to two fingers in width. Burkart‡ says that he saw, in the possession of Señor Chialiva in Zacatecas, a mass of meteoric§ iron weighing between ten and twelve pounds that was said to have been found in the vicinity of Catorze—or rather Alamos de Catorze as it is known—which is in San Luis Potosi, about 200 miles southwest of Durango, 40 miles north of Charcas, and 340 miles north of Toluca. There is also in the Museo Nacionale of the City of Mexico a mass‖ weighing 576 kilos which was found at Descubridora in San Luis Potosi; it was described in 1873.

The well-known Charcas mass, weighing 780 kilos, was found in the corner of the church at Charcas, San Luis Potosi, Mexico, by some French soldiers and taken by them to Paris in 1866. This mass was first mentioned by Sonnenschmid,¶ and afterwards by Humboldt.** From all appearances, however, I am inclined to believe that the iron now under consideration is a new and distinct fall.

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* Pogg. Ann., iv, 1, 1854. † Tablas Mineralogicas, vol. i, p. 57; ii, p. 40.

‡ Neues Jahrbuch für Mineralogie, 1856, p. 286.

§ Perhaps part of the iron here described, since it showed an old break on one side.

‖ A specimen of this iron in the Yale University Collection, received from Professor Barcena is accompanied by a copy of an analysis by P. Murphy, as follows: Fe 89·51, Ni 8·05, Co 1·94, S 0·43, Cr and P 0·95=100.—Eds.

¶ Berg. Rev., Mexico, p. 228, 1804.

** Essai Politique, Paris, 1811, vol. iv, p. 107.

# SCIENTIFIC INTELLIGENCE.

## I. Chemistry and Physics.

1. *On the production of Fluorine by the electrolysis of Hydrogen Fluoride.*—In June last, Moissan communicated to the French Academy the results which he had obtained by submitting liquid hydrogen fluoride to electrolysis. The anhydrous liquid was contained in a V-tube of platinum cooled to −50°, and the current needed was supplied by 50 Bunsen cells. Hydrogen was evolved at the negative electrode, and there appeared at the positive electrode a gas having the following properties: In contact with mercury it was completely absorbed, forming yellow mercurous fluoride; with water, it formed ozone; phosphorus spontaneously inflamed in it, forming phosphorus fluorides; sulphur heated and melted; carbon had no action; fused potassium chloride was attacked in the cold, evolving chlorine; crystallized silicium, carefully purified, took fire in the gas, producing silicium fluoride. The positive electrode of platinum-iridium was corroded, while the negative electrode of platinum was not affected.

In a second paper, the author gives the details of subsequent experiments. The hydrogen fluoride was obtained pure and anhydrous by heating hydrogen-potassium fluoride in a platinum alembic, and collecting the product in a platinum receiver immersed in ice and salt. In this way a colorless liquid was obtained, boiling at 19·5°, very hygroscopic and fuming strongly in the air. The platinum V-tube used for the electrolysis carried a small evolution tube near the top of each limb. Its ends were closed by stoppers of fluorite, through which passed platinum rods to serve as electrodes; that on the positive side being alloyed with ten per cent of iridium. This V-tube was placed in a glass jar and surrounded with methyl chloride. The liquid hydrogen fluoride was then transferred to it, the methyl chloride boiling quietly at −23°, and the current of 20 Bunsen cells, having an ammeter in circuit, turned on. If a trace of water be present, ozone is at first evolved; and then as it disappears, the resistance of the liquid rises; so that the current ceases when it becomes anhydrous. A small quantity of hydrogen-potassium fluoride must therefore be added; and then the evolution of gas is continuous and regular. At the positive electrode this gas is colorless, and silicium takes fire and burns brilliantly in it, as does adamantine boron, arsenic, antimony, sulphur and iodine. The metals also burn in it but less actively. Organic matters are violently attacked by it. A fragment of cork, near the delivery tube, took fire, and alcohol, ether, benzine, turpentine and petroleum are at once inflamed on contact with it. The gas combines with hydrogen spontaneously in the cold and with detonation. Since direct experiment showed that neither ozone saturated with hydrogen fluoride, nor hydrogen fluoride itself, would produce these results, and that chlorine was entirely absent, the conclusion is that this gas is either fluorine itself or is a higher fluoride of hydrogen.

In a third paper, Moissan describes the production of this gas by the electrolysis of carefully dried hydrogen-potassium fluoride kept in fusion at 110°. But the apparatus is rapidly attacked. In electrolyzing the liquid hydrogen fluoride, a yield at each electrode of from one and a half to two liters of gas per hour, is readily obtained. To test the question whether this gas contained hydrogen, it was passed over red-hot iron. The delivery tube was connected first with a platinum tube containing dry potassium fluoride, to absorb any hydrogen fluoride; and second, with a similar tube, also $20^{cm}$ long, containing a bundle of iron wires and previously tared. To the end of this tube is attached, by means of a rubber joint, first a test tube and then a flask both inverted and filled with pure carbon dioxide. The liquid hydrogen fluoride is cooled to $-50°$ by passing a rapid current of air through the surrounding methyl chloride, and the current is turned on. Immediately the platinum tube containing the iron is raised to incandescence by the chemical action going on within it, the form of the brilliantly burning wires being visible through the walls. After ten minutes, the operation was closed and the tube weighed. The iron was found as white crystallized fluoride, and on examining the collected gas remaining after absorption of the $CO_2$ by potassium hydrate, it was found to be only the air which the platinum tubes had contained. On the negative side $78^{cc}$ of hydrogen was collected, weighing 0·006942 gram. Multiplying this by 19, to give the corresponding weight of the fluorine disengaged, gives 0·132 gram; the increase in the weight of the iron having been 0·130 gram. Hence the gas obtained must be fluorine.—*C. R.*, cii, 1543; ciii, 202, 256, July, 1886. G. F. B.

2. *On Methods of avoiding errors due to polarization, in the use of double image prisms.*—In order to measure the relative intensity of two images, a double image prism is often employed. Two images of A and B are thus brought near together and polarized at right angles. These images are observed with an analyzer, which is attached to a divided circle, and which allows the equalization of the images. When the original bundle of rays is polarized, the photometric measures are complicated, since the double image prism acts itself as an analyzer and alters unequally the intensity of the two sources of light. Thus it is necessary to make a preliminary determination of the amount of error thus introduced. M. Cornu believes that the cases in which the bundle of rays are partially polarized are more frequent than is generally supposed and gives several methods of avoiding this error. These methods are simple and are explained in detail in his article.—*Comptes Rendus*, Dec. 20, 1886, p. 1227. J. T.

3. *Electromotive force due to the Voltaic arc.*—Many efforts have been made to determine this contrary electromotive force; but the results obtained by different observers have not been concor-

dant. LEO ARONS has applied to this problem, with certain modifications, Cohn's method for the measurement of polarization in fluids (Wied. Ann., xiii, 665, 1881), which in general terms is as follows:—One branch of a Wheatstone's bridge contains the polarizing element and the liquid. In place of the latter a metallic resistance can be interposed. The bridge contains a galvanometer and one coil of a dynamometer, while the other with the secondary coil of an induction apparatus forms the second diagonal of the parallelogram. The resistance together with the interposed liquid are so arranged that the dynamometer gives no indication when the induction coil is excited. At the same time the deflection of the galvanometer is read. Then the liquid is replaced by a metallic resistance until the dynamometer again gives no indication, and the galvanometer is again read. These observations can be applied to a simple expression which gives the contrary electromotive force of the liquid. Instead of the liquid the voltaic arc can be substituted. In preliminary trials, Arons, obtains with a current strength of 3·4 amperes, a contrary electromotive force, in the electric lamp employed, of 40·6 volts, together with an arc resistance of 2·1 ohms. With 4·1 amperes; the contrary electromotive force was 39·6 volts, and resistance 1·6 ohms. Arons is apparently unacquainted with the investigations of Professor Cross of the Massachusetts Institute of Technology upon this subject.—*Ann. der Physik und Chemie*, No. 1, 1887, p. 95–99. J. T.

4. *Generalization of the Wheatstone Bridge.*—O. FRÖHLICH investigates the conditions of equilibrium when sources of electromotive forces are interposed in one of the branches of the bridge or in one of its diagonals, and shows that Mance's method is only a special case of a more general law; and that the statement in Maxwell's Electricity and Magnetism, vol. i, p. 411, that Mance's method is the only one in which the current of the cell remains unchanged, is not correct.—*Ann. der Physik und Chemie*, No. 1, 1887, pp. 156–161. J. T.

5. *On a nearly perfect simple pendulum.*—Mr. J. T. BOTTOMLEY, of the University of Glasgow, suspends a small shot of about $\frac{1}{16}$ of an inch in diameter, by a single silk fibre (half a cocoon fibre) two feet long, in a glass tube three quarters of an inch in internal diameter and exhausts the latter to about one tenth of a millionth of an atmosphere. Starting with a vibrational range of $\frac{1}{4}$ inch on each side of its middle portion, the vibrations can be easily counted after the lapse of 14 hours.—*Phil. Mag.*, *Jan.*, 1887, p. 72. J. T.

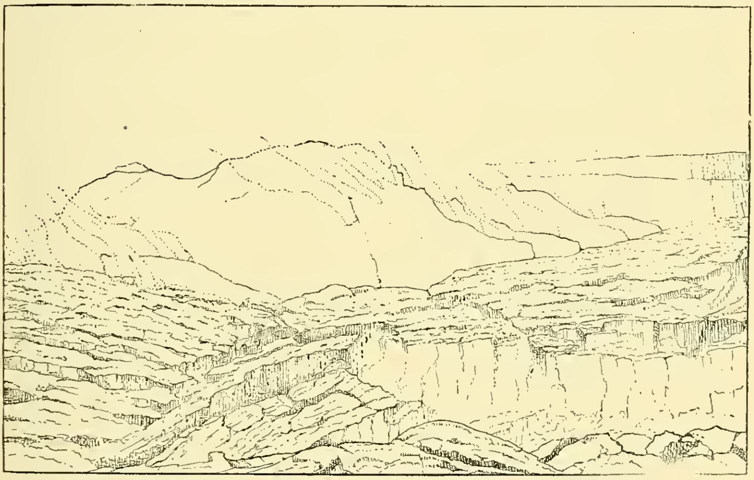
6. *Acoustical Investigations.*—F. MELDE continues his communications upon his acoustical experiments, with an account of the vibrations of bell-shaped vessels, together with the movements of fluids which they may contain. Ingenious methods of studying the movements of the fluids are given, together with the figures obtained. In certain cases a thin layer of petroleum covers the surface of the water, which fills the vessel; in other

cases light powder is sprinkled upon the water. The bell-shaped vessels are set with vibration in various ways.—*Ann. der Physik und Chemie*, No. 1, 1887, pp. 161–189. J. T.

## II. Geology and Mineralogy.

1. *Kilauea.*—The map of Kilauea by Mr. F. S. Dodge making Plate II, in the last number of this Journal, is reduced to one-fourth from the manuscript map received from Mr. Alexander, Director of the survey of the Islands, and the words on it, "scale 1:6000" should be changed to 1:24,000. Plate I is reduced to two-thirds the original; the scale is 1:18,000.

The writer is indebted to Prof. W. D. Alexander for a photograph (an outline copy of which is here given) of the cone *within* Halema'uma'u described by Mr. Dodge (p. 99.) It was taken from a point on the northeast edge of the pit on the 14th of last October, a few days after he finished his survey. In the copy the cone is in mere outline because the photograph fails to give any surface details. The height of the cone, as the figures in the explanation of the map, page 99, indicate, is very nearly that of the surrounding floor of Kilauea; and the height in the figure shows that the view is one looking down into the pit, with the broken pahoehoe floor of Halema'uma'u (between its walls and the cone) in the foreground. The dotted lines indicate the positions of vapor-streams and clouds issuing from apertures in the sides of and about the cone; above it only vapors are indicated, as if those of the inside crater. The lower wall on the right is the wall of the northwest side of Halema'uma'u.


The cone in Halema'uma'u from a photograph taken October 14, 1886.

Mr. Dodge, in a letter dated January 14th, states that the cone is made of broken rock, large and small fragments, derived from the fallen walls of the pit and old cones within it, material older therefore than the lava that surrounds it. He states that according to observations of others in November and early January the cone had increased in height so as to be one hundred and perhaps two hundred feet above the sides of the pit, instead of *on a level* nearly, as in early October; moreover the activity in the southwest part had increased and portions of the southwest wall had fallen in. J. D. D.

2. *The Origin of Mountain Ranges considered experimentally, structurally, dynamically, and in relation to their Geological History*, by T. MELLARD READE, C.E., F.G.S., etc., 360 pp. 8vo, with numerous illustrations. London, 1886. (Taylor & Francis).--The chief fact on which Mr. Reade bases his theory of the origin of mountains is that of the expansion of rocks by increase of heat. From his own numerous trials he arrives at 1/190,192 as the mean coefficient of expansion for 1° F., which is equivalent to 2·77 feet per mile for every 100° F. (which he takes at 2·75 feet). The special mean result for various sandstones arrived at by the author was 1/178,825 ; for marbles, 1/184,797; for slates, 1/193,827; for granites, 1/203,322. Mr. Reade observes that as expansion downward and laterally cannot take place, the whole is upward; consequently the rise of surface would be $3\times2·75=8·25$ feet nearly. Hence a crust 20 meters thick heated 1000° F., which would expand in each direction 550 feet (made the amount of consequent elevation by Lyell), would rise 1650 feet; and if the total rise went to form a ridge having a base one-tenth of the total area heated, the whole height would be 16,500 feet. A rising of molten or half-molten rock below would follow the rise; and the tension above would cause great fractures and this would lead to great denudation.

Periods of increased heat have alternated with those of diminished heat, and thus may have come contractions as well as expansions, and so alternations in conditions and in catastrophes, in the same mountain region. The increase of heat is due to a great increase in the thickness of sediments over the region,—the preliminary stage in mountain making, as first suggested by James Hall. This cause produces a rise in isogeothermal lines from below; and through this accession of heat the lower beds become most expanded. Thence come uplifts, fractures, flexures, faults, volcanic outflows, and the mountain range. The greatest mountain elevations have taken place in recent times because the Tertiary and Cretaceous rocks added vastly to the thickness of accumulations over large areas of the earth's surface.

Mr. Reade in illustrating his views, and opposing others, appeals chiefly to North American rocks for his illustrations and dwells especially upon the Appalachians of eastern America, and the Great Basin system studied by Powell, Gilbert and others, of western, quoting largely from American reports on the subjects.

As regards the Appalachians the conditions were just what the theory requires, if a thickness of 30,000 feet of rock in a sinking geosynclinal trough, with such additions as may be assumed for loss by degradation, is sufficient. The accumulation began in the Cambrian, and ended, according to the present state of facts, with the Permian, taking for its completion all of Paleozoic time. Supposing the thickness of the deposits made to have been 50,000 feet, and the time elapsed during the making 50,000,000 years, the mean rate of sinking was 1 foot in 1000 years. The isogeothermal plane consequently rose at the mean rate of 1 foot in 1000 years, and the expansion through the rise of temperature went forward correspondingly, so far as was possible. At this rate the heating and the expansion continued in progress during the 50,000,000 years; and still, through all that time, *sinking* continued as the mean result. Such a rate of rise in the isogeothermal plane is so extremely slow—a thousandth of a foot a year—that it is hardly probable that the expansion could have been resisted through the long era to appear catastrophically at the end of it; and unless so it would seem that something more than a rise in the isogeothermal plane was needed in order to make the deposits into a mountain range.

The theory of mountain-making brought forward by Mr. Reade does not explain the inequilateral feature of most mountains. Like most others that have been presented, it takes little note of the system of events in the progress of the globe and the system of structure in the results of that progress. American geologica study has made out plainly that there was first, in the continent, Archæan ranges of elevations of one or more epochs; that on the eastern border there were three or four other periods in the course of geological time when other ranges of elevations were made, but all parallel in general and often in special trend, with the Archæan, although stretching on for a thousand miles or more. The facts are similar, so far as is understood, in Western America. Here is system, working from a beginning, under some continued method of progress, ending in making a continent of systematic features. Mr. Reade says that "Dana looks upon the development of continental land as analogous to animal growth." Nothing could be farther from the truth; for all that the comparison used by the writer meant was that there was systematic progress, in some way, as much so as in animal development. There is system also in the courses of the feature lines of the globe, which courses are as far removed as possible from meridional as required by some theories. The fact that the writer formerly made all these results to depend on contraction from cooling and the nature of the earth's crust, shows that the accordance with animal growth, was only accordance with the universal law of progress or development (Man. Geol., p. 830). What theory now to attribute the results to he does not know; but he believes that no theory of mountain-making will find general acceptance that does not take this system of progress, of structure, of topographical features into consideration. If the speculator thinks, like Mr. Reade, the linear arrangement of islands of little importance, let him consider, instead, the great depressions of the ocean's bottom between the lines which teach the same great truths with regard to the earth's features.

Mr. Reade's work is a valuable contribution to the perplexing subject of mountain-making; for the principle to which he appeals has greater importance than has been supposed. But something more appears to be needed to give the theory full sufficiency.

3. *Skeleton of a Whale found over* 130 *years since in the St. Lawrence River Valley, near Quebec.*—A letter to the editors from Professor O. P. Hubbard states that in Kalm's Travels in North America and Canada, on page 15 of the third volume, mention is made of the finding of the skeleton of a whale some French miles from Quebec and one French mile from the River St. Lawrence, "in a place where no flowing water occurs at present." The skeleton was of considerable size, and the Governor of Fort Frederick said he spoke with several persons who had seen it. Kalm, the Swedish botanist, was in America during the years 1748 to 1751, and he learned the fact in 1750.

4. *Geological History of Lake Lahontan, a Quaternary Lake of Northern Nevada;* by ISRAEL COOK RUSSELL. Volume xi of the Monographs of the U. S. Geological Survey, 288 pp. 4to, with 4 plates, the last a folded map, 1885.—An abstract of Mr. Russell's results after his first season's work, published in the third Annual Report of the Director of the U. S. Geological Survey, has been briefly mentioned in a former volume of this Journal. The final Report, recently issued makes a volume of great general interest and scientific importance. The facts relating to the Lahontan Lake basin of the past and present, its terraces, the chemistry of its waters, the remarkable tufa deposits of the terraces, the lake and shore-made beds of sand, gravel and clays (the last largely pumiceous), the life of the varying waters, the drying up of the lake with the climatic changes, and the later Quaternary orographic movements, have all been carefully studied and a large amount of instruction drawn from them for physical geography, geology and economical science. The many maps and plates, illustrating the volumes are excellent. The descriptions of the thinolite tufa deposits and of the conditions of their origin are illustrated by several fine plates, and supplemented by extracts from a crystallographic study by E. S. Dana.

5. *The Geographical and Geological Distribution of Animals;* by ANGELO HEILPRIN, Prof. Invert. Paleontology, etc., 436 pp. 12mo. New York, 1887 (D. Appleton & Co.).—Professor Heilprin has endeavored to combine in this work a consideration of the geographical distribution of existing faunas with that of the ancient, and so present a general review of the historical as well as actual associations of species. The subject is a very broad one for the space allotted to it; but it has been so handled as to make a valuable and readable work for students in both geology and biology.

6. *Manual of Mineralogy and Lithology*, containing the elements of the science of Minerals and Rocks for the use of the practical Mineralogist and Geologist and for instruction in Schools and Colleges; by JAMES D. DANA, 4th edition, 518 pp. 8vo, New York, 1887 (John Wiley and Sons).—This new edition of the author's "small" mineralogy, like the preceding, places together, all the ores of the same metal, and in this and other ways the Manual is adapted to the needs of the mining and practical mineralogist. As the preface states, the work has been revised throughout, and brought down to the year 1886 in its descriptions and in the introduction of new species; and the chapter on Rocks has been revised, rearranged, much enlarged, and supplied with additional illustrations.

7. *On the chemical composition of the orthoclase in the Cortlandt Norite.* (Communicated.)—Since the publication of the writer's description of this interesting mineral in the February number of this Journal (p. 139), a complete analysis of it has been made by Mr. Wm. M. Burton of the Chemical Laboratory of the Johns Hopkins University. The results are worthy of publication as placing beyond all doubt the nature of the mineral in spite of its very unusual association.

The material for analysis was separated by the Thoulet solution, all that portion of the rock being used which possessed a specific gravity of 2·62 or less. The results of two complete analyses of lead fusion (I–II) and one partial analysis of fusion with potassium and sodium carbonate (III) are as follows:

| | (I.) | (II.) | (III.) | (Mean.) |
|---|---|---|---|---|
| $SiO_2$ | 61·71 | 61·76 | 61·65 | 61·71 |
| $Al_2O_3$ | 21·50 | 21·36 | 21·55 | 21·47 |
| CaO | 2·82 | 2·70 | ---- | 2·76 |
| $K_2O$ | 12·74 | 12·88 | ---- | 12·81 |
| $Na_2O$ | ·88 | 1·04 | ---- | ·96 |
| Total | 99·65 | 99·74 | --- | 99·71 |

Now on account of the very intimate admixture of the orthoclase with the accompanying and included andesine, it was doubtless impossible to perfectly separate the two minerals, as is made more probable by the specific gravity which is somewhat high for orthoclase. If, therefore, we deduct from the above mean analysis the amounts of $SiO_2$ and $Al_2O_3$ necessary to satisfy the 2·76 per cent of CaO and 0·96 per cent of $Na_2O$ in the anorthite and albite molecules respectively, we obtain: 50·23 per cent $SiO_2$, 14·75 per cent $Al_2O_3$ and 12·81 per cent $K_2O$; and these proportions, calculated as percentages, give: $SiO_2$ 64·57, $Al_2O_3$ 18·96, $K_2O$ 16·47, while the proportions calculated from the formula $K_2Al_2Si_6O_{16}$ are: $SiO_2$ 64·68, $Al_2O_3$ 18·43, $K_2O$ 16·89.

GEORGE H. WILLIAMS.

Baltimore, Feb. 18th, 1887.

8. *Nickeliferous metallic Iron from New Zealand* (from a letter to the Editors dated Dunedin, October 14, 1886).—In the drift of the Gorge River (which empties into Awarua or Big Bay, on the west coast of the middle island of New Zealand), derived in part from the so-called "Red Hill"—a high mountain mass consisting of older peridotite, more or less converted into serpentine—there occurs, associated with gold, platinum, cassiterite, chromite, magnetite, a nickel-iron alloy. According to an analysis by Mr. W. Skey, our government analyst, it is composed of Ni 67·63, Fe 31·02, Co 0·70, S 0·22, $SiO_2$ 0·43, and has the formula $Ni_2Fe$. Specific gravity 8·1 and hardness about 5. This as a new mineral he has named *Awaruite.* Mr. Skey also discovered the curious fact of this alloy not being able to reduce copper from its acid solution of cupric sulphate and argues from this the unreliability of the copper test for demonstrating the absence of iron alloys from rock masses. That the new alloy has been derived from the peridotite (olivine-enstatite rock, as far as I have found) of the Red Hill there can hardly be a doubt, as specimens of serpentine—partly resembling the antigorite, partly picrolite—have been found on the mountain, containing specks of it abundantly impregnated. It is certainly a very close terrestrial relative of the iron meteorite, octibbehite (FeNi), mentioned in Dana's System of Mineralogy and in Wadsworth's comprehensive table of analyses, given in "Lithological Studies," as found in Octibbeha Co., Mississippi. GEORGE H. F. ULRICH.

## III. BOTANY AND ZOOLOGY.

1. MINOR BOTANICAL NOTES.—That immense repertorium of botany, Baillon's *Dictionaire de Botanique*, makes steady progress. Fascicle 21, which is the first of vol. ii (pp. 104), carries the letter H down to the article *Hypericum.*

Of *Hooker's Icones Plantarum*, the third and concluding part of vol. xvii—a Fern volume—was issued in January. The North American and Northern Mexican species figured are *Nothochlæna Palmeri*, Baker, and *N. Hookeri*, Eaton.

H. N. Patterson, of Oquawka, Illinois, has brought out a new and attractive *Check-List of North American Plants, including Mexican Species which approach the U. S. Boundary.* It fills 150 large 8vo pages in double columns, of rather large and very clear type, printed upon one side only of the paper, and sufficiently spaced for cutting up into labels, when that is desired, or for intercalation of new names.

DR. W. F. TOLMIE, who died at Victoria, British Columbia, toward the close of last year, was one of the last survivors of those men of the Hudson Bay Company's service in its palmiest days who helped to develop the botany of our northwest coast. He was, we believe, one of Sir William Hooker's pupils at Glasgow, and, going out to Fort Vancouver as medical officer in 1832, he became one of the principal contributors of materials from that district for his Flora Boreali-Americana. In that work he is commemorated by a peculiar genus of *Ericaceæ*, which, however, had been previously named by Bongard upon specimens from Alaska. Consequently the name of *Tolmiea* was applied in Torrey and Gray's Flora to a peculiar saxifragaceous plant of that coast. In his later years Dr. Tolmie devoted himself very much to the ethnology and linguistics of the Indian tribes with which he had so long been intimate. His name should have appeared in the botanical necrology of the year 1886. A. G.

Professor Delpino, who as early as in the year 1873 announced the idea that most extra-floral nectar-glands in plants are useful to the plants that bear them, by attracting a body-guard of ants, has now published the first part of an elaborate memoir on the topic. His *Prodromo d'una Monografia delle Piante Formicarie*, taking up the orders *seriatim*, although in this first part it includes only the Polypetalous and a few of the earlier Gamopetalous orders, fills 111 pages, 4to, in the Memoirs of the Royal Academy of Sciences of Bologna, ser. 4, tome vii, 1886. The number of species recorded as having *extra-nuptial* glands is much larger than would have been expected. This term 'extra-nuptial' is coined to distinguish the glands under consideration from certain extra-floral glands which, no less than those in the flower, are subservient to pollination. The *funzione myrmecofila* performed by the ants so attracted and fed is the keeping off of caterpillars and other insects which prey upon the foliage, young fruits, etc. Fruit-growers and tree-planters, thankful though they be for these small favors, must wish that this *function* were still more extensive and effectual. A. G.

The February number of the Botanical Magazine gives a figure of the new Compass Plant, *Silphium albiflorum*, Gray, a very recently published species, from Texas, raised in England from seed sent by one of its discoverers, Mr. Reverchon, whose name in the Botanical Magazine unfortunately appears as a place instead of a person.

Alphonse de Candolle has a short article in the Archives des Sciences of January 15, on the botanical origin of some cultivated plants. It treats mainly of *Vicia Narbonnensis* and *Vicia Faba*, and goes against the idea of Bentham that the latter (the proper bean of Europe) is a cultivated derivative of the former. It is also maintained that wheat should be regarded as a species distinct from *Triticum Spelta* and *T. monoccocum*, notwithstanding that some recent experiments have been successful in intercrossing them. Horse Bean (*Vicia Faba*), Chick-pea, Lentils, Wheat, and Maize,—species of which the botanical originals appear to be extinct,—all agree in having large farinaceous seeds, therefore peculiarly subject to be eaten up by animals, such as mice, etc. To such depredations, M. de Candolle suspects that the unguarded native types of those species may have succumbed.

2. *Bibliotheca Zoologica II.* Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten und vom

Jahre 1861–1880 selbstständig erschienen sind etc., von Dr. O. TASCHENBERG. Lief 1, pp. 1–320; 2, pp. 321–640. 8vo, Leipzig, 1886 (Wilhelm Engelmann).—The former issue of the Bibliotheca Zoologica in 1861 under the editorship of Professor V. Carus contained a catalogue of zoological papers published during the years 1846 to 1860. The present work, of which two parts are now completed, with Dr. O. Taschenberg as editor, is to continue and complete this great undertaking for the period from 1861 to 1880. In style and method the present volume corresponds to those issued twenty-five years ago. The first part opens with the literature, a list of catalogues of books, and then a very minute and exhaustive enumeration of periodical publications of all kinds, with the number of pages, plates, etc., of each volume—this portion of the work covers nearly 200 pages. Then follow the lists of zoological memoirs and articles arranged by the author's name under a number of general heads, as: acclimatization, aquaria, museums, public and private collections, zoological gardens, laboratories and stations; the collection and preservation of objects of natural history and comparative anatomy; the microscope, and so on. This statement of the contents of Part I will give some idea of the nature and scope of the work. Evidences of the tireless industry of the editor and his never relaxing effort to ensure accuracy and completeness are apparent on every page. The value of such a work can hardly be overestimated at this time when the literature of the science is increasing so rapidly and the memoirs on the various topics are scattered through so wide a range of publications. It is difficult to see how any worker in the science can get along without it. The work when finished will fill twelve parts of about 320 pages each, forming four large volumes; the year 1888 is set as the time for its completion.

## IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The American Naturalist.*—Professor A. S. Packard, for twenty years one of the editors of the Naturalist, and a large contributor to its pages, has withdrawn from it, and hereafter it will be in charge of Professor E. D. Cope.

2. *The Swiss Cross, A Monthly Magazine of the Agassiz Associations:* N. D. C. Hodges editor.—With January, the first number of this new Journal of Popular Science appeared, in a broad octavo form of forty pages. It promises to be a valuable journal for the distribution of scientific knowledge, right opinions, and news, and to be adapted not only for the young readers of the Agassiz Associations but for all who are interested in having science in a popular form. The Journal is published in New York at 47 Lafayette Place, at $1.50 a year or 15 cents a number.

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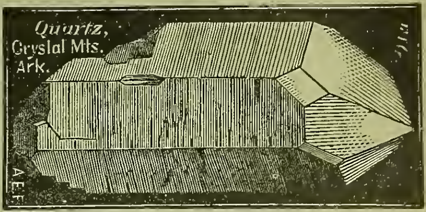

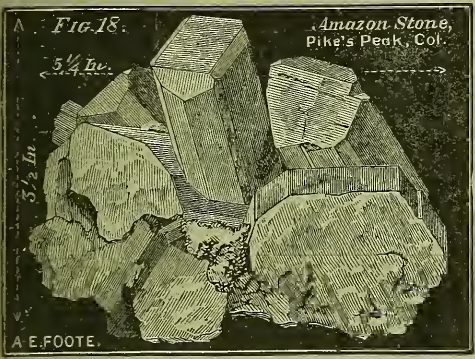

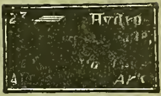

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U. S. Geological Survey.

VOL. XXXIII. APRIL, 1887.

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## ART. XXVIII.—*Contributions to Meteorology;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Twenty-second paper. With Plate V.

### *Areas of high pressure. Their magnitude and direction of movement. Relation of areas of high pressure to areas of low pressure.*

IN several former papers I have examined the form and magnitude of areas of high pressure, the position of the major axis of the isobars, the direction and velocity of their movement, and the low temperature which accompanies them—the laws of the wind's motion within these areas—the circumstances under which areas of high pressure originate, and the relations which they bear to areas of low pressure. This examination has been made for the United States by the aid of the Signal Service maps and the published volumes of the Signal Service observations; and it has been made for Europe by the aid of Hoffmeyer's Weather Maps. It was found that areas of unusually high pressure sometimes extend from the Pacific Ocean to the Atlantic; and stretch northward far beyond the limits of the United States. The maps of the United States Signal Service are therefore not large enough to exhibit satisfactorily the phenomena of areas of unusually high pressure, and especially to exhibit their relations to areas of low pressure; and the same is true of Hoffmeyer's charts of the Atlantic Ocean and Europe. I have therefore extended this examination to the maps of the

International Bulletin. These maps begin with Oct., 1877 and extend to June, 1884. Table I exhibits all the cases which I have found in which these maps show an isobar of 31·0 inches over any part of the Northern Hemisphere. Columns 3 and 4 show the latitude and longitude of the station at which the barometer was highest. This station is generally near the center of the highest isobar but may not coincide exactly with it. Columns 5 and 6 show the pressure and temperature at the station where the barometer was highest. Columns 8 and 9 show (in degrees of a meridian) the dimensions of the high area measured in an East and West direction, and also in a North and South direction. Since a large part of the isobars represented on the maps are incomplete, I have extended them about each high center up to the isobar 30·0 inches in such a manner as seemed to correspond best to the incomplete curves shown on the maps. The numbers in columns 8 and 9 give the results obtained for the isobars thus completed. The lines measured in the two different directions run nearly through the centers of the high areas. In many cases the high areas stretch out to a great distance toward the East and West, particularly in a latitude somewhat south of the high center. In such cases the numbers in column 8 do not indicate the full extent of the isobar, 30·0 inches, but only its extent near the parallel which passes through the center of high pressure.

TABLE I.—*Barometer above* 31·0 *inches, International Bulletin.*

| No. | Date. | | Lat. | Long. | Barom. highest. | Therm. Fahr. | Therm. below mean. | Breadth, Deg. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | E.-W. | N.-S. |
| 1 | 1877, Dec. | 14 | 56°·8 | 60°·6 E. | 31·37 | −31° | −38° | -- | 60° |
| | | 15 | 53·3 | 83·8 E. | ·30 | −55 | −61 | -- | 55 |
| | | 16 | 53·3 | 83·8 E. | ·63 | −54 | −60 | 90 | 58 |
| | | 17 | 53·3 | 83·8 E. | ·63 | −50 | −56 | 88 | 57 |
| | | 18 | 53·3 | 83·8 E. | ·45 | −41 | −47 | 68 | 59 |
| | | 19 | 58·4 | 92·1 E. | ·37 | −17 | − 8 | 78 | 59 |
| | | 20 | 55·8 | 49·1 E | ·26 | 1 | −12 | 80 | 56 |
| | | 21 | 53·8 | 48·6 E. | ·08 | 6 | − 7 | 80 | 51 |
| 2 | Dec. | 31 | 58·4 | 92·1 E. | ·08 | −21 | −11 | 74 | 46 |
| | 1878. Jan. | 1 | 58·4 | 92·1 E. | ·01 | −26 | −16 | 80 | 48 |
| | | 2 | 53·8 | 48·6 E. | ·02 | − 6 | −17 | 79 | 45 |
| | | 3 | 53·8 | 48·6 E. | ·01 | − 1 | −12 | 76 | 41 |
| | | 4 | 41·3 | 69·3 E. | ·09 | −10 | −40 | 83 | 44 |
| | | 5 | 41·3 | 69·3 E. | ·02 | − 4 | −34 | 76 | 47 |
| | | 6 | 58·4 | 92·1 E. | ·06 | −28 | −16 | 71 | 52 |
| | | 7 | 58·4 | 92·1 E. | ·25 | −30 | −18 | -- | 60 |
| | | 8 | 58·4 | 92·1 E. | ·15 | −28 | −16 | 63 | 58 |
| | | 9 | 58·4 | 92·1 E. | ·20 | −33 | −21 | -- | 62 |
| 3 | Dec. | 11 | 53·3 | 83·8 E. | ·09 | −42 | −48 | 66 | 55 |

TABLE I—*continued.*

| No. | Date. | | Lat. | Long. | Barom. highest. | Therm. Fahr. | Therm. below mean. | Breadth, Deg. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | E.-W. | N.-S. |
| 4 | Dec. | 20 | 58°·4 | 92°·1 E. | ·01 | −28° | −19° | 58° | 60° |
| | | 21 | 58·4 | 92·1 E. | ·08 | −35 | −26 | 70 | 60 |
| | | 22 | 58·4 | 92·1 E. | ·22 | −39 | −30 | 61 | 63 |
| | | 23 | 58·4 | 92·1 E. | ·26 | −36 | −27 | 70 | 60 |
| | | 24 | 58·4 | 92·1 E. | ·10 | −18 | − 9 | 67 | 64 |
| 5 | Dec. | 28 | 58·4 | 92·1 E. | ·09 | − 0 | + 6 | 80 | 60 |
| 6 | 1879. Jan. | 18 | 56·8 | 60·6 E. | ·00 | −15 | −20 | 70 | 56 |
| | | 19 | 56·8 | 60·6 E. | ·12 | −22 | −27 | 84 | 55 |
| | | 20 | 53·3 | 83·8 E. | ·25 | −28 | −27 | 85 | 66 |
| | | 21 | 53·3 | 83·8 E. | ·15 | −23 | −22 | -- | 67 |
| | | 22 | 55·8 | 49·1 E. | ·09 | − 4 | −13 | 83 | 63 |
| | | 23 | 55·8 | 37·7 E. | ·09 | 3 | −12 | 76 | 65 |
| 7 | Feb. | 24 | 56·8 | 60·6 E. | ·00 | − 3 | −15 | -- | 53 |
| 8 | Nov. | 24 | 41·3 | 69·3 E. | ·00 | 13 | −30 | 72 | 28 |
| 9 | Dec. | 25 | 41·2 | 112·0 W. | ·14 | − 3 | ---- | -- | -- |
| 10 | 1880. Jan. | 16 | 58·4 | 92·1 E. | ·07 | −33 | −21 | 70 | 56 |
| | | 17 | 51·3 | 119·6 E. | ·03 | −35 | −13 | 60 | 60 |
| | | 18 | 51·3 | 119·6 E. | ·10 | −35 | −13 | -- | 60 |
| | | 19 | 58·4 | 92·1 E. | ·17 | −16 | − 7 | -- | 59 |
| | | 20 | 51·3 | 119·6 E. | ·16 | −27 | −10 | -- | 62 |
| 11 | Jan. | 24 | 58·4 | 92·1 E. | ·00 | −14 | − 4 | 58 | 62 |
| 12 | Jan. | 28 | 51·3 | 119·6 E. | ·02 | −33 | −11 | -- | 61 |
| | | 29 | 51·3 | 119·6 E. | ·15 | −36 | −14 | -- | 68 |
| 13 | 1881. Mar. | 1 | 58·4 | 92·1 E. | ·36 | −10 | −24 | 67 | 54 |
| | | 2 | 58·4 | 92·1 E. | ·41 | − 9 | −23 | -- | 57 |
| | | 3 | 58·4 | 92·1 E. | ·22 | 0 | −14 | -- | 62 |
| 14 | Mar. | 9 | 58·4 | 92·1 E. | ·02 | − 3 | −17 | -- | 62 |
| 15 | | 23 | 53·3 | 83·8 E. | ·02 | 17 | − 1 | 50 | 46 |
| 16 | Nov. | 4 | 58·4 | 92·1 E. | ·07 | 5 | − 4 | -- | 44 |
| 17 | Dec. | 14 | 58·4 | 92·1 E. | ·08 | − 7 | 0 | 73 | 62 |
| | | 15 | 58·4 | 92·1 E. | ·06 | −14 | − 8 | 73 | 63 |
| 18 | Dec. | 27 | 58·4 | 92·1 E. | ·04 | − 9 | − 3 | 78 | 50 |
| 19 | 1882. Jan. | 4 | 51·2 | 71·4 E. | ·01 | −28 | −30 | 71 | 42 |
| 20 | | 15 | 52·2 | 21·0 E. | ·06 | 28 | + 3 | 77 | 50 |
| 21 | | 23 | 49·8 | 97·1 W. | ·03 | −35 | ---- | 32 | 52 |
| 22 | Feb. | 17 | 49·8 | 97·1 W. | ·09 | −29 | ---- | 25 | 55 |
| 23 | | 20 | 49·9 | 7·8 W. | ·20 | −50 | 0 | -- | 50 |
| 24 | Oct. | 28 | 50·4 | 80·2 E. | ·05 | − 7 | −46 | 87 | 47 |
| 25 | Nov. | 13 | 58·4 | 92·1 E. | ·13 | −15 | −22 | -- | 55 |
| 26 | Nov. | 22 | 50·4 | 80·2 E. | ·06 | 2 | −18 | 62 | 46 |
| | | 23 | 50·4 | 80·2 E. | ·16 | − 4 | −24 | 64 | 44 |
| 27 | Dec. | 7 | 39·3 | 94 9 W. | ·01 | − 5 | ---- | 38 | 46 |
| 28 | Dec. | 7 | 58·4 | 92·1 E. | ·03 | −42 | −33 | 50 | 56 |
| 29 | Dec. | 9 | 56·5 | 85·0 E. | ·01 | −37 | −39 | 82 | 59 |
| | | 10 | 50·4 | 80·2 E. | ·04 | −27 | −33 | 76 | 58 |
| 30 | Dec. | 13 | 50·4 | 80·2 E. | ·11 | −27 | −33 | 83 | 47 |
| | | 14 | 50·4 | 80·2 E. | ·01 | −29 | −35 | 90 | 51 |
| | | 15 | 58·4 | 92·1 E. | ·11 | −31 | −22 | 70 | 51 |
| | | 16 | 50·4 | 80·2 E. | ·12 | − 9 | −15 | 77 | 56 |
| | | 17 | 58·4 | 92·1 E. | ·24 | −29 | −20 | 77 | 67 |
| | | 18 | 58·4 | 92·1 E. | ·08 | −19 | −10 | 74 | 71 |
| | | 19 | 58·4 | 92·1 E. | ·01 | −13 | − 7 | 80 | 78 |
| 31 | Dec. | 29 | 53·3 | 83·8 E. | ·04 | −15 | −18 | 62 | 51 |
| | | 30 | 58·4 | 92·1 E. | ·06 | −19 | − 9 | 60 | 54 |
| 32 | 1883. Feb. | 11 | 63·8 | 162·0 W. | ·21 | − 4 | 0 | 66 | 59 |
| 33 | Nov. | 9 | 52·3 | 104·3 E. | ·05 | 3 | −11 | 80 | 47 |
| | | 10 | 52·3 | 104·3 E. | ·03 | 0 | −14 | 75 | 56 |
| 34 | Nov. | 15 | 58·6 | 49·7 E. | ·00 | 24 | 0 | 90 | 61 |
| 35 | Dec. | 22 | 58·4 | 92·1 E. | ·02 | −12 | − 6 | 77 | 60 |
| 36 | 1884. Jan. | 18 | 51·3 | 119·6 E. | ·02 | −32 | −10 | 65 | 68 |
| | | 19 | 51·4 | 119·6 E. | ·01 | −27 | −10 | 80 | 68 |
| 37 | Jan. | 23 | 50·7 | 103·7 W. | ·03 | −36 | ---- | 57 | 39 |

Of the 81 cases enumerated in this table, the number for each month in the year was as follows:

January, 29; February, 4; March, 5; October, 1; November, 8, and December, 34. We thus see that 79 per cent of the whole number of cases occurred in the months of December and January; and none occurred during the six warmer months of the year.

Of these 81 cases, 74 occurred over Europasia; 6 over North America and one over the Atlantic Ocean near the Southwestern extremity of Ireland. Table II shows the latitude and longitude of the 74 stations over Europasia at which a pressure above 31·0 inches was recorded; and also the number of cases occurring at each of these stations.

TABLE II.—*Latitude and longitude of the high centers.*

| Station. | Lat. | Long. | Cases. | Station. | Lat. | Long. | Cases. |
|---|---|---|---|---|---|---|---|
| Viatka | 58°·6 | 49°·7 E. | 1 | Barnaul | 53°·3 | 83°·8 E. | 9 |
| Yeniseisk | 58·4 | 92·1 | 32 | Irkutsk | 52·3 | 104·3 | 2 |
| Ekaterinburg | 56·8 | 60·6 | 4 | Warsaw | 52·2 | 21·0 | 1 |
| Tomsk | 56·5 | 85·0 | 1 | Nertchinsk | 51·3 | 119·6 | 7 |
| Kasan | 55·8 | 49·0 | 2 | Akmolinski | 51·2 | 71·4 | 1 |
| Moscow | 55·8 | 37·5 | 1 | Semipalatinsk | 50·4 | 80·2 | 7 |
| Krotkowo | 53·8 | 48·6 | 3 | Taskend | 41·3 | 69·3 | 3 |

With but one exception, these stations are all situated between the parallels of 50° and 60°. Taskend, being situated so far south of the other stations, has a suspicious appearance. According to the International Bulletin its altitude above sea level is 1607 feet, but the altitude is marked by ? as if considered doubtful. It seems probable that the assumed elevation is a little too great, and that the barometric pressure, reduced to sea level, is consequently somewhat too great. With but one exception, all of the 81 cases included in Table I are situated over the continents, and almost invariably at a considerable distance from both the Atlantic and Pacific Oceans, and the exception named occurred near the coast of Ireland. Not a single case of pressure amounting to 31·0 inches has been found over the Pacific Ocean, although one case occurred in the northwestern part of North America near Behring Strait. These facts clearly show the influence of the continents in favoring the formation of areas of very high pressure; and over Europasia these cases occur chiefly between the parallels of 50° and 60°.

The observations in Table I indicate that these high areas are nearly stationary in position. At each station from day to day there are slight fluctuations of pressure which give to the high center the appearance of moving rapidly to and fro, but in general for the 14 cases in which the pressure of 31·0 inches was maintained for at least two successive days, the position of the high center on the last day did not differ greatly from its position on the first day. In No. 1 the high center did not fluctuate greatly in position for eight days, but apparently advanced a little toward the south and west. No. 2 continued for ten days, and on the last day the center was found at the same station as on the first day. No. 4 remained stationary for five days; No. 12 stationary for two days; No. 13 for three days; Nos. 17, 26, 33 and 36 stationary for two days; No. 6 moved slightly toward the south and west; No. 10 moved slightly toward the south and east; No. 30 continued for seven days and apparently moved a little toward the north and east; No. 31 also appeared to move a little toward the north and east. We thus find that in the 14 cases in which the pressure of 31·0 inches was maintained for at least two successive days, in eight of them the center apparently made no progress; in three cases there was a slight movement toward the east, and in three cases a slight movement toward the west; in two cases there was a slight movement toward the north, and in four cases a slight movement toward the south. The facts all indicate that these high areas had no very distinctly marked progressive movement.

The mean diameter of these high areas measured in a direction from north to south (which was generally the shortest diameter) is 55 degrees of a meridian, or about 3800 English miles. The mean diameter in an East and West direction is 71 degrees of a meridian, or about 4900 English miles; and if we had measured the actual extent of the isobar 30·0 inches near a parallel a little south of the high center, we should have found considerably larger dimensions.

The low temperature attending these high areas is quite remarkable, the mean temperature from the 74 cases over Europasia being −18° Fahr.; and the observations were taken at 7 A. M. Washington time, which for the center of Europasia is near the warmest part of the day. Column 7th of Table I shows how much the thermometer at each station was depressed below its mean height for the given time and place. The average of the numbers in this column is −19° F., which is considerably less than for like cases in the United States; but this appears to be mainly due to the fact that in Central Asia the thermometer is almost uninterruptedly low at this season of the year. There were however several cases in which the thermometer was but slightly below its mean height, and there were two cases in which the thermometer was slightly above the mean. In Table III, I have given all the cases in which the depression of the thermometer below its mean height for the given time and place was less than 6 degrees, and I have added various particulars which are designed to shed some light upon the cause of this peculiarity. Column 1st gives the dates of the cases; column 2d gives the station of highest pressure; column 3d gives the depression of the thermometer below its mean height at this station. Column 4th shows the degree of cloudiness at this station (scale 0–10); column 5th gives a station not very remote from the preceding where the thermometer was more depressed below the mean; column 6th shows the temperature at this station; column 7th shows how much the thermometer at this station was depressed below the mean, and column 8th gives several stations where the sky was entirely overcast with clouds, and at most of these stations there was some precipitation in the form of snow or rain.

TABLE III.—*Cases of unusually high temperature with high pressure.*

| Date. | Maximum pressure. | Below mean. | Cloud. | Extreme cold. | | | Sky entirely overcast. |
|---|---|---|---|---|---|---|---|
| | | | | Station. | Therm. | Below mean. | |
| 1878. Dec. 28 | Yeniseisk. | +6° | 0 | Irkutsk. | −29° | −10° | Turuchansk, Kainsk. Irkutsk. |
| 1880. Jan. 24 | Yeniseisk. | −4 | 0 | Ekaterinb. | −17 | −22 | Turuchansk, Ekaterinburg. |
| 1881. Mar. 23 | Barnaul. | −1 | 1 | --------- | ---- | ---- | Turuchansk, Ekat. Kainsk. |
| Nov. 4 | Yeniseisk. | −4 | 9 | Barnaul. | − 2 | −19 | Turuch., Tomsk, Akmolinsk. |
| Dec. 14 | Yeniseisk. | 0 | 4 | Barnaul. | −12 | −18 | Turuchansk, Akmolinsk, Ekat. |
| 27 | Yeniseisk. | −3 | 10 | Barnaul. | −23 | −29 | Yeniseisk, Turuchansk, Ekat. |
| 1882. Jan. 15 | Warsaw. | +3 | 1 | Kiew. | +14 | − 9 | Dorpat, Moscow, Munich. |
| Feb. 20 | N. Ireland | 0 | 8 | --------- | ---- | ---- | Valencia, Plym., Bordeaux. |
| 1883. Nov. 15 | Viatka. | 0 | 10 | Semipalat. | + 6 | −14 | Viatka, Dorpat, Kasan. |

We see that in these cases there was generally a station not very remote from the center of high pressure where the thermometer was more depressed than it was at the high center, which agrees with what has been found for the United States. We also see that in only two of the cases was the sky at the center of high pressure entirely free from clouds, and in each case there were stations not very remote where the sky was entirely overcast and there was some precipitation in the form of rain or snow. These facts seem to indicate that the comparatively high temperature attending these high areas was due to local disturbances which gave rise to cloudiness and the consequent development of heat.

In order to ascertain whether an unusually low temperature in Central Asia is generally attended by a barometric pressure considerably above the mean, I have selected all the cases in which the thermometer at Yeniseisk fell as low as −36° C., during a period of seven years (1876–1882) and opposite to each temperature I have placed the barometric pressure for the same dates. The particulars are shown in Table IV.

TABLE IV.—*Thermometer —36° Cent. at Yeniseisk, Central Asia.*

| Date. | Ther. | Bar. | Above mean. | Date. | Ther. | Bar. | Above mean. | Date. | Ther. | Bar. | Above mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1876. | | | | 1877. | | | | 1879. | | | |
| Jan. 7 | −39°·1 | 772·5 | + 8·7 | Dec. 27 | −37°·8 | 774·4 | + 8·8 | Nov. 28 | −37°·3 | 761·1 | − 0·1 |
| 8 | −38·0 | 73·8 | +10·0 | 1878. | | | | 29 | −40·6 | 72·4 | +11·2 |
| 31 | −36·1 | 62·7 | − 1·1 | Jan. 2 | −37·0 | 72·8 | + 9·0 | 1880. | | | |
| Feb. 1 | −45·9 | 65·1 | + 3·9 | 7 | −39·2 | 80·8 | +17·0 | Jan. 16 | −38·8 | 78·5 | +14·7 |
| 7 | −38·2 | 63·9 | + 2·7 | 8 | −38·2 | 83·1 | +19·3 | 17 | −41·5 | 80·0 | +16·2 |
| 13 | −38·2 | 57·1 | − 4·1 | 9 | −39·5 | 80·6 | +16·8 | 19 | −36·7 | 82·6 | +19·8 |
| 14 | −40·3 | 51·6 | − 9·6 | 10 | −38·7 | 79·9 | +16 1 | 26 | −36·1 | 72·0 | + 8·2 |
| Nov. 30 | −39·0 | 71·0 | + 9·8 | 25 | −37·8 | 71·8 | + 8·0 | Feb. 16 | −36·1 | 75·2 | +14·0 |
| Dec. 1 | −43·1 | 73·2 | + 7·6 | 26 | −37·7 | 76·8 | +13·0 | 17 | −37·0 | 73·7 | +12·5 |
| 13 | −36·9 | 75·0 | + 9·4 | 27 | −37·1 | 74·3 | +10·5 | 18 | −38·2 | 68·9 | + 7·7 |
| 14 | −39·0 | 73·1 | + 7·5 | 28 | −37·6 | 72·1 | + 8·3 | Dec. 10 | −37·6 | 70·2 | + 4·6 |
| 29 | −37·7 | 72·9 | + 7·3 | Feb. 1 | −37·0 | 67·9 | + 6·7 | 11 | −37·9 | 72·8 | + 7·2 |
| 1877. | | | | Nov. 5 | −37·4 | 69·2 | + 8·0 | 12 | −38·0 | 76·9 | +11·3 |
| Jan. 9 | −39·7 | 81·5 | +17·7 | Dec. 5 | −36·6 | 56·5 | − 9·1 | 1881. | | | |
| 10 | −46·1 | 81·8 | +18·0 | 6 | −41·0 | 59·9 | − 5·7 | Feb. 2 | −39·2 | 76·7 | +15·5 |
| 18 | −36·1 | 62·4 | − 1·4 | 7 | −36·6 | 68·1 | + 2·5 | 12 | −40·0 | 77·2 | +16·0 |
| 20 | −36·4 | 62·7 | − 1·1 | 8 | −38·0 | 65·6 | 0·0 | 21 | −37·3 | 63·1 | + 1·9 |
| 21 | −46·6 | 64·6 | + 0·8 | 9 | −44·9 | 69·9 | + 4·3 | 22 | −36·8 | 72·6 | +11·4 |
| 22 | −48·8 | 74·9 | +11·1 | 10 | −48·0 | 74·4 | + 8·8 | 23 | −39·6 | 68·8 | + 7·6 |
| 28 | −42·4 | 60·3 | − 3·5 | 11 | −40·3 | 77·6 | +12·0 | Mar. 1 | −37·1 | 84·0 | +23·7 |
| 29 | −45·5 | 67·5 | + 3·7 | 13 | −37·6 | 77·9 | +12·3 | Nov. 29 | −37·0 | 68·3 | + 7·1 |
| 30 | −41·7 | 68·3 | + 4·5 | 21 | −42·9 | 78·7 | +13·1 | 30 | −38·0 | 70·0 | + 8·8 |
| 31 | −36·1 | 74·1 | +10·3 | 22 | −42·9 | 82·2 | +16·6 | Dec. 1 | −38·0 | 66·3 | + 0·7 |
| Feb. 4 | −36·1 | 64·9 | + 3·7 | 23 | −40·2 | 82·7 | +17·2 | 2 | −36·6 | 65·7 | + 0·1 |
| 5 | −41·7 | 63·9 | + 2·7 | 1879. | | | | 23 | −36·2 | 71·1 | + 5·5 |
| 6 | −38·1 | 66·1 | + 4·9 | Jan. 17 | −41·0 | 63·1 | − 0·7 | 1882. | | | |
| 7 | −37·8 | 71·4 | +10·2 | 18 | −50·0 | 66·9 | + 3·1 | Dec. 1 | −41·8 | 58·3 | − 7.3 |
| 8 | −36·8 | 72·6 | +11·4 | 19 | −54·1 | 73·5 | + 9·7 | 3 | −42·0 | 64·6 | − 1.0 |
| 9 | −40·6 | 75·0 | +13·8 | 20 | −46·6 | 74·1 | +10·3 | 6 | −38·4 | 73·4 | + 7·8 |
| Dec. 11 | −38·5 | 51·6 | −14·0 | 24 | −38·0 | 72·0 | + 8·2 | 7 | −46·7 | 77·2 | +11·6 |
| 12 | −46·4 | 61·9 | − 3·7 | 25 | −42·7 | 73·8 | +10·0 | 8 | −49·0 | 76·3 | +10 7 |
| 13 | −50·7 | 65·1 | − 0·5 | 26 | −43·7 | 74·4 | +10·6 | 9 | −48·6 | 75·5 | + 9·9 |
| 14 | −50·5 | 72·8 | + 7·2 | 27 | −43·9 | 66·3 | + 2·5 | 17 | −39·6 | 84·4 | +18·8 |
| 15 | −46·5 | 81·1 | +15·5 | Feb. 15 | −38·4 | 68·5 | + 7·3 | 24 | −42·1 | 75·3 | + 9·7 |
| 16 | −44·5 | 87·9 | +22·3 | 16 | −45·4 | 74·9 | +13·7 | 25 | −44·4 | 77·9 | +12·3 |
| 23 | −37·6 | 77·0 | +11·4 | 17 | −40·5 | 69·7 | + 8·5 | 26 | −40·8 | 76·6 | + 5·0 |
| 26 | −37·0 | 76·7 | +11·1 | 22 | −37·7 | 69·2 | + 8·0 | | | | |

The mean pressure at Yeniseisk (not reduced to sea level) is as follows: January 763·8$^{mm}$; February 761·2$^{mm}$; March 759·3$^{mm}$; November 761·2$^{mm}$; December 765·6$^{mm}$. From these values I have deduced the numbers given in column 4th of the table, showing for each date in millimeters how much the barometer was above or below its mean height. The average of the numbers in this column is +7·8$^{mm}$ (=0·31 inch); that is when the thermometer at Yeniseisk sinks as low as −36° C. the barometer is generally 0·31 inch above its mean height. In only one case (Dec. 16, 1877) did the barometer rise as high as 31·0 inches. We find then that extremely low temperatures are generally attended by a pressure somewhat above the mean, but seldom by an extremely high pressure. Moreover we find

15 cases (one-seventh of the whole number) in which the pressure was below the mean.

The most remarkable case of low pressure occurred Dec. 11, 1877. On the 9th of December there was an area of low pressure near Yeniseisk (29·63 inches) accompanied by a temperature very much above the mean. On the next day the barometer rose slowly and the thermometer sunk rapidly. On the 11th the thermometer continued to sink and the barometer also descended slightly, but the stations of observation are not sufficiently numerous to indicate clearly the cause. For six successive days the thermometer remained below −36° C. and the barometer rose steadily, standing at $790{\cdot}4^{\mathrm{mm}}$ at 9 P. M. Dec. 16th. This cold wave came from the northeast and preceded the high pressure, and the high pressure of Dec. 16th was apparently the effect of the long continued and severe cold which preceded it.

The case of Dec. 5 and 6, 1878, was similar to the preceding. On the 4th of December there was an area of low pressure near Yeniseisk (29·69 inches) accompanied by a high temperature. On the next day the thermometer fell rapidly, but the barometer rose slowly. The thermometer continued very low until the 13th, and the barometer rose steadily during the same period, with the exception of a slight check on the 8th, the reason of which does not fully appear. In this case the cold wave appeared to come from the northeast, and preceded the high pressure which was apparently the effect of the long continued and extreme cold.

The case of Feb. 14, 1876, was similar to the preceding. On the 10th of February there was an area of low pressure near Yeniseisk (29·06 inches) accompanied by a temperature much above the mean. After this, the thermometer sunk steadily until the morning of the 14th, and the barometer rose slowly until the 13th.

The case of Dec. 1, 1882, was also similar to the preceding. On the 28th of November there was an area of low pressure near Yeniseisk (29·68 inches) accompanied by a high temperature. After this, the thermometer fell rapidly, but the barometer rose slowly.

All of these exceptional cases appear to have been preceded by an area of low pressure, after which the barometer rose slowly but the thermometer sunk rapidly, and this sudden fall of the thermometer appears to have resulted mainly from the previous existence of a cold area in the northeast, which cold air pressed rapidly into the area of low pressure as soon as the barometer began to rise.

We have thus found that over Europasia, areas of high pressure frequently cover a vast extent of territory; the barometer rises to a height unknown in any other part of the world; the thermometer sinks very low; and the center of the high area, although it vibrates to and fro, from day to day, appears to have no decided progressive motion. The highest pressure shown in table I is 31·63 inches at Barnaul, and is the highest pressure at any of the stations reported in the International Bulletin. The number of Russian stations from which reports were received is only 22, whereas the number reported in the Annalen des Physikalischen Central Observatoriums is over 100, and one of these stations shows a pressure higher than Barnaul. At Ssemipalatinsk, on Dec. 16th, 1877, the pressure was 784·5$^{mm}$, which reduced to sea level (altitude 607 feet and temperature − 49° Cent.) amounts to 31·72 inches. This is the highest pressure I have found reported at any time for any part of the globe.

These high areas are characterized by another circumstance no less remarkable, viz: their long duration. For eight successive days from Dec. 14th, 1877, a pressure of 31·0 inches was maintained near the center of Europasia, and it was renewed on the 31st to continue for ten successive days. Moreover between these two periods, the high area steadily maintained its position, and the pressure at the center at no time sunk below 30·78 inches. A high area had also existed in nearly the same region for twelve days preceding Dec. 14th, and it continued for eleven days succeeding Jan. 9th, so that for 50 successive days there was an area of high pressure covering nearly the whole of Europasia, exhibiting considerable fluctuations in magnitude, but having no very decided progressive movement, and during this whole period the pressure at the center never fell as low as 30·5 inches. In order to exhibit these phenomena more clearly I have prepared table V, which shows the most important facts which can be collected from the International Bulletin.

The arrangement is similar to that of preceding tables. Columns 2 and 3 show the position of the station where the barometer was highest, and the six succeeding columns show the pressure, temperature, humidity, direction and force of the wind, and amount of cloudiness at the same station.

On Dec. 2d the isobar of 30 inches enclosed the principal part of Europasia. The barometer at Archangel stood at 30·58 inches, and at Kasan it stood at 30·55 inches, the center of the high area being near lat. 60°. The temperature was somewhat above the mean for that season of the year, and the winds blew outward from the high area, at some places with considerable force. Apparently this high pressure resulted from the air which rose from an area of low pressure prevailing near South Greenland, which air moved eastward and settled down over

TABLE V.—*Long continued high pressure over Europasia.*

| Date. | | Lat. North. | Long. East. | Barom. highest. | Therm. Fahr. | Relative humidity | Wind. | | Clouds. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | From. | Veloc. | |
| 1877. | | | | | | | | | |
| Dec. | 1 | 53°·3 | 83°·8 | 30·48 | + 5° | 91 | Calm. | 0 | 0 |
| | 2 | 64·5 | 40·5 | ·58 | +26 | 96 | E.S.E. | 18 | 10 |
| | 2 | 55·8 | 49·1 | ·55 | +18 | 63 | Calm. | 0 | 0 |
| | 3 | 56·5 | 60·6 | ·73 | + 6 | 100 | Calm. | 0 | 0 |
| | 4 | 55·8 | 37·7 | ·74 | +19 | 100 | S. | 9 | 10 |
| | 5 | 55·8 | 37·7 | ·75 | +21 | 98 | S.S.E. | 4 | 10 |
| | 6 | 55·8 | 37·7 | ·80 | +11 | 93 | S. | 7 | 0 |
| | 7 | 55·8 | 37·7 | ·73 | +15 | 91 | S. | 9 | 7 |
| | 8 | 41·3 | 49·3 | ·63 | +27 | 87 | Calm. | 0 | 3 |
| | 9 | 41·3 | 49.3 | ·64 | +30 | 94 | Calm. | 0 | 0 |
| | 10 | 55·8 | 37·7 | ·52 | +15 | 94 | S. | 7 | 5 |
| | 11 | 55·8 | 37·7 | ·60 | +12 | 93 | S. | 9 | 10 |
| | 12 | 53·8 | 48·6 | ·68 | +25 | 88 | N.W. | 4 | 10 |
| | 13 | 56·8 | 60·6 | ·87 | −22 | 79 | Calm. | 0 | 0 |
| | 14 | 56·8 | 60·6 | 31·37 | −31 | 76 | Calm. | 0 | 1 |
| | 15 | 53·3 | 83·8 | ·30 | −55 | 73 | Calm. | 0 | 0 |
| | 16 | 53·3 | 83·8 | ·63 | −54 | 74 | S. | 2 | 0 |
| | 17 | 53·3 | 83·8 | ·63 | −50 | 72 | Calm. | 0 | 1 |
| | 18 | 53·3 | 83·8 | ·45 | −41 | 75 | Calm. | 0 | 10 |
| | 19 | 58·4 | 92·1 | ·37 | −17 | 83 | Calm. | 0 | 0 |
| | 20 | 55·8 | 49·1 | ·26 | + 1 | 95 | Calm. | 0 | 2 |
| | 21 | 41·3 | 69·3 | .08 | + 2 | 85 | Calm. | 0 | 10 |
| | 22 | 58·4 | 92·1 | 30·95 | −26 | 85 | W. | 2 | 0 |
| | 23 | 58·4 | 92·1 | ·97 | −30 | 85 | Calm. | 0 | 0 |
| | 24 | 58·4 | 92·1 | ·78 | −15 | 87 | Calm. | 0 | 10 |
| | 25 | 58·4 | 92·1 | ·90 | −22 | 86 | Calm. | 0 | 0 |
| | 26 | 58·4 | 92·1 | ·91 | −30 | 85 | Calm. | 0 | 0 |
| | 27 | 53·4 | 92·1 | ·87 | −27 | 86 | W. | 2 | 10 |
| | 28 | 53·3 | 83·8 | ·93 | −28 | 82 | Calm. | 0 | 0 |
| | 29 | 56·8 | 60·6 | ·93 | − 1 | 74 | W. | 11 | 0 |
| | 30 | 56·8 | 60·6 | ·96 | − 3 | 72 | W. | 2 | 0 |
| | 31 | 58·4 | 92·1 | 31·08 | −21 | 87 | Calm. | 0 | 0 |
| 1878. | | | | | | | | | |
| Jan. | 1 | 57·6 | 76·3 | ·01 | −26 | 86 | Calm. | 0 | 0 |
| | 2 | 53·8 | 48·6 | ·02 | − 6 | 82 | S. | 2 | 0 |
| | 3 | 53·8 | 48·6 | ·01 | − 1 | 80 | S.S.W. | 2 | 4 |
| | 4 | 41·3 | 69·3 | ·09 | −10 | 92 | Calm. | 0 | 0 |
| | 5 | 41·3 | 69·3 | ·02 | − 4 | 87 | Calm. | 0 | 0 |
| | 6 | 58·4 | 92·1 | ·06 | −28 | 85 | Calm. | 0 | 0 |
| | 7 | 58·4 | 92·1 | ·25 | −30 | 85 | Calm. | 0 | 0 |
| | 8 | 58·4 | 92·1 | ·15 | −28 | 86 | Calm. | 0 | 0 |
| | 9 | 58·4 | 92·1 | ·20 | −33 | 85 | Calm. | 0 | 0 |
| | 10 | 58·4 | 92·1 | 30·98 | −21 | 86 | Calm. | 0 | 0 |
| | 11 | 58·4 | 92·1 | ·93 | −20 | 86 | Calm. | 0 | 0 |
| | 12 | 53·3 | 83·8 | ·86 | −17 | 85 | Calm. | 0 | 0 |
| | 13 | 53·3 | 83·8 | ·77 | − 8 | 89 | Calm. | 0 | 5 |
| | 14 | 58·4 | 92·1 | ·98 | −13 | 86 | Calm. | 0 | 0 |
| | 15 | 58·4 | 92·1 | ·85 | − 5 | 78 | E. | 2 | 0 |
| | 16 | 40·0 | 116·5 | ·77 | +10 | 24 | N.W. | 40 | 0 |
| | 17 | 40·0 | 116·5 | ·68 | +12 | 34 | S.W. | 22 | 0 |
| | 18 | 40·0 | 116·5 | ·73 | +20 | 30 | Calm. | 0 | 0 |
| | 19 | 41·3 | 69·3 | ·84 | +31 | 92 | Calm. | 0 | 0 |
| | 20 | 58·4 | 92·1 | ·74 | − 5 | 82 | N.W. | 2 | 5 |
| | 21 | 53·8 | 48·6 | ·44 | −11 | 68 | S.S.E. | 2 | 0 |

Northern Russia. A small area of low pressure which prevailed over Southwestern Europe, and a low area which apparently prevailed near the northern boundary of Asia may have contributed to this effect. For the four following days, the phenomena remained nearly the same, but the pressure near the center of the high area increased, and on the 6th the isobar of 30 inches included almost the whole of Asia, extending into the Pacific Ocean on the east, and it also included a large part of Europe. On the 7th there was a slight diminution of pressure which continued during the three following days, and this was apparently the effect of a low area in Northern Asia which drew off the air from the Northern side of the high area, and the center of the high area was thereby carried southward. On the 10th the pressure on the north side was restored, and the center of the high area moved northward, but the barometer did not commence rising until the following day. On the 11th the barometer began to rise, and now the small low area which had prevailed over Southern Europe since Dec. 2d was obliterated by the advance of a high area from the Atlantic Ocean. On the 12th the barometer rose somewhat higher; at most places the wind had subsided almost to a calm, and the air was generally less humid. On the 13th the rise in the barometer was more decided, and now a great change of temperature which for several days had been steadily advancing from the eastward, had reached the center of high pressure.

On the 14th the isobar 31·0 inches included an area about 1400 miles in length and 800 in breadth, and the pressure attained its maximum between the 16th and 17th. On the 19th the isobar 31·0 inches apparently included an area 3400 miles in length, and 1450 miles in breadth. Throughout the central portions of this high area, the air was dry, the wind subsided almost to a calm, and the sky was generally cloudless. After the 17th the barometer began to fall, the temperature rose somewhat, the humidity of the air increased, and there was some cloudiness, but the clouds were reported *light.* This decline of pressure may have been due to the fact that the outward movement of the air from the high area had become greater than the supply from the low areas before named, two of which had now become extinct. After the 20th the low area which had prevailed over the Atlantic Ocean advanced eastward, and on the 14th the isobar 29·0 inches included the whole of Norway, by which means the pressure throughout Europe and Western Asia was greatly reduced. At the same time there was some increase of temperature, but the rise of the thermometer indicated by Table V on the 20th and 21st, was due mainly to a change of position of the high center. The thermometer at Barnaul still continued 30 degrees below zero of Fahrenheit.

After the 24th the low area over Norway was diverted westward, perhaps by the warmer and more humid air upon that side, and after the 27th the pressure over Asia began to increase, and reached 31·0 inches on the 31st, at which time the conditions were similar to what they had been on the 14th, but the cold at the center of the high area was less intense. The region of greatest cold was near the center of Asia, but up to Jan. 5th the center of the high area was in Eastern Europe or in Western Asia. The high area was apparently attracted westward by a second high area in the neighborhood of Spain which coalesced with the Asiatic area on the 3d. On the 4th a considerable area of low pressure, which on the preceding day had prevailed near the coast of Norway, pushed farther eastward, by which means the pressure in Northern Europe was diminished and the center of high pressure moved eastward. It now came into the region where a very low temperature had been prevailing since the beginning of December. Simultaneously with the fall in temperature, the pressure at the center increased and continued thus through the 9th. On the 10th the barometer fell below 31·0 inches and for the next 10 days continued with some fluctuations to decline until it fell below 30·5 inches. The most important cause for this decline, as far as can be learned from the International maps, was the eastward progress of the low area in Europe already mentioned. This low area drew off the air from the western side of the Asiatic high area, and after the 9th the high area was not built up on its eastern side as fast as it was reduced on its western side. On the 16th and 17th a low area from the Pacific Ocean crowded the high area on its northeast side, in consequence of which the center of the high area moved southward. The rise of the thermometer shown by Table V, from the 16th to the 19th was the result of this southward movement of the center of high pressure. At Nertchinsk the thermometer still remained below zero of Fahrenheit. On the 19th the Pacific low area was filled up by the air which pressed in from the north, and the result was a slight increase of the high area over Central Asia. This increase was however but temporary, for on the 21st the storm which had long prevailed in Europe gained a considerable increase of intensity while a low area of moderate extent pushed northward from the Persian Gulf, and by the union of these two low areas the high area over Asia was completely broken up, and on the 22d the highest pressure reported at any of the Russian stations was 30·3 inches.

The history of this high area which for 50 successive days covered a large portion of Europasia, and which obtained a maximum greater than has ever been known at any other time in any part of the world, ought to furnish a basis for some important conclusions. If it should be asked what is the cause of areas of high pressure, the answer is plain, they are the *necessary* concomitants of areas of low pressure. If at any place of the earth's surface the barometer sinks below its mean height, it must rise above its mean height at some other place. If we find an area of low pressure of vast extent, we know that there must be a corresponding area of high pressure in some other part of the world. For the entire globe, the total amount of air which at any instant is elevated above the mean level surface must be exactly equal to the total amount which in other regions is abstracted from beneath the mean level surface. Areas of high pressure are therefore built up by air which comes from areas of low pressure. We also know that within an area of low pressure at the surface of the earth, there is a general movement of the air *inward;* that near the central portion of this area the air ascends and flows off to other portions of the globe. Also within an area of high pressure at the surface of the earth, there is a general movement of the air *outward;* and since high areas often continue many days and sometimes many weeks, there must be a fresh accession of air at the top to supply the place of the air which is drawn off by the outward movement near the surface of the earth. The air which ascends from an area of low pressure goes therefore to maintain the descending movement within an area of high pressure. This deduction seems so obvious as scarcely to require confirmation from direct observations. It has however been abundantly confirmed by an extensive series of observations on the movement of cirrus clouds made in 1875 and '76 under the direction of Dr. Hildebrandsson. By these observations it has been shown that the air which ascends from an area of low pressure, after reaching an elevation corresponding to the usual height of the cirrus clouds, recedes from the center of the low area, and moves toward an area of high pressure.

When we attempt to apply this general principle to a particular case we are frequently in doubt as to the particular low area from which a given high area draws its supply of air. In the observations collected by Dr. Hildebrandsson, when a low area prevailed over the Atlantic Ocean and a high area over Eastern Europe, the cirrus clouds generally moved toward the area of high pressure on the east side; but when a low area prevailed over Eastern Europe with a high area over the Atlantic Ocean the cirrus clouds generally moved toward the area of high pressure on the west side. It is noticeable that the period of greatest barometric pressure over Europasia corresponds with the period of least pressure over the Atlantic Ocean. There does not therefore seem to be any room for doubt that the high areas of Europasia derive their chief supply of air from the low areas which prevail over the Atlantic Ocean.

If we enquire for the cause of the low temperature which generally attends areas of high pressure, I think we must admit that the low temperature is in part the cause and in part the effect of the high pressure. A low temperature increases the density of the air, and the height of a given weight of air is thereby diminished. Its pressure is not however thereby increased, but the void left in the upper regions of the atmosphere must be filled by air flowing in from neighboring regions, and the pressure over the cold area is thus increased. The reduced temperature becomes indirectly a cause of increased pressure. This high pressure accompanied by extreme cold generally results in a calm and dry atmosphere free from clouds. The heat of the earth's surface is now rapidly dissipated by radiation, and thus the high pressure becomes a source of increased cold. High pressure and low temperature reënforce each other, and they are almost invariably associated, particularly in the extremely high pressures which occur during the colder months of the year.

The long duration of areas of high pressure over Europasia appears to be due to the favorable conditions for the formation of such areas which prevail in this part of the world during the winter months. During this period, areas of low pressure of extreme violence prevail almost uninterruptedly over the Atlantic Ocean, and the air which here ascends moves eastward and settles down over Europasia. This is a vast continent, the central portions of which are removed to a great distance from any large body of water. Here the sources of atmospheric disturbances are few—the air is generally tranquil and without much cloudiness—the heat of the earth is rapidly wasted by radiation—and the low temperature reënforces the high pressure. Thus during the winter months, high pressure over Asia becomes as habitual as low pressure over the Atlantic Ocean.

During each of the winters from 1878 to 1884 the areas of high pressure over Europasia exhibited characteristics similar to those we have found for the winter of 1877–8. In the winter of 1878–9 from Dec. 18, 1878 to Feb. 11, 1879, a period of 56 days, an area of high pressure prevailed over a large portion of Europasia, and during this period the pressure at the center at no time sunk below 30·5 inches. At three different times during this period the barometer rose above 31·0 inches and it attained a maximum of 31·26 inches. During the winter of 1879–80 an area of high pressure prevailed over Europasia from Jan. 5th to March 4th, 1880, a period of 60 days without at any time sinking below 30·5 inches; and on eight different days the pressure was as high as 31·0 inches, the maximum being 31·17 inches. During the winter of 1881–2 an area of high pressure prevailed over some part of Europasia from Nov.

27, 1881 to Feb. 25, 1882, a period of 91 days, during which time the barometer at some one of the stations was observed as high as 30·5 inches. On six days the barometer rose above 31·0 inches and it attained a maximum of 31·2 inches.

In reviewing the history of these seven years we must conclude that the areas of high pressure which are so prevalent over Europasia during the winter months show no decided progressive movement in any fixed direction. They often remain nearly stationary for weeks in succession, with only such apparent motion as is due to a slight decline in some places and a slight reënforcement in other places, resulting perhaps from local causes, or from some change in the circulation of the upper strata of the atmosphere.

We also see that a pressure of at least 30·5 inches is almost uninterrupted over some portion of Europasia during the winter months, and the interruptions which occasionally occur are due to areas of low pressure which push southward from the higher latitudes. The rarity of this phenomenon, and the smallness of the depression when it does occur, illustrate the difficulty which an area of low pressure experiences in penetrating a huge mass of very cold air.

The accompanying plate, derived from the International observations, will give a more distinct idea of the relation of areas of high and low pressure, and will show the magnitude which these areas sometimes attain. The plate gives the isobars for Dec. 15, 1882, and shows a high area covering nearly the whole of Europe and Asia and extending somewhat over the Pacific Ocean. Another high area covers nearly the whole of North America; an area of low pressure, with its isobars very much elongated, stretches entirely across the Atlantic Ocean, overlapping portions of Europe and America; and another area of low pressure covers a large part of the North Pacific Ocean. Two high areas, combined with two low areas, make the entire circuit of the northern hemisphere near the parallel of 50°. A third high area, of moderate elevation, is found over the southern part of the North Atlantic, and there is a fourth high area of small extent over the Pacific Ocean near the coast of California. This map represents in an exaggerated form the average distribution of pressure during the winter months, viz: high pressure over the continents and low pressure over the oceans.

It is very rare that so small a number of areas of high and low pressure complete the circuit of the northern hemisphere. Generally the areas are much more numerous and of smaller dimensions; the areas are of very unequal size and are combined in very irregular positions; but during the colder months of the year, low areas are most prevalent over the Atlantic and

Pacific oceans; a high area generally prevails over Europasia, frequently showing more than one center of maximum pressure, and a moderately high area generally prevails over some part of North America, but it is not as persistent as the high area over Asia.

The facts stated in this paper clearly show that the movement of areas of high pressure depends upon very different causes from that of areas of low pressure. Areas of low pressure seem to be endowed with a power of locomotion which resides within themselves. The heat liberated in the condensation of vapor develops a power which draws in the surrounding air, and this motion, combined with the movement which results from the general system of atmospheric circulation, causes a rapid displacement of the low center. Areas of high pressure exhibit no such power. Their low temperature creates a tendency to crowd toward a warmer region; and this tendency is obscurely seen in the high areas of Europe and Asia. It is more distinctly seen in the high areas of the United States, probably on account of the proximity of a much higher temperature, viz: the Gulf of Mexico on the south, and the Atlantic Ocean with the Gulf Stream on the east. Aside from this cause, the movement of areas of high pressure seems to depend entirely upon external forces. A neighboring area of low pressure may draw off the air from one side, and thereby cause a displacement of the center of maximum pressure; or the high area may be reënforced at the top in such a manner as to cause a rapid movement of the center of maximum pressure, in a direction and with a velocity which are apparently subject to no law.

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## ART. XXIX.—*The Faults of Southwest Virginia*; by JOHN J. STEVENSON, Professor in University of the City of New York.

THE existence of great faults in southwest Virginia was made known in 1836 by Professor Wm. B. Rogers, three principal faults being shown on the long cross-section appended to his "Reconnaissance."* The existence of the Saltville and New Garden faults is asserted in a paper on Thermal Springs by the same author and in a long memoir on the structure of the Appalachian Chain by Professors W. B. and H. D. Rogers.† At a much later date, Professor J. P. Lesley ran several lines across portions of the faulted area on both sides of New River

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* Report of the Geological Reconnaissance of the State of Virginia, 1836.

† These papers are contained in the volume of the Transactions of the Association of American Geologists and Naturalists, 1840–42.

and added greatly to the knowledge of the general structure,* of which he first appears to have had a clear conception. Professor Safford's map of Tennessee shows the extent of the faults in that State. The writer has made a reconnaissance of the faulted region in Virginia from the Tennessee line to almost twenty miles beyond New River, a distance of 150 miles, and has given the results in several memoirs read before the American Philosophical Society.† As these last are independent, information respecting the several faults is broken in such a way that a summary statement is necessary to render it available. If more of detail should be needed, the reader is referred to the memoirs cited.

The "Great Valley" follows the northerly or northwesterly foot of the Blue Ridge from New England to Alabama and, except where broken by faults, is underlaid by Lower Silurian and Cambrian rocks. In New York, Pennsylvania and Maryland, it is bounded on the northerly side by anticlinals and synclinals carrying the newer rocks so that within a little distance one is in the Upper Devonian. The conditions are simple, there being no faults of great longitudinal extent cutting off the valley on that side. The only faults lie at a considerable distance beyond the valley and, though of much interest, are utterly insignificant in comparison with those found farther south.

At no great distance southward in Virginia, strips of Lower Silurian are shown beyond the line of the "Great Valley." These are more numerous near New River and become wider thence to the Tennessee line; while near and beyond the same river the valley itself is broken by patches of Upper Silurian, Devonian and even Lower Carboniferous rocks. These great changes are due to faults as remarkable for their longitudinal as for their vertical extent.

The greatest width of the faulted area in southwest Virginia is about forty miles, measured along a line passing through Wythe, Giles and Tazewell Counties of Virginia. The faults, separated by varying intervals, show Knox limestone on the southerly or upthrow side, while the beds on the northerly or downthrow side may belong anywhere from Lower Silurian to Upper Carboniferous. Thus the region is broken into a series of alternating "rich" and "poor" valleys, underlaid in the former by Lower Silurian limestones and in the latter by Upper Silurian and Devonian shales. The sections shown by

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* Professor Lesley's papers were read before the American Philosophical Society on May 16th, 1862, and on April 21st, 1871.

† The dates of these papers are August 20th, 1880, January 21st, 1881, October 7th, 1881, November 21st, 1884, and one not yet read before the Society.

the blocks held between the faults vary much in length, the most extended being that between the Copper Creek and Saltville faults, where the column reaches from the bottom of the Knox calcareous rocks to the top of the Umbral, possibly in some places to the Coal Measures.

The blocks between the faults are not always monoclinals, as might be inferred from a hasty perusal of some papers presented prior to those of the writer; far from it. Where the blocks are broad, seven or eight miles, groups of anticlinals occur, canoe-shaped and overlapping, thus reproducing the features so characteristic of Upper and Lower Silurian areas in Central Pennsylvania. But these folds are not parallel to the faults and any relationship appearing to exist between the faults and such folds is evidently fortuitous.

Three faults entering Virginia from Tennessee, termed by the writer, the Poor Valley, the Wallen's Ridge and the Pattonsville, and having a vertical extent of 2400, 2800 and 500 feet respectively, disappear within a few miles, being simply fissures on the southeasterly side of a bold anticlinal, that of Powell-Stone Mountain, which also disappears within a short distance. The important, persistent faults are—

The Clinch Group, the Copper Creek, the Saltville, the Walker Mountain; beside which are the short faults of Draper and Price Mountains in the valley, with the cross-faults, Max Meadows and Pulaski, extending from the Draper Mountain fault toward that of Walker Mountain.

The *Clinch Group* of faults includes the Clinch Uplift and Abb's Valley fault of Professor Lesley's 1871 memoir; as the writer ran some lines between those of Professor Lesley, he has been enabled to elaborate the group somewhat and to discover a more complicated structure than was at first supposed. The group consists of—

*a.* The Hunter Valley fault or Clinch Uplift; *b.* The New Garden fault; *c.* The Stony Ridge fault; *d.* The Abb's Valley fault.

The Clinch Uplift enters Scott County, Va., from Tennessee, continues through that county into Russell without interruption; but midway in the latter county, after bending northward, it gives off a cross fault and holds its new course into Buchanan County where it is soon lost. The New Garden fault begins in Russell County not far from the line of Scott and almost accurately in the place where the former fault ought to have been found had its course been unchanged; it is joined by the cross fault from the Clinch Uplift and it continues through Russell and Tazewell Counties of Virginia into Mercer County of West Virginia, where it follows the northerly foot of East River Mountain to certainly twenty-five miles beyond

New River. The Stony Ridge fault begins in Russell County and continues thence through Tazewell into Mercer County of West Virginia. The Abb's Valley begins in Tazewell County and extends into Mercer County. These two faults do not appear to reach New River, but of this the writer may not speak positively as he has not crossed their place near the river. The intervals between these faults increases eastwardly.

The *Copper Creek* fault enters from Tennessee, passes through Scott County and within a few miles in Russell County disappears in the Elk Garden anticlinal, a fold with double or triple crest, which is followed easily through Russell and Tazewell Counties into Bland; but soon after entering the last county a double fault, the Winonah, arises from the anticlinal, which, at a few miles farther, gives off from its northerly side a second, that of Buckhorn Mountain. These two faults cross the New River and enter Craig County, but they evidently disappear a little way beyond, as they do not appear there in Rogers's cross-section. Where the Buckhorn fault begins, the interval to the other is only a few rods, but at New River it is almost two miles. The Winonah, like the Copper Creek fault, is in Knox, but it holds a vertical wall of white Medina in the crevice. It evidently gives off a similar branch beyond New River, for there two lines of white Medina appear in the Knox limestones.

The *Saltville* fault, the *North Holston* fault of Lesley's 1871 memoir, is, so far as the writer has been able to determine, a continuous fracture from Tennessee to thirty miles beyond New River. How much farther it extends, the writer has not yet ascertained. It is of especial interest in that its course exhibits total indifference to that of the anticlinals and to the strike of the rocks. It shows no material variation in the extent of its throw.

The fault of *Walker Mountain* enters Washington County from Tennessee as a throw in the Knox beds, but soon after entering Smyth County the throw becomes stronger and before entering Wythe County, Umbral shales are shown on the downthrow side. Thence to twenty miles beyond New River the fault remains the same. How much farther it extends was not ascertained, but like the Saltville it gives promise of many miles. One of these two is, no doubt, the "great fault" so often spoken of as following the northerly or northwesterly side of the valley.

The *Draper* Mountain fault is a short fracture in Wythe and Pulaski Counties, which brings up the Potsdam as a rugged mountain in the heart of the valley. Two cross-faults pass from it, the Max Meadows in a westward direction and the Pulaski in a northwestward direction, toward the Walker

Mountain fault; so that in the very heart of the "Great Valley" there is a block of Upper Silurian, Devonian and Lower Carboniferous with Lower Silurian on two sides, Cambrian on the third and Lower Carboniferous on the fourth.

A curious double fault, that of Price Mountain in Montgomery County, brings up a short anticlinal ridge of Lower Carboniferous midway in the valley. This V-shaped fault is short and its branches are separated by an interval of not more than three miles and a half at the widest place.

The faults do not follow straight lines and their courses show much variation. The intervals show equal variation.

As has been said already the vertical extent of a fault is not the same along the whole line. It was observed that the faults where followed out proved to be merely cracked anticlinals; the most notable illustration being found in the Copper Creek fault, which disappears in the Elk Garden anticlinal, only to reappear after a distance of seventy miles in the Winonah and Buckhorn faults, which in their turn disappear in an anticlinal. The Max Meadows, Draper Mountain, Abb's Valley faults and the three small faults of Lee and Scott Counties illustrate the matter almost equally well. Such being the origin of the fault, variation in the vertical extent must be looked for.

But the strength of the throw may be the same for a long distance while the apparent strength may be very different. The development of anticlinals on one side or the other, anticlinals belonging to a time prior to the formation of the faults, may cause the appearance of successive groups on one side. An admirable illustration is found in the Saltville fault, which has Knox limestone on the upthrow side throughout the whole distance examined, while on the downthrow side one finds the whole series from the Knox limestone to the Umbral shales, possibly to the Coal-measures. But the extent of the throw is the same throughout, the variation being due to the presence of anticlinals crossed by the fault.

The Hunter Valley fault or Clinch uplift illustrates well the variation in strength of the throw. Where it enters from Tennessee it shows Knox on the upthrow and Clinton on the downthrow side; but within a few miles Hamilton is on the downthrow, while within ten miles farther, Lower Coal-measures (Quinnimont) are in the fault on the downthrow side. The upthrow diminishes in Russell County beyond the origin of the New Garden fault so that Middle Coal-measures are in contact first with Devonian and then with Lower Coal-measures. The Walker Mountain fault illustrates the same thing equally well, for though it enters as a fault in the Knox the downthrow gradually increases until in Wythe County the whole series to the top of the Umbral is seen.

The extent of the faults, both vertical and longitudinal, is as follows:

| | Vertical. | Longitudinal in Virginia. |
|---|---|---|
| Poor Valley | 2,400′ to 0′ | 40 miles. |
| Wallen's Ridge | 2,800′ to 0′ | 25 “ |
| Pattonsville | 500′ to 0′ | 20 “ |
| Clinch Group— | | |
| *a.* Hunter Valley | 8,500′ to 0′ | 65 + “ |
| *b.* New Garden | 7,500′ to 0′ | 102 + “ |
| *c.* Stony Ridge | 2,300′ to 0′ | 50 + “ |
| *d.* Abb's Valley | 1,700′ to 0′ | 40 + “ |
| Copper Creek, etc. | 3,000′ to 0′ | 45 “ |
| Saltville | 10,000′ to 500′ | 130 + “ |
| Walker Mountain | 10,000′ to 1,000′ | 130 + “ |
| Max Meadows | 9,800′ | 20 “ |
| Pulaski | 9,600′ | 8 “ |
| Draper Mountain | 12,500′ to 0′ | 20 “ |
| Price Mountain | 10,000′ | 10 + “ |

The conditions in the immediate vicinity of the apparent fault lines are not easily ascertained, for ordinarily the line of contact and the area to a considerable distance on each side are covered by rubbish. More than that: the thrust has been sufficient to shove the upthrown beds to a considerable distance over on the downthrown beds as is shown by the Hunter Valley fault on Big Stony Creek in Scott County, so that the place of the fault is necessarily somewhat obscure. That the faults are practically cracked anticlinals, however, is sufficiently evident from their origin and disappearance; but traces of the anticlinal structure are not wanting along the faulted lines. Thus the great Clinch or Hunter Valley fault shows, near the Tennessee line, Clinton and Knox in contact but each dipping from the fault. A similar structure was seen thirty miles farther eastward, where Lower Carboniferous and Devonian are upturned on the northerly side of the fracture; while still farther east the Lower Coal-measures (Quinnimont) are shown on the northerly side dipping away from the fault at sixty to seventy degrees, with the Knox beds on the other side also dipping away from the fault but at a less rate. But the conditions vary, and at several localities along this fault the dip on the downthrow side is toward the fault, the thrust evidently having been sufficient to carry the upthrown rocks over the line to a considerable distance. This is apparently the condition along the Walker Mountain fault everywhere within the area examined; for the conformability is so close that the existence of a fault would not be suspected by one depending only on the local stratigraphy.

Rocks in the immediate vicinity of the apparent fault line—

where the upthrown and downthrown rocks are in contact—frequently show no signs of disturbance other than abrupt dip; but the proof of disturbance is much more distinct on the upthrow side at a distance of somewhat more than half a mile and beyond; while even on the downthrow side the dip may be greater at some distance than it is at the fault line itself. Where New River crosses the Walker Mountain fault, the dip on the downthrow is fourteen or fifteen degrees, but at barely half a mile farther down the stream, the dip is fifty-five degrees; yet within fifteen miles toward the east, the conditions are altogether reversed, the shales dipping very abruptly near the fault, while, at about one-fourth of a mile away, the sandstones are dipping at but twenty-five degrees.

But on the upthrow side the disturbance in any case is not confined to mere variations in rate of dip; the crushing is proved by numerous narrow, crowded, abrupt folds, beginning at half a mile or so from the fault and continuing for even a mile or more. These are especially noteworthy near the faults of the Clinch Group, but they are shown in some places near the Walker Mountain fault. The crushing at several localities near Clinch River is excessive and at one locality the shales are folded as closely as micaceous shales on Manhattan island, but they show no evidence of metamorphism.

That the faults are closely related in several instances to anticlinals has been stated already more than once; but a system of folds still remains, though in fragments, with which the faults have but a fortuitous connection. The conditions cannot be exhibited here without the aid of somewhat complicated diagrams; but the colored maps accompanying the writer's memoirs already cited make the matter sufficiently clear.

The Saltville fault, best of all in Virginia, shows the conditions, for it cuts off several folds existing in the interval between it and the Copper Creek fault at the north, a space ten to twelve miles wide. The first fold at the west, the "Great Garden" axis of W. B. Rogers, is an inverted canoe, about eighty miles long and attaining its maximum in Burk's Garden of Tazewell County. As the fault does not follow the strike but simply cuts along the side of the canoe, it is clear enough that the section on the northerly or downthrow side must show noteworthy variations as the line approaches or leaves the higher, wider portion of the canoe, while no change is shown on the opposite or upthrow side. And this is the condition; for while the Knox limestone is on the upthrow side throughout, changes enough appear on the other side. Thus in Washington County opposite Mendota, the width of Lower Carboniferous is nearly four miles, in which a magnificent section of Umbral and Vespertine is shown. But at the edge of

Bland and Smyth Counties, where the Garden fold is greatest, the strip of Lower Carboniferous is barely half a mile wide and the presence of both divisions is due only to a remarkable decrease in thickness of the Umbral. As the anticlinal diminishes, the width of Lower Carboniferous increases; but the higher rocks are not reached, for within fifteen miles in Bland County, the fault cuts off the Kimberling anticlinal near its origin.

This fold rapidly increases in height and under its influence Lower Carboniferous rocks soon disappear from the downthrow side and the Knox is in contact with Lower Devonian near the line between Bland and Giles Counties. A third anticlinal, the Sinking Creek, is cut by the fault a little farther on; and as it increases in height, the Knox is brought into contact with the successive groups of the Upper Silurian, with the Hudson, the Trenton, and finally with the upper Knox before New River has been reached; while beyond that river, the diminution of the fold permits the presence of Trenton, Hudson, and, before the eastern limit of Giles County has been reached, of Medina on the northerly side of the fault.

The axes of these anticlinals are approximately parallel and make a considerable angle with the fault.

A similar condition exists in the curious block within the Great Valley enclosed by the Walker Mountain, Draper Mountain, Max Meadows and Pulaski faults. The Walker Mountain fault cuts off, in succession, Lower Silurian, Upper Silurian and Devonian on the upthrow side, while on the downthrow side Umbral shales are shown continuously. Within the block is an anticlinal which apparently is in no way connected with any of the folds observed in the Knox beds outside of the block.

The Great Cove fault of Fulton County, Pennsylvania, as described by the writer* shows, as far as it goes, equally well with the Saltville, this indifference to the course of the preexisting folds. The Cove anticlinal, like the Garden axis, is an inverted canoe with its eroded cove surrounded by a wall of Medina. The fault, which holds a jagged wall of Medina in the crevice, makes but a small angle with the axis of the anti-

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* Second Geol. Surv. of Penn. Rep. on Bedford and Fulton Counties, p. 55. This reference affords an opportunity of satisfying the "long-felt want" of some acquaintances, who are at a loss to reconcile my maps of these counties as appended to the report with the maps of the same counties as given in the Geological Atlas of Pennsylvania. The maps *cannot* be reconciled. Those appended to the geological report on the counties are by the writer, except in so far as they refer to the Broad Top region, and, except in so far as they refer to that region, they are fairly good. The maps in the Geological Atlas, though credited to me, were not made by me in any sense whatever; they were printed three years or more before I even thought of doing any work in Bedford and Fulton Counties.

clinal, but sufficient for curious variations, as may be seen by consulting the writer's map of Fulton County.

The facts that have been given lead the writer to the conclusion that the faults are of later date than the system of folds and that they may have been produced at a time possibly as late as the era of Mesozoic disturbance marked by dikes throughout the Triassic area of the Atlantic border.

## ART. XXX.—*On Taconic Rocks and Stratigraphy, with a Geological Map of the Taconic Regions;* by JAMES D. DANA.

[Continued from vol. xxix, p. 443, March, 1885.]

### PART II.—THE MIDDLE AND NORTHERN PART.

THIS part of my memoir, with the map illustrating it, covers the region from the southern boundary of Great Barrington to the northern limit of Berkshire, together with the towns of Pownal and Bennington in southern Vermont, and the eastern border of New York for a breadth of about three miles. The map, as with the former part, has only the limestone areas colored. Over the rest the kinds of rocks are indicated by letters. The scale of the map is half an inch to the mile.*

The following are the subdivisions adopted beyond in the discussion of the subject.

I. General facts relating to the geographical distribution of the limestone and other rocks.
II. The limestone and the overlying Taconic strata.
III. The underlying quartzyte formation.
IV. General conclusions.

### 1. *General facts relating to the geographical distribution of the limestone and other rocks.*

1. *Williamstown the birthplace of the Taconic system.*—The map accompanying this paper contains, in its northwestern part, the town of Williamstown; and there in connection with Williams College were Prof. Amos Eaton in 1817 (for a single season), Prof. Chester Dewey from 1817 to 1827, and Prof. Ebenezer Emmons in 1833 and for many years afterward. There Dewey investigated and was the first to investigate the Taconic rocks, the first to give the term "Taconic," as applied to the ridges, its present form (in 1819); the first to publish a geological map of the region.† As the history at this point has been writ-

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* The map will be inserted in the following number.

† For his papers see this Journal, vols. i (1819), ii, (1820), viii (1824); the last contains his geological map of western Berkshire.

ten incorrectly, I add here that Eaton gives credit for what he knows of the region to Dewey.*

But Prof. Dewey's work was only a beginning. Prof. Emmons took up the investigation thus initiated and made thorough work of it; and finally, adding to his study of the Williamstown region that of western Berkshire and Eastern New York, gathered the facts upon which he based the Taconic system, and his opinions as to the contrast between them and the oldest Paleozoic strata of central and northern New York.

2. *General features.*—The general trend of the chief Taconic Range and of the Taconic belt of rocks is very nearly that of the western New England boundary—or about N. 15° E. along the limit of Massachusetts, and about N. 5° E. along that of Vermont.

The topography of the part under consideration is similar to that of the more southern section already described. The limestone is intersected from north to south by ridges of schist and the other overlying rocks, and the most of these schist ridges stand isolated within the limestone area, or run out into the area from the larger ridges like peninsulas. Few limestone areas on the map are wholly enclosed by the schist, and thus detached from the main mass.

3. *The old subdivision of the Taconic limestone into an eastern and western belt not valid.*—The distinction of two ranges or belts of limestone, an *eastern*, east of the main Taconic Range, and a *western*, west of it, was first recognized by Dewey, who named them, in the language of the day, the *Primitive* and the *Transition*, the latter name being given to the western, because the rock was but feebly crystalline. The subdivision, as has been before explained, is a fundamental feature of the "Taconic system." The former of the two limestones is distinguished by Emmons as the Stockbridge limestone—a name adopted by Prof. Edward Hitchcock for the Berkshire limestone, while for the Eastern Vermont belt he used the term Eolian limestone.

*a.* The *eastern* or Stockbridge limestone belt is continuous from near Towner's (on the Harlem R. R., 45 miles from New York city), and also by a more eastern branch, from New Fairfield, Connecticut, nearly in the latitude of Towner's, to Clarksburg, on the northern border of Berkshire, a distance of about 95 miles. In North Adams, the town next south of Clarksburg, the belt approaches on its west side the Williamstown limestone within less than a mile, but nowhere has a direct connection with it at surface. From Williamstown the limestone enters Vermont and (as the Vermont geological map indicates),

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* Index to the Geology of the United States, 1820, in which he acknowledges the "assistance, for two or three years, of that able and accurate naturalist, Prof. Dewey, of Williams College."

stretches on uninterruptedly to Weybridge, beyond Middlebury, making within the limits of Vermont another 95 miles.

The *western* limestone, or that west of the main Taconic Range, is, in the first place, not a continuous belt; and, secondly, two of its long pieces west of Massachusetts are nothing but branches from the eastern limestone, being directly continuous with it, instead of distinct lines. It includes in the region here considered, three parts, a northern, a middle and a southern, all in eastern New York. The *northern* is confined to the towns of Hoosic and Petersburgh. The *middle* commences five miles south of the northern, in northern Berlin, and extends about 25 miles through Stephentown and New Lebanon to the southern part of the town of Canaan, N. Y. The *southern* has its north end in Hillsdale, N. Y., 8 to 9 miles south of Canaan; and thence it continues southward through Copake into Ancram (11 to 12 miles), where it divides into two branches, each of which, except for a break of 4 to 5 miles, extends southwestward to the Hudson, reaching it near Poughkeepsie and Fishkill—a distance in all of 50 to 60 miles. Thus there is no one independent western belt.

The two pieces that are only branches from the great Vermont eastern limestone are (1) the northern and (2) the middle; and (3) the southern makes a very near approach to a junction with the Massachusetts eastern limestone.

In further explanation I state that the northern area, or that of Petersburg and Hoosic, passes bodily from Hoosic into northern Bennington where it joins the Vermont eastern belt, or becomes identified with it. This same northern portion *nearly* makes another junction with the eastern belt, along the Hoosic valley in northern Pownal; but about two-thirds of a mile of slate intervene.

The middle one of the western areas, or that which extends from Berlin southward to Canaan, stretches northeastward from Stephentown through Hancock, Mass., to Williamstown; or, viewed from the other direction, the Williamstown limestone, which is a southern part of the Vermont eastern (or Eolian) limestone, continues on southwestward (as Hitchcock first showed) through Hancock to Stephentown and Canaan; so that this western limestone is the southern termination of the eastern. The distance from northern Williamstown to its extremity in Canaan is about 35 miles, and hence the Vermont eastern belt, or Eolian, with this its continuation, is 130 miles long.

The approach to a junction between the middle western and the Massachusetts eastern limestone takes place at the southern end in Canaan, where a long tongue runs out eastward in the open valley which there crosses the Taconic Range and makes a nearly level pathway through the mountains for the Boston and Albany railroad. The tongue-shaped prolongation of the limestone area extends eastward through the range, but half a mile of schist intervenes between it and the limestone area of West Stockbridge and Richmond.

The southern of the western areas is the only one that makes no complete junction with the eastern belt; but it approaches it, as explained in the former part of this paper, at the low and broad gap in the Taconic range, between Salisbury, Ct., and Millerton, N. Y.

The deep gaps or open valleys that cross the range are deep openings through the Taconic schists, and hence the outcrop of the limestone through, or nearly through, the gaps.

These facts touch a fundamental point in the Taconic system, for they show that the difference in grade of the metamorphism between the limestone areas of the eastern and western sides of the Taconic range—a point of difference dwelt upon by Emmons—has no stratigraphical importance. The rocks are one in mass beyond possible question. We thus take one member out of the Taconic system by showing its continuity with one of the others. We find, in other words, that the great limestone of the Taconic series is stratigraphically one single formation. This statement does not imply that the limestone is all of one period; but that it is one in mass and general conformability.

This conclusion is fortified by the proof already presented of a synclinal structure in Mt. Washington, that is, of the passing of the limestone from east to west underneath the mountain; and also by that of another synclinal, as long since pointed out by Emmons, and also afterward by Hitchcock, in the Greylock mass, by which the Williamstown and Adams limestones —the Eolian and Stockbridge—join one another. Additional evidence on the latter and related points will be found beyond.

4. *Irregularities in the courses of the belts of the Taconic series that appear to be, in part at least, due to earlier topographical conditions.*—Two abrupt east-and-west shifts in the course of the Taconic belt are indicated on the map.

*a.* The most extensive of these abrupt changes of line is in the northern part of Berkshire. Here the eastern or Stockbridge limestone, as above stated, stops off abruptly in the town of Clarksburgh, and begins again to the westward in Williamstown. This change in geographical position amounts to four or four and a half miles, measuring from the eastern limits of the two limestone areas.

The quartzyte is shifted to the same extent. To the south, through Cheshire, East Lenox and beyond, the line of quartzyte outcrops is in general four to five miles east of the line of the quartzyte range of Bald Mountain on the boundary between Clarksburg and Williamstown; and its continuation northward. The shift is also exhibited in the Archæan rocks. For directly north of the Stockbridge limestone of Clarksburg there is an undoubted Archæan area—that of the "Stamford granite"—of the Vermont survey,* and this Archæan area stands against the eastern side of the quartzyte range of Bald Mountain. So again to the south, in Berkshire, the quartzyte has in several places similar hornblendic Archæan rocks not far east of the outcrop of quartzyte. Thus the shift is marked in the three great formations of the country.

*b.* Another westward shift, or apparent shift, occurs in Southern Vermont, in the latitude of Bennington, and is about a mile in extent. The limestone limit on the *east* of the village of Bennington with the quartzyte range west of it shows, on the map, the abrupt shift very strikingly; and it is seen also in the limestone limit *west* of the village.

Such apparent shifts may correspond to actual westward or eastward displacements produced since the time when the deposits were formed; or they may indicate the course of the shore-lines of the ancient sea in which the deposits accumulated. Which is the right explanation is an important question.

*c.* In central Berkshire, within the limestone limits, south of the line of Lee and Stockbridge, a region of high hills and ridges comprising Bear Mountain, covers the northern part of the town of Monterey and small parts of adjoining towns. It has an east-and-west course, cuts short the limestone area, gives an east-and-west course to the Housatonic River (and to roads and railways), and to the limestone area of southern Monterey, (see map), and thus disturbs or goes athwart the feature-lines and Taconic trends of the valley. But the eastern limit of the limestone has no abrupt shift in its course. The summit of this Bear Mountain region is probably Archæan. The disturbance in the direction of the feature lines, which is apparently due to this area, extends also to ridges west and southwest, as that of Monument Mountain, and those between Monterey and Great Barrington, which have a northwest trend instead of the usual north-by-east.

The question as to the origin of these changes in the courses of the rocks, or those of their outcrops, requires, for a safe reply, a consideration of the facts over a wider range of the formation; and I recall here some of the features in Salisbury, Ct., and farther south.

*d.* In Canaan and Salisbury the eastern or Stockbridge

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* See description of Section I, vol. ii, p. 601, by C. H. Hitchcock. The granite is hornblendic, and I found it to contain zircons.

limestone belt, which has there a width of 3½ miles, comes, on the south, bluntly against the high range of hills of Sharon, Cornwall and Kent, and sends off a southward branch either side; this obstruction is the *occasion* of the subdivision of the limestone into two branches, mentioned on page 271, one in eastern New York to Towner's, the other in Connecticut to New Fairfield. Now, this range of hills has much quartzyte in some parts over the northern end, and also, beyond the quartzyte, gneisses and other rocks, part of which at least (as chondroditic limestones, and other characteristics show) are Archæan. Archæan hills which antedate in uplift and erosion the limestone seem to have determined in this case the shore lines of the early Paleozoic seas, and the area of limestone-making in the waters. At the southern end of this Archæan range (Percival's K1) the two branches of limestone, as Percival first pointed out, make a junction across from Dover to South Kent, which is about half the way to Towner's and New Fairfield; thus binding in one mass the chief range of Canaan-Salisbury limestone that goes to Towner's with the more eastern part that goes to New Fairfield, although the latter has its course among mica schists and gneisses.

*e.* Another region of abrupt change in the Taconic outlines is that of Pittsfield, at the summit level of the great valley of Berkshire. The height of the wide plain is about 1,000 feet above tide level. It is the place of union of the headwaters of the Housatonic River. The longest of the tributaries, which carries the name of the river, comes in from the eastward along the valley which is made use of by the Boston & Albany railroad. For this and other unexplained reasons, the Pittsfield plain spreads eastward of the usual limestone-limit (as the map shows) by more than a mile; and it is equally remarkable that while, both to the north and south of Pittsfield throughout Berkshire, the limestone area is intersected from north to south by two or more ridges of schists, the Pittsfield region, for a breadth from north to south of four miles, is all limestone, from the Taconic range on the west to the eastern limit in Dalton. Further, this eastward extension of the Pittsfield part of the limestone area is accompanied by a long eastward extension also of the quartzyte formation adjoining it; this formation occurring to the southward of the extension over a large part of northern Washington, to and beyond Ashley Lake, and from there returning westward to Dewey's Station; and less widely to the northeast of the Pittsfield plain. Moreover, within two or three miles east of the quartzyte formation occur zircon-bearing hornblendic rocks, and in one region (in Hinsdale) chondroditic limestone, giving definiteness to the indications of Archæan age.

We thus have evidence of an old Archæan valley opening from a higher region to the eastward into what is now the Pittsfield part of the Housatonic Valley. Besides the chondroditic limestone, in the village of Hinsdale, along a wider part of the valley, southwest of Hinsdale, west of the railroad, I found a large mass of the same limestone, which I think is in place; so that it is probable that limestone of Archæan age first determined the formation of that part of the upper Housatonic valley leading into Pittsfield.

*f.* The wide Tyringham Valley, which extends southeast from South Lee for five or six miles, and is the course of a broad arm of the Stockbridge limestone, is another case in which the limestone spreads eastward beyond its usual limit, although not by an abrupt shift. The valley is not narrow, like those shaped by modern erosion, although owing much to this cause for its present condition. Moreover, it has the quartzyte formation on much of its eastern side, and, beyond this, Archæan gneisses and hornblende and augitic rocks, with some localities of chondroditic limestone. The South Lee valley, coming down from Becket to the eastward, has similar features for a mile and a half. On the high hill in South Lee between the entrances to the two valleys, the Tyringham and South Lee, there is a large area of hornblendic rocks of Archæan age, where the associated limestone afforded me chondrodite in masses as large as the fist, recalling similar localities in Sussex County, N. J., and Orange County, N. Y.; and the same rocks occur on the opposite side of the South Lee Valley to the northeastward. Archæan limestone occurs also in the bottom of the South Lee valley itself, about a mile from the village.

These facts are here introduced as other illustrations of the influence on the outlines of the Stockbridge limestone areas exerted by preëxisting Archæan channels or bays. They further prove that the great quartzyte formation, which makes the foundation of the Paleozoic of the region, derived its material from Archæan formations of the vicinity not from the fabled Atlantis, which some geologists have looked to for aid in the making of American stratified rocks.

[To be continued.]

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## ART. XXXI.—*Irish Esker Drift;* by G. H. KINAHAN, M.R.I.A.

UNFORTUNATELY, as I have already pointed out in this Journal, American observers, like the early recorders of the Scotch and the Scandinavian later drifts, have "got mixed;" they confounding together true "Esker drift" and ridges of

"Esker-like drift." This appears to be the case in reference to Prof. Carvill Lewis's statement in the December number of this Journal, where he says that the "Irish Eskers" appear to be adjuncts of the melting of the ice sheets. A protracted and careful examination into the subject seems however to demonstrate that this could not be the case.

On the examination of the adjuncts of the present "live ice" or a snow field, it will be found that the drifts due to the ice or the melting of the snow fields, have more or less an argillaceous character, they rarely except in spots, being clean sands or gravel. Of course rivers, having their origin in glaciers or an ice field, after some time may wash these gravels comparatively clean, but this occurs nearly invariably at some distance from the edge of what may be defined as the margin of the present moraine or glacial drift. Recent washing, that is the washing due to river action since the "great glacial period," cannot be taken into account.

In connection with the marine gravels of the present day, we find that in the open sea-currents, all the detritus is well washed and sifted. Where the sea-currents are strong there is coarse sand or fine gravels; this is generally outside the banks; and in other places there is finer, but still well washed sand; while rarely in eddies or "heads of currents," silt accumulates in small quantities. In bays or estuaries, the sand and gravel accumulations are not as well washed and cleaned; while still higher up in such situations, that is near the head of the bay, the accumulations due to marine action graduate in character into those of this drift from the destruction of which, they have been supplied. The true Irish eskers—that is the eskers of the plain and its associated valleys—have no characters in common with those of the ridges of drift due to the melting of ice or snow fields; and the latter are the ridges now erroneously classed with the Irish eskers. On the other hand, all the characters of the true drift are similar to those of the washed marine drifts; they in some places being well washed fine gravel, in others, sand; in eddies on "heads of current" silt; and in such places as must have been bays and estuaries they graduate into half washed accumulations.

Besides, what seems to have altogether escaped Prof. Lewis's attention is the margin of what I have called the "Esker sea." This everywhere throughout Ireland can be traced, as below it the Esker drift occurs and never above it. This margin varies in altitude, but in general not more so than the present spring tide line round the coasts, as I have already pointed out in papers read before the different Irish and English scientific societies. The tide line at the present time is higher on the east coast of Ireland than on the west; and at the heads of the different long bays than at their mouths; so with the margin of the Esker sea, it rises as it is followed up the valleys. In some exceptional cases, as in the County Wicklow, the marginal beach of the Esker sea is at an excessive height. But these excessive heights are south of a regular line, they gradually rising from the west, eastward; while south of that line they do not rise. Therefore it seems evident that the line is a fault north of which the land to the eastward rose considerably more than to the westward, subsequent to the accumulating of the Esker drift. The details of this phenomenon are fully given in the Geology of Ireland and need not be here repeated.

The regular relative heights at which the true Esker drift terminates seem to me to be positive proof that it must be an adjunct of a widespread action like that of a sea which had comparative level margins, and not to an erratic water supply like that due to the melting of an ice sheet or snow field, either of which is necessarily "martyr to circumstances," sometimes low, at others high. I would suggest that before positive statements are made in connection with the *true* Irish eskers—that it should first be learned what is a *true esker*.

## ART. XXXII.—*Physical Characteristics of the Northern and Northwestern Lakes*; by L. Y. SCHERMERHORN, C.E.

IN the following memoranda an attempt has been made to assemble a part of the latest and most reliable information relating to the Great Lakes. The lately completed lake surveys, made by the United States, have reduced to exactness much that previously was only approximate and the perfection of methods used give a perfection to the results which seldom obtains in surveys covering so great geographical extent and involving so many details.

The water surface of the Great Lakes with the land draining into it presents a total drainage basin of over 270,000 square miles, assembled as follows:

| | Area of water surface, square miles. | Area of water shed, square miles. | Aggregate area of basin, square miles. |
|---|---|---|---|
| Lake Superior | 31,200 | 51,600 | 82,800 |
| St. Mary's River | 150 | 800 | 950 |
| Lake Michigan | 22,450 | 37,700 | 60,150 |
| Lake Huron and Georgian Bay | 23,800 | 31,700 | 55,500 |
| St. Clair River | 25 | 3,800 | 3,825 |
| Lake St. Clair | 410 | 3,400 | 3,810 |
| Detroit River | 25 | 1,200 | 1,225 |
| Lake Erie | 9,960 | 22,700 | 32,660 |
| Niagara River | 15 | 300 | 315 |
| Lake Ontario | 7,240 | 21,600 | 28,840 |
| | 95,275 | 174,800 | 270,075 |

The water surface of Lake Superior nearly equals the combined areas of New Hampshire, Vermont, Massachusetts and Connecticut, Lakes Michigan and Huron together nearly equal the area of the State of New York, Lake Erie the combined areas of New Jersey and Delaware, and Lake Ontario about three-fourths of the area of Maryland. The combined area of the lakes exceeds the area of England, Wales and Scotland.

1

The drainage basin of the Great Lakes shown on fig. 1, is a reduction of a very careful compilation of the best authorities and shows at a glance the details stated in the previous table. It shows also that while the line of deepest water does not coincide with the middle line of the lakes, it does approximately coincide with the medial line of lake basin. It will be further observed that, with the exception of Lake Erie, the points of greatest depth quite nearly coincide with the center of figure of each basin. This is believed to be a fact never before noticed, and one that may cast some light upon the geological evolution of the Great Lakes.

The length of shore line of the lakes and their connecting rivers is about 5400 miles, or about equal to the coast line from

Maine to the isthmus of Panama, if the distance be measured along the general contour of the coast, ignoring minor indentations.

The recently perfected levels of the U. S. Lake Surveys, between tide water and the lakes, fixes the elevation of their mean surfaces above mean sea level as follows:

| Lake. | Feet. |
|---|---|
| Ontario | $246\frac{6}{10}$ |
| Erie | $572\frac{9}{10}$ |
| Huron and Michigan | $581\frac{2}{10}$ |
| Superior | $601\frac{8}{10}$ |

(See fig. 2.)

The difference of $20\frac{1}{2}$ feet between Lakes Superior and Huron occurs in the rapids of St. Mary's River; the $8\frac{4}{10}$ feet between Lakes Huron and Erie mainly in Detroit River.

The difference of 326 feet between Lakes Erie and Ontario occurs in the vicinity of Niagara Falls and is principally assembled as follows (see fig. 3): 100 feet in the five miles of rapids between Lewiston and the lower Suspension Bridge, 10 feet in the rapids between the Bridge and the Falls, 160 feet at the Falls,* 50 feet in the rapids immediately above the Falls, and 6 feet in the upper Niagara River.

The mean depth of Lake Superior is about 475 feet; the deepest point (see fig. 2) marks a depth of 1008 feet, or over 406 feet below the level of the sea. Lake

2.

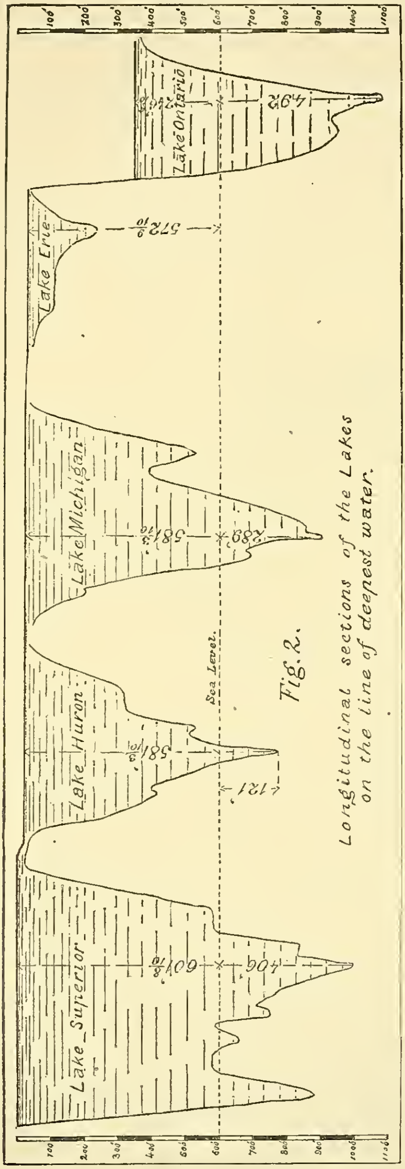

Fig. 2.

Longitudinal sections of the Lakes on the line of deepest water.

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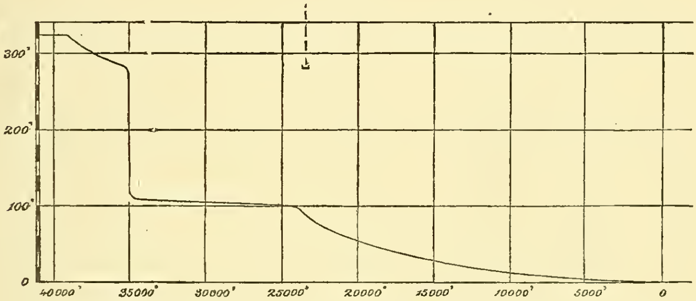
* The height of the Falls is 155 feet on the Canadian side, 161 feet near the site of Terrapin Tower and 169 feet near the east side of the American Falls.

Huron has a mean depth of about 250 and a maximum depth of 702 feet. Lake Michigan has a mean depth of 325 feet and a maximum depth of 870 feet. Lake Erie is comparatively shallow, having an average depth of less than 70 feet and a maximum of 210 feet. Lake Ontario has a mean depth of about 300 feet and a maximum of 738, or nearly 500 feet below the level of the sea. The channels of the rivers connecting the lakes seldom exceed the depth of 50 feet. If the lakes could be drained to the level of the sea, Lake Erie would disappear, Lake Huron reduced to quite insignificant dimensions, Lake Michigan to a length of about 100 miles with a width of 25 or 30 miles, Lake Ontario and Superior, although with diminished areas, would still preserve the dignity of their present titles as *Great Lakes.*

3.



A chemical analysis of water taken from the deepest part of Lake Superior failed under the application of delicate tests to indicate the presence of salt.

The beds of the lakes away from the vicinity of the shorelines, and at depths exceeding 100 feet, are almost invariably covered with clay. Specimens from the deep soundings of Lake Superior were invariably soft clay varying in color from red, yellow to blue. In the deepest parts the drabs and bluish tints predominate.

The temperature at the deepest points varies little from the mean annual temperature of the surrounding air. The temperature of Lake Superior at depths exceeding 200 feet varies but slightly from 39° F. In Lake Huron, at depths of about 300 feet the temperature in the months of June and August was 52° F., while at a depth of 624 feet the temperature was 42° F., the surface temperature being 52° F. and the air 64° F.

The mean annual rain and melted snow-fall of the several lake basins is as follows: Lake Superior, 29 inches, Lake Huron, 30 inches, Lake Michigan, 32 inches, Lakes Erie and

Ontario, 34 inches. This is about equal to 31 inches on the entire lake basin.

The following represent the average discharges at the outlets of the lakes:

| | | | |
|---|---|---|---|
| Lake Superior, at St Mary's River | 86,000 | cu. ft. | per. sec. |
| Lakes Michigan and Huron, at St. Clair river, | 225,000 | " | " |
| Lake Erie, at Niagara | 265,000 | " | " |
| Lake Ontario, at St. Lawrence river | 300,000 | " | " |

The aggregate discharge of the lakes is double that of the Ohio and nearly equals half the discharge of the Mississippi. The area of the lake basin is a third larger than the basin of the Ohio, or about a fifth the combined areas of the basins of the Mississippi and its affluents. The outflow of the lake basin is slightly less than half the rain fall, while on the Mississippi and Ohio the discharge is about a fourth the rainfall. If the average discharge of the lakes passed through a river one mile wide with a mean velocity of one mile per hour, such a river would have a depth of 40 feet from shore to shore.

The volume of water in the lakes is about 6000 cubic miles, of which Lake Superior contains a little less than one-half. Perhaps a better idea of this volume may be obtained when it is said that it would sustain Niagara Falls in its present condition for about 100 *years.*

In relation to the depth of water on the crest of Niagara Falls it can be easily demonstrated that if the water passed over the Falls in a sheet of uniform thickness for the entire length of the present water way, which is about 3600 linear feet, the depth of the sheet would not exceed 4 feet. It is highly probable that at the apex of the Horseshoe Falls the depth is nearly 20 feet, consequently it may be inferred that the depth of the sheet except in a few places is less than 4 feet.

The principal changes in the elevation of the lake surfaces are those due to the wind and to rainfall. Prof. Whittlesey states that on Aug. 18, 1848, a gale from the N.E. reduced the water level at Buffalo, N. Y., to a point 15½ feet lower than the surface of the lake on Oct. 18, 1849, at which time a terrible gale occurred from the S.W. This was an excessive difference of level and one of rare occurence.

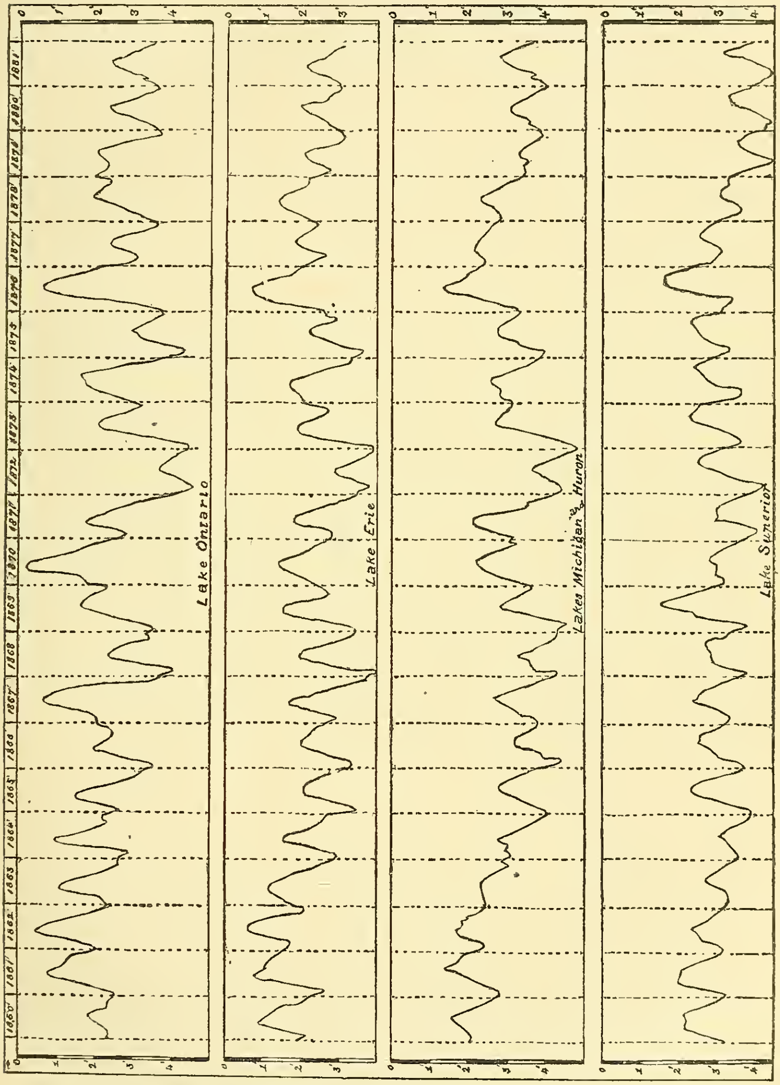
During protracted autumn gales waves have been observed which through reliable means, measured from 15 to 18 feet above the normal surface.

The second class of variations, those due to rainfall, occur with considerable regularity. The lowest water in the year generally occurs in Lakes Ontario, Erie, Michigan and Huron in the months of November and March, and on Superior in March. The highest water occurs on the first named lakes in

June and July, while on Superior it is delayed until September. The average difference, derived from 20 years observation, between the high and low water of the year is as follows:

Lake Superior, 1·2 feet, Michigan and Huron, 1·3, Erie, 1·6, and Ontario, 1·9 feet.

4



The highest observed stage of the lakes occurred in the summer of 1838, and the lowest in the summer of 1847: the difference between the two stages being about 4½ feet.

The water level of the lakes for the last 20 years is shown in fig. 4 and fails to show, as has been claimed, any recurring cycle of high or low water.

The curves of the last 10 years show a tendency to irregularities which may be due to changes in rainfall and water-shed produced by the rapid destruction of the forests which 10 years ago covered the basin of the upper lakes.

Observations made by the U. S. Survey have established the existence of small tides, which at Chicago had an amplitude of $1\frac{1}{2}$ inches for the neap tide and about 3 inches for the spring tides.

There is still another class of oscillations called *seiches*, which have been already observed in the Swiss Lakes and for which a solution in all respects satisfactory has not been offered. Whenever the lakes are sufficiently free from the disturbing action of wind to permit observations, a quite regular series of small waves, or pulsations can be detected, which have an in- erval of about 10 minutes from impulse to impulse. These pulsations seem to occur almost without cessation on Lake Superior. Besides having tides in common with the ocean, the lakes have well-defined land and lake breezes; the breeze from the lakes landward commencing in summer at 8 or 10 o'clock A. M., and continuing until sunset and the breeze from the land lakeward from 9 or 10 P. M. until sunrise.

The modifying effect of these large bodies of water upon land areas contiguous to the lakes is noticeable. At Milwaukee, Wis., which is directly upon the shore of Lake Michigan, the mean annual temperature is as follows: winter, 24° F., spring, 41° F., summer, 67° F., autumn, 49° F., annual range, 110° F. At points in the same latitude but from 50 to 100 miles inland, the mean winter and autumn temperatures are about 2° F. lower, and mean spring and summer temperatures nearly 5° F. higher, while the annual range is about 5° F. greater.

## ART. XXXIII. — *Mineralogical Notes from the Laboratory of Hamilton College;* by ALBERT H. CHESTER.

### 1. FUCHSITE.

THIS interesting variety of mica occurs in considerable abundance on Aird Island, a small island in the northern part of Lake Huron near the mouth of the Spanish River and consequently in the district of Algoma, Canada. The matrix is a coarsely crystalline dolomite, and in this the fuchsite occurs in small layers and masses, sometimes associated with white quartz and generally accompanied by small flakes of silvery mica, from which it is somewhat difficult to separate it for analysis. An analysis* of a pure sample resulted as follows:

| | Cairns. | Schafhäutl. |
|---|---|---|
| $SiO_2$ | 45·49 | 47·95 |
| $Al_2O_3$ | 31·08 | 34·45 |
| $Cr_2O_3$ | 3·09 | 3·95 |
| $Fe_2O_3$ | trace | 1·80 |
| CaO | 0·51 | 0·59 |
| MgO | 3·36 | 0·71 |
| $K_2O$ | 9·76 | 10·75 |
| $Na_2O$ | 0·90 | 0·37 |
| F | | 0·35 |
| $H_2O$ | 5·85 | |
| Total | 100·04 | 100·92 |

An analysis of the Tyrol mineral is quoted for comparison. Another determination of the chromium gave 2·88 per cent of $Cr_2O_3$. The occurrence of chrome mica allied to fuchsite, at various places in Canada, has been mentioned by Dawson,† but I think no analysis has heretofore been published.

The dolomite in which this mineral occurs is interesting, not only on that account, but because of its peculiar appearance, its color, cleavage and crystalline characteristics, causing it to be readily mistaken for calcite.

The analysis‡ is as follows:

| | | |
|---|---|---|
| $CaCO_3$ | 52·83 | per cent. |
| $MgCO_3$ | 40·39 | " |
| $FeCO_3$ | 5·77 | " |
| $SiO_2$ | 0·20 | " |
| $Al_2O_3$ | 0·60 | " |
| $CaSO_4$ | 0·34 | " |
| $H_2O$ | 0·14 | " |
| Total | 100·27 | |

This shows it to be a true dolomite in which part of the carbonate of magnesium is replaced by carbonate of iron. It is the common rock of the vicinity, but the fuchsite is found in it only at one place, on the eastern end of the island, the area containing the mineral measuring not more than thirty by fifty feet.

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* By Mr. F. I. Cairns.

† Geology of Canada for 1863, p. 494.

‡ By Mr. William N. DeRegt.

### 2. PINK CELESTITE.

The occurrence of celestite, in connection with strontianite, in the rocks of the Clinton group, has received casual notice by Professor O. Root,* and it has also been noticed since in various lists of mineral localities. It occurs in nodules and geodes, not only in the limestone and sandstone beds, but also in the oölitic iron ore beds of this vicinity. The best examples are to be found at the stone quarries near Lairdsville, about two miles west of Hamilton College, where it occurs abundantly in masses made up of prismatic crystals, sometimes so slender as to give a fibrous appearance to the specimens. In rare instances the crystals are bladed, and radiate from a center in fan-like shapes. These specimens are often coated with strontianite, which is generally of a mealy character, though sometimes in small crystals. The peculiarity of this celestite which makes it most interesting is its color, which is usually a delicate pink or flesh color, though sometimes it has the ordinary dull bluish tint. Occasionally both colors are seen on the same specimen, but more often it is distinctly one or the other.

An analysis† of this celestite gave the following results:

| | | |
|---|---|---|
| SrO | 46·71 | per cent. |
| BaO | 7·28 | " |
| CaO | 2·01 | " |
| $SO_3$ | 43·20 | " |
| $SiO_2$ | 0·28 | " |
| Total | 100·38 | |

This corresponds to the following proportions of the three sulphates:

| | |
|---|---|
| $SrSO_4$ | 84·09 |
| $BaSO_4$ | 11·05 |
| $CaSO_4$ | 4·86 |

The mineral has frequently been called baryto-celestite, though as far as I can find there is no published analysis of it. From the above calculation the ratio of $S_2SO_4 : BaSO_4 : CaSO_4$ is about 10 : 1 : 1, but the mineral is undoubtedly a mere mixture of the three nearly isomorphous sulphates. A similar mixture, but without the $CaSO_4$ is described by Collie,‡ from Clifton, near Bristol, England, who gives a number of analyses of celestite containing barium sulphate in varying proportions and

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* This Journal, II, vol. xiii, p. 264.

† By Mr. F. I. Cairns.

‡ Min. Mag., ii, p. 220.

arrives at the same conclusion. The crystals I have been able to find on these specimens are few, small and imperfect, but the faces *O*, 1-ĭ and ½-ī have been recognized showing angles approximately near the correct ones.

### 3. ZINKENITE.

A sample of bindheimite from the Stewart Mine, Sevier County, Ark., has at its center a compact massive mineral of dark gray color, consisting of lead, antimony and sulphur only. A partial analysis of the pure homogeneous mineral shows 34·77 per cent of lead, and indicates that it is zinkenite. The occurrence of this rare mineral among the Arkansas antimony ores is suggested by Professor Charles E. Wait;* and Mr. W. F. Hildebrand† describes zinkenite from Colorado very similar to that noticed above.

### 4. BROCHANTITE.

A specimen of brochantite from Chili gave the following analysis, after deducting 4·45 per cent of insoluble matter, and calculating to one hundred per cent.

| | |
|---|---|
| CuO | 71·73 |
| $SO_3$ | 18·21 |
| $H_2O$ | 10·06 |

This corresponds well with the formula $Cu_4SO_7+2\frac{1}{2}H_2O$, which requires CuO 71·84, $SO_3$ 18·16 and $H_2O$ 10·00. The mineral occurs in small tufts of delicate fibrous crystals, verdigris to emerald-green in color, associated with linarite, in a quartz matrix.

### 5. PECTOLITE.

A specimen of okenite, so-called, from Disco Island, Greenland, afforded the following analysis:

| | |
|---|---|
| $SiO_2$ | 52·86 |
| CaO | 34·33 |
| $Al_2O_3$ | 0·71 |
| $Na_2O$ | 7·50 |
| $K_2O$ | 0·47 |
| $H_2O$ | 4·70 |
| Total | 100·57 |

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* Trans. Am. Inst. Min. Eng., vol. viii, p. 51.

† U. S. Geol. Surv. Bull. 20, p. 93.

This is evidently pectolite, as is probably much that is now called okenite from the same locality. The specimen examined is made up of a mass of fine interlaced fibers, pure white in color, with a sub-pearly luster, and forming a layer about an inch in thickness.

### 6. Hemimorphic crystals of Barite.

The crystals of barite from DeKalb, St. Lawrence Co., N. Y., described by G. H. Williams,* exhibit the following macrodomes besides the one he mentions: $1\cdot\bar{\imath}$ (*d*), $\frac{1}{4}\cdot\bar{\imath}$ and the rare one $\frac{2}{3}\cdot\bar{\imath}$ (*w*). The crystals are generally so grouped together that one doubly terminated cannot often be obtained, but a study of the few that have been observed shows them to be hemimorphic and quite different from any heretofore described. The crystals are all alike and have the form given below; fig. 1 shows one in the usual position, while in fig. 2 the brachydiagonal is made vertical. Measured with a hand-goniometer $O \wedge \frac{2}{3}\text{-}\bar{\imath}$ ($c \wedge w$) is found to be 133°, corresponding closely with the angle given by von Kokscharow,† 132° 58′ 25″. As mentioned before, all the doubly terminated crystals found show this dome on one end, and it is also quite often seen on the broken and grouped crystals which show but one termination, though the face $\frac{1}{2}\text{-}\bar{\imath}$ (*d*) is rather more common. A few singly terminated crystals were found with both domes. In these cases the curious alteration noticed by Williams is well shown, the faces $\frac{2}{3}\text{-}\bar{\imath}$ being changed to the chalk-like material which he describes, while the next face, $\frac{1}{2}\text{-}\bar{\imath}$, is colorless and transparent, or sometimes altered on the edges, leaving a triangular spot of unaltered material in the center of the face. It is worthy of notice that this form, so rarely seen heretofore, should be so common in this one locality.

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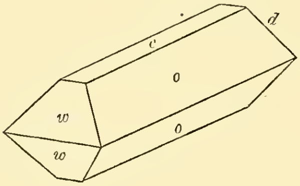

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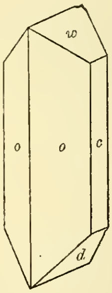

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* Johns Hopkins Univ. Circ., No. 29, p. 61, 1884.

† Min. Russl., vii, p. 54, 1875.

Other hemimorphic crystals of barite have been described by Reuss,[*] by Zepharovich,[†] and by Schrauf.[‡] These forms are all given in Schrauf's Atlas, figs. 4, 12 and 15, under Baryt. The first two are hemimorphic in the direction of the same axis as the crystals from DeKalb, and the other in the line of the vertical axis. While all three are much more complicated than the simple one described here, none of them shows the face $\frac{2}{3}$-$\bar{\imath}$.

The symbols used here correspond to the more common position of barite, where the plane of the principal cleavage is made the basal pinacoid. The hemimorphism is better shown, as in fig. 2 above, by returning to the old system, still used by some authorities, where this plane is made the brachypinacoid, requiring of course a change of the symbols.

### 7. PSEUDOMORPHS OF CERARGYRITE AFTER PYRARGYRITE.

These interesting pseudomorphs were found among some ores and minerals from the Horn Silver Mine at Frisco, Utah, and are apparently not uncommon there. The matrix is sometimes a white amorphous silica, easily crumbled and containing much water. It is evidently a variety of opal and closely related to the geyserite of our Western hot springs. In other cases the matrix is nearly pure barite, always distinctly crystalline and occasionally seen in minute crystals. In color it is generally white or grayish, but occasionally it takes delicate lilac tints. Scattered somewhat sparsely through these two we find crystals of a dark color which grade all the way from pure pyrargyrite to pure cerargyrite. They are from 2 mm. to 4 mm. in diameter and up to 10 mm. in length. Though rough externally they are easily seen to be in hexagonal prisms and occasionally show rhombohedral terminations.

Some of these crystals are found on examination to be pure unaltered pyrargyrite, consisting of sulphantimonide of silver with a little arsenic. Many of them are partially altered to cerargyrite, usually in an irregular manner, but occasionally are only altered on the outside leaving a core of pyrargyrite. Quite a number of them are completely changed and are chloride of silver throughout. This is then a case of pseudomorphism by alteration and not a simple filling with chloride of silver of cavities left after the removal of pyrargyrite crystals.

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[*] Ber. Ak. Wien, lix, p. 623, 1869.

[†] "Lotos," p. 8, 1870.

[‡] Ber. Ak. Wien, lxiv, p. 199, 1871.

### 8. SCORODITE.

This mineral is also found among the specimens from the Horn Silver Mine, and particularly in connection with the amorphous sulphate of lead so common there. It does not occur abundantly, but in very thin crystalline crusts of the characteristic pale green color. and also in amorphous layers which shade from yellow to dull brown. The mineral occurs in such thin layers, and so mixed with foreign matters, that a pure sample for analysis can hardly be obtained, but before the blowpipe it reacts for arsenic acid, iron and water, and behaves in all respects like scorodite. So few localities of this mineral have been found that this occurrence is thought worth a notice here.

### 9. BISMUTITE.

Some samples of a mineral from near Casher's Valley, Jackson Co., N. C., sent here for identification, prove to be bismutite. It occurs in a narrow vein affording only small masses, the largest being about the size of a pigeon's egg, associated with dark red or black garnet, white mica and quartz, and rarely black tourmaline, the bismutite forming the matrix of the other minerals. As usual it has various colors, the purest and most unaltered being light apple green, while some parts are dark gray. It shades from these colors through yellow and light gray to chalky white in the amorphous parts. It has a laminated structure, in some instances appearing almost columnar. The specific gravity of the purest is 7·4 to 7·5.

Analysis of the mineral* gave results as follws:

| | | |
|---|---|---|
| $Bi_2O_3$ | 86·36 | per cent. |
| $CO_2$ | 7·79 | " |
| $H_2O$ | 2·02 | " |
| Insoluble | 3·63 | " |
| Total | 99·80 | |

It was not easy to select material entirely free from gangue but this was not necessary, as the solution of the mineral in dilute nitric acid is complete, leaving a residue of mica and quartz only. Deducting this residue and calculating to one hundred per cent gives:

| | | |
|---|---|---|
| $Bi_2O_3$ | 89·80 | per cent. |
| $CO_2$ | 8·10 | " |
| $H_2O$ | 2·10 | " |

The formula suggested is $Bi_2C_3O_9+2Bi_2H_2O_4$, requiring $Bi_2O_3$ 89·31, $CO_2$ 8·40 and $H_2O$ 2·29, which agrees very

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* By Mr. F. I. Cairns.

well with the figures given above. The mineral is therefore a combination of bismuth carbonate and hydrate. Comparing this formula with $BiC_5$ which is given by Weisbach[*] for his bismutosphærite, or rather with its equivalent $Bi_2C_3O_9+2Bi_2O_3$, we see that they differ only in the hydration of the bismuth oxide. If we regard the loss in Winkler's analysis as water, and after deducting the silica found, calculate to one hundred per cent, it becomes $Bi_2O_3$ 88·83, $CO_2$ 8·90 and $H_2O$ 2·18, also quite near the figures required by the formula.

It is to be hoped that there will be a new examination of bismutosphærite, for it certainly is a suspicious circumstance that the loss in the analysis given, an analysis on which a new name is based, should be exactly the amount of water required to make it the well-known mineral bismutite.

Clinton, N. Y., February 16, 1887.

## Art. XXXIV.—*The Topography and Geology of the Cross Timbers and surrounding regions in Northern Texas*; by Robert T. Hill.[†] With a Map, Plate VI.

The Cross Timbers of Texas are two long and narrow strips of forest region between the 96th and 99th meridians, extending parallel to each other from the Indian Territory southward to the central portion of the State, forming a marked exception to the usual prairie features of that country. They have been delineated upon several maps, but most accurately upon the one accompanying the "Report on the Cotton Production of the State of Texas, with a Discussion of the Agricultural Features of the State," by R. H. Loughridge, Ph.D., Special Agent of the Tenth Census,[‡] which has been adopted in the map illustrating the areal distribution of the geologic formations of the United States, published in vol. v, of the Annual Reports of the Director of the U. S. Geological Survey.

The traveler, in crossing this region of Texas from east to west, along the line of the Texas and Pacific railroad, views the Cross Timbers merely as a grateful relief to the monotony of the prairies, and sees little in them worth remembering. To the more careful observer, however, there are numerous points of interest bearing on their topographic and geologic relations, some of which are worthy of presentation.

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[*] Jahrb. Berg-Hütt., 1877.

[†] Read before the Philosophical Society of Washington, Jan. 29, 1877.

[‡] Rep. Tenth Census, vol. v, pt. I, 1884, pp. 653–831.

The literature hitherto published on the subject conveys but vague ideas of the real nature of the Cross Timbers, and usually ignores the discussion of their physical features. In fact they have always been treated together as one phenomenon, and but little intimation has been made of the differences existing between them. Neither has much of definite value been published on the surrounding region, for which reason it will be necessary to include it in this discussion.

### *The Upper Cross Timbers.*

From their greater altitude and their position relative to the flow of the rivers, the more western of the Cross Timbers, although geologically lower in the series, is known as the Upper, in distinction from the eastern, or Lower. It extends southward from the Indian Territory, through the counties of Montague, Wise, Jack, Parker, Hood, Erath and Comanche, to near the Colorado River. Its eastern border at every point is clearly defined, the adjoining prairie region being invariably much higher in altitude. The western border is not so sharply marked, but it approximately coincides with the 98th meridian until near the 32d degree of latitude, when it bends to the westward, losing its identity by "thinning out," so that the boundary between the wooded and prairie region is not always apparent. The surface soil usually consists of an exceedingly fine-grained siliceous sand, which is the detritus of the underlying strata. This sand is utterly untenacious, except when wet, and is readily distributed by the high winds over the surface so as to effectually conceal the underlying strata. A small amount of red clay from a neighboring stratum gives to the sand, when mixed with it, a dirt-yellow color. Although destitute of turf, the surface is covered with a thick growth of stunted trees and bushes, consisting mainly of the post oak (*Quercus obtusiloba*) and the black jack (*Q. nigra*), accompanied by elms and hackberries, and many annuals and perennials that accommodate their appearance to the time of rainfall. This flora is nearly constant throughout the entire extent of the Upper Cross Timbers, and most of its species also occur in the lower member. The character of the soil, as above described, is also constant along the eastern edge, but is varied along the western half of the timbers by the presence of a crumbling, fine-pebble conglomerate.

### *The Lower Cross Timbers.*

The lower Cross Timbers are located about fifty miles east of the upper belt, and extend in a direction approximately parallel to it. They are separated their entire length by a prairie region, utterly destitute of timber. The western margin of the Lower Cross Timbers is clearly defined, as is the case with the eastern edge of the Upper member; but, instead of being below the level of the prairie it is always at a higher altitude. The soil of the Lower Cross Timbers, although also arenaceous, differs from that of the Upper in many respects. It is ferruginous and more fertile, averaging less than ninety per cent of insoluble silica, while that of the Upper usually exceeds ninety-seven. The difference in fertility of the soils produces a varietal difference in the flora, the trees attaining much larger proportions and the number of species being slightly greater. The average width of the Lower Cross Timbers does not exceed fifteen miles, and they lose their identity near the Brazos River, at Waco.

It is now evident that the resemblances of the two belts of timber are only of a general character, and an examination into their geologic relations will show many more important differences than those already pointed out.

### *Prevalent Theories as to the Cross Timbers.*

The occurrence of these anomalous belts of timbered region, extending in a direction at right angles to the streams, has been productive of many hypotheses concerning their origin. Unfortunately, very few geologists have heretofore visited the country, and hence most of these hypotheses have been based upon compilation or tradition. Most of them imply that the arenaceous soils of the Cross Timbers have resulted from the sediments of post-Cretaceous aqueous channels or basins, which have been preserved intact from destructive denudation. These theories are partially derived from the relative position of the timbers to the adjacent prairies. One of them is that they represent arms, or inlets, of the Tertiary sea*—a theory made plausible by the proximity of their southern termini to the western borders of the Tertiary area, and the occurrence in one of the Timbers of a molluscan fauna, presenting at the first glance a Tertiary facies. A second theory is that they are the beds of extinct lakes, and a third, that they represent the channels of Quaternary rivers,† the directions of which indicate the former general slope of the surface of the country. The current opinions concerning their geologic age have been as

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* "First Annual Report of the Geological and Agricultural Survey of the State of Texas, by S. B. Buckley, State Geologist," pp. 61, 62. Houston, 1874.

† Dr. Loughridge speaks thus of the river channel theory: "In many points along its course the general surface of the belt is lower than the adjoining prairies, and the general features of the lower Cross Timbers almost lead to the conclusion that at some time a deep trough-like valley connected Red (perhaps the Canadian) and Brazos rivers, probably forming the bed of the former river and conveying its waters to the Gulf through the present channel of the Brazos, and that by some agency this valley was filled with clays and sands and the present channel of the river formed."—Rep. on Cotton Production, p. 29.

diverse as those concerning their origin. Dr. S. B. Buckley, in his "First Annual Report of the Agricultural and Geological Survey of the State of Texas," erroneously calls the lower member the "upper" (p. 61) in one place, and refers them to the "Miocene," and on the next page he speaks of them both as probably "Tertiary." Messrs. Blake and Hitchcock, on their geological map of the United States (1876), delineate only the lower member of the Cross Timbers, and color it Eocene. Mr. A. R. Roessler's series of county maps of Texas represent the upper timbers as Tertiary. A prominent authority on the Southern States Tertiaries, in a private letter, maintains that the upper member is Carboniferous, and the lower one of the Cretaceous period (Ripley). Dr. R. H. Loughridge, in the valuable treatise so often mentioned in this paper, gives the best account of them that I have seen in print, and calls them "stratified Quaternary drift." Mr. W. J. McGee, naturally accepting Dr. Loughridge's theory as the most plausible, incorporated it in his Map of the United States, accompanying the Fifth Annual Report of the Director of the U. S. Geological Survey, Washington, D. C., 1886.*

With all of these theories in mind, I must confess that I visited the region this summer with a preconceived idea that I should find some one of them approximately true, and I was greatly surprised to find them all equally erroneous.

### *Topographic and geologic characteristics.*

Before a proper appreciation of the relations of the two members of the Cross Timbers to each other can be arrived at, it is necessary to briefly review the salient topographical features of this portion of the State of Texas.† The river drainage of the State indicates the only general feature in its topography—a slope of the surface from northwest to southeast; but even to this feature there are several important exceptions. For my own convenience I have divided the topographic features of the State into the following broad areas:

*First.*—The Coast Plain, a continuation of the topographic features of the Gulf States so far as they represent old outlines of Post-Cretaceous sedimentation of the Gulf of Mexico. Although a portion of the Cretaceous strata for a short distance west of it could be classified geologically with this Coast plain, its topographic border is made to coincide with the interior border of the marine Tertiary, the plain being mostly a forest-covered section of country, and at a much lower altitude than the prairie region.

*Second.*—The "Black Prairie Region." This constitutes an elongated, triangular region continuing from Arkansas and

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* Mr. C. H. Hitchcock also accepts this in his late map, 1886.

† See map.

Indian Territory into Northern and Central Texas, and immediately adjoining the foregoing topographical division on the west. Its western border follows a line drawn through Dallas and Austin, from Denison to San Antonio, where it makes a western deflection to the Rio Grande. Geologically, this region is also a continuation of the features of the other Gulf States, but beyond its western edge the continuity ceases. It differs from the Coastal Plain in being at a much greater altitude, and consisting almost entirely of a level prairie region. Its altitude is from 450 to 750 feet.

*Third.*—The Central Denuded or Hilly Region. This area, in itself, embraces a great number of unique and well-marked topographic features, each of which is worthy of a more detailed description than can be here given. It might be called the "butte" region, the "drouth" region, or by any of a dozen local descriptive names equally applicable to it; but its general features are all the result of one great cause, an excessive amount of superficial denudation. It includes all the country west of the Black Prairie Region to the escarpment of the plains, in the northwest, and to the Trans-Pecos mountainous region of the southwest. It embraces a multitude of geologic formations, but there is in it little* or no evidence of local disturbance in the strata. Its altitude is generally between 750 and 2000 feet.

*Fourth.*—The Plateau, or Pan Handle Region. This comprises the northern and most extensive half of the Llano Estacado, and is a southern continuation of the great plains of Kansas.

*Fifth.*—The Mountainous or Trans-Pecos Region. Most of the country west of the Pecos consists of highly disturbed, mountainous areas. The general direction of the axes of the disturbances is parallel with the course of the Pecos, the Rio Bravo, and the Sabinas river in Mexico, all which flow nearly due southeast. The eastern border of this area crosses the Rio Grande west of the Pecos, continues in Mexico for a distance, but again crosses the Rio Grande eighteen miles west of Eagle Pass, and for a hundred and fifty miles it extends along the Texas side of that river to below Laredo, where it again crosses it into Mexico.

I have endeavored to delineate this classification of the topographic features upon the accompanying map, plate VI.

The two belts of the Cross Timbers are entirely within the third, or Central Denuded Region, the eastern border of the lower timbers coinciding almost exactly with the western border of the second topographical area. The chief geologic agency in modifying the surface of this region, as before stated, has been subaerial erosion. The only elevation apparent is that which

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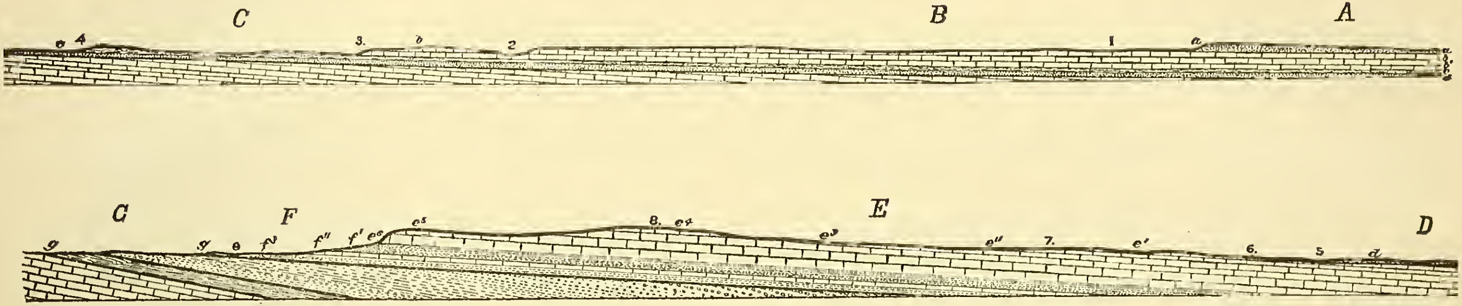
* No recorded disturbance, I should say. There is an important dislocation of strata in this region to which I shall soon call attention.



Geologic Section along the line of the Texas and Pacific Railway, from Elmo, Kaufman County, to Millsap, Parker County.

1. Terrel; 2. Dallas; 3. Eagle Ford; 4. Arlington; 5. Handley; 6. Fort Worth; 7. Ben Brook; 8. Weatherford; 9. Millsap.

A. Coast Plain—Marine Tertiary. B. Black Waxy Prairie—Riply and Rotten Limestone, of Gulf Series. C. Eagle Ford Shales, and accompanying prairies. D. Lower Cross Timbers—Timber Creek Group ("Dakota sandstone?" of Shumard). E. Grand Prairie Region—Comanche (Texas) Division of the Cretaceous. $e'$, $e''$, $e^3$, Washita, or upper, division; $e^4$, $e^5$, $e^6$, Lower, or Fredricksburg (Comanche Peak) division. F and G. Upper Cross Timbers—$f'$, $f''$, $f^3$, Dinosaur Sands; $g$, $g$, Carboniferous Coal-measures. Faunal horizons—$e^8$, Toxaster elegans Fauna; $e''$, Horizon of Gryphæa Pitcheri (var. Dilatata) with Ostrea carinata; $e^3$, Gryphæa Pitcheri, var. Fornicula (Exogyra forniculata; $e^4$, Ammonites vespertinus; $e^5$, Hippurites (Caprina) Limestone; $e^6$, Comanche Peak Fauna, including horizon of Gryphæa Pitcheri with Ostrea Matheroniana.

is common to the other areas, and which was due to the rising of the Rocky Mountain axes. The denudation resulting from the subaerial erosion has been very great, the whole of the geologic series, from the recent to far down into the Carboniferous, having been removed from its center or place of greatest denudation. In traveling in either direction from the center of this region, east or west, and sometimes south, the geologic formations will be passed in ascending series, from the Carboniferous into the Tertiaries. The denudation is progressing now at a rate probably greater than in any time past, and the geologic features are being constantly modified by it. The Tertiary, if it ever existed there,* has already been removed from this vast area, and the Cretaceous is rapidly yielding—in places entirely gone. This fact being true, it is evident that the Cross Timbers cannot represent any post-Cretaceous sediments.

Going from east to west along the line of the Texas Pacific Railway, as I have represented upon the accompanying profile and geologic section—from the area of the least denudation to that of the greatest—let us examine more closely into the relations of the strata, and their connection with the present topographic features. The second topographic area, after passing west of the first, or Coast Plain (with which I shall not deal in this paper), is locally known as the "black waxy," or "white rock" prairie, two names derived respectively from the character of the soil and of the underlying rock. It has such topographic, geologic, and paleontologic resemblance to the "Rotten limestone" of the other Gulf States, as well as direct geographic continuity, that there is no doubt but that it, as well as its immediately adjacent strata, is a continuation of the same formations from those States. The underlying rock (*b*)† is a soft, almost structureless, slightly foraminiferous limestone rich in magnesium, which, on dry exposure, hardens and bleaches to a yellow-white, and on contact with moisture readily decomposes and crumbles. Natural sections, wherever exposed by the creeks or rivers, show that there is a gradual transition from rock to marl and marl to soil. In other words, the top of the rock, when acted upon by infiltrating moisture, is decomposed into the marls and soils. The uniformity of this under-surface decomposition over a large area, together with the tenacity of the soil, results in a level and well-defined prairie region. The eastern edge of this Rotten limestone, where it dips under the higher protecting strata, is much thicker than

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* The land divide which probably separated the brackish and fresh-water Tertiaries of the west from the purely marine Tertiaries of the Gulf region may have occupied this region at one time. The marine Tertiaries end in the vicinity of Elmo, Kaufman County (*a′*).

† Letters in parentheses refer to the letters upon the profile and geologic section accompanying.

*Geologic Section of the Cretaceous Strata of the State of Texas, as seen along the Line of the Texas thickness, as it occurs throughout the State.*

| | | | POSITION. | HISTORY AND SYNONYMY. | STRATIGRAPHY. |
|---|---|---|---|---|---|
| | | | BASAL TERTIARIES. | | |
| GULF SERIES. | UPPER CRETACEOUS. | | NAVARRO BEDS.<br>Exogyra ponderosa Marl. | Ripley Group of Shumard, 1861. (3) (2)<br>Loughridge, 1884. (4)<br>Included by Rœmer in Kreidebildungen am Fusse des Hochlandes. (5) | Marls, clays, and limestones of varying hardness, and in beds of limited extent. Mostly concealed by the prairie soil. |
| | | | DALLAS LIMESTONE.<br>Zone of Ostrea bellaplicata. | "Austin" Limestone of Shumard, 1860. Wrongly placed by him in series.<br>Part of Rœmer's Kreide. am Fusse des Hochlandes.<br>Part of "Lower Cretaceous" of Shumard, 1860. | Soft magnesian limestone, earthy fracture, fine texture, highly foraminiferous. Blue upon fresh exposure, but decomposing and bleaching shortly after. Agrees, in main, with the same formation as described in other Gulf States.<br>Conformable with above by position and faunal continuity. No line of demarkation yet made between the above groups. |
| | MIDDLE CRETACEOUS. | | EAGLE FORD SHALES. | "Arenaceous Group" and "Fish Bed" of Dr. Shumard's "Lower Cretaceous," 1860.<br>Kreide. am Fusse des Hochlandes. Rœmer. | Argillaceous shales, varying from blue at top to yellow in middle, and to blue again at base, but with marked faunal zones. |
| | | | TIMBER CREEK GROUP. | | Coarse-grained, friable, ferruginous sands, alternating with thin seams of yellow clays. Lignitic. |
| | | | | | PLANE OF UNCON |
| COMANCHE SERIES. | LOWER CRETACEOUS. | This series is one of unbroken sedimentation and faunal continuity from base to top. Subdivisions are temporarily designated by horizons of prominent fossils. Many species continue throughout the entire series.<br>Upper or Washita Division | Upper Denison Fauna. | "Lower Cretaceous." (1) | Thin alternations of limestone, sandstones, and shales. |
| | | | Cidaris hemigranosus.<br>Toxaster elegans.<br>Exogyra arietina. | "Washita Limestone." (1)<br>" "<br>"Indurated Blue Marl" (1) | Alternating bands of firm yellow limestones and calcareous marls, growing thicker downward. The "blue marl" is the same material. |
| | | | Gryphæa Pitcheri (with O. carinata). | "Washita Limestone." (1)<br>Jurassic and Neocomian of Marcou. | Loose bedded or cemented Gryphæas. |
| | | | Ammonites vespertinus. | | Harder, chalky limestone. |
| | | | Exogyra forniculata. | | Ferruginous, calcareous marls, limited. |
| | | Lower or Fredricksburg Div | Ammonites acuto-carinatus. | Upward extension of next two. | Upward continuation of Comanche Peak features from groups below. |
| | | | Hippurites Limestone. | "Caprina Limestone." (1) | Hardest limestone of series. Flints. Chalk. |
| | | | Comanche Pk. fau.<br>Gryphæa Pitcheri (with O. Math.) | "Fredricksburg" of Rœmer.<br>"Comanche Peak Group." | Crumbling chalky at top; thin hard bands at base, and great bed of Gryphæa Pitcheri. |
| | | | Requienia Texana. | "Caprotina Limestone." (1) | Firmer bands of limestone. Fossiliferous. |
| | | | DINOSAUR SAND. | Upper Cross Timber. (1) | Pure, uncemented pack sands. |
| | | | CARBONIFEROUS. | | |

(1) Trans. St. Louis Acad. of Science, Aug., '60. (2) Trans. St. Louis Acad. of Science, Aug., '61.
(5) Kreidebildungen von Texas, '52.

the western, the latter constantly undergoing the process of oblique truncation by erosion. As a result of this action it becomes thinner and thinner toward the west, until it is finally

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* For convenient reference and brevity, I have formulated into a section the synonymy, lithology, hitherto published paleontology, and occurrence along the Texas Pacific Railway of these strata. With a variation of thickness according to locality, this section is applicable to the Austin or New Braunfels region.

*Pacific Railroad, from Elmo, Kaufman County, to Millsap, Parker County, and, with local Variations of Based upon personal Observation. By Robert T. Hill.* *

| PALEONTOLOGY. | OCCURRENCE ALONG TEXAS PACIFIC R.R. |
|---|---|
| | Van Zandt Co. west to Elmo. |
| "I have been able to recognize the following species common to the Tippah (Miss.) and Navarro (Texas) beds: Nautilus Dekayi, Baculites Tippaensis, B. Spillmani, Purpurea cancellaria, Rapa supraplicata, Strombus densatus, Ficus subdensatus, Pleurotoma Ripleyana, Pholadomya Tippana, P. elegantula, P. chycardium Spillmani, Legumen elliptica, Siliquaria biplicata, Pecten simplicus, P. Burlingtonensis, and Exogyra costata."—B. F. Shumard, Proc. Bost. Soc. Nat. Hist., 1861. | Elmo and Terrell. |
| | Terrell to concealed point fifteen miles west of Dallas. |
| | Narrows southward towards Rio Grande. This and all the succeeding members are exposed along north and south lines from Denison to beyond New Braunpels, and can be transected by going from east to west. They thicken southward. |
| Inoceramus biformis, Gryphæa vesicularis, Exogyra costata, Ostrea anomiaformis, Arca vulgaris, Radiolites Austinensis, Nautilus Dekayi, Baculites anceps, Helicoceras, Ammonites, Cassidulus æquorus, Hemiaster parasutus.—B. F. Shumard, Aug., 1860. Most of Rœmer's species from the Cretaceous at the foot of the highlands are from the Austin Limestone and the upper (Ripley) beds.<br>Dr. Shumard's list includes forms of the over and underlying beds.—R. T. H. | From above point east of Dallas to Eagle Ford, seven miles west of Dallas. |
| Ostrea bellaplicata Shum. | Escarpment, two miles south of Eagle Ford, and along north and south line to Denison. |
| Corax, Lamna, Otodus, and other vertebrates in the upper half.<br>Only zone of Inoceramus problematicus, Ostrea congesta, and various undetermined Ammonitidæ. Blue shales at base are barren. | Along face of escarpment and underlying prairie from Eagle Ford to seven miles west. Also at Denison. |
| Ostreidæ, lignites, etc. | Lower Cross Timbers, from point few miles east of Arlington to eight miles west. Thins out to south. |
| FORMITY BY EROSION. | |
| Ostrea crenulimargo, Turritella Marnochii, Nucula, Corbula, etc. | Missing at Fort Worth, having been eroded away previous to deposition of above group. |
| Many species of off-shore fauna, mostly undescribed, in upper bed. Many forms from below. Ananchytes ovatus, Lima Wacoensis, Ammonites Swallovii, Janira occidentalis, J. Texana, Gryphæa sinuata, Marcou; Ostrea Marshii, Marcou; G. Pitcheri bed accompanied by O. carinata. | This upper portion of the Texas Cretaceous occupies a narrow area from Fort Washita to San Antonio; is especially well exposed along Missouri Pacific R.R. Nearly the entire series can be found in a short distance from the city of Fort Worth. |
| A. vespertinus, formerly A. Texanus. Ancyloceras annulatus, Inoceramus. | Between Fort Worth and Weatherford, forming base of high prairies. |
| The forniculate and naviate varieties of G. Pitcheri abundant. | Six miles west of Fort Worth, south of Ben Brook, etc. |
| Ammonites acutocarinatus, Shum., and all of Shumard's typical Comanche Peak fauna in greater abundance. | Top of this group first exposed in bed of Trinity, Fort Worth. Highest summit Ben Brook Station. |
| "Comanche Peak" fauna, with Hippurites Texanus: Caprina, Requienia, etc. | Traces on buttes S. of Weatherford; typical at Comanche Peak. |
| Over fifty species have been described which belong here. See Shumard's section. The Gryphæa bed No. 2, with O. Matheroniana, is part. | Well displayed in vicinity of Weatherford, from which point to Millsap, ten miles west, the remainder of this section is regularly exposed in descending series. |
| Culmination of Requienia Texana; Panopæa and many bivalve casts. | |
| Vertebrate remains only, Dinosauridæ, Chelonidæ, etc. | Upper Cross Timbers, few miles west of Weatherford, to Millsap Station; Sand Hills of Staked Plains. |
| | Millsap Station. |

(3) Proc. Bost. Soc. Nat. Hist., vol. viii, '61. (4) Tenth Census Rep. on Cotton Production, '84, p. 18.

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worn away entirely. In the section of the State under consideration this western edge forms an escarpment, as seen along Mountain Creek, in Dallas County (*b*).†

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† In the region of the State between San Antonio and Austin the escarpment relation of the two formations is reversed, the Gulf Cretaceous being deposited there at the foot of the disturbed Texas.

Immediately underlying this Rotten limestone, and chiefly exposed beneath its projecting stratum, along the escarpment base, are several hundred feet of barren argillaceous shales (*c*), yellow above, and gradating into blue black at the base, with the huge septaria so familiar to one who has seen the Niobrara shales of the west. Where the protecting limestone has been washed away, the shales weather into a gently undulating prairie, with a predisposition to that character locally known as "hog wallow." This is the second character of prairie, a prairie resulting from weathering of shales; it extends as a narrow strip along the western edge of the Rotten limestone region, but fades out before reaching the center of the State.

Continuing westward the next topographic feature is the belt of forest region known as the "Lower Cross Timbers." Geologically the area occupied by these timbers consists of a series of coarse, friable, arenaceous sandstones, (*d*) alternating with clays, whose position is beneath the shales and limestones; and, like them, its western projecting margin is constantly wearing away. The unique fauna, now being studied by Dr. C. A. White, and the presence of lignites, indicate that the sediments are those of shallow waters; they resemble the basal groups of the cis-Mississippi region,* and, Dr. White believes, the Dakota sandstones of Kansas. Elsewhere than in Texas this group would be considered the base of the Cretaceous; but such is not the case here, for it clearly rests upon four hundred feet of a second, and lower series of limestone strata (*e*) and one that was greatly eroded before these sands were deposited. This is the "Texas" group of the American Cretaceous—the probability of the existence of which I pointed out in a previous paper, and which is now demonstrated to be lower than any of the hitherto described marine Cretaceous of this country.

This limestone formation underlies the third character of prairie, which extends parallel with and between the two Cross Timbers. The strata are bands of varying thickness of yellow-white limestones of a peculiar structure, alternating with calcareous clays and marls of the same color. The prairie extends from four miles east of Fort Worth to seven miles west of Weatherford. In crossing it the strata from top to bottom are successively passed. Its surface is barren and rocky, excepting in rainy seasons, and slopes at a much greater angle to the southeast than the others we have described. This was known to old travelers as the "Grand Prairie," a term which is worthy of preservation. One of the strata of limestone ($e^3$) presents a

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* This and all strata above it in Texas are a continuation of the Alabama, Tennessee, Mississippi and Arkansas Cretaceous and Tertiaries, to which I give the name of Gulf series.

much greater resistance to the constantly attacking forces of erosion than the others. As a result of this fact it forms a table land for many miles, and is the highest portion of the prairie. The huge ammonites* which are characteristic of this horizon, project everywhere through the thin soil. This is the third character of prairie, a prairie resulting from resistance. The western edge of this prairie projects as an escarpment above the next topographic feature that we here describe. The ragged edge is well marked, and from it we look down upon the Upper Cross Timbers to the westward. Sometimes we can see the flat topped buttes,† left by the constantly receding line, as remnants of the formation's former extent. These buttes sometimes appear like islands rising from the depression occupied by the Cross Timbers, but usually they are situated on the edge of the adjacent prairie region. They are generally capped by the same peculiar stratum of limestone,‡ resting upon looser strata that quickly wash away when the cap succumbs. Sometimes they appear as mere hillocks, representing remnants of the buttes from which this protecting stratum has been eroded. These buttes are the most prominent features of this area of greatest denudation, and are distributed over it usually upon and around the edge of the Carboniferous exposures. From the top of these buttes and the edge of Grand Prairie, the Cross Timbers look like the waters of a long and narrow lake viewed from an adjacent highland, and in some cases, the opposite shore, as in Comanche county, may be recognized. But the resemblance to a lake is only superficial. It is a case of pseudomorphism, if I may be allowed to use that expression, wherein the forces of sub-aerial erosion have imitated those of wind and wave. The essential features of shore topography and lacustrine sedimentation are absent. The marks of erosion are plainly evident.

On descending the escarpment at the western edge of the Grand Prairie, we reach the sandy soil of the Upper Cross Timbers. A geologic section will show that the surface soil is detritus of the underlying strata (*f*, *g*), which dip to the east, under the adjacent limestone prairie. This series of sandy strata varies in structure as we descend them. The upper strata abound in Dinosaurian bones and teeth, the lower in Lepidodendrons and Calamites. They mark the contact of the basal Mesozoic and the Carboniferous.

The sands of the eastern half of the Upper Cross Timbers are purely siliceous, fine-grained, and utterly free from any cement-

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* *A. vespertinus* Morton, 1834; *A. Texana* Roemer.

† Caprina Limestone of Shumard ($e^4$).

‡ Comanche Peak Group of Shumard ($e^5$).

ing matrix. They are so friable that they quickly lose all appearance of original stratification on exposure, and were it not for railroad-cuts and well-borings through the overlying Cretaceous limestone, their true stratigraphic position would still remain obscure. The pure white sands of this series can be traced along the eastern border of the Cross Timbers for over a hundred miles. These sands constitute the receiving reservoir for the artesian wells of Fort Worth and Dallas, their strata dipping at such an angle under the Grand Prairie, that they are reached at a depth of 350 feet beneath the first named place, and about 750 at the latter. The detritus of this stratum has been distributed over most of the Upper Cross Timbers, so as to obscure the exact contact of the Cretaceous—if the Dinosaurian sands be Cretaceous—and the Carboniferous. But close inspection will reveal the underlying Carboniferous sands and conglomerates *in situ*, accompanied by characteristic fossils.

West of the Upper Cross Timbers the Texas Pacific road traverses the Carboniferous for a hundred miles. In places, patches of the Cretaceous are preserved upon it; in others, the Carboniferous itself is greatly eroded. At a point between the 97th and the 99th meridians the greatest denudation has taken place. West of this the succession of the strata is again an ascending one. The red beds of the Jura Trias are intercalated between the Cretaceous and the Carboniferous on the western side of the latter formation. The arenaceous beds are again exposed in places, especially at the white sand hills of the Llano Estacado. Traces of the Laramie and fresh-water Tertiaries may be preserved on the plains, but these are beyond the province of this paper.

With this somewhat lengthy explanation of the relations of the topography and stratigraphy of the region, I think the character of the two Cross Timbers will now be apparent. It is certain that they do not represent lacustrine basins or fluviatile channels, but are simply the detritus of arenaceous strata which occupy well-defined horizons in the geologic series, and which have been exposed by the denudation of the overlying strata. The reason why the timber confines itself to these arenaceous belts is also evident. They afford a suitable matrix for the penetration of the roots of trees, and a constant reservoir for moisture, thus furnishing two of the greatest essentials to forest growth. The absence of fertilizing ingredients in the Upper Timbers also accounts for the exceedingly scrubby growth of the timber, which peculiarity, however, the inhabitants always ascribe to the burning of the adjacent prairies. The barrenness of the prairies, so far as forest growth is concerned, is owing to the absence of the requisite structural conditions for preservation of moisture, as well as the excess of carbonate of lime in their soils. The difference in fertility between the sandy loams of the Lower Cross Timbers and the dirty sands of the Upper, accounts for the varietal differences of their respective floras. The flora of the Cross Timbers is by no means confined to those two areas, but exist in smaller tracts wherever the soil and structure are favorable. In fact the finest development of the flora has been observed in some of these local patches.

The Cross Timbers end so abruptly upon the maps to the south and north for two reasons. To the south the arenaceous strata are either covered by higher strata, or washed away entirely; the northern termination is usually placed at Red River, because of the absence of correct topographical knowledge concerning its extent in the Indian Territory. It is well known, however, that they extend into that region, and it is probable that the two members there merge into one—the surface becoming more fertile, and the rains more abundant and regular, so that the timber's growth is not necessarily confined to the sandy soils.

It is also now evident that many important differences in the two members of the Cross Timbers are seen in Texas, and that they can no longer be treated alike from an agricultural or geologic standpoint, the lower one being far more fertile and better adapted to human habitation than the upper, which is mostly an arid and sterile region.

## SCIENTIFIC INTELLIGENCE.

### I. Chemistry and Physics.

1. *On the Phosphorescence of Alumina.*—E. Becquerel has replied to de Boisbaudran concerning the phosphorescence of alumina. He had examined this earth in 1859 and had found that the phosphorescent light emitted by it was red and that it gave a characteristic spectrum. Precipitated alumina imperfectly calcined emits sometimes a greenish light in the phosphoroscope; but when heated to 1200° or 1400°, the light it gives is always red. Moreover the author had observed the influence of other substances and especially of chromium, upon the intensity of the light, rubies being more luminous than white corundum, though the composition of the light is the same. He has now repeated his experiments, using for the purpose substances furnished by de Boisbaudran himself and therefore identical with those experimented upon by the latter.* Fragments of this alumina, con-

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* See the February number of this Journal.

sidered pure, were fixed, by means of gum, upon a piece of mica, placed in the phosphoroscope and excited by the light of the electric arc. They emitted a red light, which, however, was much weaker than that given out by alumina containing chromium under the same circumstances. But after having calcined this pure alumina for fifteen minutes in a porcelain crucible in a blast furnace, it became quite as luminous in the phosphoroscope as the alumina containing chromium and of the same color. Hence he concludes that the alumina upon which de Boisbaudran operated, was not sufficiently calcined. The experiment was then repeated upon pure alumina prepared by himself by calcining pure ammonia alum. The light emitted was the characteristic red light so long ago studied. The addition of chromium then does not change the color of the phosphorescent light, but simply increases its intensity. Becquerel also calls attention to the difference in the luminous phenomena according as they are produced by the electric light in the phosphoroscope or by the electric discharge in vacuo; the former effects being simpler, but not obtainable with all bodies.—*C. R.*, ciii, 1224, Dec., 1886. G. F. B.

2. *On the Crimson Line of Phosphorescent Alumina.*—CROOKES has presented to the Royal Society a paper on the color emitted by pure alumina when submitted to the electric discharge in vacuo, in answer to the statements of de Boisbaudran. In 1879 he had stated that "next to the diamond, alumina in the form of ruby is perhaps the most strikingly phosphorescent stone I have examined. It glows with a rich full red; and a remarkable feature is that it is of little consequence what degree of color the earth or stone possesses naturally, the color of the phosphorescence is nearly the same in all cases; chemically precipitated amorphous alumina, rubies of a pale reddish yellow and gems of the prized 'pigeon's blood' color glowing alike in the vacuum." These results, as well as the spectra obtained, he stated further, corroborated Becquerel's observations. In consequence of the opposite results obtained by de Boisbaudran, Crookes has now reëxamined this question with a view to clear up the mystery. On examining a specimen of alumina prepared from tolerably pure aluminum sulphate, shown by the ordinary tests to be free from chromium, the bright crimson line, to which the red phosphorescent light is due, was brightly visible in its spectrum. The aluminum sulphate was then, in separate portions, purified by various processes especially adapted to separate from it any chromium that might be present; the best of these being that given by Wöhler, solution in excess of potassium hydrate and precipitation of the alumina by a current of chlorine. The alumina filtered off, ignited and tested in a radiant matter tube gave as good a crimson line spectrum as did that from the original sulphate. A repetition of this purifying process gave no change in the result. Four possible explanations are offered of the phenomena observed: "(1) the crimson line is due to alumina, but it is capable of being suppressed by an accompanying earth

which concentrates toward one end of the fractionations; (2) the crimson line is not due to alumina, but is due to the presence of an accompanying earth concentrating toward the other end of the fractionations; (3) the crimson line belongs to alumina, but its full development requires certain precautions to be observed in the time and intensity of ignition, degree of exhaustion, or its absolute freedom from alkaline and other bodies carried down by precipitated alumina and difficult to remove by washing; experience not having yet shown which of these precautions are essential to the full development of the crimson line and which are unessential; and (4) the earth alumina is a compound molecule, one of its constituent molecules giving the crimson line. According to this hypothesis alumina would be analogous to yttria."—*Nature*, xxxv, 310, Jan., 1887. G. F. B.

3. *On Phosphorus pentafluoride.*—MOISSAN has continued his researches on phosphorus pentafluoride. He finds that when this gas is submitted to the action of the electric spark, employing Berthelot's arrangement of apparatus, great care being taken to have it absolutely dry, there is no decomposition with sparks which in air do not exceed four centimeters in length; thus confirming the observation of Thorpe. But when sparks were employed which were 15 to 20 centimeters in air, then the walls of the glass vessel were attacked and became dim and the mercury lost its brilliancy. After an hour, the experiment was concluded and the apparatus allowed to cool; the volume had diminished. On adding water, silica was produced, showing the presence of silicium fluoride. The remaining gas, in some cases 15 per cent of the whole, is not absorbed by water and gives the reactions of phosphorus terfluoride. It appears therefore, that under the influence of powerful electric discharges, phosphorus pentafluoride is decomposed into the terfluoride and free fluorine, the latter attacking both the mercury and the glass. Heated in a recurved bell jar to a red heat in presence of an excess of phosphorus vapor, the pentafluoride yields no terfluoride. It is not decomposed by sulphur at 440° nor by iodine at 500°; but preserved in glass vessels, it attacks the glass if a trace of moisture be present, forming silicium fluoride and phosphoryl fluoride. The analysis of the pentafluoride was effected by the author in two ways: (1) a measured volume of the gas was absorbed by an alkaline solution, the filtered solution precipitated by molybdic acid, the precipitate filtered off, washed, dissolved, and the phosphoric acid precipitated as ammonium-magnesium phosphate. (2) the alkaline solution, after absorbing the gas, is decanted into a capsule, and, with the wash waters, is evaporated to dryness on the water bath with the addition of a little pure silica. The saline residue is treated with sulphuric acid and evaporated till white fumes of the acid appear. After cooling, the whole is diluted, neutralized with ammonia and in the filtrate, the phosphoric acid is determined as ammonium-magnesium phosphate.—*C. R.*, ciii, 1257, Dec., 1886. G. F. B.

4. *On Phosphorus Tetroxide.*—THORPE and TUTTON have studied the products obtained by the slow combustion of phosphorus in dry air. If these products are aspirated through glass tubes heated by steam, they are free from admixed phosphorus. A quantity of these mixed oxides was transferred to a tube previously filled with dry carbon dioxide, the end of the tube was drawn out, attached to a Sprengel pump, carefully exhausted and sealed. On heating it to about 290°, the white mass appeared to change; a considerable amount of the orange-red suboxide was seen to form, and at some distance beyond was a sublimate of clear, transparent and highly lustrous crystals, which could be heated to 100° without change, their edges remaining perfectly sharp. On heating to 180° in a sulphuric acid bath, they volatilized and re-condensed just above the level of the acid. They polarized light powerfully and are probably orthorhombic in form. The crystals are extremely deliquescent and are dissolved instantly by water with considerable evolution of heat, forming an acid solution. This solution precipitates silver nitrate solution, the white precipitate blackening rapidly. It also reduces mercuric to mercurous chloride, but decolorizes permanganate only very slowly. With magnesia mixture, it gives at once a precipitate of ammonium-magnesium phosphate; and the filtrate which contains magnesium chloride in excess, gives, after standing for some time, an abundant precipitate of phospho-molybdic acid. Hence this solution contains both phosphoric and phosphorous acids. To fix the composition of the crystals, weighed quantities were allowed to deliquesce in the air, and the diluted solution was evaporated with nitric acid, the phosphoric acid in it being determined as usual. In two determinations the percentage of phosphorus present, was 49·09 and 49·46; the calculated value for $P_2O_4$ being 49·20. Hence the authors think the new oxide is the tetroxide corresponding to the analogous oxides of nitrogen and antimony. The molecular weight however is yet to be obtained by means of a vapor density determination.—*J. Chem. Soc.*, xlix, 833–839, Dec., 1886. G. F. B.

5. *On a hydrated Silicium phosphate.*—HAUTEFEUILLE and MARGOTTET have obtained a compound, having the formula $SiO_2 . (P_2O_5)_2 . (H_2O)_2$ by evaporating a solution of silica in phosphoric acid at 125°. Globular spherical concretions are formed consisting of concentric zones of prismatic crystals, which polarize light strongly. Water at the ordinary temperature decomposes the new body into phosphoric acid and gelatinous silica.—*C. R.*, civ, 56–57, Jan., 1887. G. F. B.

6. *The Freezing of Aerated Water.*—Mr. GEORGE MAN has made a number of experiments upon this subject and thus sums up the experimental results: (1) In a thin ice coating, the upper or surface half contains barely a trace of eliminated air, while its under or bottom half contained 0·08 cubic inch of air in each pound of ice. (2) A surface coating of ice 1½ inch thick contained 0·15 cubic inch of air in each pound weight, while an

entirely frozen mass contained 0·59 cubic inch of air in each pound weight. (3) The freezing of a limited body of water which had first been frozen over and the surface ice removed, points still more strikingly to the concentration of air in solution; for this contained 0·89 cubic inch of air in each pound weight, compared with 0·15 cubic inch in surface ice, and 0·59 cubic inch in an entirely frozen mass.—*Nature*, Feb. 3, 1887, p. 325.

J. T.

7. *Transmission of Electricity of feeble tension by hot air.*—In 1853, M. Ed. Becquerel discovered that gases of a high temperature became conductors of electricity even of feeble electromotive force. M. **Blondlot** has confirmed the results of Becquerel. With an electromotive force of $\frac{1}{1000}$ of a Volt, the transfer of electricity took place when the gas or air attained the temperature of red heat. Ohm's law does not seem to be fulfilled by this phenomenon. Hot air has not electrical resistance properly so-called. The author believes that the mechanism of the transmission of electricity in this case is due to what Faraday termed convection of electricity.—*Comptes Rendus*, No. 5, Jan. 31, 1887, p. 283. J. T.

8. *Aperiodic Electrometers.*—M. Ledeboer brings the needle of a quadrant electrometer quickly to rest by making the quadrants of steel highly magnetized. The movement of the needle produces currents of induction and is dampened thereby. The suspension is unifilar.—*Nature*, Feb. 3, 1887, p. 331. J. T.

9. *Earth Currents.*—At a meeting of the Physical Society held in Berlin, Dec. 3, 1886, Dr. **Weinstein** gave some of the results of his observations on earth currents on the telegraph lines of the German Empire. The earth's currents showed a daily period with eight fluctuations, which did not occur through the whole year and were not constant in direction. These fluctuations were least in the morning between five and seven o'clock. The earth's current showed an intimate relation to the earth's magnetism and especially to the declination. The author found no relation between the earth's current and the sun's rotation, and also doubted the relation supposed to exist between the earth current and the earth's magnetism.—*Nature*, Feb. 3, 1887, p. 336. J. T.

10. *Photography by Phosphorescence.*—In a recent number of the Scientific American, Dr. John Vansant gives an account of some experiments by him in taking photographs by the light radiated from a phosphorescent surface. A piece of paper coated with calcium sulphide and covered by a plate in which several letters were cut out, was exposed to the sunlight for two minutes. The light from the phosphorescent surface was sufficiently strong to make an image of the letters on a sheet of sensitive paper, developed in the usual way. A similar experiment with a photographic negative, placed upon a sheet of glass covered with the calcium sulphide which had been exposed to the sun several minutes, gave on the sensitive paper a good positive picture of

the negative; this was developed and fixed by the usual processes. Even when an interval of a number of hours had elapsed after the exposure, the light from the calcium sulphide surface was still intense enough to produce the effects described.

11. *The Coefficient of Viscosity of Air;* by HERBERT TOMLINSON.—In the previous experiments by the author on this subject the coefficient of viscosity of air was determined from observations of the logarithmic decrement of amplitude of a torsionally vibrating wire, the lower extremity of which was soldered to the center of a horizontal bar. From the bar were suspended vertically and at equal distances from the wire a pair of cylinders, or a pair of spheres. The distances of the cylinders or spheres from the wire were such that the *main* part of the loss of energy resulting from the friction of the air may be characterized as being due to the *pushing* of the air. A small part, however, of the whole logarithmic decrement was due to the rotation of the spheres or cylinders about their axes, and Professor Stokes has kindly added to the paper a note in which are deduced formulæ which serve to correct for this effect of rotation.

Acting on a suggestion of Professor Stokes, the author proceeded to determine the coefficient of viscosity of air by suspending a hollow paper cylinder about 2 feet in length and ½ foot in diameter, so that its axis should coincide as to its direction with the axis of rotation. The cylinder was supported by a light hollow horizontal bar, about 7 inches in length, to the center of which the vertically suspended wire was soldered. The wire was set in torsional vibration, and the logarithmic decrement determined with the same precautions as before.

The mode of eliminating the effect of the internal friction of the metal wire, and also the effect of the air on the ends of the cylinder, is fully described in the paper.

The following were the results:—

| Vibration-period in seconds. | Coefficient of viscosity of air, $\mu$. | Temperature in degrees Centigrade. |
|---|---|---|
| 3·6038 | 0·00017708 | 12·225 |
| 8·8656 | 0·00017783 | 13·075 |

In these experiments the loss of energy arising from the friction of the air may be characterized as being due to the *dragging* of the air, and it is very remarkable that there should be such close agreement in the values of $\mu$ as determined by this and the previous methods. The mean value of the coefficient of viscosity of air obtained by this method is 0·00017746 at a temperature of 12·650° C., and the mean value deduced from the previous experiments when proper correction has been made for the rotation of the spheres and cylinders about their axes is 0·00017711 at a temperature of 11·79° C. The above values of $\mu$ are given in C.G.S. units.—*Proc. Roy. Soc.*, No. 248.

12. *Note on Barus and Strouhal's paper on the Viscosity of Steel;* by W. F. BARRETT, Professor of Physics, Royal College

of Science; letter dated Dublin, March 1, 1887.—In Messrs. Barus and Strouhal's paper on the Viscosity of Steel, published in the January number of your Journal, the authors refer (p. 35) to the various physical changes which steel undergoes at a certain critical temperature. They do not seem to be aware of the investigations I have published on the "Molecular changes that accompany the Magnetization of Iron and Steel," for they refer to "Baur" (Wied. Ann., 1880) the disappearance of the magnetic state at the critical temperature. This fact they will find noticed in the report of a lecture of mine at the London Institution on April 23, 1873, published in the Journal of that institution in July, 1873; it was also mentioned in my papers in the Philosophical Magazine for December, 1873, and January, 1874. Messrs. Barus and Strouhal appear also to have overlooked the curious "after-glow" in steel wire, a discovery I made in September, 1873, and published in the Philosophical Magazine for December of that year. Perhaps you will allow me to state the main points in that paper, which are as follows: 1. Mr. Gore, in 1869, had discovered that a momentary *elongation* of iron occurred in cooling after heating a wire of that metal to a white heat. In 1872 I found a similar but reverse action took place in *heating* the wire. 2. This anomalous deportment was found both in heating and cooling to coincide with, on the one hand the *loss*, and on the other with the *resumption* of the magnetic state of iron or steel. 3. At the critical temperature the wire, having cooled down to a dull red heat, suddenly flashed into a bright glow; likewise during the *heating* of the wire the temperature remains stationary for a short time when the critical temperature is reached; a rise in the specific heat of wire and steel therefore occurs at the critical temperature. 4. A curious crepitation occurs at the critical temperature, similar to that heard in the magnetization of iron, or in the production of the scales of oxide on the wire. 5. Thermo-electric inversion occurs at this same temperature. 6. Hard iron wire and steel wire exhibit the phenomena but certain specimens of good soft iron failed to show it, and even in the wires that exhibit it the phenomenon grows less marked after repeated heating and cooling and finally disappear.

To these observations I may add that a recent investigation on the properties of manganese steel wire (Proc. Royal Dublin Society, December, 1886) shows that this body, which is almost a non-magnetic metal,* does *not* exhibit the anomalous deportment observed in ordinary steel wire. This fact is of considerable interest as linking the foregoing phenomena more closely with the magnetic state of iron and steel.

In conclusion, permit me to thank Messrs. Barus and Strouhal for their very carefully conducted and admirably devised series

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* In the paper referred to I have shown that if the magnetic susceptibility of iron be 100,000, that of manganese steel is only 300, about the same as ferric oxide.

of experiments, and to express a hope that they will continue the work they have so excellently begun, stating, I hope in future, somewhat more fully the conclusions deduced from their formidable tables of experimental results.

## II. GEOLOGY AND MINERALOGY.

1. *Eruption of Mauna Loa, Hawaii, in January.*—The recent eruption of Mauna Loa was like that of 1868 in being preceded by many earthquakes, though much less violent, and also in having its principal discharge in the Kahuku region, Southern Hawaii, and also nearly parallel in course, but situated two to four miles farther west and starting eight to ten farther north. The information here given with regard to it is from copies of the Pacific Commercial Advertiser and Hawaian Gazette of Honolulu, received from the Surveyor General, Mr. W. D. Alexander, and from a much reduced copy (photographic) of a large map of Hawaii made by the survey which has just gone to the engraver.

Mr. D. H. Hitchcock reports that from early in December last, earthquakes steadily increased in number and heaviness, and averaged three a day by the 12th of January. In Kahuku, according to Mr. George Jones, there were 314 shocks between $2^h$ 12′ A. M. of Jan. 17th and $4^h$ A. M. of the 18th, 67 between that time and midnight and 3 the following day, making 383 in all. Ten miles west, in Hilea, the number reported by Mr. C. N. Spencer between 2 A. M. of the 16th and 7 P. M. of the 18th is 618.

With the sudden increase in the earthquakes on the night following the 16th, there was an outbreak of fires on the summit of Mauna Loa, three or four miles northeast of the crater, near Pohaku o Hanalei; they disappeared after a few hours. Three hours after the cessation of the earthquakes at Kahuku, at 7 A. M., on the 18th, according to Mr. Jones, the outflow of lavas began in Kau, north of Kahuku, or was first known to be in progress. It came from a fissure, the highest point of which was about 6,500 feet above the sea, and about twenty miles from its terminus on the sea coast, which it reached about noon of the 19th, near Puuhue, nearly four miles west of the terminus in 1868. Mr. Spencer, who visited the point of chief outflow on the 20th, says that there were fifteen fountains of molten lava, the highest one rising to a height by estimate of about 200 feet. The stream flowed off bearing bowlders weighing tons, and with explosions at intervals sending up columns of smoke sometimes 500 feet high. He states that during the first 24 hours the rate of flow was only a mile and a half an hour, and the lava field made was of the a-a kind, rough clinkers; but on the 20th the flow was rapid and the lava of the smooth kind, or pahoehoe. No cinders or volcanic ashes were made along the coast or elsewhere. By noon of the 24th the flow had nearly stopped, though the fires were still active along the stream above. Mr. E. S. Bishop, who was in the region on the 2d of February, states in a paper in Science, of March 4th, that the area of lava was mostly of the a-a kind, and that the stream extended out beyond the shores 300 to 500 feet, adding much to the island.

On the 23d, earthquakes began again and continued through the 24th. They were heavy enough at Kahuku to throw over walls and destroy or move some houses. Damage was done also at other places and to some extent at Hilo, where a heavy shock was felt near noon on the 23d and many others, but lighter, on that day and the next.

The oscillations at Hilo are stated to have been from S.S.E. to N.N.W. According to Mr. F. L. Clarke, of the Government Survey, the walls that fell in Kau had a northeast and southwest direction and were thrown to the southeast, and the houses (light wooden buildings) were moved 8 or 10 inches in the same direction or down the slopes. Mr. Severin, a photographer, accompanied Mr. Clarke to the region of the outflow and many photographs were taken.

A "heavy cloud of smoke, the heaviest ever seen there [by the writer] was resting over Mauna Loa all day Sunday and Monday, Jan. 23d and 24th;" and on the 25th the sun was scarcely visible on account of the smoky atmosphere. On the afternoon of that day a heavy storm of thunder and rain set in.

The paper of the 21st of February has a letter from Hilo, dated February 17th, announcing that at 8 A. M. of that day a dense volume of smoke extended from the summit crater eastward along the ridge of the mountain six or seven miles toward Kilauea, apparently indicating a summit outflow in that direction supplementing that in Kau.

The Hawaian Gazette of March 1st states that Mr. D. W. Hitchcock was on Mauna Loa, February 20th, and found vapors issuing from large fissures, nearly in a line with those of 1880, but no lava had reached the surface. Kilauea has been moderately active during this period of eruption, rather increasing in activity since it began, but without any show of special disturbance or sympathy.

2. *Volcanic Eruption in Niua-fu, Friendly Islands.*—Earthquakes began at Niua-fu on the 8th of June last, and occurred on the 11th, nearly cotemporaneously with the New Zealand eruption; and the outbreak occurred on the 31st of August, the date of the Charleston earthquake. The eruption continued for ten days and the chief destruction was produced by the finer cinder ejections; the stones thrown up "fell straight, or nearly straight, back." Two preceding eruptions occurred 19 and 40 years ago. —*From a letter of Mr. C. Trotter, F.R.G.S., in Nature of Dec.* 9, p. 127.

The volcanic line of Central New Zealand trends about N. 30° E., and, if followed northward with a small variation in direction, it passes along the Kermadec group and that of the Tonga or Friendly Islands, the variation being to N. 22° E. in the northern part; moreover the body of New Zealand conforms in trend. The groups of islands having this nearly common course are parts of a great mountain system of the ocean, and of the one prominent system in the Pacific having a north-northeast direction. The length is 1,500 miles, reckoned from Central New Zealand, and over 2,000 from its southern end. The whole line may be viewed as having been, at the beginning and since, the course of a series of fractures, outflows and uplift, and in an important sense, a line of common genetic action and results. It is not improbable therefore that sympathy should appear between distant parts of the line, in fractures, earth-shocks and outflows.

The Friendly Islands and Charleston are nearly 100 degrees of longitude apart, and 50 degrees of latitude; and the approximate parallelism of trend in the mountain system of Eastern America and that of the New Zealand system in the Pacific, is hardly a sufficient reason for simultaneous earth-movements, unless the earth is working as a unit in its geographico-geological development. J. D. D.

3. *The Earthquake in Switzerland.*—Professor Forel, the meteorologist, of Morges, on the Lake of Geneva, has just issued a report on the earthquake of February 23. He classifies the shocks under three heads—namely, preparatory shocks, strong shocks, and consecutive shocks. It is difficult, in the absence of trustworthy data, to indicate the precise locality of the first-named, but Switzerland was undoubtedly the region of the second; but it was to the third—that is, the consecutive shocks—that all the mischief was due. The professor traces the course of the phenomenon in Switzerland over a radius of at least four hundred square miles. Its force was greater in the southern parts of the country than in the north, though the shocks were felt throughout Geneva, Berne, Neuchâtel, Fribourg, Vaud, Valais, and Tessin; and observations go to prove that these shocks traveled almost due north and south, although the direction of the oscillations does not coincide with this course. The oscillations in Switzerland were characterized by their number and repetitions. In some localities they were longitudinal; that is, running parallel to the meridian; in others they were transverse, running or flowing from east to west. The vertical movements were marked by their feebleness where indicated, but in the greater part of the territory affected vertical oscillations were entirely absent. One of the peculiarities of the oscillations generally was the length of duration, which is set down as varying from 10 to 30 seconds. But the collected reports prove that the mean of these figures more nearly represents the prevailing duration. The intensity of the shocks was greater in the central and southern areas of the disturbance, and it would seem as if the shocks only just failed to attain the necessary strength which would have produced disastrous effects. As it was, church bells were rung, in some places violently; windows were rattled, doors thrown open, ceilings slightly cracked, and morsels of plaster

were brought down, and here and there stacks of wood were thrown over. One of the most striking features of the phenomenon was the extraordinarily large number of clocks that were instantly stopped, and this fact has afforded the best possible means of determining with something like perfect accuracy the time of the shocks, which varies from three to four minutes past six in the morning, Berne time. The large astronomical clock of the Observatory at Basle stopped exactly at 6h. 4m. 7s. This, taken as representing Berne time, corresponds with 5h. 43m. 35s. of Paris, 5h. 55m. 43s. of Marseilles, 6h. 3m. 2s. of Nice, and 6h. 24m. 3s. of Rome.

The consecutive shocks, which were responsible for all the loss of life and damage to property, were centralized in the region of the Riviera. The greatest damage was done by the first two shocks, which occurred with an interval of fifteen minutes between them. The reports from the Swiss observatories also show that a series of feebler shocks were experienced in Switzerland later on in the same day, and also on several succeeding days.—*Nature*, March 10, No. 906.

4. *Earthquakes of Andalusia on the 25th of December*, 1884. (Atti R. Accad. d. Lincei, iii, Roma, 1886.)—Messrs. T. TARAMELLI and G. MERCALLI have made a thorough study of the Andalusian earthquakes of 1884, and published a very valuable memoir on the subject, illustrated by geological and seismic maps. It is in three parts. The first treating of the orographic and geological constitution of Andalusia and the Province of Almeria; the second, a relation of the facts in order of occurrence and the general conclusions from these and those of other earthquakes in Spain; the third, a review of the facts with reference to the isoseismic zones, the position and form of the seismic vertical or epicentrum, the velocity of propagation, the depth of the centre, intensity of the shocks, the dynamical effects as exemplified in the condition of buildings; also the consideration of the subsequent shocks until January, 1886, comparisons with those of other seismic areas of the Mediterranean basin, the nature and cause of the Andalusian earthquakes, and relation to other volcanic centers.

In the second part, the following important conclusions are deduced:

1. Earthquakes are much more frequent in the littoral region than in the interior of Spain, and more frequent in the southern than in the northern.

2. The topographic and chronological distribution of the earthquakes reveals the fact that there are several localized seismic centers in Spain, distinct and independent in their movements, yet not without reciprocal influence.

3. Considering the chronological distribution of the earthquakes in the different Iberian regions, the seismic activity, as regards its more energetic manifestations, is transferred from one region to another at long intervals of time.

4. A fact very characteristic of the earthquakes of Southern

Spain is the great number of minor shocks which usually follow, and which at times also precede the maximum shock of each seismic period; but in these seismic periods the position of the maximum shock of the period with respect to the others is not constant. In general the period opens with the maximum shock, yet with some preceding small shocks; then follow many minor shocks; then, after a few months, a second seismic period commences in the same area which begins with a shock that is even heavier than the maximum of the first period and is preceded sometimes also by small shocks.

5. Considering the chronological distribution of earthquakes in a given region, or in the whole peninsula, no periodical return of the maxima is made out, neither decennial nor of any other period; but there is a certain approximately secular return, bisecular or trisecular.

6. As regards the seasons, the greater number of earthquakes in Spain occur in the autumn and winter, as compared with the summer and spring.

The able discussion leads the authors to the following general conclusions:

The great earthquake of 1884 shook an area not volcanic, but one that was in line with the perimeter of the Mediterranean basin, with the volcanic and seismic zone of Southern Italy, Greece, Asia Minor, etc.; and should be classified therefore with the perimetric earthquakes, of so frequent occurrence in Southern Italy. The seismic movement radiated from a center of ellipsoidal form, at a depth of 12 or 13 kilometers, and was thence propagated in the earth's crust according to the fundamental laws of molecular movement in solids. The seismic wave was deviated by refraction, and especially by reflexion, in traversing rocks of different density and elasticity.

The velocity of transmission could not be determined; yet it is made evident that in all directions the rate was less than the propagation of sound in the earth's crust.

The seismic wave was propagated most easily and uniformly, and with relatively less destruction, in the compact crystalline rocks of the Archæan and Paleozoic. The general direction of the bedding favors transmission of the seismic movement propagated parallel to it, and is an obstacle to movement in a transverse direction.

The seismic movement in passing from the more compact and relatively elastic Archæan and Paleozoic rocks to a region of marls, clays, travertine and the like is transformed into movement of mass, producing more disastrous effects the less the compactness, continuity and homogeneity of the superficial beds.

The intensity of the Andalusian earthquakes of 1884 at the center was greater than that of the Neapolitan of 1857, the Ischian of 1883, etc.; but it reached the surface with less energy, producing less disastrous effects in proportion to the greater depth of the center and the greater width of the shaken area. Yet the disastrous effects became somewhat increased in the mountainous country, owing especially to the miserable construction of the houses and their sites on the edges of crumbling precipices, or on steep declivities.

The effects at the surface consisted in the opening of cracks, slipping of the surface material, especially the Tertiary and Quaternary, and in temporary and permanent changes of level upward and downward.

The first shock was preceded and accompanied by low barometric pressure and followed by abundant rain, with lightning and other atmospheric electrical phenomena.

The Andalusian seismic period, begun in 1884, and probably not yet ended, is referable to the same seismic heat-center which caused the disastrous earthquakes of Malaga in 1581 and 1680, for these were wholly similar to the recent earthquake in area and center of movement.

5. *Holocrystalline granitic structure in eruptive rocks of Tertiary age.*—As is well known, the age-classification of massive rocks has, within the last few years, been largely invalidated by the discovery of several localities where Tertiary surface rocks of the ordinary type pass gradually into coarsely crystalline, granitoid varieties as they are traced downward. The "Nevadite" of von Richthofen, although shown by Hague and Iddings to contain some glassy base, is essentially a granitoid dacite. The investigations of Hague and Iddings at the Comstock lode; of Judd on the tertiary peridotites and gabbros of the western coast of Scotland; and of Lotti on similar rocks in northern Italy, conclusively prove that the physical conditions under which a rock mass solidifies, and not the geological *time* of its solidification, determine its structure. Coarsely granular rocks are more abundant in earlier formations because their superficial equivalents have been removed by erosion, while in the younger deposits there has been no time for this and hence the coarser rocks are mostly still deeply buried. Only as expressing this fact, is the age-classification of massive rocks now to be considered as useful.

A very important contribution has recently been made to this interesting subject by Professor Alfred Stelzner of Freiberg, in his newly published volume on the Geology of the Argentine Republic. (Beiträge zur Geologie und Paläontologie der Argentinischen Republik. I. Geologischen Theil. 4°. Cassel und Berlin, 1885, pp. 329, with a colored geological map and three sheets of profiles.) This work contains the results of the scientific expeditions made in the region of the Andes by the author during his residence as professor in the National University at Cordova, between the years 1871 and 1874. It is filled with valuable observations relating to all the geological formations encountered and contains detailed petrographical descriptions of the massive rocks. It is, however, to the contents of chapters xviii and xix (pp. 198–213) which relate to the Tertiary Eruptive Rocks with a granitic habit, that it is desired to call particular attention.

In the heart of the South American Cordilleras, almost on the boundary between Chili and the Argentine Republic, northeast of Santiago, the author met four different localities where typical granitic and dioritic rocks occur in the midst of the prevailing andesitic lavas, tuffs and breccias. One of these is in the San Antonio, and three in the Juncal valley, which penetrate the mountains in a northeastward and eastward direction from San Felipe. These localities were seen by Darwin, who described the rock under the name of "*andesitic granite*" in his Geological Observations in South America. (London, 1846.)

Professor Stelzner concludes that from a purely petrographical standpoint these rocks are totally distinct from the andesites, and are in no way to be distinguished from the most typical Archæan granites and diorites. From a study of their field relations, however, he finds that they are undoubtedly the *youngest* rocks of the region, breaking through and sending apophyses into the andesite tuffs and accompanying sediments. To reconcile these two facts, he assumes that they are late-Mesozoic or Tertiary eruptive masses which have slowly solidified under conditions of high pressure and temperature. Inasmuch as Darwin's descriptions of these "*andesitic rocks*" laid specific stress upon their recent formation, the author proposes to reserve this term (Andengesteine" for granitic rocks of tertiary age; and speaks of "Andengranit" (andesitic granite), "Andensyenit" (andesitic syenite), "Andendiorit" (andesitic diorite), etc.

Many other descriptions are quoted from Darwin, Stübel, E. Williams, Clarence King and Zirkel, which indicate the occurrence of similar rocks at many localities in the Cordilleras of both North and South America.

In urging a more careful examination of these rocks in future, Professor Stelzner expresses the following opinion, with which geologists the world over are daily becoming more and more willing to agree. "Sie (die Andengesteine) werden uns, wie ich meinerseits glaube, immer mehr und mehr erkennen lassen, dass die grössere oder geringere Krystallinität eruptiver Gesteine keineswegs, wie man so lange und so hartnäckig behauptet hat, von der Alter der letzteren abhängig ist, sondern lediglich von den physikalischen Umständen, unter denen die mineralische Differenzirung und Erkaltung der gluthflüssigen Magmen vor sich ging." GEO. H. WILLIAMS.

6. *Report for* 1885, *Geological Survey of Canada;* A. R. C. SELWYN, Director.—This volume contains reports of much valuable geological work. A few facts are here cited. Mr. Selwyn states, in his review of the work of 1885, that Mr. Ells has been investigating Quebec, north of Vermont, New Hampshire and Maine; and besides mapping the Silurian area, which in part includes metamorphic rocks, has found, from the intimate connection between the altered Silurian slates and associated granites, that the granites are, "as in New Brunswick, probably Devonian."

In the report on New Brunswick, by Mr. CHALMERS, it is stated that the marine seashore beds, the Leda clay and the overlying Saxicava sand, occur around the Baie des Chaleurs basin, having a maximum thickness above the sea level west of Bathurst harbor of 125 to 135 feet (75 + 50 or 60); in the Restigouche estuary, the Saxicava sand is 150 feet thick; and in St. Ann Settlement the sand reaches an elevation of 150 to 175 feet. In the Bay of Fundy, the same two strata occur nowhere above 200 feet; on pp. 42, 43, GG, a list of the fossils is given. Mr. Chalmers also treats in detail of the drift, and has a long table of directions of glacial scratches.

Mr. George M. Dawson has a preliminary report on the Physical and Geological Features of the Rocky Mountains between latitudes 49° and 51° 30′ north of the headwaters of the Missouri. The Rocky Mountain region, or the Western Cordillera belt, becomes narrowed and runs to the 56th parallel with an average width of about 400 miles. It comprises four parallel ranges, (1) the Rocky Mountains proper, (2) the Gold ranges (next west), (3) the Coast Range, as a continuation of the Cascade Mountains of Oregon and Washington Territory; (4) the Island Range including Vancouver and the Queen Charlotte Islands, outside of which the ocean bottom sinks rapidly to abyssal depths. Between the 2d and 3d of these ranges lies the Interior Plateau of British Columbia, averaging 100 miles in width, and 3500 feet in mean elevation above the sea. The Rocky Mountains proper, about 50 miles wide, and N.N.W. in mean trend, have a well-defined valley on the west, occupied by the Columbia, Kootanie and other rivers, and known to preserve its general direction and character for over 600 miles. The eastern base is about 4360 feet above tide level, the valley on the west 2450 feet. The Cretaceous and Laramie rocks, much upturned for a breadth of 15 miles, make the eastern foot hills. The rocks of the range are folded or upturned and consist chiefly of Cambrian, Devonian and Carboniferous strata; and the folding in some parts continues into the Cretaceous on the east. The highest summits, the culminating region of the Rocky Mountains, are found about the 52d parallel, and between this and the 53d, Mount Brown and Mount Murchison occur with reputed altitudes of 16,000 and 13,500 feet. These are a few facts from the earlier part of Mr. Dawson's report.

Mr. Ch. Hoffman mentions the occurrence at Aldfield, Pontiac Co., Quebec, of the mineral molybdenite in large crystals, one of the less perfect weighing very nearly 2½ pounds, and a very perfect tabular hexagonal prism measuring five centimeters across, or about two inches.

7. *Mineral Resources of the United States, Calendar year* 1885. 576 pp. 8vo. Washington, 1886. — This volume, the third of the series, contains like its predecessors, a large amount of valuable and interesting information upon the mining industries of the United States. The preparation of the volume has been accomplished in part by Mr. Albert Williams, Jr., the former editor, and in part by Mr. David T. Day. A fourth report for

1886 is promised early in 1887; the value of the series increases with each additional volume because of the opportunity thus offered for study and comparison together of the facts presented in the succeeding years.

8. *Geological Collections: Mineralogy;* by W. O. CROSBY, Assistant. 184 pp. Boston, 1886.—This is a well prepared guide to the mineralogical collection of the Boston Society of Natural History; the general chapters forming the introduction give it something more than a local interest and value.

## III. BOTANY AND ZOOLOGY.

BOTANICAL NOTES.—*Entomophilous Flowers in Arctic regions.* In the *Botanisk Tidsskrift*, (with its French title of *Journal de Botanique*), published by the Botanical Society of Copenhagen (which Journal is now in its sixteenth volume), Professor Warming has published a series of articles mainly concerning the adaptations of entomophilous flowers in an arctic district of scanty insect life. His interesting biological notes are illustrated by figures interspersed in the letter press, and the whole is happily made available to us by a French *résumé* of the Danish text, a most commendable feature. These papers comprise the results of Dr. Warming's observations in Greenland in the summer of 1884 and a comparative series in Arctic Norway in 1885. Greenland is very poor in insects, especially of insects which perform an important part in the fertilization of the entomophilous blossoms of northern regions generally. Dr. Warming undertook a careful comparative study of these northern flowers, to learn whether those in Greenland were identical in floral biology with the same species in Europe. In many no differences were found, but in not a few certain modifications were detected in the Greenland flowers which rendered them more adapted to self-fertilization than those of the same species on the European continent, where the appropriate visiting insects are more abundant. In answer to the question whether the attractiveness of these blossoms for insects remained unaltered in Greenland, Dr. Warming is able to state that with three or four exceptions, the nectar-secretions seemed not to be diminished; but that the odors were feebler, the size of corolla less, and the colors not so vivid as in the same species on the continent. As the entomophilous flowers of Greenland manifest an increased adaptation to self-fertilization, it might have been expected that the diœcious or polygamous tendency of some of them would disappear, but it proved not to be so. But the Salices were found to be remarkably fruitful, and it seems that they had become anemophilous.

Fascicles 98 and 99 of the *Flora Brasiliensis* have appeared. In the former Dr. Schumann gives the Brazilian *Tiliaceæ* and *Bombaceæ.* In the other Professor Cogniaux continues the elaboration of the large order *Melastomaceæ.*

In vol. vi, part 3, of Hooker's Icones Plantarum, issued in February, one North American species is figured, *Cotyledon viscida*,

S. Watson, collected in Southern California by the Rev. Mr. Nevin. There is also *Anemone Henryi*, of Oliver, from Central China, a true *Hepatica*, with round-cordate leaves crenate-lobulate, but yellow-flowered. The ovaries are figured with a terminal stigma; but that is probably not quite right.

Sir Joseph Hooker has edited and brought out the fifth edition of that most popular book, Bentham's *Handbook of the British Flora* (Reeve & Co.), in the same form as the fourth, but condensed into rather fewer pages, the specific names and characters being brought into one paragraph. This condensation has enabled the editor to incorporate a good many notes and needful alterations, and some few recently added species, in all respects following the author's lines. Botanists will be glad to have this characteristic work kept up.

Professor Volney Rattan, of the San Francisco High School for Girls, has brought out an *Analytical Key to West Coast Botany*, "containing descriptions of sixteen hundred species of flowering plants, growing west of the Sierra Nevada and Cascade crests, from San Diego to Puget Sound," in 128 pages. It should be helpful to students.

Mr. Thomas Howell, of Arthur, Oregon, has issued a *Catalogue of the Known Plants of Oregon, Washington and Idaho*, down to and including the Pteridophytes, pp. 28, 8vo.

Dr. T. F. Wood and Gerald McCarthy have brought out a *Wilmington Flora, a List of Plants growing about Wilmington, North Carolina, with date of Flowering.* A map of the county is annexed. It is published by the Elisha Mitchell Scientific Society. The district is of peculiar interest.

The California State Board of Forestry has issued its First Biennial Report, pp. 252, with maps. There are reports on the forests of the most southern counties, by the chairman of the State Board, Mr. Kinney; on those of the Sierra-district farther north, by Mr. Wagner; on the trees and shrubs of San Diego Co., by C. R. Orcutt; and a detailed and important one on the Redwood, by the engineer, Mr. Vischer, with a supplement relating to the quantity of standing timber other than Redwood.

Dr. Arthur, the Botanist to the New York Agricultural Experiment Station, communicates his Report for the year 1885 and also that of 1887. In both the pear-blight is treated at large; also the rotting of tomatoes, of cherries and plums, the plum-leaf fungus, the mildew of strawberries, lettuce, etc., and several illustrations are given in the letter press; those of the earlier report are neat and well printed.

A small supplementary fasciculus now completes the second volume of Dr. Beccaris' *Malesia*, with very full indexes of the two volumes, both of names and subjects.

*Sympetaleia*, Gray, Proc. Am. Acad. xii, 161, is an anomalous gamopetalous genus of Loasaceæ, of which Dr. Streets collected a solitary specimen in Lower California at Pulpito Point. As it was published in the same year with the first volume of the Genera Plantarum (1877), it was not there taken up, and consequently does not appear in that work. So Professor Baillon was not aware of it when, in January last, he published the same singular genus (in Bull. Soc. Linn. Paris, no. 82, p. 660) under the name of *Loasella*, with some interesting remarks. He found a specimen in the Mexican herbarium of M. Thiebault, who collected it long ago, at Guaymas, which is on the Mexican side of the Gulf of California, almost opposite Cape Pulpito. The characters of *Sympetaleia aurea* are exactly those of Baillon's *Loasella rupestris*, except that the corolla-lobes of the latter were thought to be "perhaps valvate," whereas we found them to be imbricate in the bud.

*Index to Plant-Names.*—It is generally known to botanists that Mr. Darwin—wishing to supply to this generation an advantage which he had experienced the want of himself—provided the means of preparing and publishing, under the superintendence of the Director of Kew Gardens, a new and complete *Index of Phanerogamous Plant-Names.* The formidable task has been assigned to Mr. Daydon-Jackson, one of the secretaries of the Linnean Society, who is particularly well versed in botanical bibliography, and to a number of assistants. Their work was commenced five years ago. The editor now publishes, in the Journal of Botany, British and Foreign, for March, the first portion of a report of progress, in which the plan adopted is to a certain extent explained. The work was at first intended to be a kind of new edition of Steudel's Nomenclator, based systematically on Bentham and Hooker's Genera Plantarum; but it was soon determined that the names should be followed by references, and that in other respects it would have to be constructed upon original lines. We judge that this great undertaking has been most carefully planned as to system and details. Two or three condensed extracts from this report suffice for noting certain points.

"Our starting-point, then, is the publication of Linnæus's first edition of the Systema, in 1735, which he followed up by the Genera, in 1737. . . . Where Linnæus ascribes the genus to an earlier author, we say 'Tourn. ex Linn.,' etc., but do not refer directly to pre-Linnean literature." This is well.

"The first edition of the Species Plantarum was issued in 1753, and that we must regard as the introduction of *nomina trivialia.*" So we shall have the earlier Linnean species cited correctly, and not from a later edition. The same, no doubt, of genera.

"Robert Brown published a genus as *Eleocharis*, which Lestihedris altered to *Heleocharis*, as more accordant with the Greek, an alteration adopted by many subsequent writers, who nevertheless employ Beauvois's *Oplismenus*, which is equally faulty, without a sign of reprobation." Whatever small emendations of a name may be allowed, it will never do to change the initial letter for the sake of classicalness.

"While on the subject of fixity of name, I would remark that our practice is to take the name under which any given plant is placed in its true genus as the name to be kept up, even though the author may have ignored the proper rule of retaining the specific name when transposing it from the old genus to the new, when at least that name is not already in the genus receiving the accession. Wantonly to set aside the joint name thus given, and to publish a new name by joining the oldest specific to the true generic, is a mischievous practice which should never be condoned; it is adding to the already vast mass of useless synonyms, and is more likely the offspring of vanity than of a sincere desire to promote science." This is putting the case a little more decidedly than Bentham did, but not too strongly; for it follows implicitly from the principle of the accepted rules.

The re-paging of separate memoirs extracted or reprinted from serial or other works is justly deprecated; and the American Academy of Arts and Sciences is mentioned as an example to be followed. This Academy absolutely forbids all tampering with the original pagination. A. G.

2. *Gilded Chrysalides;* by Edward B. Poulton, Esq. (Roy. Inst. Gt. Britain.)—Mr. T. W. Wood in 1867 published the observation that certain pupæ (*Pieris brassicæ, P. rapæ*, &c.) resemble in color the surface on which they are found. Although this was disputed by some naturalists, it was confirmed by Mr. A. G. Butler and Prof. Meldola. In 1874 Mrs. M. E. Barber published some very striking observations on the colors of the pupa of *Papilio nireus* (South Africa) confirmation being afterwards afforded by Mr. Trimen, from the case of *Papilio demoleus*. Dr. Fritz Müller, however, shows that *Papilio polydamus* is not sensitive to surrounding colors. The observations were explained by supposing the moist skin of the freshly formed pupa to be "photographically sensitive" to the color of surrounding surfaces; but Prof. Meldola pointed out that there can be no real analogy with photography. Furthermore, many pupæ are formed at night when the surrounding surfaces are dark. The present investigation was undertaken with the belief that the influence would be found to work upon the larva as it rests upon some colored surface before pupation.

I. *Experiments upon Vanessa Io.*—This pupa appears in two varieties, being commonly dark gray and much more rarely yellowish-green. Six larvæ placed in a glass cylinder covered with green tissue paper, produced six green pupæ; one of these transferred to a black surface while still moist and fresh, became a green pupa precisely like the others.

II. *Experiments upon Vanessa urticæ.*—The pupæ have no green form, but appear in many shades of dark gray, the lighter ones having golden spots on them, while the extreme forms are almost covered with the golden appearance. These latter are very rarely seen in nature, except when the pupa is diseased. Over 700 pupæ were obtained in the following experiments:—

(1.) *Effects of Colors.*—*Green* and *orange* surroundings caused no effect on the pupal colors; *black* produced, as a rule, dark pupæ; *white* produced light pupæ, many of them being brilliantly golden. This last result suggested the use of *gilt* surroundings, which were found to be more efficient than white, and produced pupæ with a color which even more resembled gold.

(2.) *Mutual Proximity.*—The larvæ being dark, it was found that when many of them became pupæ on a limited (white or gilt) area, the pupæ were darker than when they had been more isolated. The colors of each were in fact affected by that part of the surroundings made up by the black skins of its neighbors.

(3.) *Illumination.* — Black surroundings produced rather stronger effects in darkness than in light, but the pupæ were dark in both cases.

(4.) *Time of Susceptibility.*—The mature larvæ, after ceasing to feed, wander (stage i) until they find a surface on which to pupate; they then rest upon it (stage ii), and finally hang, head downward, suspended by their last pair of claspers (stage iii), in which position pupation takes place. Stage i is variable in length, stage ii may be estimated at 15 hours (but it is also variable), while stage iii is fairly constant, and lasts about 18 hours; while the whole period is commonly about 36 hours in length. The larvæ are probably affected by surrounding colors for about 20 hours, before the last 12 hours of the whole period, and in this time the pupal colors are determined. These facts were discovered by a very large number of experiments, in which larvæ were placed in surroundings of one color, and then after a variable time were transferred to another color producing an opposite effect. It was thus found that stage ii is more sensitive than stage iii, although there is some susceptibility during the latter stage.

(5.) *The Part of the Larvæ which is Sensitive to Color.*

(*α*) *The Ocelli.*—The most obvious suggestion was that the larval eyes (or ocelli, six on each side of the head) saw the colors, and being influenced, transmitted an impulse to the nervous centres which regulate the formation of the pupal colors. When, however, these organs were covered with black varnish, the pupæ resembled surrounding surfaces to the same extent as when they were produced from normal larvæ.

(*β*) *The Complex Branching Spines.*—It seemed possible that these structures might contain some organ which was influenced by the color, but after cutting them off, the larvæ remained normally sensitive.

(*γ*) *The General Surface of the Skin.*—This was tested by *conflicting color experiments.* It had been previously shown that the larvæ were sensitive during stage iii, and therefore they were covered in this stage with compartmented tubes, so constructed that the head and anterior part of the body hung in the lower chamber of one color, while the posterior part of the body was in the upper chamber in another color. In another method, the larvæ were hung upon a vertical surface, while the head and front part of the body passed through a hole in a shelf, the vertical surface above the shelf, and the upper side of the shelf itself being one color, while the vertical surface below the shelf and the lower side of the shelf were of the color tending to produce the most opposite effects. The result of all these experiments was to show that the color influence does act on some element of the larval skin, and that the larger the area of skin exposed to any one color the more does the pupa follow its influence. Parti-colored pupæ were not obtained, thus probably pointing toward the action of the nervous system rather than toward the direct action of light on or through the skin itself.

(6.) *The Nature of the effects produced.*—The coloring matter of the dark pupæ is contained in a thin superficial layer of the cuticle; below this is a thicker layer divided into exceedingly delicate lamellæ between which fluids are present, and the latter form the thin plates which, by causing interference of light, produce the brilliant metallic appearance. The thinner upper layer being dark, acts as a screen in the dark pupæ. Precisely the same metallic appearances are caused by the films of air between the thin plates of glass which are formed on the surface of bottles long exposed to earth and moisture. Both have the same spectroscopic characters and the same transmitted colors (complementary to those seen by reflection). The brilliancy of the cuticle can be preserved in spirit for any length of time; it disappears on drying, but can be renewed on wetting (this had been previously known), and the colors are seen to change during the process of drying, and when the cuticle is pressed, for the films are thus made thinner. The same lamellated layer exists in non-metallic pupæ, and is used as a reflector for transparent coloring matter contained in its outer lamellæ. Thus the structure which rendered possible the brilliant effects due to interference, probably existed long before these special effects were obtained, and was used for a different purpose.

(7.) *The Biological Value of the Gilded Appearance.*—It is probable that the gilded pupæ of Vanessidæ resemble glittering minerals such as mica (which is very common in many places); their shape is very angular, and like that of minerals: conversely the gray pupæ resemble gray and weathered rock-surfaces, and the two conditions of rock would themselves act as a stimulus for the production of pupæ of corresponding color. The power was probably gained in some dry hot country, where mineral surfaces do not weather quickly. Once formed it may be used for other purposes, and in certain species is probably a warning to the enemies that the insect is inedible. It is interesting to note how the Vanessidæ, primarily colored so as to resemble mineral surroundings, are modified for pupation on plants. Thus *Vanessa Io* has a green form which is produced among leaves; *V. atalanta* has no green form, and spins together the leaves for concealment, but both these species commonly pupate freely exposed on mineral surfaces; *V. urticæ* has neither the green form nor the habit, and it has a strong disinclination to pupate on its food plant, as many observations concurred in proving.

III. *Experiments upon Vanessa atalanta.*—This species was also made brilliantly golden or dark-colored by the use of appropriate surroundings in the larval condition.

IV. *Experiments upon Papilio machaon.*—This species, like *P. polydamus* (Fritz Müller) has no power of being influenced by surrounding colors. A brown pupa was obtained on the food-plant, and many green ones upon brown twigs, &c. It is probable that less healthy and smaller larvæ often produce the brown form, just as diseased Vanessa larvæ produce gilded pupæ.

V. *Experiments upon Pieris brassicæ and P. rapæ.*

(1.) *Effects of Colors.—Black* produced dark pupæ, and the greater the illumination the darker the pupæ (*P. rapæ*), this result being the reverse of that obtained with *V. urticæ; white* produced light pupæ, and the greater the illumination the lighter the pupæ (*P. rapæ*); *dark red* (*P. brassicæ*) produced dark pupæ; *deep orange*, in both species, produced very light pupæ of a green color; *pale yellow* and *yellowish-green* produced rather darker pupæ than the orange; *bluish-green* produced much darker pupæ, while *dark blue* produced still darker pupæ (*P. rapæ* only). Hence there is a remarkable and sudden fall, followed by a slow and gradual rise in the amount of pigment formed as the light from various parts of the spectrum from red to blue predominates in the reflected rays which fall on the larval surface. But their effects on the formation of superficially placed dark pigment are accompanied by changes affecting the formation of greens and yellows, &c., in the deeper subcuticular tissues. Hence the results of any given stimulus are exceedingly complicated.

(2.) *Other Experiments.*—It was shown by the method described above that the ocelli are not sensitive in this species, and by similar transference experiments it was proved that the influence acts on the larva and not on the pupa itself.

VI. *Experiments upon Ephyra pendularia.*—In this genus of moths the exposed pupæ are often green and brown in different individuals, but these colors follow the corresponding tints of the larvæ, and therefore cannot be influenced unless the latter themselves were changed, and such susceptibility in the larval state has not been proved for this genus. This is the only known instance of a constant relation between the larval and pupal colors.

VII. *Experiments upon the Cocoon of Saturnia carpini.*—It was found that the larvæ spin dark cocoons in black surroundings, but white ones in lighter surroundings.

## IV. ASTRONOMY AND MATHEMATICS.

1. *The form of the area in the heavens from which the Meteors of Nov.* 27, 1885, *appeared to radiate.*—Mr. RANYARD in the Monthly Notices of the R. Ast. Soc. has discussed the evidence from observations by himself, Captain Tupman, Professor Young, M. Perrotin, and M. Thallon concluding that "there therefore appears to be some very definite evidence that the paths of these meteors did radiate from an elongated area with its axis north and south." Mr. Ranyard further says, "in order to account for the elliptic area, on the assumption that the deflection from the

original path takes place within the earth's atmosphere, it is necessary to find some cause which would account for the deflection being greater in one plane than in the direction at right angles to it. This would be the case if there were some arrangement of the particles in space which caused them to set themselves with their longer axes north and south. I would suggest that if the particles are magnetic they would, on coming up to the earth, tend to arrange themselves with their longer axes parallel to the earth's magnetic axis."

2. *The Boyden Fund.*—By the will of the late URIAH A. BOYDEN, property, the present value of which exceeds two hundred and thirty thousand dollars, was left in trust for the purpose of astronomical research " at such an elevation as to be free, so far as practicable, from the impediments to accurate observations which occur in the observatories now existing, owing to atmospheric influences."

The Trustees of this fund have transferred the property to the President and Fellows of Harvard College, in order that the researches proposed by Mr. Boyden may be directed at the Harvard College Observatory. These researches will be supported by a portion of the means of the Observatory, in addition to the trust fund itself. Professor Pickering has issued a circular requesting information with regard to the altitude, accessibility, and climate of various mountainous regions which might naturally be selected as suitable places for the proposed observations.

A location in the southern hemisphere will be preferable for various reasons. The southern stars invisible in Europe and the United States have been less observed than the northern stars, and by the aid of a southern station the investigations undertaken at Cambridge can be extended upon a uniform system to all parts of the sky.

3. *A Treatise on Algebra ;* by Professors OLIVER, WAIT and JONES, of Cornell University.—This work was undertaken as a text book, and was developed, as the authors inform us in the preface, with the wants of their classes ever before them. But it grew beyond a manual; it is a treatise. It departs from the traditional forms of development of algebra in the arrangement of the subject, in the notations employed, in the forms of demonstration, and by introducing at an early stage the extensions of meaning of terms and processes required in higher algebra.

Experience in the class-room will show whether selections from this original and thoughtful work can be successfully used in elementary teaching. But the advanced student and the teacher will surely find in it an abundance of helpful ideas and methods. There is one serious deficiency, it has no alphabetic index.

## IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Scientific Writings of Joseph Henry.* Vols. i and ii, pp. 523 and 559 large 8vo. Washington, 1886. Published by the Smithsonian Institution.—The contributions to science by Profes-

sor Henry, extending as they did over more than half a century, played so important a part in the development of science in this country that it is well, alike for the reputation of their author as for the interests of the worker of to-day in the same fields, that they should be collected and given to the world in convenient form. This is especially true in view of the fact that the original papers were much scattered and many of them are now hardly accessible. The collection is published by the Institution of which he was Director for more than thirty years, and to which he devoted a large part of his life's energies. The first volume contains the greater part of the papers on physical subjects, extending from 1824 to 1855, with also the acoustical researches of 1874 to 1877. The second volume is largely occupied with the more popular Meteorological Essays, with also papers on some other kindred subjects; the volume closes with the addresses to the National Academy of Sciences in April, 1878. The life of Professor Henry was conspicuously active and productive, and his original contributions to Physical Science, particularly in the branch of electro-magnetism, have given him a place he will always hold in the foremost rank of American workers.

2. *The American Naturalist.*—The American Naturalist will be in future published by the house of J. B. Lippincott & Co. of Philadelphia, under a slight change of editorial management. Dr. Packard retires, and Dr. J. S. Kingsley becomes with Professor Cope assistant editor-in-chief. The remainder of the editorial corps continues as before, excepting the addition of Professor J. H. Comstock of Cornell University, who will have charge of the Entomological Department. As stated on its title-page it is "A Monthly Journal devoted to the Natural Sciences in their widest sense," and, we add, value to all interested in its departments.

3. *Van Nostrand's Science Series.*—Recent issues of this series are No. 90, Analysis of Rotary Motion as applied to the Gyroscope by Major J. G. Barnard, a reprint of the well-known paper first published in 1858 in the Journal of Education. Also, No. 91, Leveling, barometric, trigonometric and spirit by Ira O. Baker; this gives a clear and simple statement of the methods applied to the determination of altitudes.

## OBITUARY.

JOHN ARTHUR PHILLIPS, F.R.S.—Mr. Phillips, the distinguished author of works on Ores, Mining and Metallurgy and of papers on petrography, died on the 5th of January, in his 60th year. He was engaged, at the time of his death, on a new edition of his work on "Metallurgy," in conjunction with Mr. Bauerman. In connection with his study of gold deposits he visited the gold regions of California in 1861 when he made observations of much interest on the formation of veins. "Nature," of January 13th, closes a notice of Mr. Phillips with the words: "He was a large-hearted and open-handed man, fond of taking every chance that came in his way of doing a good deed and helping any one to whom his help could be of service."

# APPENDIX.

## ARTICLE XXXV.—*American Jurassic Mammals;* by Professor O. C. MARSH. (With Plates VII, VIII, IX, and X.)

IN previous numbers of this Journal, the writer has announced the discovery of Jurassic Mammals in this country, and has given brief descriptions of the more important forms brought to light.* Since the last article on this subject, a large amount of new material has been secured, including representatives of several hundred individuals. The remains consist not of lower jaws alone, but of various portions of the skull, and not a few vertebræ, limb bones, and other parts of the skeleton.

These fossils, although fragmentary, are usually well preserved, but owing to the peculiar conditions under which they were entombed, no two bones of the skeleton are as a rule found together. This fact, taken in connection with the very diminutive size of the animals themselves, and especially with the present brittle nature of the teeth and jaws, has rendered their investigation a work of great difficulty. The importance of the subject, however, and the fact that all the known remains of mammals from the Jurassic of this country are in the collection made by the writer, have led to a careful study of the whole material, and the results will be brought together in a Memoir now in preparation for the United States Geological Survey.

Some of the results of this investigation, and notices of several new forms recently discovered, are given below in the present article.

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* This Journal, vol. xv, p. 459, 1878; vol. xviii, pp. 60, 215, and 396, 1879; vol. xx, p. 235, 1880; and vol. xxi, p. 511, 1881. See, also, Proceedings British Association, Montreal Meeting, p. 734, 1884.

In connection with this work, the writer has also examined the more important specimens from the Jurassic of Europe, and, likewise, the few specimens known from the Trias, in both Europe and this country.

The American Jurassic Mammals hitherto found are all from essentially the same geological horizon, in the Atlantosaurus beds, of the Upper Jurassic. The principal locality is in Wyoming, on the western slope of the Rocky Mountains, and remains of two or three hundred individuals have been obtained at this place alone. At other points in the same region, a few remains have been found. A second locality of importance is in Colorado, about three hundred miles south of the most northern known limit of these remains.

The other vertebrate fossils from this horizon are mainly dinosaurs, many of them of gigantic size, but some scarcely larger than the mammals. Crocodiles, turtles, small lizards, and fishes, are also well represented. A single bird (*Laopteryx*), and one small pterodactyl, have likewise been recognized from these deposits. More recently, various bones of small, anourous amphibians (*Eobatrachus agilis*) have been found, the first detected in any Mesozoic formation.* The deposits are lacustrine, as shown by the fresh-water shells they contain.

In investigating these American Jurassic Mammals, it was necessary to compare them, first of all, with those from the same formation in Europe. On this subject, the elaborate memoir of Owen, on British Mesozoic Mammals, was taken as the main authority.†

The first specimens discovered in this country proved to be very near allies of European forms, and most of those since found show a remarkable resemblance to others described by Owen. Some fragmentary specimens cannot indeed be distinguished from the English fossils, but where the remains are more complete, various differences are seen, which appear to be distinctive. A few, well-marked, American genera have no known representatives in Europe, while some forms found there are unknown here.

One difficulty in the investigation of the remains from the two widely-separated regions arises from the necessity of relying mainly upon figures for comparison. Again, these minute, delicate fossils are often embedded in a matrix from which they cannot be removed without great danger of injury or destruction. Hence, the jaws and teeth in many cases must be examined and described from the single side exposed. If

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* Proceedings British Association, Aberdeen Meeting, p. 1033, 1885.

† Monograph of the Fossil Mammalia of the Mesozoic Formations. Palæontographical Society, vol. xxiv, London, 1871.

the opposite side of a similar jaw should be shown in another specimen, the two may easily be regarded as distinct. This may also be the case where upper and lower jaws are found separately. Hence, a large amount of material becomes necessary for even a proximate correlation of the closely related forms.

### *Plagiaulacidæ.*

One of the first American specimens discovered resembled strongly the minute lower jaws first described by Falconer, under the name *Plagiaulax*, and since investigated by Owen, Flower, and others, whose discussion of the habits and affinities of these peculiar mammals forms a well-known chapter in the history of palæontology. Of this genus, only the lower jaws were known, and this is one reason for the wide divergence of opinion as to the nature of the animals they represent. The lower jaws found in America were regarded by the writer as indicating a distinct genus, *Ctenacodon*, two species of which he has since described.

Among the separate upper jaws found in the Jurassic of England were two or three described by Owen, under the generic name *Bolodon*, but with no suspicion that they were in any way related to *Plagiaulax*. From American deposits, also, somewhat similar jaws were obtained more recently, and as they were apparently quite distinct from *Bolodon*, they were described by the writer as representing a new genus, *Allodon*. The molar teeth in one specimen resembled those of *Plagiaulax*, and the writer in his description expressed the opinion that *Allodon* should probably be placed in the *Plagiaulacidæ*. A natural inference was that *Bolodon* was the upper jaw of *Plagiaulax*, and *Allodon*, of *Ctenacodon*. However this may be in regard to the European forms, the specimens now known make it clear that the American genera are quite distinct.

The molar teeth of *Allodon* and *Ctenacodon* are of the same general type, and it is still difficult, if not impossible, to distinguish them when detached from the jaws. The premolars, however, and especially the incisors, differ in the two genera, and when well preserved may often be separated with certainty.

### ALLODON.

In *Allodon*, the superior dentition on each side appears to be as follows:

Incisors 3; canine 0; premolars 5; molars 2.

The lower dentition is uncertain, but is probably the following:

Incisors 1; canine 0; premolars 4; molars 2.

The upper molar series in the type specimen of *Allodon* is well shown in Plate VII, figures 1 and 2. The five premolars have tuberculate crowns, and all appear to be inserted by two fangs. The first and second have each one external, and two internal cones. The third premolar has a small additional cusp. These three premolars diminish in size from before backward. The next premolar, or fourth, is much larger, and has its crown flattened on the inner side. There are three tubercles on the outer border, and four, on the inner margin. The fifth in the series is still larger, and has a more rounded crown. There are three lobes on the outer side, and the same number on the interior face.

The two true molars have low crowns, which are divided into an outer and inner half, by a deep-worn groove. Each half bears three low tubercles, of nearly equal size. The last molar has its longitudinal groove on a line with the inner margin of the other teeth.

The superior incisors of this genus now known are represented in the detached premaxillary of *Allodon fortis*, Plate VII, figures 7–10. The first incisor was very small. The second was the main front tooth, much larger than the third. In the type specimen of *Allodon*, represented in Plate VII, figures 1 and 2, no suture is visible behind the first small tooth (*a*), hence, this may possibly be a weak canine instead of the third incisor. In *Allodon fortis*, figure 7, and also in the type of *Bolodon*, Owen, the suture between the premaxillary and maxillary is distinct.

The large second incisor of *Allodon* is a peculiar tooth, and was evidently exposed to the full wearing action of a strong lower incisor, somewhat similar to that of a rodent. This lower tooth has not been found in place, but the one represented in Plate VII, figures 14 and 15, may, with considerable probability, be referred to this position. The remaining lower teeth have not been found associated with the upper jaws, but they evidently resembled those of *Ctenacodon*, in some of their most important characters.

In comparing *Allodon* with *Bolodon*, we evidently have two nearly related forms. So far as at present known, *Allodon* has three incisors instead of two, a larger number of teeth in the premolar and molar series, and likewise shows other differences of less importance.

The affinities of these peculiar fossils, and the inferences in regard to their habits and food, which may be drawn from the specimens now known, will be fully discussed by the writer elsewhere.

### *Allodon fortis*, sp. nov.

The present species appears to be generically identical with the type specimen of *Allodon laticeps*, but is represented by remains of much larger size. The premaxillary shown on Plate VII, figures 7–10, may be taken as the type specimen. A number of upper molar teeth, and the large lower incisor (figures 14 and 15, of the same Plate), are also referred to this species.

The first incisor in this premaxillary was very small, and situated close to the median line. It is wanting in the present specimen, but its size and position are indicated in the above figures. The second incisor is large and prominent, and is the principal front tooth. It has a distinct crown, which is covered with enamel, and consists of one large main cusp, with a small posterior cone. The lower surface is much worn, evidently by an opposing lower tooth which bore directly against it, from its apex to the small posterior prominence. The sides of the crowns show no signs of wear. The third and last incisor is much smaller, and is separated from the second by a short diastema. It has a distinct crown covered with enamel, but shows no marks of attrition. It is situated a little in advance of the suture with the maxillary, shown in figure 7, *s*, Plate VII.

A second specimen referred to this species is shown in figures 11–13, Plate VII. It is a portion of a left upper jaw containing three premolars, apparently the first, second, and third. The first two of these have a single external cone, and two inner cones, and the second tooth is larger than the first. The third premolar is still larger, unlike the corresponding tooth in *Allodon laticeps*, and has a second exterior cone behind the main one. Above this tooth, there is a large cavity, apparently the entrance of the antorbital foramen. This is shown in figure 11, *f*, Plate VII.

The large lower incisor which met the prominent one above is probably represented in figures 14 and 15. This tooth is faced with enamel in front, and grew from a persistent pulp, like the incisor of a rodent. The summit is incomplete, and hence, the shape of the worn surface cannot be determined.

The specimens here described indicate that *Allodon fortis* was the largest mammal of this group hitherto discovered in the Jurassic. In bulk, it was three or four times as large as *Allodon laticeps*, and about the size of a rat.

The only known remains of this species are from the Atlantosaurus beds of the Upper Jurassic, in Wyoming.

### CTENACODON.

The genus *Ctenacodon* was based upon lower jaws, one of which is represented in Plate VIII, figure 1, and others, in figures 4, 7, and 8. The single, long, pointed incisor, the four, compressed, cutting premolars, and the two, minute, tubercular molars, form together a peculiar dentition. The long, sharp incisor shows no signs of wear whatever, and hence could not be opposed to the large upper incisor of *Allodon*. Its position was close to its fellow, and the two evidently acted together, as indicated in figure 9, Plate VIII. The four premolars form a close-set series, with their upper margins on a curve, all more or less notched. Some specimens, at least, show distinct marks of wear on the outer sides of the crowns, which are sometimes worn to a uniform surface. The two small tuberculate molars are of the *Microlestes* type, with a deep longitudinal groove on the upper surface of the crowns.

The entire upper dentition of *Ctenacodon* is not known with certainty, but it probably corresponded in its main features to that of *Allodon*. A portion of the upper jaw, with typical premolars, is shown in Plate VIII, figures 2 and 3. The posterior premolars, especially the last two, show strong marks of attrition on the inner sides of the crowns, and these were opposed to the compressed premolars below, forming together a most effective apparatus for cutting.

Some of the lower jaws at present referred to *Ctenacodon* apparently show no signs of wear on the premolars, and as the large incisor is not preserved, it is impossible to say definitely that they may not pertain to *Allodon*. It is likewise quite probable that some of the lower jaws considered as *Plagiaulax* may belong with some of the specimens now known as *Bolodon*. The exact correlation of the two forms cannot be determined with certainty until the upper and lower jaws are found together in position.

*Ctenacodon* may be distinguished from the type of *Plagiaulax* (*P. Becklesii*) in having four premolars instead of three. The summits of these teeth alone are notched, and the sides smooth, not obliquely grooved as in *Plagiaulax*. The condyle, moreover, is separated from the angle of the jaw, not confluent with it. *Ctenacodon*, also, has the angle of the jaw not only strongly inflected, but its outer margin effected into a wide horizontal shelf, making this one of the most peculiar features of the genus.

The vertical posterior condyle in *Ctenacodon* implies a strong post-glenoid process, that would confine the jaw to a vertical motion.

In *Ctenacodon*, the mental foramen is large, and situated below the middle of the diastema. The dental foramen is under the last molar, but its entrance is partially concealed by a ridge descending from the base of the tooth to the inflected border of the angle.

In none of the specimens of *Ctenacodon* preserved is there any trace of a mylohyoid groove.

### *Ctenacodon potens*, sp. nov.

A third species of *Ctenacodon*, much larger than *C. serratus*, is represented by several jaws and isolated teeth, discovered since the first species was described. The most important of these specimens, which may be taken as the type, is the right upper jaw represented in Plate VIII, figures 2 and 3. The lower jaw with incisor, figured on the same Plate, may also be referred to this species. A second lower jaw in better preservation, but without the incisor, may likewise be included, although somewhat larger in size.

The upper jaw above mentioned agrees in its general shape with that of *Allodon*. It indicates a short, broad skull, with strong, expanded, zygomatic arches. There is a small antorbital foramen, as in *Allodon*. The four premolars present increase in size from before backward. The first and second are of the *Allodon* type. The last two have strong marks of attrition on the inner surface of their crowns, as shown in figure 2, of the same Plate. They differ from the corresponding teeth in *Allodon*, in being more compressed, and adapted to cutting.* There were apparently two true molars, which are wanting in the present specimen, but their position and size are similar to those of the same teeth in *Allodon*.

The left lower jaw represented in figures 7, 8, and 9 shows that the incisor in this species was very large in size, and a most effective weapon. It grew from a persistent pulp, and its massive base extended back under the fourth premolar. The crown is oval in outline at the margin of the jaw, somewhat more compressed above, and sharply pointed at the apex. There is a shallow groove on the outer surface of the lower half of the crown, and a corresponding depression along the middle of its inner face. A careful examination shows no signs of wear on any part of the crown.

The premolars are separated from the incisor by a long diastema. The first premolar is small, without serrations, and is placed close to the second. The latter is larger, inserted by two fangs, and has the summit faintly notched. The third premolar was still larger, but is so much fractured in the

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* A somewhat similar tooth of *Microlestes* is figured by Owen in Mesozoic Mammals, Plate I, fig. 16.

present specimen that its form and dimensions are uncertain. The fourth premolar is very large, notched at the summit, and with its outer face showing distinct marks of wear.

The first true molar is small, and its crown much inclined backward. The second true molar is wanting, but its alveoli show that it was also small, and placed below the first molar.

In this species, the series of four lower premolars is placed on a curve, and acts as a single cutting blade against the compressed upper premolars. This curve is completed behind by the two molars, which have their crowns inclined outward.

The second and larger lower jaw referred to this species gives some additional characters. The third and fourth premolars show distinct traces of wear on their outer surfaces. The first true molar is placed obliquely, as in the previous specimen, and has been subjected to much attrition. The last true molar was situated lower than the first, and was also oblique. In *Ctenacodon serratus*, the two lower molars are nearly on a level. The present specimen shows that the angle of the jaw was strongly inflected, and there was likewise a ridge on the opposite outer margin. The coronoid process had its front border more nearly perpendicular than in *Ctenacodon serratus*. There is no trace of a mylohyoid groove.

The known specimens of this species are from the Upper Jurassic deposits of Wyoming.

### *Dryolestidæ.*

The first American mammal found in the Jurassic, and a large proportion of those since discovered, belong to a peculiar family which the writer has called the *Dryolestidæ.* It includes several genera and numerous species from this country, and is likewise represented among the forms found in Europe.

The type species of the group, *Dryolestes priscus*, was based upon a characteristic lower jaw, although the specimen was imperfect. A nearly complete lower jaw of the species is represented on Plate IX, figure 2. An allied species, *Dryolestes vorax*, is shown on the same Plate, by figures 3 and 4. *Stylacodon*, *Asthenodon*, and *Laodon*, other genera of this family, are likewise represented on the same Plate.

The upper jaws of several genera of this family are now known with tolerable certainty, and these will be figured and described fully in the Memoir now in preparation.

All the genera of this family have more than the typical number of teeth (44), and the general characters of the inferior dentition are well shown in Plate IX. The lower teeth form a close-set series, without diastemas, or marked interspaces.

There are three, or four, incisors, and in those preserved, each has a distinct crown, and the series diminishes in size from in front backward. The canine is inserted by two fangs, more or less distinct, and in most forms, its crown is prominent and trenchant. Three or four premolars follow, increasing in size backward, with the last usually very prominent, and in some forms, larger than the canine. These premolars all have two roots, and a compressed crown. All have one main cusp, and a small posterior heel. There is usually a small anterior cusp, especially on the posterior teeth.

The molar teeth are from six to eight in number, and are essentially identical in form, and usually distinct from the premolars. The crown consists of one main external cone, high and pointed, and three internal cusps, which vary much in development in the different genera. Seen from the outside, these teeth appear to be inserted by a single fang, but, in most cases, each has two roots, although these are nearly or quite connate. When the jaw is embedded in the matrix, and the diminutive teeth uncovered as far as safety will permit, the features of one side only of the molars can be determined. Thus in figure 1, Plate IX, the outer exposed side of one lower jaw (*Stylacodon*) is shown, while in figure 2, the inner side of another, jaw (*Dryolestes*) is represented. In figures 3 and 4, the two sides of the same jaw are placed together, and the main characters of the lower molar teeth of *Dryolestes* are thus made evident.

There are seven superior molars, and these have one main inner cone, and three outside cusps that vary in size and proportions in the different genera.

## DRYOLESTES AND STYLACODON.

The two genera most nearly allied in dentition are *Dryolestes* and *Stylacodon*, typical examples of which are shown on Plate IX. The number of lower teeth in the best preserved specimens appears to be the same in each, while the incisors, canine, and four premolars, show no marked differences. In *Dryolestes*, the eight molars which follow are all of one type, and differ but little except in size. All have the inner middle cone of the crown as high as, or higher than the outer main cone. In *Stylacodon*, the first two of these teeth resemble the anterior premolars in shape, and like them show from the outside double fangs. The main external cone is quite as high as the opposite cusp.

In *Dryolestes*, moreover, the lower jaw is comparatively short and massive, deep below the molar teeth, with its lower margin strongly convex. The condyle in the best preserved specimen is concave transversely, and has its lower margin nearly on a line with the summits of the molar teeth.

In *Stylacodon*, the lower jaw is long and slender, and constricted in front of the coronoid process, which slopes well upward and backward. The condyle is convex transversely, and placed considerably above the line of the teeth. The jaw is shallow below the molars, scarcely exceeding the height of the teeth themselves, while the lower border in this region is nearly straight. These differences may be readily seen in the two specimens shown on Plate IX, figures 1 and 2. The mylohyoid groove is well developed in both genera, and its position is essentially the same in each.

In *Dryolestes*, the mental foramen is below the first premolar. The dental foramen is beneath the front margin of the coronoid process, and at this aperture, the mylohyoid groove begins.

### ASTHENODON.

The genus *Asthenodon*, the type species of which is described below, agrees with the above genera in the more important characters of the lower dentition, but differs, in having the entire series of teeth much more uniform in size, and but eleven teeth behind the canine. The type of this species is the lower jaw shown in Plate IX, figure 7. A second specimen referred to this species is the anterior part of another jaw, shown in figure 6. The former jaw shows a weak canine (*a*), followed by three premolars, each with two fangs. Behind these, in place of the large, trenchant premolar seen in *Dryolestes* and *Stylacodon*, is a small tooth, which from its shape may be regarded as the first molar. The remaining teeth agree in their more important characters with the corresponding molars of *Dryolestes*. The second specimen, figure 6, shows a similar weak canine, and, in front of it, the four incisors in place, increasing rapidly in size forward, the front one being larger than the canine.

### *Asthenodon segnis*, gen. et sp. nov.

In the genus *Asthenodon*, the inferior dentition on each side is as follows:

Incisors 4; canine 1; premolars 3; molars 8.

The largest tooth in the entire lower series is the first incisor, Plate IX, figure 6, 1. The remaining incisors decrease in size backward, as shown in the same figure, 2, 3, and 4. The canine (*a*) is small and weak, and its crown resembles that of the incisors. It is implanted by two roots, which are nearly connate. The three premolars behind the canine have each two fangs, and increase in size from first to last, as shown in figure 7, of the same Plate. The following seven teeth, judging from the shape, are molars, and behind them is the alveole of one more. These molars agree in general form with those of *Dryolestes.* The form of the lower jaw also is similar in the two genera. The upper jaw of this genus is not known.

The specimens representing this species indicate an animal about the size of a weasel. They are from the Atlantosaurus beds of Wyoming Territory.

### LAODON.

A fourth genus, *Laodon*, while agreeing in the general type of lower molar teeth with the above forms, differs widely from them in other respects. The molars in this genus have the outer main cone high and pointed, as in the above genera, but the inner opposite cusp is greatly reduced in size, as shown in the type specimen represented in Plate IX, figure 5. There appear to have been eight molar teeth, six of which are well preserved. In front of these, are two premolars of nearly equal size, and between these and the canine, there were apparently three more, each with two fangs, making thirteen teeth in the premolar and molar series. The canine had two roots, and the last incisor was placed closely in front of it.

In this specimen, the dental foramen is situated below the summit of the coronoid process. Its aperture is placed obliquely, opening backward and upward, and from its outer margin, the deep mylohyoid groove extends forward and downward, rapidly descending below the lower border of the ramus.

This lower jaw is intermediate in form between *Dryolestes* and *Stylacodon.* It has the slender straight ramus of *Stylacodon*, with even a stronger constriction behind the molar teeth, but the jaw is deeper below the molar series, and the lower margin is convex, as in *Dryolestes.* The molar teeth resemble those of *Peraspalax*, Owen, but in that genus there is a less number of teeth, and other features not seen in the present specimen.

The upper jaw of this genus has not yet been identified.

### *Laodon venustus*, gen. et sp. nov.

In the type specimen of this species, the inner side only of the lower jaw is shown. The alveolar border is nearly straight, while the lower margin is strongly convex. The anterior portion of the ramus is very shallow, but little, if any, deeper than the crowns of the teeth it contained. There is a well-marked mylohyoid groove, which begins at the dental foramen, and extends forward and downward, until it is lost below, directly under the second molar. The angle of the jaw extends well backward, and was not inflected, although somewhat thickened along the lower margin. The pterygoid fossa is deep and wide. The coronoid process was large, but its exact form cannot be determined.

The type specimen of the present species is from the Upper Jurassic deposits of Wyoming.

### *Diplocynodontidæ.*

A third group of Jurassic Mammals is known at present from three genera, which have been found only in this country. The most typical form, *Diplocynodon*, is represented on Plate X, figure 3, by the specimen first described. This fossil indicates one of the largest mammals yet found in the Jurassic. In this genus, there were at least three lower incisors, directed well forward. The canine is very large, elevated, and trenchant, and inserted by two strong fangs. Behind this, there are twelve teeth, all essentially of the same type, so that, from the outer side alone, it is difficult, if not impossible, to distinguish the premolars from the molars. The crowns of these teeth are composed of a main external cone, with a small, elevated lobe in front, and a lower one behind. This is repeated on a reduced scale on the inner side, except that the posterior cusp is rudimentary, or wanting. The antero-posterior faces of the crowns are deeply excavated, and grooved.

The jaw is elongate, and gently curved below. The coronoid process is large, and elevated. The condyle is placed very low, nearly on a line with the teeth. The angle of the jaw is produced into a distinct process (*d*), the lower margin of which bends outwards, although the process as a whole has a slight inward direction.

In *Diplocynodon victor*, the mental foramen is beneath the interspace between the second and third premolars. The dental foramen is large, and is situated intermediate between the last molar and the angle of the jaw. From its front margin, the narrow straight mylohyoid groove extends forward, nearly parallel with the lower margin of the ramus.

An upper jaw referred to this species contains the canine and eight succeeding teeth in excellent preservation. The canine is very large, and has two distinct fangs. The molar teeth have one, main, external cone, and two lateral cusps, which rise from a strong basal ridge. On the inner side, there is one main cone, with a small posterior heel. The outer face and the sides of the upper molars are deeply sculptured with irregular grooves.

The European genus *Amphitherium* may possibly belong to this family, but the lower canine has only a single root, and the molars appear quite different from those of the American forms.

### DOCODON.

Another genus (*Docodon*) of this family may be distinguished from *Diplocynodon* by having, in the lower jaw behind the canine, eleven teeth instead of twelve. The canine has two fangs, as in the latter genus, and the molar teeth correspond closely in form. The symphysis is very long, and the mylohyoid groove extends forward to its upper border. The type specimen of this genus is shown in Plate X, figure 2.

In *Docodon*, the dental foramen is further back than in *Diplocynodon*, and the mylohyoid groove, leading out of it, is deep and straight as far as the last premolar.

### ENNEODON.

A third genus, *Enneodon*, described below, is represented by two specimens, one of which is shown on Plate X, figure 4. The lower jaw is comparatively short and robust, and contained only nine post-canine teeth, all of the same type.

### *Enneodon crassus*, gen. et sp. nov.

The canine in *Enneodon* is large, and, as in the other genera of this family, is inserted by two well-separated fangs. Seen from the outside, its crown resembles that of a true molar, but the anterior lobe is wanting. The second premolar is larger than the first, not smaller, as in the type of *Diplocynodon*. The premolars, although of the same general form as the molars, have the surface of the crown more grooved, or striate.

### *Enneodon affinis*, sp. nov.

A second specimen of this genus agrees with that last described in the main features of its dentition, but the lower jaw is less robust. The canine is also more slender, and there is a small diastema behind it. The first three premolars increase in size backward, but are all of similar form. The angle of the jaw is considerably below the lower margin of the ramus.

The principal dimensions of this specimen are as follows:

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|---|---|
| Space occupied by nine premolar and molar teeth | 16·mm |
| Depth of jaw below first premolar | 2· |
| Depth of jaw below first molar | 3·25 |
| Height of first premolar above jaw | 1·5 |
| Height of second molar above jaw | 2· |
| Antero-posterior diameter of second molar | 2· |

The fossils on which the two species of *Enneodon* are based were found in the Atlantosaurus beds of the Upper Jurassic, in Wyoming.

### *Spalacotheridæ.*

The type genus of this family is *Spalacotherium* of Owen, but it is probable that he included more than one generic form under this name, in the various specimens described. In this country, one well-preserved jaw has been found, which appears to indicate a distinct genus (*Menacodon*), and is described below. This specimen is represented on Plate X, figures 5 and 6.

In the typical specimens of *Spalacotherium*, the premolar and molar teeth are ten in number, and of the same general form. The crown consists of one, main, external cone, high and pointed, and two, short, inner cusps, nearly equal in size, in front of and behind the main cone. The canine has two fangs, and there is little or no diastema behind it.

In *Menacodon*, the molars have the same general form, but there appear to be but seven in the post-canine series. The crowns also are shorter and more robust. The canine is small, and has two roots.

### *Menacodon rarus*, gen. et sp. nov.

In this species, the lower jaw is comparatively slender, and its inferior border is strongly convex, longitudinally. The canine was small, and directed well forward. The first three premolars are separated slightly from the canine, and from each other. The three following teeth, which may be regarded as true molars, are larger and more elevated, and behind these was the last molar, somewhat smaller in size.

In the type specimen of *Menacodon*, there is no sharply defined mylohyoid groove, but a shallow depression takes its place, as indicated in Plate X, figure 6.

In *Spalacotherium*, there is a well-defined mylohyoid groove.

The unique specimen on which the present species is established was found in the Upper Jurassic of Wyoming.

### *Tinodontidæ.*

This family is well represented by American forms, one of which, the type species of *Tinodon*, is shown on Plate X, figure 1. *Phascolotherium*, Owen, appears from its dentition to be an allied form, but differs in several important points, and may yet be found to represent a distinct family. The premolar and molar teeth have nearly the same form in both genera, but in *Tinodon*, there is a larger number of post-canine teeth. The coronoid process, also, is vertical, and the angle of the jaw is not inflected. The premolars have the same general shape as the molars, the crowns being composed essentially of three pointed cusps, one, main, outer cone, and two, smaller cusps, one in front and one behind, on the inner side. There is a strong cingulum on the inner surface, which may develop into an anterior lobe, or posterior heel. The mylohyoid groove is distinct. The condyle in *Tinodon* is rounded, and somewhat transverse, and is separated from the jaw by a distinct neck.

In *Tinodon bellus*, the dental foramen is large (Plate X, figure 1, *f*), and looks downward and backward. It is placed somewhat behind the anterior margin of the coronoid process, and somewhat above the middle line of the ramus. The deep mylohyoid groove (*g*) leads from this opening, forward and downward.

### *Triconodontidæ.*

Another family related to the one last described is represented by the genus *Triconodon* of Owen, and by one or two American forms. In this group, the premolars are unlike the molars. The latter are large, and their crowns are composed of three, nearly equal, trenchant cusps. The premolars are compressed and trenchant, but lack the anterior cusp. There is apparently more than one genus included under the specimens referred by Owen to *Triconodon*, but more specimens will be required to separate them.

### PRIACODON, gen. nov.

One of the American forms, which appears to be generically distinct from the type of *Triconodon*, is represented below, on Plate X, figure 9, under the name *Priacondon ferox*. The type specimen, on which it is based, was originally placed by the writer in the genus *Tinodon*, and the species named *Tinodon ferox*. This specimen is a right lower jaw, with most of the teeth in position. There are three premolars, and four molars. The premolars have one main cone, pointed and compressed, with a low cusp in front, and a larger one behind. The last premolar is large. The penultimate molar has four distinct cones instead of three. The canine was large, and directed well forward. The coronoid process is high, and inclined backward. The mylohyoid groove is nearly parallel with the lower margin of the jaw, and extends forward to the symphysis. The latter is strongly marked.

### *Paurodontidæ.*

A peculiar genus, *Paurodon*, widely different from any form hitherto found in this country or Europe, is represented at present by a single specimen, a left lower jaw. This is shown on Plate X, figures 7 and 8. The entire premolar and molar series consists of only six teeth, the main features of which are seen in the figures cited. The canine is large, nearly erect, and is apparently inserted by a single fang. There is a distinct diastema between this and the first premolar. The latter is small. The lower jaw is short and massive, and there is a deep mylohyoid groove (*g*).

The molar teeth of *Paurodon* appear to agree in the general features of their crowns with those of *Achyrodon* and *Peralestes*, but the figures given by Owen of the specimens described under these names show them to be quite distinct from the present genus.

### *Paurodon valens*, gen. et sp. nov.

In this genus, there were apparently two lower premolars, and four molars, all separated somewhat from each other. The premolars have a single main cusp, and a low posterior heel. Each is implanted by two roots. The molars have a single main external cone, and two low inner cusps. The mylohyoid groove extends from the pterygoid fossa to the symphyseal surface, which is large. The mental foramen is below the diastema between the canine and the first premolar.

The upper jaw of this peculiar fossil is not known.

The type specimen of this unique form is from the Upper Jurassic deposits of Wyoming Territory.

The main object of the present article is to present a typical series of the remains of known American Jurassic mammals. A discussion of the closer relations of these to the mammals from the same formation in Europe, as well as to both older and more recent forms, will be reserved for the Memoir now in course of preparation.

The vertebræ, limb bones, and other parts of the skeleton of mammals, found with the jaws and teeth here described, cannot yet be definitely associated with the latter, but an attempt to do this will be made in the Memoir.

The genera and species of American Jurassic mammals now known are given in the list below. All have been described by the writer, in this Journal. One figure, at least, of a typical form of each new genus proposed, has also been given, either in the original description, or in the present article.

The list is as follows:

### *Plagiaulacidæ.*

| | | | | |
|---|---|---|---|---|
| Allodon laticeps. | Amer. Jour. | Sci., | vol. | xxi, p. 511, 1881. |
| “ fortis. | “ | “ | “ | xxxiii, p. 331, 1887. |
| Ctenacodon serratus. | “ | “ | “ | xviii, p. 396, 1879. |
| “ nanus. | “ | “ | “ | xxi, p. 512, 1881. |
| “ potens. | “ | “ | “ | xxxiii, p. 333, 1887. |

### *Dryolestidæ.*

| | | | | |
|---|---|---|---|---|
| Dryolestes priscus. | Amer. Jour. | Sci., | vol. | xv, p. 459, 1878. |
| “ vorax. | “ | “ | “ | xviii, p. 215, 1879. |
| “ arcuatus. | “ | “ | “ | xviii, p. 397, 1879. |
| “ obtusus. | “ | “ | “ | xx, p. 237, 1880. |
| “ gracilis. | “ | “ | “ | xxi, p. 513, 1881. |
| Stylacodon gracilis. | “ | “ | “ | xviii, p. 60, 1879. |
| “ validus. | “ | “ | “ | xx, p. 236, 1880. |
| Asthenodon segnis. | “ | “ | “ | xxxiii, p. 336, 1887. |
| Laodon venustus. | “ | “ | “ | xxxiii, p. 337, 1887. |

### *Diplocynodontidæ.*

| | | | | |
|---|---|---|---|---|
| Diplocynodon victor. | Amer. Jour. | Sci., | vol. | xx, p. 235, 1880. |
| Docodon striatus. | “ | “ | “ | xxi, p. 512, 1881. |
| Enneodon crassus. | “ | “ | “ | xxxiii, p. 339, 1887. |
| “ affinis. | “ | “ | “ | xxxiii, p. 339, 1887. |

### *Spalacotheridæ.*

| | | | | |
|---|---|---|---|---|
| Menacodon rarus. | Amer. Jour. | Sci., | vol. | xxxiii, p. 340, 1887. |

### *Tinodontidæ.*

| | | | | |
|---|---|---|---|---|
| Tinodon bellus. | Amer. Jour. | Sci., | vol. | xviii, p. 216, 1879. |
| “ robustus. | “ | “ | “ | xviii, p. 397, 1879. |
| “ lepidus. | “ | “ | “ | xviii, p. 398, 1879. |

### *Triconodontidæ.*

| | | | | |
|---|---|---|---|---|
| Triconodon bisulcus. | Amer. Jour. | Sci., | vol. | xx, p. 237, 1880. |
| Priacodon ferox. | “ | “ | “ | xxxiii, p. 341, 1887. |
| (*Tinodon ferox*). | “ | “ | “ | xx, p. 236, 1880. |

### *Paurodontidæ.*

| | | | | |
|---|---|---|---|---|
| Paurodon valens. | Amer. Jour. | Sci., | vol. | xxxiii, p. 342, 1887. |

None of the known Mesozoic mammals appear to have been truly herbivorous. *Stereognathus*, which has been considered as such, from its molar teeth, cannot fairly be regarded as evidence, since it was based, not upon part of a lower jaw, as described by Owen, but upon a fragment, evidently the posterior portion of the maxillary, and the teeth resemble the superior molars of some insectivorous forms.

Nearly all the mammals older than the Tertiary, judging from their dentition alone, may have lived mainly upon insects, with such accessory diet as modern Insectivores affect. The *Plagiaulacidæ*, however, show evidence of marked adaptation to some peculiar food, whether animal or vegetable cannot yet be determined with certainty. Now that the upper teeth of *Ctenacodon* are known, and trenchant teeth are found opposed to the lower cutting premolars, and tubercular molars to those below, the problem is simplified, but not solved. The evidence at present points to an animal, rather than to a vegetable, diet for all the *Allotheria.*

It is not improbable that there was a gradual change in diet in the later forms, until vegetable food predominated. The fact that the Tertiary genus *Neoplagiaulax*, Lemoine, has only a single lower premolar coincides with this view, and if *Hypsiprymnus* is a still later descendant, the additional molars, and other herbivorous features, may be the result of this gradual change.

The few Mammals known from the Trias may be placed in two families, *Dromotheridæ*, including the American specimens, and *Microlestidæ*, those of the old world. They are all quite distinct from any of the Jurassic forms, either those found in this country or in Europe. Below the Trias, no Mammals have hitherto been discovered; and none are known with certainty from the Cretaceous.

Mesozoic Mammals have very generally been referred hitherto to the *Marsupialia*. An examination of the known remains of American Mesozoic Mammalia, now representing upwards of two hundred distinct individuals, has convinced the writer that they cannot be satisfactorily placed in any of the present orders. This appears to be equally true of the European forms which the writer has had the opportunity of examining. With a few exceptions, the Mesozoic mammals best preserved are manifestly low generalized forms, without any distinctive Marsupial characters. Many of them show features that point more directly to Insectivores, and present evidence, based on specimens alone, would transfer them to the latter group, if they are to be retained in any modern order. This, however, has not yet been systematically attempted, and the known facts are against it.

In view of this uncertainty, it seems more in accordance with the present state of science, to recognize the importance of the generalized characters of these early mammals, as at least of ordinal value, rather than attempt to measure them by specialized features of modern types, with which they may have little real affinity. With the exception of a very few, aberrant forms, the known Mesozoic mammals may be placed in a single order, which the writer has named *Pantotheria*.[*] Some of the more important characters of this group are as follows:

(1.) Cerebral hemispheres smooth.
(2.) Teeth exceeding, or equalling, the normal number, 44.[†]
(3.) Canine teeth with bifid or grooved roots.[†]
(4.) Premolars and molars imperfectly differentiated.
(5.) Rami of lower jaw unankylosed at symphysis.
(6.) Mylohyoid groove on inside of lower jaw.
(7.) Angle of lower jaw without inflection.
(8.) Condyle of lower jaw near horizon of teeth.
(9.) Condyle vertical or round, not transverse.

The generalized members of this order were doubtless the forms from which the modern, specialized, Insectivores, at least, were derived.

Another order of Mesozoic mammals is evidently represented by *Allodon*, *Bolodon*, *Ctenacodon*, *Plagiaulax*, and a few other genera. These are all highly specialized, aberrant, forms, which apparently have left few, if any, descendants later than the Tertiary. This order, which the writer has termed the *Allotheria*,[‡] can be distinguished from the previous group by the following characters:

(1.) Teeth much below the normal number.
(2.) Canine teeth wanting.
(3.) Premolar and molar teeth specialized.
(4.) Mylohyoid groove wanting.
(5.) Angle of lower jaw distinctly inflected.

These characters alone do not separate the *Plagiaulacidæ* and *Microlestidæ* from some of the Marsupials, and the facts now known seem to prove that they belong in that group, where they represent, at least, a well-marked sub-order.

Of the two families of Triassic Mammals now known, the *Dromotheridæ* may be placed in the order *Pantotheria*, and the *Microlestidæ*, in the *Allotheria*. According to present evidence, the former were probably placental, and the latter, non-placental, and marsupial.

---

[*] This Journal, vol. xx, p. 239, 1880.
[†] The genus *Paurodon* may be an exception.
[‡] This Journal, vol. xx, p. 239, 1880.

The modern Placental mammals were evidently not derived from Marsupials, as is generally supposed. Each group has apparently come down to the present time, by separate lines, from primitive, oviparous, forms, of which, the living Monotremes may be the more direct but specialized representatives. Among the diversified members of Placental mammals, the Insectivores are probably the nearest to the early type, and hence they show many features seen in the Jurassic and Triassic mammals of the order *Pantotheria*.

Among the various existing Marsupials, the Rat-Kangaroos, (*Hypsiprymnidæ*) appear to be nearest to the oldest known forms represented in the order *Allotheria*, but future discoveries may, at any time, bring to light new Mesozoic mammals allied to other Marsupials.

So far as at present known, the two great groups of Placental and Non-placental mammals appear to be distinct in the oldest known forms, and this makes it clear that, for the primitive generalized forms (*Hypotheria*), from which both were derived, we must look back to the Palæozoic.

Yale College, New Haven, March 16, 1887.

## EXPLANATION OF PLATES.

### PLATE VII.

FIGURE 1.—Left upper jaw of *Allodon laticeps*, Marsh; outer view.

FIGURE 2.—The same specimen; seen from below.

FIGURE 3.—Left upper jaw of same species; inner view.

FIGURE 4.—The same specimen; seen from below.

FIGURE 5.—Left upper jaw of same species; outer view.

FIGURE 6.—The same specimen; seen from below.

FIGURE 7.—Right premaxillary of *Allodon fortis*, Marsh; outer view.

FIGURE 8.—The same specimen; seen from below.

FIGURE 9.—The same specimen; seen from in front.

FIGURE 10.—The same specimen; inner view.

FIGURE 11.—Portion of left upper jaw of *Allodon fortis*; outer view.

FIGURE 12.—The same specimen; seen from below.

FIGURE 13.—The same specimen; inner view.

FIGURE 14.—Lower incisor of *Allodon fortis;* side view.

FIGURE 15.—The same incisor; seen from in front.

*a*, last incisor; *a''*, second premolar; *b*, fourth premolar; *b'*, third premolar; *c*, second true molar; *c'*, first molar; *f*, antorbital foramen; *m*, malar arch; *s*. suture with maxillary.

Figures 1–4 are four times natural size; 5 and 6, six times natural size; 7–15, three times natural size.

### PLATE VIII.

FIGURE 1.—Right lower jaw of *Ctenacodon serratus*, Marsh; outer view.

The small figure is natural size, and the larger one is magnified four diameters.

FIGURE 2.—Right upper jaw of *Ctenacodon potens*, Marsh; inner view.

FIGURE 3.—The same jaw; seen from below.

FIGURE 4.—Left lower jaw of *Ctenacodon serratus*; inner view.

FIGURE 5.—Incisor, probably of same species; seen from in front.

FIGURE 6.—The same incisor; seen from the side.

FIGURE 7.—Left lower jaw of *Ctenacodon potens;* outer view.

FIGURE 8.—The same jaw; inner view.

FIGURE 9.—The same jaw; front view, with its fellow restored in place.

In figures 2 and 3, *a'*. first premolar; *b*, fourth premolar; *c*, second molar; *m*, malar arch. In the lower jaws, *a*, incisor; *b*, condyle; *c*, coronoid process; *m*, molar; *r*, root of incisor; *s*, symphyseal surface.

Figures 2, 3, 5, and 6, are four times natural size, and figures 4, 7, 8, and 9, are three times natural size.

## PLATE IX.

FIGURE 1.—Left lower jaw of *Stylacodon gracilis*, Marsh; outer view.

FIGURE 2.—Left lower jaw of *Dryolestes priscus*, Marsh; inner view.

FIGURE 3.—Left lower jaw of *Dryolestes vorax*, Marsh; outer view.

FIGURE 4.—The same jaw; inner view.

FIGURE 5.—Left lower jaw of *Laodon venustus*, Marsh; inner view.

FIGURE 6.—Left lower jaw of *Asthenodon segnis*, Marsh; anterior part. outer view.

FIGURE 7.—Right lower jaw of same species; outer view.

*a*, canine; *b*, condyle: *c*, coronoid process; *d*, angle; *g*, mylohyoid grove; *s*, symphyseal surface.

All the figures are three times natural size, except figure 5, which is four times natural size.

## PLATE X.

FIGURE 1.—Right lower jaw of *Tinodon bellus*, Marsh; inner view.

FIGURE 2.—Right lower jaw of *Docodon striatus*, Marsh; inner view.

FIGURE 3.—Right lower jaw of *Diplocynodon victor*, Marsh; outer view.

FIGURE 4.—Right lower jaw of *Enneodon crassus*, Marsh; outer view.

FIGURE 5.—Left lower jaw of *Menacodon rarus*, Marsh; outer view.

FIGURE 6.—The same jaw; inner view.

FIGURE 7.—Left lower jaw of *Paurodon valens*, Marsh; outer view.

FIGURE 8.—The same jaw; inner view.

FIGURE 9.—Right lower jaw of *Priacodon ferox*, Marsh; inner view.

*a*, canine; *b*, condyle; *c*, coronoid process; *d*, angle; *f*, dental foramen; *g*, mylohyoid groove; *s*, symphyseal surface.

Figures 2 and 3 are twice natural size, and the others, three times natural size.

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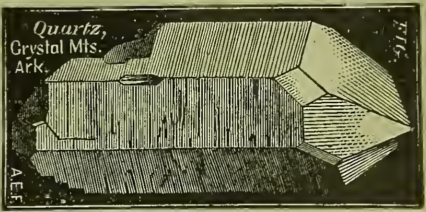

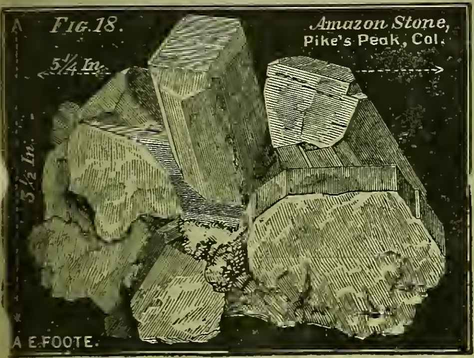

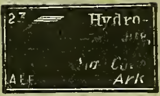

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**THIRD SERIES.**

VOL. XXXIII.—[WHOLE NUMBER, CXXXIII.]

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WITH PLATE XI.

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# THE

# AMERICAN JOURNAL OF SCIENCE.

## [THIRD SERIES.]

## Art. XXXVI.—*On Red and Purple Chloride, Bromide and Iodide of Silver; on Heliochromy and on the Latent Photographic Image;* by M. Carey Lea, Philadelphia. Part I.

In this series of papers it will be my object to show:

(1.) That chlorine, bromine and iodine are capable of forming compounds with silver exhibiting varied and beautiful coloration, peach-blossom, rose, purple and black. That these compounds (except under the influence of light) possess great stability: that they may be obtained by purely chemical means and in the entire absence of light.

(2.) That of these substances the red chloride shows a tendency to the reproduction of colors. It seems not improbable that the material of the infinitesimally thin films obtained by Becquerel, Niepce de St. Victor, Poitevin and others in their experiments on heliochromy may be the red chloride.

(3.) That these substances, formed by purely chemical means, constitute the actual material of the latent or invisible photographic image, which material may now be obtained in the laboratory without the aid of light and in any desired quantity. They also form part of the visible product resulting from the action of light on the silver haloids.

For more than a generation past, the nature of the latent photographic image, that which forms the basis of development, has been in dispute. Two theories have been maintained.

According to the one, the first effect produced by light is simply a physical change, predisposing the elements of the silver haloid to dissociation, so that when a reducing agent is applied, the molecules so affected, yield more quickly to its influence. According to the other theory, the invisible image is formed of a sub-salt (sub-chloride, etc.). Observations which I published many years ago led me strongly to the first-mentioned of these theories. But of late years, results have been obtained not easily reconcilable with it. On the other hand, the theory that the latent image is formed of subsalt is opposed to striking facts. Silver subchloride for example is an unstable substance, quickly destroyed by dilute nitric acid. But I have formed a latent image on silver chloride and after exposing it for five minutes to the action of strong nitric acid (sp. gr. 1·36) have developed the image without difficulty: the same with silver bromide. Evidently these images, which so strongly resisted the action of undiluted acid could not be formed of simple subchloride and subbromide of silver, substances quickly destroyed by it.

In the desire to find a satisfactory explanation of the nature of the image based on adequate chemical proof, I have devoted nearly three years of laboratory work to this and to closely allied subjects. I am led to the conclusion that neither of the older views is correct. A truer theory seems to be deducible from the result of some experiments which I published in 1885, to the effect that the silver haloids were capable of uniting with certain other substances, much in the same way that alumina forms lakes. When a silver haloid was precipitated in the presence of certain coloring matters they combined with it, and though soluble in water, they could not be subsequently washed out. They had formed a somewhat stable compound, although the proportion of coloring matter was very small in comparison with the haloid; evidently much too small to represent a stoichiometrical composition.

Now I find that a silver haloid may in the same way, unite with a certain proportion of its own subsalt, which by this union quite loses its characteristic instability and forms a compound of great permanence.

Another explanation is possible: the subsalt may combine with the normal salt, not in the manner above described, but in stoichiometrical proportion, and this compound may be diffused through ordinary silver haloid. I have not been able to find any reaction decisive between these explanations,* but the general behavior of the substance seems rather to indicate the

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* Silver chloride may be dissolved out by hot solutions of sodium or ammonium chloride, but the subchloride is at the same time decomposed. See beyond under head of "Reactions."

first named explanation as the true one. When the red chloride, for example, has been boiled with dilute nitric acid for a few moments to eliminate any uncombined subchloride, the proportion of subchloride left has never exceeded 8 or 9 per cent in over thirty specimens analyzed. If we took this to represent a compound in equivalent proportions, we should have to suppose the union of at least twenty equivalents of AgCl with one of $Ag_2Cl$, which is improbable. If we suppose that these colored substances containing from less than one-half per cent up to eight or nine per cent of $Ag_2Cl$ consist of a compound of one equivalent of subchloride united to a small number of equivalents of normal chloride, mixed mechanically with a large quantity of normal chloride, then it would be improbable that specimens could not be obtained containing a larger proportion of this compound and consequently of $Ag_2Cl$, but as already said, specimens containing more than 9 per cent after thorough treatment with nitric acid to remove the uncombined subchloride I have never obtained: generally the amount is less.

Even when silver chloride, bromide or iodide contains as little as one-half of one per cent of subsalt combined, its properties are greatly changed. It has a strong coloration and its behavior to light is altered. Even a much less quantity, one inappreciable to analysis, is capable of affecting both the color and the behavior to light.

It is one of these latter forms of this substance that constitutes the actual material of the latent photographic image: adequate proof of this will be given in the second part of this paper.

## RED SILVER CHLORIDE.

Of the three haloids, the chlorine salt is the most interesting, because of its relations to heliochromy; it is also the most stable of the three compounds and exhibits perhaps a finer variety of coloration, though the bromide and iodide are also obtainable of very beautiful tints. The chloride shows all the warm shades from white to black through the following gradations: white, pale flesh color, pale pink, rose color, copper color, red purple, dark chocolate, black.

These compounds are obtained in an endless variety of ways: by chlorizing metallic silver; by acting on normal chloride with reducing agents; by partly reducing silver oxide or silver carbonate by heat and treating with HCl; by forming suboxide or a subsalt of silver and treating with HCl followed by nitric acid; by acting on subchloride with nitric acid or an alkaline hypochlorite, etc.; by attacking almost any soluble salt of silver with ferrous, manganous or chromous oxide, etc., followed by HCl; by reducing silver citrate by hydrogen and treating it with HCl; by treating a soluble silver salt or almost any silver solution with potash or soda and almost any reducing agent, cane sugar, milk sugar, glucose, dextrine, aldehyde, alcohol, etc., and supersaturating with HCl; there is no organic easily oxidizable substance that I have tried that has failed to give this reaction. Also almost any salt of silver exposed to light, treated with HCl and then with hot strong nitric acid yields it. Almost any of these classes represents a long range of reactions, each susceptible of endless variation. In fact, the more the matter is studied, the more extended the range of reactions is found to be that give rise to the formation of this substance. To show how slight an influence will lead to the production of red chloride instead of white: if freshly precipitated argentic oxide is mixed for a few moments with starch or tragacanth paste and is then treated with HCl, the result is, not white, but pink silver chloride. Even raw starch flour mixed with silver oxide will in a few moments cause it to give a pale flesh colored chloride with HCl. Boiled starch or tragacanth paste does this more quickly and acts more strongly, even in the cold, and still more if heat is applied.

Although red is probably the most characteristic color of this substance, so that I have spoken of it above as red chloride, nevertheless this hardly seems a proper name for a substance that is often purple, chocolate or black, sometimes brown or even ochreous, sometimes lavender or bluish, and is probably capable of assuming every color of the spectrum. To call it argento-argentic chloride would infer a stoichiometrical composition that as already mentioned, seems very uncertain, too much so to serve as the basis of the name. Therefore, and as these substances have been hitherto seen only in the impure form in which they are produced by the continued action of light on the normal salts, it might be convenient to call them photosalts, photochloride, photobromide, and photoiodide instead of red or colored chloride, etc., and thus to avoid the inexactness of applying the term red chloride to a substance exhibiting many other colors.

### *Photochloride by action of Alkaline Hypochlorites.*

Black or purple black chloride is easily obtained by the action of an alkaline hypochlorite on finely divided silver such as obtained by reduction in the wet way. Commercial sodium hypochlorite may be used to act on it. It is to be poured over the silver and after standing a few minutes, is to be replaced with fresh. After an hour or two this is again to be replaced with a new portion, which is to be allowed to act half an hour to insure the total conversion of the silver. The product varies somewhat in color, is sometimes black, oftener purple black. If the treatment with hypochlorite has been thorough, strong cold nitric acid of 1·36 sp. gr. extracts from it no silver. This reaction with nitric acid is important as it shows that not only metallic silver was not present, but that the product contained absolutely no uncombined subchloride. For if any were present it would instantly be decomposed by the acid, in which one-half of its silver would dissolve. The action therefore appears to take place in this way. First subchloride is formed, part of this is further chlorized into normal chloride which at once combines with other subchloride, thus taking it out of the further immediate action of the hypochlorite and this goes on until an equilibrium is reached and neither metallic silver nor uncombined subchloride is left, as is proved by the action of nitric acid. Alkaline hypochlorite, as will presently be shown, attacks uncombined subchloride very rapidly, the combined very slowly; by many days' contact the quantity of combined subchloride is gradually reduced.

Prolonged treatment with hot strong nitric acid destroys all the varieties of photochloride. The time needed varies a good deal. A specimen of that obtained with hypochlorite required twenty-five hours' heating with acid of 1·36 in a water-bath at 212° F. to bring it to the condition of white normal chloride. Considering that cold dilute nitric acid instantly destroys freshly precipitated argentous chloride in the free state, this long resistance to strong acid at the temperature of boiling water must be considered most remarkable.

When the red or photochloride is formed with the aid of a ferrous salt or ferrous oxide, I prefer to boil the product with dilute HCl to get rid of the last traces of iron, after a preliminary treatment with hot dilute nitric acid has removed silver and uncombined subchloride. The photochloride will sometimes even resist boiling aqua regia for a time.

Protected from light, photochloride is perfectly stable. Specimens obtained eighteen months ago appear to be quite unchanged.

When treated with ammonia, it is far more slowly attacked than the normal. The ammonia dissolves the normal chloride only. The union between the two must therefore be broken up and this takes place slowly. The first action of the ammonia is to change the red or purple color to greenish black and then to slowly dissolve out silver chloride. Hours are required even with a large excess of ammonia. Whilst this is going on, if the ammonia is poured off and replaced with nitric acid, the original color reappears. If the action is continued sufficiently long, silver only remains and dissolves readily in nitric acid. A little short of this, treatment with nitric acid leaves a black residue of dark chloride mixed with metallic silver; the dark chloride being insoluble in any acid has led to some strange mistakes in a similar reaction which occurs in treating with ammonia silver chloride that has been exposed to the light. Even a theory has been had recourse to of a "passive condition" of silver. This passive silver is simply black chloride.

A specimen of purple black chloride was treated with warm strong aqua regia until whitened by conversion of the subchloride to normal. By this treatment 2·563 grams of photochloride gained nine milligrams, indicating the presence of 2½ per cent of subchloride, or more exactly

| | |
|---|---|
| Subchloride | 2·49 |
| Normal chloride | 97·51 |

This is not to be taken in any sense as representing a constant composition. The proportion of subchloride varies between certain limits, not only according to the method of preparation used but independently of it. Another specimen of black chloride formed with hypochlorite gave figures that indicated a content of less than half of one per cent of subchloride.

### *Photochloride by Reduction of Normal Chloride.*

This is an excellent means of obtaining red chloride. The white chloride is to be dissolved in ammonia and ferrous sulphate added, producing an intensely black precipitate. After standing a minute, the mixture is to be treated with dilute sulphuric acid until it shows a strong acid reaction.

The precipitate is to be first well washed by decantation, then boiled first with dilute nitric, then after washing with dilute hydrochloric acid, which must of course be thoroughly washed out.

The product obtained in this way is often of singular beauty. It might easily be taken for metallic copper. Sometimes it is as rich and bright in color as the copper obtained by electric deposition. Everyone knows the richness and brilliancy of that form of copper and I have seen it fully equalled by this silver salt.

The beauty of the color depends always on the thorough removal of any metallic silver that may be present, and still more on getting rid of every trace of iron. The boiling with dilute hydrochloric acid should be continued until, after thorough washing, a fresh treatment extracts no more and the acid remains colorless in presence of alkaline sulphocyanide.

Instead of an ammoniacal solution of silver chloride, we may make a solution of any other silver salt in ammonia and reduce it in the manner just described with ferrous sulphate. But in this case hydrochloric acid must be used instead of sulphuric after the reduction. This single reaction includes an almost endless variety of methods. The acid with which the silver was originally combined seems to be not without influence on the result; in some cases, for example, with arseniate and molybdate, the action of colored light on the red chloride seems to be somewhat modified. Silver phosphate on account of the ease with which it suffers reduction is very well adapted for this treatment.

### *Photochloride by Partial Reduction of Oxide by Heat, and Treatment with* HCl.

This method has the advantage of avoiding all admixture of foreign substances, the last traces of which are very hard to get rid of, and seem to exert an effect on the color disproportionate to their quantity. Accordingly the photochloride obtained in this way is very beautiful, the shades are from pink to copper red, and a tint resembling burnt carmine.

Heat may be applied to the oxide in either of two ways, long continued heat at 212° F., or near it; or the change may be effected by roasting.

When slow heat is to be applied care must be taken that the oxide does not carbonate itself, which it easily does superficially; this is an objection because the carbonate, under these circumstances yields white chloride with which the other becomes mixed. The air of a drying oven heated by a gas burner is especially bad in this respect. I have seen a surface of oxide form a coat of yellow carbonate in a few hours in this way. (Most oxide that has been kept sometime will effervesce briskly with an acid.) The method is uncertain, sometimes giving strongly colored products and sometimes pale pink.

The oxide may be roasted in a shallow flat-bottomed porcelain basin. With a very moderate heat it changes from brown to black. When this is thoroughly accomplished and before gray reduction sets in, the oxide is to be treated with HCl. If this be done in the basin itself after cooling and without disturbing the position of the oxide, a curious variety of tints will be noticeable, depending upon slight differences in the heat affecting different portions.

*Silver Carbonate* may be roasted in the same way as silver oxide, and yields a similar product. By heat its color changes from yellow to black; it is probable that the carbonic acid is driven off at a lower temperature than that at which oxide is reduced to silver, and that with it escapes part of the oxygen. The residue is converted by HCl into deep red chloride.

### *Action of Various Metallic Oxides on Silver Oxide.*

If we precipitate ferrous oxide with potash and add to this silver oxide, or what amounts to the same thing, if we add to ferrous sulphate potash in excess and pour over this silver nitrate solution, the silver oxide separated by the potash is partly reduced by the ferrous oxide, and when treated with HCl forms red chloride, the intensity of the color of which depends within certain limits on the amount of reduction of the silver oxide.

Similarly if we treat solution of manganous sulphate with excess of potash and then add silver solution, we get an analogous reaction, except that it is much weaker and heat is necessary.

With chromous oxide the action is still weaker, but evident. With cobaltous oxide it is scarcely perceptible without heat and long continued action.

### *Action of Ferric Chloride on Metallic Silver.*

It has been long known that silver was blackened by ferric chloride, and this action has been proposed in the text books as a means of obtaining subchloride, for which it is quite unsuited.

Ferric chloride acts on silver much as sodium hypochlorite does, but less rapidly. With hypochlorite the action is complete in a few hours or often in an hour or less; with ferric chloride one or two days are required before the product ceases to yield silver to hot dilute nitric acid. In both cases the action appears to be alike in this: that no subchloride is finally left uncombined with normal chloride.

The product is an intensely dark purple black, when the action takes place in the cold. With heat continued for many hours, ferric chloride can be made to attack the purple salt and gradually convert it into AgCl. With a strong solution in large excess kept at or near 212° F. for sixty hours the color was gradually reduced to pink and finally to a dingy pinkish gray. Pure white cannot be obtained, as it can by aqua regia.

In order to observe more exactly the course of the action, a strong solution of ferric chloride was allowed to act on reduced silver in fine powder for four minutes, and then a fresh portion (always in large excess) for the same time. Analysis showed that at this stage of the action the material contained:

| | |
|---|---|
| Ag (determined) .... | 76·07 |
| Cl (by difference) .... | 23·93 |
| | 100·00 |

If we suppose that all the silver was combined with chlorine, the constitution of the substance would be:

| | |
|---|---|
| $AgCl$ | 92·49 |
| $Ag_2Cl$ | 7·51 |
| | 100·00 |

but this was probably not the case, there was almost certainly free silver present and consequently a less proportion of subchloride. Another specimen, treated repeatedly with hot acid until every trace of free silver was removed was found to contain 1·52 per cent of subchloride, color purple. Another similarly treated contained 7·3 per cent subchloride.

### *Action of Nitric Acid on Silver Subchloride.*

When freshly precipitated and still moist subchloride of silver is treated with nitric acid, a sharp effervescence accompanied with a disengagement of red fumes, sets in; presently the strong red coloration of the photochloride appears and the action ceases. This production of the red and not the white chloride in the decomposition of $Ag_2Cl$ is precisely what might have been expected, for when $AgCl$ is formed in the presence $Ag_2Cl$ more or less combination always takes place.

The action is interesting in this respect: the $AgCl$ first formed is at the moment of formation in presence of all the yet undecomposed portion of $Ag_2Cl$, and whatever part it combines with is removed from the action of the acid. It would therefore seem probable that this method would be one of those that yielded a product having the largest proportion of $Ag_2Cl$, but analysis showed that different specimens were extremely variable—of those analyzed, one contained 8·62 per cent of $Ag_2Cl$, another 6·56, and a third 1·96. All that analysis can do with such substances is to fix the limits within which they vary. The quantity of subchloride left after treatment with nitric acid depends partly on the strength of the acid and the time for which it is allowed to act, but also to some extent on variations in the resistance of the substance itself. These specimens were of shades between rose and purple.

The color of any particular specimen is always lightened in shade by abstracting $Ag_2Cl$ from it by continued boiling with nitric acid. But as between different specimens, especially when formed by different reactions, it by no means follows that the darkest in color contains the most subchloride.

Argentous chloride when treated with sodium hypochlorite yields a purple form of photochloride. A specimen so treated contained 2·57 per cent of $Ag_2Cl$.

### *Action of Cupric Chloride on Silver.*

When metallic silver is submitted to the action of either cupric chloride, or what gives the same result, a mixture of copper sulphate and ammonium chloride, an action takes place very similar to that of ferric chloride, but more energetic, and the resulting red chloride is apt to be lighter in shade, though in this respect it varies very much. As in the case of ferric chloride this action of cupric chloride on silver is given in some text books as a means of obtaining argentous chloride for which purpose it is as little suited as the iron salt.

As a mode of obtaining red chloride it is not to be recommended. It is troublesome to get the copper completely removed.

A specimen analyzed was found to consist of white chloride with 6·28 per cent of subchloride.

### *Action of Protochlorides on Silver Solutions.*

*Cuprous Chloride.*—When very dilute solution of silver nitrate is poured over cuprous chloride, a bulky black powder results which by boiling with dilute nitric acid turns red, the acid extracting little or no silver.

*Ferrous Chloride.*—When silver nitrate is dissolved in a slight excess of ammonia, and this solution is poured into a strong one of ferrous chloride there results a precipitate which is sometimes grayish, sometimes olive black. By washing with dilute sulphuric acid, this product becomes brownish purple, and brightens by boiling with dilute nitric acid. It was found to contain 4·26 per cent of subchloride.

### *Photochloride by Action of Hydrogen.*

When hydrogen is passed over argentic citrate at 212° F., as in Wöhler's process, there results a black or dark brown powder consisting of argentous citrate, metallic silver, and perhaps other substances. When this is treated with hydrochloric acid and subsequently with nitric, the resulting product is photochloride, the characteristic color of which sometimes appears as soon as the HCl is added. But more frequently the material after the action of HCl has precisely the appearance of silver reduced in the wet way, and the red color appears only after treatment with nitric acid. Even cold dilute acid (by some hours' contact) will isolate the red chloride; boiling acid does so at once.

Color, beautiful purple. A specimen analyzed was found to consist of normal chloride combined with 3·11 per cent. of subchloride.

### *Photochloride by Action of Potash with Oxidizable Organic Substances.*

There is no better method of obtaining photochloride than by acting on a salt of silver with potash and certain organic substances. Milk sugar, dextrine and aldehyde, give particularly good results. Milk sugar acts rapidly, dextrine slowly. Other substances with which, combined with potash, I have obtained chloride, are: gum, tannin, gallotannic acid, manna, glycerine, alcohol, carbolic acid, etc. The number might doubtless be indefinitely multiplied. After the action has reached a proper stage, which with milk sugar is apt to be in less than a minute and with dextrine may take half an hour, HCl is added, whereupon the precipitate changes in appearance but does not exhibit its characteristic color until after boiling with nitric acid; the best result is obtained when the precipitate, after addition of HCl, has a rich chestnut brown shade,* which by nitric acid changes to shades of purple and burnt carmine, when milk sugar, dextrine or aldehyde has been the reducing agent. When the salt of silver employed has been the chloride, of course treatment with HCl is superfluous.

A specimen obtained by acting on silver nitrate with potash and dextrine was found to contain 2·26 per cent of subchloride. Another obtained with silver nitrate, potash and milk sugar contained only 0·34 per cent. As in former instances these determinations are useful only in indicating the extreme variability of these substances and their approximate limits of composition.

### *Other Reactions leading to the formation of Photochloride.*

A few more instances are here added, indicating the variety of ways in which this product may be obtained.

The following is an interesting reaction. If a solution of ferrous sulphate is made strongly acid with HCl and solution of silver nitrate added, the silver is thrown down as white chloride. But if to the silver solution is first added a little ammonia, enough to re-dissolve the oxide, but much less than enough to neutralize the acid added to the iron solution, then on pouring the silver solution into the iron, the silver falls as red chloride. So obtained it has at first a dull purple or shade, but by purification, as before described, a good product is obtained. This method, however, scarcely tends to the production of the splendid copper red shades of color that are got by acting on silver chloride dissolved in ammonia with fer-

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* A specimen in this stage and before treatment with nitric acid was found to contain 92·68 per cent of silver, showing it to be a mixture of metallic silver with chloride and sub-chloride.

rous sulphate and then adding dilute sulphuric acid. The shade of color shown by any particular specimen is always of interest, because as before mentioned, it modifies the effect exerted upon it by the spectrum.

*Potassio-ferrous oxalate.*—The now well-known "oxalate developer" which I described in this Journal some years ago, throws down from silver nitrate a black powder; this precipitate treated with HCl scarcely alters in appearance, but washed and boiled with dilute nitric acid, changes to a deep purple.

*Pyrogallol* is capable of leading to the formation of photochloride. When ammoniacal solution of silver nitrate is poured into solution of pyrogallol in water made strongly acid with HCl, in such proportion that the mixed solutions remain strongly acid, there falls a grayish product which by washing and treatment with hot dilute nitric acid, becomes bright pink.

*Ferrous oxide* differs essentially in its action on silver solutions from ferrous sulphate. A silver nitrate solution added to one of ferrous sulphate, precipitates gray metallic silver. But if potash or soda is first added to the ferrous solution and then silver nitrate followed by HCl, the red chloride is formed abundantly. This reaction is similar to that already described in which an ammoniacal solution of a silver is added to one of ferrous sulphate.

To the same class of reactions belongs the following: silver carbonate with excess of sodium carbonate is thrown into solution of ferric sulphate, and after standing a few minutes HCl in excess is added. The silver is converted into red chloride.

It seemed possible that silver itself might be made the means of reducing its chloride. The experiment was made in this way: freshly precipitated and still moist chloride was intimately mixed with metallic silver in fine powder and a little water. This was heated till the water boiled and nitric acid was added. After the action was over the chloride had assumed a deep pink color. A similar result is obtained without the aid of heat, but the resulting color is much paler.

Analogous to this is the following: When a cake of fused silver chloride in a crucible is reduced with dilute sulphuric acid and zinc, if the reduction is interrupted when not quite finished, and the metallic silver is dissolved out with hot nitric acid, the residue of silver chloride will be found to be pink.

When HCl is brought into contact with Ag together with an oxidizing agent such as a bichromate or permanganate, it gives rise to formation of colored chloride. These I have not specially examined, but there can be little doubt that they are identical in nature with the foregoing. So too when silver in contact with mixed potassium chloride and chlorate is cautiously treated with dilute sulphuric acid.

The reactions above described will serve to show under what a vast variety of conditions the photosalts are formed. Most of the methods here described represent each a whole class of reactions, all resulting in the same general way, and these classes might doubtless be largely added to. Almost any silver solution brought into contact with almost any reducing agent and then treated with HCl, gives rise to the formation of photochloride. Almost any chlorizing influence brought to bear on metallic silver, has the same result. Or when silver is brought into contact with almost any oxidizing agent and HCl. It may be said without exaggeration that the number of reactions that lead to the formation of photochloride is much larger than that of those leading to production of normal chloride.

### *Reactions of Photochloride.*

Exposed to ordinary diffuse light all the bright shades of silver photochloride quickly change to purple and purple black. The darker shades are more slowly influenced.

Mercuric chloride gradually changes it to a dirty white.

Mercuric nitrate dissolves it easily and completely, but apparently with decomposition, as it can only be recovered as white chloride.

Potassic chloride seems to be without effect.

Potassic bromide soon converts it to a dull lilac, which at the end of twelve hours, showed no further change.

In contact with potassic iodide the color instantly changes to blue gray; this change is produced by a quantity of iodide too small to dissolve even a trace of silver; the filtrate is not darkened by ammonium sulphide. With a larger quantity silver is dissolved abundantly. By acting with renewed iodide solution, the substance continually darkens and diminishes until only a few black points, barely visible, are left.

Treated with dilute solution of potassium chlorate and HCl, the red substance gradually passes to pink, to flesh color, and finally to pure white.

The action of heat on the photochloride is very curious; its tendency is generally toward redness. Specimens appearing quite black, are rendered distinctly purple or chocolate by heating to 212° F. in a drying oven. Often when the substance first separates by addition of HCl, it is pure gray; this gray will often be changed to pink by simply heating to 212°. (This happens when a gray form is produced; if the grayness is due to admixed metallic silver, it is only removed by boiling with nitric acid.)

The somewhat surprising change of color which is often seen when the crude substance is boiled with nitric acid (sometimes from dull dark gray to crimson) is due to three concurrent actions: that of the mere heat, the removal of the silver, and the breaking up of uncombined subchloride.

It is not possible to dissolve out the normal chloride by a solvent like ammonium chloride from the photochlorides, leaving the subchloride behind. When red chloride is boiled with successive portions of strong solution of ammonium chloride in large excess, the material gradually diminishes until, if the operation is continued long enough, there remains a small residue of a warm gray color, which consists of metallic silver and dissolves without residue in nitric acid.

If sodic chloride is substituted for ammonium chloride, the same result follows, except that the operation is greatly more tedious. If persevered in until the hot solution no longer removes traces of silver chloride, the residue consists of nothing but metallic silver.

### *Action of Light on Normal Silver Chloride.*

When silver chloride precipitated with excess of HCl is exposed to light, it becomes with time very dark. Cold, strong, nitric acid 1·36 sp. gr. extracts a trace only of silver.

The principal action of light on AgCl (precipitated in presence of excess HCl) consists in the formation of a small quantity of subchloride which enters into combination with the white chloride not acted upon, forming the photochloride, and thus is able to withstand the action of strong nitric acid. At the same time a trace is formed, either of metallic silver or of uncombined subchloride, it is impossible to say which. After a certain very moderate quantity of photochloride is formed, the action of light seems to cease. This cessation has been noted by many observers, perhaps most exactly by Dr. Spencer Newbury.

The nature of the product formed by the continued action of light on silver chloride seems to support the conclusion that the subchloride is combined with the whole of the normal chloride after the manner of lakes rather than in equivalent proportions. If the latter were the case it seems probable that the continued action of light would extend to much greater decomposition than it is found to do.

The action of light in the formation of the so-called latent image will be examined in the second part of this paper.

## PHOTOBROMIDE AND PHOTOIODIDE.

It has been already mentioned that bromine and iodine form with silver combinations in all respects analogous to those of chlorine. A more particular account of the bromine and iodine compounds must wait for the next succeeding number of this Journal; here it can only be mentioned that these substances are formed much in the same way as the chlorine compound. They are less stable than it, and consequently the number of reactions that lead to their production is somewhat more limited. Each, however, is formed in a great variety of ways, and with the same ease as the chloride. In color they are for the most part indistinguishable from it, but exhibit different reactions.

### RELATIONS OF PHOTOCHLORIDE TO HELIOCHROMY.

The photochloride was examined both with the spectrum and under colored glass.

The rose-colored form of photochloride was that which gave the best effect. In the violet of the spectrum it assumed a pure violet color, in the blue it acquired a slate blue, in green and yellow a bleaching influence was shown, in the red it remained unchanged. The maximum effect was about the line F, with another maximum at the end of the visible violet, less marked than the one at F.

Under colored glass the colors obtained were brighter; under two thicknesses of dark ruby glass, the red became brighter and richer. Under blue glass some specimens gave a fair blue, others merely gray. Under cobalt a deep blue was easily obtained, and under manganese violet, a fine violet, very distinct in shade from the cobalt. Green produced but little effect—yellow was sometimes faintly reproduced but rarely. But the yellow glass of commerce, even the dark yellow, lets through portions of nearly the whole spectrum, as can readily be seen by testing it with the spectroscope.

The dark purple forms of chloride do not give as good results as the rose and coppery shades. These last have many points of resemblance with the material of Becquerel's films, resemblance of color, probably of composition, as far as we can judge of the constitution of those films from their origin; they were far too attenuated to admit of analysis; and resemblance in the curious way in which their color is affected by heat, so that the conclusion seems inevitable, that they are at least closely related.

There is certainly here a great and most interesting field for experiment; hardly any two specimens of photochloride give exactly the same results with colored light, and this suggests great possibilities. There is the very great advantage in this method over any previous, that the material is easily obtained in any desired quantity and in a condition most favorable for experiment.

The action of light on photochloride can be a good deal affected by placing other substances in contact with it. Any substance capable of giving up chlorine seems to influence the action somewhat; ferric chloride often acts favorably, also stannic and cupric chlorides.

Evidently an important point in all heliochromic processes is that as white light must be represented by white in the image, it is an essential condition that white light must exert a bleaching action on the sensitive substance employed. Red chloride does not bleach but darkens in white light, but the property of bleaching, to a very considerable extent, may be conferred on it by certain other chlorides, and particularly by lead chloride and zinc chloride.

This I look upon as very important.

Another matter of interest is exaltation of sensitiveness, and this I find is accomplished in quite a remarkable way by sodium salicylate, the presence of which at least trebles the the action of light on these substances. And probably on others.

I am persuaded that in the reactions which have been here described, lies the future of heliochromy, and that in some form or other this beautiful red chloride is destined to lead eventually to the reproduction of natural colors.

Philadelphia, March 23, 1887.

## ART. XXXVII.—*On the Inter-Relation of Contemporaneous Fossil Faunas and Floras*; by CHARLES A. WHITE.

IT is apparent to every paleontologist who aims at a comprehensive knowledge of his subject that the idea which has heretofore prevailed, that for every epoch or period of geological time certain characteristics have been so impressed upon every class of animals and plants which then existed that their remains, if properly investigated, will be found to bear intrinsic evidence as to the particular epoch in which they respectively lived, must be accepted with a good degree of qualification. We ought naturally to expect to find that the rate of progress of evolutional differentiation from epoch to epoch has been variable, when comparisons are made between marine faunas on the one hand and continental faunas and floras on the other, because the conditions under which they respectively lived are so different; but it is scarcely less apparent that such differences have often been very great among the different classes which contemporaneous continental faunas and floras have embraced. In a former publication for example* I have shown that dino-

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* See this Journal, III, xxvi, pp. 120–123.

saurian remains of Cretaceous types, molluscan remains of both Tertiary and living types, and plant remains of both Tertiary and living species, have been found in such intimate association in strata of the Laramie Group as to indicate that they all lived contemporaneously. In another publication[*] I have shown that remains of living species of land mollusks have been found associated in the same strata with those of extinct genera and families of Miocene vertebrates. In still another,[†] I have shown that a fresh-water mulluscan fauna, nearly all the known species of which are closely related to living forms, has been found in Jurassic strata associated with a great variety of dinosaurian remains.

The following remarks in support of the opinion just advanced have reference to other cases which have been observed in connection with the great series of intra-continental strata which is found occupying a large region in the western part of our national domain; the vertical range of the series being from the Laramie Group to the Bridger, the uppermost of the fresh water Eocene Groups, inclusive.[‡] This series is one of unusual interest because of its intra-continental origin, of its great thickness and geographical extent for a series of such an origin, and of the importance of the fossil remains which have been collected from it. Indeed a large part of our present knowledge of the extinct land vertebrate life of North America has been derived from this series of strata; and yet that knowledge is strikingly imperfect and fragmentary. It is of course not strange that any record of extinct vertebrate life should be imperfect, but the broken character of this one is the more noteworthy because the record of both the invertebrate and plant life for the same series of strata and within the same region, seems to have never been wholly broken. Besides this evidence of the continuity of invertebrate and plant life in the series referred to, studies which I have prosecuted in the field, and also among the collections which have from time to time been obtained from those formations, have disclosed satisfactory proof that for the whole series there was continuous sedimentation within a large area.[§] How large that area was has not been determined, but it is known to have embraced a considerable part of central and northern Utah.

It is probable also that in northeastern Montana and the adjacent part of Dakota, sedimentation was continuous from

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[*] Bull. U. S. Geol. Survey, No. 18, pp. 10–16.

[†] Bull. U. S. Geol. Survey, No. 29.

[‡] For a tabular exposition of the principal formations of the Rocky Mountain region, showing the relations of this series to other formations, see Ann. Report U. S. Geol. Surv. Terr. for 1876, p. 22.

[§] See Bull. U. S. Geol. Survey, No. 34.

the Laramie up into the equivalent of the Wasatch, and perhaps also into that of the Green River Group.*

This result of those studies makes it necessary to deny the correctness of the claim, which certain authors have made, that there was an entire stratigraphical break in the series referred to at the close of the Laramie period. Still, it is not denied that the Wasatch strata usually, if not always, rests unconformably, if at all, upon the strata which have been called the Bear River Laramie; and in some cases also upon other Laramie strata. In short it is admitted that the area of continuous sedimentation was materially restricted at the close of the Laramie period; but it was not wholly interrupted until the close of the Bridger epoch.

Besides the recognition of proof that sedimentation was continuous through the whole vertical range of this intra-continental series of deposits within at least certain portions of the area they occupy, the studies referred to have resulted in showing that certain of the species of the fresh-water gill-bearing mollusca of the Laramie period survived into the Wasatch epoch and became an integral part of the then existing purely fresh-water molluscan fauna.† Furthermore, it is well known that certain other molluscan species range through the whole fresh-water Eocene series, from the Wasatch to the Bridger Group, inclusive. Again, Professor Lester F. Ward has shown that more than twenty species of plants are common to the Laramie and Green River Groups; thus indicating that a large proportion of the species of the Laramie flora long survived the close of the Laramie period and mingled with the floras of the succeeding epochs.‡

Here then, we have what is regarded as satisfactory proof that the stratigraphical series is complete from the Laramie to the Bridger Group, inclusive. And yet within the vertical range of that series the remains of several distinct land vertebrate faunas are found, which are not only widely diverse in their characteristics, but seem to have been introduced and extinguished with a suddenness that has left us with little or nothing learned concerning either their ancestry or their progeny. Indeed, a considerable proportion of the fossil vertebrate faunas which have been discovered in the North American Mesozoic and Cenozoic strata are so clearly defined from one another by their own distinguishing characteristics that they appear to have been suddenly introduced and as suddenly extinguished. Moreover the differences in the characteristics

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* See Bull. U. S. Geol. Survey No. 34, pp. 16, 17; also this Journal, III, xxv, pp. 411–413.

† Bull. U. S. Geol. Survey, No. 34.

‡ Sixth Ann. Report Director U. S. Geol. Survey; table covering pp. 443–514.

of these faunas is very great, even when they are found to occupy stratigraphical horizons so closely approximating each other as to indicate that they were not separated by any considerable interval of time. This condition of things is sufficiently perplexing from a purely zoological point of view, but it assumes an additionally serious aspect when these sudden appearances and disappearances of peculiar faunas are used as indices of the exact limits of geological epochs.

While it is clear that many faunas may have been rapidly extinguished by sudden changes in their environment, we cannot admit that any have been introduced into a given area with anything like the suddenness that is indicated for certain of the faunas presently to be mentioned, except by some physical change that should cause the enlargement of the area previously occupied by such a fauna, or its transference from one region to another. That is, it is assumed that in case a distinct fauna has been suddenly introduced into any given region, it has been by transference from some other region which it had previously occupied, and where its evolution had been accomplished.

The first of the vertebrate fauna which I shall mention in this connection is that of the Dinosauria of the Laramie Group. This is the latest dinosaurian fauna which is known to have existed upon the North American continent, and it is probably the very latest that existed upon the earth. Its remains are comparatively rare, although large and characteristic forms existed until the close of the Laramie period. These dinosaurian remains are the only fossils yet found in the Laramie Group upon which has been based the claim that it is of Cretaceous age; and the character of the plant and invertebrate remains in the same formation is such that but for the presence of the dinosaurs no one would have thought of referring it to any Mesozoic period. The few remains of dinosaurs that have been found in the Laramie Group range up to its uppermost strata, and the extinction of those forms seems to have been simultaneous with that of the brackish water mollusca whose remains characterize the Laramie Group, so far as its invertebrate fauna is concerned.

Professor Cope has published an important mammalian fauna from certain strata in New Mexico, which he designates as the Puerco Group, the position of which is between characteristic Laramie strata beneath, and equally characteristic Wasatch strata above. These Puerco strata were originally referred to the Wasatch Group and, as they are also of fresh water origin, and not widely different in lithological character from those of the Wasatch, which rest conformably upon them, it is not probable that any other designation would have been given them if they had not been found to contain the vertebrate remains in question.* According to Professor Cope this Puerco fauna is, as a whole, quite unlike any vertebrate fauna that is now known to have either preceded or followed it upon this continent; although certain of its types are related to some that are found in the Laramie and Wasatch Groups respectively. Still, in consequence of the presence of certain types which he regards as Mesozoic, Professor Cope thinks the fauna possesses more of a Cretaceous, than of a Tertiary character. The lowest strata in which the remains of this fauna have yet been found closely coincide in position with the top of the Laramie Group; and they disappear suddenly upon a certain higher horizon which seems to come within the basal portion of the Wasatch Group. Moreover, the known area within which this Puerco fauna has been found is only a small part of that within which the Laramie and Wasatch groups occur. That is, the Puerco fauna has not been recognized at the majority of the localities where the Wasatch has been found overlying the Laramie. In some of the latter cases the two formations have been found to be closely connected, not only by strict conformity of the strata, but also by an intermingling of their molluscan faunas; and in none of them has any indication of a missing formation been observed.

The next vertebrate fauna to be considered is that of the Wasatch Group, which is a remarkable one for its abundant variety and diversity of forms. All persons who have studied this fauna agree in regarding it as of Eocene age, including as it does Coryphodont and other distinctly Eocene types. With this reference the plant and vertebrate forms agree, except that some of the former have been regarded as of later Tertiary types. The Coryphodont and other Eocene vertebrate remains referred to have been found in the lowermost of the Wasatch strata as well as at higher horizons in the group, and, as before said, some of the Laramie dinosaurs have been found in the uppermost strata of the latter group.

Above the Wasatch Group proper, the Coryphodonts soon disappear, and other changes in the Eocene vertebrate fauna gradually take place up to the close of the Bridger Group. Above the Bridger Group the vertical continuity of the intra-continental Tertiary deposits of that western region is broken. That is, the later fresh-water Tertiary deposits were formed in isolated basins, and they therefore do not constitute part of a continuous series, with that of the preceding deposits. Consequently the geological age of those later deposits must be determined by means of their fossil contents alone, without the

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* For a concise account of the Puerco by Professor Cope, see Am. Naturalist, xix, p. 985. See also same volume, pp. 385 and 493.

aid of known stratigraphical continuity. As my present object is to discuss certain of the faunas of the preceding formations with relation to the order in which the latter were deposited, those later Tertiary deposits will not be further considered on this occasion.

What we now know of the order of succession of the vertebrate faunas which have inhabited that western region, so far as that knowledge is necessary to the present discussion, may be briefly summed up as follows: Dinosaurian life continued until the close of the Laramie period and then suddenly ceased. The Puerco mammalian fauna was suddenly introduced within the limited area where its remains have been found, and as suddenly extinguished there about the close of the Laramie period or the beginning of the Wasatch. The Wasatch mammalian fauna was suddenly introduced in the region under discussion at the close of the Laramie period and coincident, or nearly so, with the extinction of the dinosaurs or, at latest, with that of the Puerco mammals.

The dinosaurs of the Laramie period were evidently not materially different in general character from those of the preceding periods; and there is no reason to doubt that they were direct descendants of the latter. They found a congenial habitat upon the borders of a great inland sea in the deposits of which their remains are found, and until the Puerco mammalian fauna was introduced into a part of the region which they occupied. They also appear to have continued their existence in at least certain parts of their former habitat after the introduction of the Puerco fauna, and until the introduction of the Wasatch mammalian fauna into the same region. We have no positive evidence that the Laramie dinosaurs continued their existence in direct association with either the Puerco or Wasatch mammalian faunas, because no Dinosaurian remains have been found associated with those of either of the faunas named. The probabilities are that the dinosaurs met their extinction in the struggle for existence which ensued upon the introduction of one or both the mammalian faunas just mentioned.

Now it seems necessary to infer that these changes in the character and continuity of vertebrate life were mainly due to important changes which from time to time took place in the physical conditions of the continent. And yet it is evident that those physical changes were not sufficient to interrupt the continuity of either the invertebrate or plant life in the same region, nor to wholly interrupt the continuity of sedimentation in the intra-continental waters. In short it is quite evident that the land vertebrate life of North America has been subject to certain influences which effected great changes in, and no doubt caused many extinctions as well as dispersions of its faunas, but which produced little or no effect upon at least a considerable part of the contemporaneous plant and invertebrate life. Concerning the nature of those changes which thus affected vertebrate life our present knowledge is quite limited, and much is therefore left to conjecture. The suddenness, however, with which the remains of land vertebrates have successively appeared within a great unbroken series of intra-continental strata seems to make it necessary to conclude that one of the results of those changes was the removal from time to time of certain physical barriers which previously restricted the dispersion of those faunas respectively.

I have already given my reasons for believing that the sedimentation of that great series of strata, from the Laramie to the Bridger Group inclusive, was at no time everywhere entirely interrupted, and that there was for the whole time, and within the region where that series was deposited, an unbroken continuity of invertebrate and plant life. If these conditions actually existed we must necessarily conclude that the Puerco and Wasatch mammalian faunas were both suddenly and independently introduced into the region where they are now found, from some other region where they previously existed.

This view of the case shows the impropriety of regarding the earliest strata in which the remains of a certain fauna happen to be found as indicating the exact time of the ushering in of the epoch to which that fauna is assumed to belong. For example, it is claimed by those who have studied the vertebrate faunas of the Puerco and Laramie groups that they ought to be referred to the Cretaceous period; and they are equally positive that the Wasatch Group should be referred to the Eocene. Now the dinosaurian remains of the Laramie are known to range up to the uppermost strata of that group; and many of those of the Coryphodonts and other Eocene mammals have been found in the lowermost strata of the Wasatch. So closely do these two fossiliferous horizons come together, and so evident is it that sedimentation was continuous from the one to the other, we cannot assume that any considerable time elapsed between the deposition of the latest strata of the one group and that of the earliest strata of the other, notwithstanding the intervention of the Puerco fauna in a part of the region where both the Wasatch and Laramie Groups are found.

Here then, we find the remains of Cretaceous dinosaurs, of a unique mammalian fauna, and of a distinctively Eocene mammalian fauna, all in an unbroken series of deposits, each occupying separate horizons which so closely approximate each other that it is evident sufficient time did not elapse during the deposition of that portion of the stratigraphical series to have allowed the successive evolution of the faunas in question. We must therefore assume that at least the Puerco and Wasatch mammalia were developed somewhere else, and that they were respectively transferred to the region in which their remains are now found.

The Puerco fauna is so unique in character that, with our present limited knowledge of it, and our present methods of paleontological study, it appears to mark an epoch in the history of vertebrate life of North America of which the invertebrate and plant remains, and the stratigraphical condition of the series of deposits in which they occur, give no indication.

At present also we know nothing of the immediate ancestry of the Wasatch mammalian fauna, but in view of its highly developed, diversified and distinctive character, we must conclude that it existed somewhere, possessing essentially the same characteristics which its known remains now exhibit, long before the earliest Wasatch strata were deposited. The stratigraphical conditions before referred to indicate so short a time for the deposition of the strata within the vertical range of which the remains of these three faunas are found, that it also seems necessary to conclude that the Wasatch fauna existed somewhere contemporaneously with the Puerco mammalia from which it differs so much, and also contemporaneously with the Laramie dinosaurs, from which it differs far more widely. The conclusion therefore seems to be irresistible that the faunal types which are regarded as diagnostic of the Eocene period existed contemporaneously with those which are equally diagnostic of the Cretaceous period.

That faunas and floras of Cretaceous and Tertiary types should have existed contemporaneously is not strange, for a similar diversity now exists as regards the living faunas and floras of different parts of the world; and they have doubtless existed in a greater or less degree ever since animals and plants came to be widely differentiated. It is strange, however, that this latter fact should be so often ignored in discussions of the relative ages of extinct faunas and floras.

The foregoing remarks are confined mainly to cases in which continental faunas and floras are compared with each other, and with reference to the usually accepted paleontological standard. The following remarks are made with reference to the fossil faunas and floras of the great intra-continental deposits of North America, as compared with those of presumably contemporaneous sea coast deposits. Ever since the publication of my views as to the inland character of the sea in which the strata of the Laramie Group were deposited, they seem to have been accepted without serious question; and the purely fresh-water character of the deposits which succeeded the Laramie, admits of no doubt as to their lacustrine origin. I have therefore referred to these as intra-continental deposits, and to the remains which they bear as those of continental faunas and floras, as contrasted with marine faunas. The term sea coast deposits is used in contrast with the forementioned term which is applied to the other deposits, and by it is of course meant the well known marine strata, the order of superposition of which can be more or less satisfactorily traced from the earlier to the later geological epochs.

Because of the isolation of the intra-continental deposits they can have no place in any observed order of superposition among marine deposits, and for this reason they must therefore be studied separately. The great difference also between the aqueous faunas of the fresh and brackish waters respectively in which the former deposits were made, and those of marine waters, makes a chronological comparison of the two categories of deposits, by such means, a matter of great uncertainty. This is an additional reason for their separate study until satisfactory data can be obtained for their correlation with marine formations. While I believe that such correlation, if ever effected, must be based mainly upon paleontological data, we ought to expect much aid from lithology and physical geology, especially when studied in connection with paleontology.

Pursuing a consideration of the latter subject we may reasonably infer that certain species among the land faunas and floras have occupied the region between any given inland sea or lake on the one hand, and the open sea on the other, across the whole intervening region, unless there were known physical obstacles to such dispersion. Therefore the remains of such species might easily occur in both inland and coast deposits. That is, remains of the same species of land animals and plants may have been entombed in lacustrine deposits on the one hand and estuary deposits along the sea coast on the other, the species having occupied the whole of the intervening land area. The contemporaneity of such deposits would be thereby apparent; and in my estimation such evidence would be more conclusive than any other.

Still, as a matter of fact, no correlations of intra-continental, with sea coast deposits of North America have yet been accomplished either by such means, or by any other practical method. It is nevertheless true that most of the authors who have written upon the formations in question have referred both the inland and sea coast series to respective subdivisions of the geological scale which was originally established for Europe, and supposed to be of universal application, with a confidence which is only warranted by positive knowledge. For example, certain deposits along our sea coasts are referred with confidence by most paleontologists to the Eocene, Miocene and Pliocene epochs respectively, as those epochs are recognized among European formations. Certain of our great intra-continental deposits are also referred to those three epochs with equal confidence; and yet no direct paleontological proof has been adduced that any one deposit of either of these two North American series was, even approximately, contemporaneous with any one of the other series. By direct proof I of course mean that which is furnished by specific identification of fossil remains or derived from well comprehended phenomena of physical changes, as contrasted with theoretical inferences derived from a foreign standard, and assumed to be of rigid application here. Still, in view of the reasonable hope that great discoveries of fossil continental faunas and floras are yet to be made, and much concerning the physical geology of the continent is yet to be learned, we ought not to despair of obtaining some of the direct proof which is so desirable. An encouraging fact in this direction is the one lately pointed out by Professor Ward that four of the species of plants which occur in the Laramie Group occur also in the Lignitic deposits of the marine Tertiary series of the Gulf States;* and when the fossil floras of the continent are thoroughly known, much more information of this kind may be expected from them.

Now in case the specific identifications referred to should be made, and the contemporaneity of the formations be thereby proved, what effect ought that circumstance to have upon the nomenclature of formations already recognized and named? For example, the Laramie formation was deposited in a great brackish-water inland sea, and it contains a characteristic aqueous fauna which is distinct from that of any other known formation. Other deposits were of course simultaneously formed along the sea coasts, and perhaps upon other parts of the continent also, all of which contain remains of faunas that, so far as known, differ materially from those of the Laramie, and also from each other. Among those which probably contain a flora similar to that of the Laramie are the Eocene Lignitic of the Gulf States, and certain deposits upon the Pacific Coast in Washington Territory, which have been investigated to some extent by Professor Newberry. Among the marine formations which were deposited simultaneously with the Laramie, is almost certainly a part of the Chico-Téjon series of California.

In view of the extent and importance of the intra-continental deposits of North America, and the radical differences of their fossil remains from those of the marine formations, it is plain

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* Sixth Ann. Report Director U. S. Geol. Survey, p. 529.

that we must range the formations of this continent under two separate categories, the nomenclature of each of which should be kept distinct, even after their contemporaneity may have been ascertained. Furthermore, correlations between the two categories should be based primarily upon phenomena observed or observable upon this continent, for it is now evident that no foreign standard will be found adequate for this purpose.

## ART. XXXVIII.—*The Eozoonal Rock of Manhattan Island;* by L. P. GRATACAP.

A BED of serpentine rock bordering the western margin of New York Island between 55th street and 60th street, and now for the most part built over, some years ago awakened a momentary interest from its display of strips of ophio-calcite which resembled the eozoonal beds of Canada, and led to some surmises as to their organic character. This area of serpentinous rock, forming a band enclosed on the west and east by mica schists or a highly micaceous gneiss and limited southward by a broad outcropping of granite, is gradually disappearing from view and may at any time become an affair of local record. At present its best exposure is on the north side of 59th street between 10th and 11th avenues, and it can be traced to near 56th street, by isolated knobs appearing above the level of the sidewalk and in back yards. It was recently uncovered to some extent when the cisterns for the immense gas-holders of Equitable Gaslight Company were being constructed, and some examinations then made both of the rock in place and of microscopic sections, may prove of interest in view of the general attention given to the discussion of the origin of serpentine, a discussion which seems to widen; and to which the later contributions by Dr. Becker* would seem to give a new impetus.

This outcropping of serpentine is intimately associated with and intermingles with an acicular fibrous partially altered hornblende or actinolite, the hydrous anthophyllite of Dana. From this area were derived the numerous bowlders of this rock which are found to the south as far as the northern margins of Long Island. Dr. L. D. Gale, as quoted by Mather,† describes this anthophyllite locality in the following words: "This rock extends from 59th street following the strike, which is N. 30° E.; varies from this to due north and south as far as 63d street, where it dips down and disappears below the river.

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* Cretaceous Metamorphic Rocks of California, by G. F. Becker, this Journal, xxxi, p. 348.

† Geological Survey of New York, Pt. 4, p. 581.

The rock varies considerably in character in different places where it has been uncovered, and occupies a series of conical hills some five or six in number, distributed in a northerly and southerly direction. In some places, as at 60th street, it is talcose in structure, and may be split into thin slabs; in others it is dark gray, almost black, composed of straight fibers arranged in a columnar form, meeting and crossing each other frequently at right angles." He further says, "it is remarkable that the granite lying on the west and the gneiss on the east of the rock in question, come in complete contact with it without intermixing. So remarkable is the line of separation on the side next to the gneiss, where there is the best opportunity to examine the two, that within the space of three inches, each rock possesses all of its own peculiarities, with none of those of its neighbor." In speaking of the serpentine, he says, "in the same vicinity are found masses of serpentine and limestone intermixed exhibiting a porphyritic appearance, the serpentine appearing green and the limestone white;" this refers to the eozoonal-like portions which would seem, so far as their microscopic appearance goes, to easily warrant their reference to a close relationship with the Canadian rock containing that debateable organism.

Cozzens, in his Geological History of Manhattan or New York Island (1843), p. 12, refers to this locality, saying, "between 54th and 62d streets, the shore and 10th avenue, there are four or more small knolls of black serpentine, with scales of silvery or golden talc, accompanied by a vein of anthophyllite about twelve feet wide. This vein is in a vertical position. At the north end of the serpentine proper, this anthophyllite shows itself in two places, *in place;* one, on the rising ground, and near the sienite, the other at high-water mark on the shore. Actinolite is found imbedded in the anthophyllite. The serpentine locality commences where the granite ends. At the south end there is a vein of carbonate of lime. This carbonate of lime has many small specks of serpentine diffused through it, and forms a kind of 'verd antique,' which, when polished, makes handsome specimens."

These early observers speak of the association of the serpentine with hydrous anthophyllite, and this association points significantly to the origin of the serpentine itself. This bed of serpentine is in all probability an altered amphibole or hornblende schist and the "porphyritic," "verde antique," eozoonal portions, the products of such, are alterations produced under conditions of strain and pressure, accompanied by aqueous infiltrations. I have not seen the vein of anthophyllite alluded to above, but on visiting the locality on 59th street, where a ledge rises up in a mound-like prominence, I found anthophyllite in masses, apparently recently blasted and removed from their beds of place, with which was seen actinolite largely serpentinized. An examination of the hill showed a vertical face where Eozoon structure (ophio-calcite) was seen at a number of points. It appeared in seam-like bands, expanding in some places and contracting at others, forming an irregular scattered prolongation of parts, varying in grain from fine to coarse, the former accompanying an apparent flexure or contortion of the original stratum. On the south side of 59th street, where the excavations were being made, mentioned above, an exposure of the serpentine bed was accessible where the ophio-calcite was seen, frequently presenting a seam-like appearance, contracting to narrow bands and again developed in broader sections, while sometimes it sporadically occupied nests or spots enclosed in the surrounding rock. Away from these parts the serpentine was fibrous or micaceous.

Should any one feel disposed to refer these eozoonal-like portions (fig. 7) to an organic origin, the extended irregular vein-like parallel strips, which they present, would form a seemingly strong objection to such a reference. Coralline bodies occur in reefs or reef-like lines, but this mosaic of serpentine and calcite has nothing coralline about it in any sense, and when placed, as it only can be placed, on the assumption of its zoological affinities, with the protozoa or metazoa, it repels all analogies with any thing in those classes of animal life, by its linear extent, the actual length of these broken strings of ophio-calcite, being in the exposed sections, from 10 to 20 feet.*

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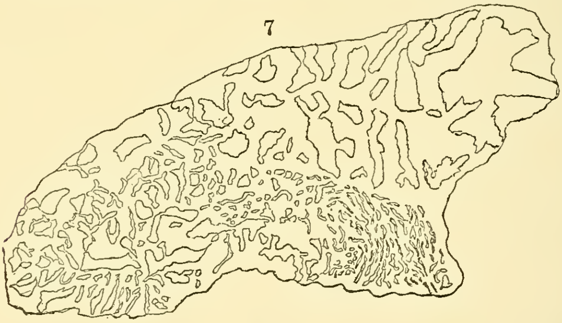

The films of this "verde antique" are not horizontal, but

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* It is true that Professor Hyatt (Science, vol. vi, p. 386) speaks of spongoid bodies *Archæocyathus*, *Ethmophyllum*, etc., as probably the reef-builders of the primordial seas, so that linear extent merely might not preclude the possibility of the eozoonal rock being referred to an organic origin. But when in connection with their length these eozoonal veins have only a moderate width of a few inches their reference to the reef-like masses of sponges seems incredible.

rise and fall as if they had undergone plication, but so strongly do they suggest the quartz or granite veins found in the folded gneiss layers of the island, that their origin may be connected with this very plication, the incipient change in the original hornblende schist having been induced at the moment of folding, the alteration involving the change of the hornblende to serpentine, with the exclusion of lime, which through the action of percolating waters finally filled the interstitial spaces as calcite.

An examination of the thin microscope slides, made of sections of this ophio-calcite, proved very satisfactorily the change of the hornblende into serpentine, threw some light upon the process of change, and lent some support to the view of the segregated character of the calcite.

Groups of hornblende crystals were constantly encountered surrounded by the serpentine (figs. 5, 6), while in these, phases of alteration were detected and separated. The change of the hornblende to serpentine seemed to be frequently preceded by a breaking up of the hornblende into fibers, giving the blade a striated appearance, while the serpentine granules develop along these. In some cases the hornblende blade is replaced in patches by serpentine, against which the remaining fibrous substance, partially changed, but not deprived of its acicular appearance, abuts with a crenulated margin. A second method of change seems to consist in a sort of exfoliation, the hornblende stripping up, the alteration entering from all sides with no apparent physical change, to the condition of asbestus. In this second process the hornblende presents an eroded appearance and frequently shows minute cavities, the whole aspect being not dissimilar to that of a melting fragment or

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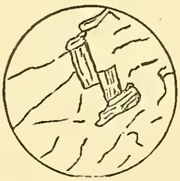

pellicle of ice. In one instance a section displayed a pavement of hornblende enclosing a strip of serpentine with a plentiful sprinkling of magnetite, and in another example, an interesting illustration of the change of the hornblende to serpentine, was observed where a long fiber of the actinolite (?) was altered to serpentine at nearly equal lengths throughout its extent. The alteration started from minute transverse breaks and progressed on either side for a short distance into the substance of the crystal. The unchanged portions of the amphibole separating these serpentinized joints, gave the fragment the appearance of an equisetum (fig. 2). This was repeated less strikingly in the same section over its entire surface. Again aggregates of viridite or chlorite were seen scattered over the serpentine in one slide (fig. 4), a possible phase in the change of the hornblende to serpentine or a secondary product of its alteration.

The formation of the calcite in an interrupted manner seemed clearly shown in many instances, as where two irregularly interlocked areas of this mineral were seen with the cleavage lines of one section abruptly terminating at the margin of the other (fig. 1). This would lead to the inference that the deposition of the two parts was not simultaneous and lend support to the view of the intermittent secretion of the calcite from aqueous solutions, in the interstices of the serpentinized hornblende. Lacunæ of calcite appear irregularly through the serpentine, the ragged and spiculate edges of the serpentine yielding inwards, while in some instances a semi-dark line marking a change of thickness, separated an interior core of calcite from the border contiguous with the serpentine, an indication of intermittent secretion.

The examination of these sections leaves little room for doubt that a bed of hornblende rock has undergone a conversion more or less complete into serpentine, and that along lines of strain incident to its folding, where thermal conditions of an intense character were developed, accompanied, or perhaps succeeded by the introduction of water, the change has been perfected most rapidly and has been assisted by the elimination of lime carbonate as calcite, and probably in some cases the double carbonate of lime and magnesia as dolomite.

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## Art. XXXIX.—*Terminal Moraines in Maine;* by George H. Stone.

One of the most obvious features of the glacial drift of Maine is its unequal distribution. Many of the multiform ridges and heaps of till which abound in the State may par-take of the nature of medial and terminal moraines. In classifying these deposits it will be needful to distinguish accumulations of till which were formed beneath or within the ice-sheet from superficial accumulations which were the result of the local movements sure to occur during the unequal melting of the retreating glacier. We know so little as to the nature of the work going on in the lower portion of an ice-sheet that this distinction is a difficult one to make. Omitting a great number of doubtful cases, there are a few places in the State where the till is piled in narrow ridges which lie transverse to the direction of glaciation and which so clearly have the form and composition of terminal moraines that they must be regarded as having been formed at the end of a moving mass of ice. In some cases kames also appear to have been deposited at the ice-front and thus were practically a part of the terminal moraine, but they are omitted from this list. So far as I know the following list includes all of these formations in the State concerning which the evidence is reasonably conclusive.

1. *The moraines of the local Androscoggin Glacier.*—After the great ice-sheet was so far melted that the general movement ceased, there was still for a time sufficient ice in the White Mountain region to cause a glacier to flow eastward along the valley of the Androscoggin River, as far as West Bethel, Maine. This local glaciation was first described by Professor G. L. Vose and Professor A. S. Packard in the first and second volumes of the American Naturalist, afterwards by Professor C. H. Hitchcock in the N. H. Geological Reports; and briefly by the writer in the American Naturalist for April, 1880. The most remarkable terminal moraine of this glacier is at the great bend of the Androscoggin near the boundary between Shelburne, N. H., and Gilead, Me. No one who sees this can hesitate to regard it as a true terminal moraine of a local valley glacier.

2. *At Readfield Village.*—In the western part of Readfield village (near the woolen mill) is a confused series of hummocks and short ridges extending from north to south across the valley of the small stream on which the mills are situated. From this point the valley continues nearly west for about one mile when it turns northward and soon widens into a valley which resembles a mountain cirque. This wider valley apparently was filled with ice which flowed down the narrow valley to Readfield village. At several places along the valley are masses closely resembling lateral and semi-terminal moraines. At the woolen mill the valley proper is only about one-eighth of a mile wide. The morainal hummocks are chiefly made up of till which is somewhat coarser and more sandy than the ordinary till of the region, as if slightly water-washed. In a

few places along the roads the deeper cuts show masses of stratified sand and gravel underneath unstratified till, and these sediments are in some cases plainly cross-bedded. There are no signs of a land-slide here, indeed the slopes of the neighboring hills are too gentle for that. Are these hummocks the work of the great ice-sheet or of a local glacier? There are in Maine very many deep sheets and ridges of till left by the ice-sheet across east and west valleys, but these hummocks in question are a different kind of ridge from the gently sloped ridge of ice-sheet construction. If these small and steep masses are remains of a broad sheet of till irregularly eroded, then in the depressions between the hillocks there ought to be found an abundance of the larger stones and bowlders of the till, such as are found in the present bed of the stream.

About one-third of a mile east of this point and at nearly the same elevation above the sea (215 to 230 feet), there is at the Fair Ground a terrace of stratified sand and silty clay. No fossils have been found in these beds, but at Winthrop Village and at an elevation only a few feet less, marine shells are common in sedimentary clay. It thus appears that in Champlain time the sea extended from the Kennebec Bay of that period westward to Winthrop. But Winthrop and Readfield are at opposite ends of Lake Maranocook and if the sea extended to Winthrop it would necessarily reach to Readfield unless kept back by a barrier of ice. Probably the sedimentary beds at and near the Fair Ground, Readfield, were Champlain shore deposits and the hummocks of mixed till and sediments in the western part of the village were formed where the local valley glacier confronted the narrow arm of the sea.

3. *The Swan Island Moraine.*—Swan Island is an island in the Kennebec River. It begins near Richmond and extends for about four miles southward. About one and one-fourth miles from the southern end and on the eastern side of the island is an east and west ridge about one-fourth mile long that is probably a terminal moraine. It appears to have suffered considerable surface erosion by the Champlain sea. A short kame is found near the western end of this ridge. The marine clays cover the flanks of both kame and moraine so as to disguise their relations to each other.

4. *The Sabattisville Moraine.*—A short distance south of the bridge at Sabattisville is a two-sided ridge of till which extends for a little more than one-eighth of a mile across the valley of the Sabattis stream. The ridge rises from eight to fifteen feet above the plain of marine clay and is composed of quite sandy till, as if gently water-washed. The steepness of the ridge on both sides and its east and west direction mark it as a terminal moraine. The ridge is partly within the village,

and considerable of it has been removed within the past few years.

5. *The Machias Moraine.*—This is situated about five miles south of Machias village, near the first fork of the road found in going in that direction. It extends from Englishman's River northeastward for about three-fourths of a mile to near an arm of the sea. It is interrupted for a few rods by a swamp and a small hill and then begins again. The part most clearly a terminal moraine lies west of the road leading south from Machias. It is a ridge which rises rather steeply on each side to a height of from fifteen to twenty-five feet above the plain of marine clay in which it is situated. At one place the deposit is wider and is double, the two ridges being separated by a shallow depression which is not, however, a kettle-hole. The southern slope of the ridge shows many bowlders from one to four feet in diameter, while just beyond the crest on the northern slope are several feet of stratified sand, gravel and pebbles. This probably was the result of the Champlain surf which broke on the southern slope and washed the finer drift over the ridge beyond the reach of the undertow and left it stratified on the northern slope. At least the western portion of this formation must be a terminal moraine, though somewhat different from some of the others here described.

6. *The Waldoboro Moraine.*—This is somewhat more than five miles long, with a few short gaps.

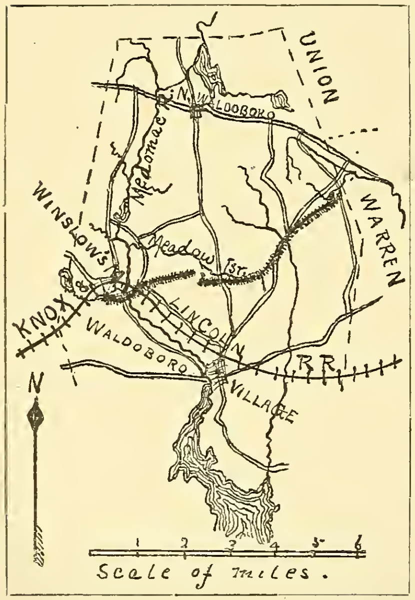
On the west this moraine appears to begin a short distance west of Winslow's Mills, a way station of the Knox and Lincoln railroad, situated about three miles northwest of the village of Waldoboro. These mills are on the Medomac River, a stream about twenty-five miles long, which empties into the sea at Waldoboro. For several miles north of Winslow's the Medomac has been flowing nearly south through a gently rolling plain, but near the mills the valley is encroached upon by a hill which here rises on the eastern side of the stream to a height of about 200 feet above the sea. This hill slopes northward and within a mile sinks to a level with the Medomac. On the west of the stream there is a moderately steep slope, but the hill is not so high as that on the east side of the valley. The moraine appears to begin on the slopes of this hill about one-fourth of a mile west of the Medomac and at an elevation of about seventy feet above the stream. There are here three nearly parallel ridges, the most southern one being only a few rods long and eight to ten feet high. The steepness of the slopes of these ridges and their irregular outline is in marked contrast with the flowing curves and rounded outlines of the granitic till of this region. The two more northern moraines extend eastward across the valley and climb the slopes of the hill beyond. They show several short, gentle zig-zags but their general course across the valley is curved, the concave side being to the north. They are nearly parallel and only a few rods apart. The more northern of these moraines is rather discontinuous, consisting of a well-defined system of ridges separated by low places in the ridge or by short gaps. The mills and the dam are built on the line of this moraine. It is composed of a somewhat sandy till, pell-mell in structure generally, but in places faintly stratified and partially water-washed, a sort of transition into kame sand and gravel. The more southern of the two long moraines is higher and more continuous than the northern one. It rises from ten to twenty feet above the marine clay of the valley and has been cut through by the railroad to a depth of about fifteen feet. It is composed of till which contains much fine clay and shows few or no signs of water-wash, and it affords a much larger proportion of well-scratched stones than do the surface layers of the ordinary till of that locality. A few rods east of the mills is a pit whence much rounded gravel has been taken. The excavation shows the till of the terminal moraine overlying the gravel and rounded cobbles. This gravel is part of a system of glacial or "kame" gravels which extends from Waldoboro about five miles northward, most of the way lying near the Medomac. It is one of the discontinuous systems of kames characteristic of that part of Maine—consisting of short ridges like kames yet arranged in long north and south lines like osars. The domes or ridges are separated by gaps of from a few rods up to one-fourth of a mile or more. Of course that part of this kame system which is south of the terminal moraines must have been deposited before the recession of the ice northward to Winslow's Mills. Even to the north of this place the main line of kames does not show an immediate change of character and it too was probably formed before the recession of the ice and deposition of the moraines. But east of the main system of kames and north of the moraines are a number of low scattered kame hummocks and short ridges somewhat parallel to the terminal moraines and probably contemporaneous with them, at least with a part of them.

I looked with especial care for exposures showing the relative positions of the moraines and the marine clay. The Champlain clay is much thinner in this valley than in that of the Kennebec. Many of the kame ridges along the Medomac are plainly overlaid by the clay, but no fresh exposure could be found showing the relations of the moraines to the clay. The surface indications were that the clay overlies the base of the moraines. My exploration was incidental to other work and did not permit excavation.

As before stated the moraines climb the hill on the east side of the Medomac. They rise to a height of about 100 feet above that stream. The more northern moraine soon almost disappears, but the southern ridge is conspicuous for about one mile. It is a two-sided ridge, its southern slope being as steep as moraine stuff will lie, and for a part of the way the northern slope is nearly as steep. The ridge everywhere contains more bowlders than the ordinary till of the region. Many of these bowlders are from five to fifteen feet in diameter. The moraine rises from ten to twenty feet and is of variable width, in a few places being ten rods wide, usually narrower. For a short distance it serves as a natural roadway through a swamp, and is locally known as the old railroad grading. It here rises steeply from eight to fifteen feet on each side, and is so narrow that there is just room enough for a log road on the top. The material is here very coarse; in fact the ridge is simply a wall of bowlders. A short distance east of this swamp the moraine disappears near the eastern brow of the hill, but begins again about one-fourth of a mile to the southeast. The topography of the country accounts satisfactorily for this gap. The hill, on its east side, overlooks the valley of Meadow brook, a small stream which flows northwestward into the Medomac. Also there is a valley which extends nearly north from the gap in the moraine. Two favorable lines for ice-flow converged at this point. Naturally the deeper ice of the valley reached a point farther south than the thinner ice which abutted against the hill to the west of Meadow brook, and its moraines are larger. After passing the gap we come upon the moraines on the eastern slope of this hill at a height of about 75 feet above Meadow brook. There are here several nearly parallel ridges extending eastward, also a line of hummocks reaching northward along the base of the hill for a short distance. They are all well sprinkled with large bowlders. The moraines cross the road leading from Waldoboro to North Waldoboro at Benner's mill, on Meadow brook, the road passing through a narrow gap in the ridges. East of this road the several ridges unite into a single ridge which rises steeply on each side from 30 to 60 feet. It is here locally known as "The Ridge," and in form resembles the osars. A broad and flat deposit of glacial gravel begins a few rods south of the moraine and extends for about one mile southward along the road to Waldoboro. I could not trace the kame quite to the moraine, though it nearly reaches the end of one of the outlying ridges which are found west of the road. The marine clay here overlies the kame and appears to overlie the base of the moraine.

A short distance east of Benner's Mill the moraine curves around from east to northeast, and within less than two miles comes out to the road leading northward from Waldoboro to Union village. This road is made on top of the ridge for more than one mile, part of the way through a somewhat swampy region which would be difficult of passage but for the natural embankment. Here also the marine clay appears to overlie the base of the moraine. Approaching the east line of the town of Waldoboro this road is about one-eighth of a mile north of the moraine, which becomes lower and less continuous, and seems to end within a short distance from the line between Waldoboro and Warren. It ends within about one-fourth of a mile from the osar system which extends from Palermo to near Warren station on the K. & L. R. R. To the east lies a level country for a half mile or more, so that it is not cut off by a line of hills or other obvious barrier in that direction.

The country lying east of the Medomac river and north of the moraine is diversified by numerous low hills, or perhaps it had better be described as a rolling plain. I estimated that few if any of these hills rose more than about 100 feet above the surrounding level. The hills did not cause a gap in the moraine except at two or three points. The country rock weathers so rapidly that the glacial scratches had disappeared from all the exposed ledges observed. The direction of glaciation near the moraine therefore was not determined. Some large ridges and heaps of till are found about a mile north of the end of this moraine, but their origin is uncertain.



The elevation of the Waldoboro moraine is such that if it was deposited at the time when the sea stood at its highest level during the Champlain epoch, it must have been formed at a depth of from 50 to 175 feet below the surface of the water. I did not find a good section showing clearly the relations of the moraine and the marine clay. Excavation will perhaps be needed in order to determine this important point. In the absence of conclusive evidence as to the time of the formation of the moraine, we can only avail ourselves of indirect evidence. In general the moraine contains a much larger proportion of clay and fine material than the terminal moraines of the Androscoggin glacier, a fact which favors the theory that it was formed in the water where the ice confronted the ocean. There are hills to the south of the moraine high enough to have formed islands in Champlain time. If the ice met the sea at the place of the terminal moraine, both the ice and moraine would be partially protected by these supposed islands from the force of the Atlantic waves. If the moraine was deposited before the water rose, then it would twice be under the surf during the rising and falling of the sea. If so, then the protection of the islands must have been very perfect, for there are few signs of marine wash on the moraine. It seems more likely that the sharpness of outline of the ridge is due to the fact that it was deposited under the sea, and only once has been under the action of the surf. Other considerations might be stated which favor the hypothesis that the moraine was formed at a time when the sea stood at a much higher level than now, but discussion of the subject is postponed until after further study in the field. On the whole, I consider it probable, but not certain, that the ice here flowed into the sea at the time the moraine was being formed.

Several lines of high hills cross the state of Maine from S. W. to N.E., transverse to the line of glaciation. The low cols in these hill-systems often served for the passage of the kame and osar rivers, and they are also often bordered by many irregular masses of till. These are not steep, transverse ridges like those above described, but are somewhat gently sloped heaps of various shapes and they lie in various directions. As the interpretation is doubtful, no detailed account of them is here given.

Colorado Springs, December, 1886.

## ART. XL.—*Note on the enlargement of Hornblendes and Augites in Fragmental and Eruptive Rocks;* by C. R. VAN HISE.

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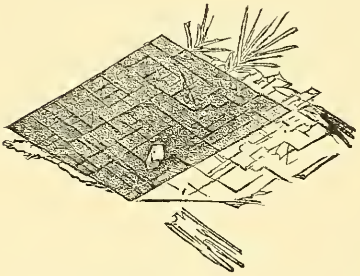
IN the number of this Journal for September, 1885, I described the enlargement of hornblende fragments in certain conglomerates of northeastern Minnesota, showing that grains of hornblende, after deposition in a sedimentary rock, may, under favorable conditions, continue their growths. The chief object of the paper was to show that enlargements of this sort may help to produce in fragmental rocks the condition ordinarily known as metamorphic. Entirely similar enlargements of hornblende, but in *massive eruptive rocks*, are described by Friedrich Becke in Tschermak's Min. und Petr. Mitth., vol. v, part ii, 1883, in a paper entitled "Eruptivgesteine aus der Gneissformation des niederösterreichischen Waldviertels." The following quotations and figures are from this paper: "Die primären compacten Hornblende-Krystalle sind sehr häufig von einer Rinde umgeben, welche aus strängeliger grüner Hornblende besteht, die ganz mit der Hornblende des Uralit übereinstimmt. In Querschnitten (fig. 1) beobachtet man die durch Kern und Hülle gleichmässig fortsetzenden Spaltrisse. Mitunter hat der so weitergewachsene Krystall andere Krystallflächen in der Prismenzone, als der Kern. In Längschnitten (fig. 2) sieht man den compacten Kern mit Bündeln parallel angewachsener Hornblendenadeln versehen, welche sich weiterhin zu divergirenden Büscheln auflösen." . . . . "Die Art des Auftretens dieser Fortwachsungen lässt keiner Zweifel, dass während der Ausbildung dieser Fortwachsungen mechanische Bewegungen innerhalb dieses Gesteins nicht mehr stattgefunden haben."

1



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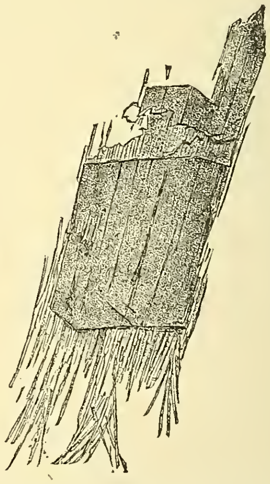

It thus appears that Becke discovered in 1883 the enlargement by secondary growth of individuals of hornblende in an eruptive rock, this change having taken place subsequently to the consolidation of the rock from the liquid state. In fragmental rocks the enlargement of hornblende grains has far greater significance because it explains, in part at least, the nature of the induration of a certain class of rocks.

In studying recently the eruptive rocks of the Penokee-Gogebic Iron-Bearing Series of Michigan and Wisconsin, I have met with cases of new growths occurring upon augite and hornblende which are corroborative of, and add something to, the observations made by Becke. The rocks in which these new growths have been found are altered diabases. In some specimens of these rocks the augite has largely changed into hornblende. In these cases in a portion of the individuals of augite the alteration of the augite is partial, while in the other portion it is complete. Ordinarily, as described by Irving,* Williams and others, a single individual of hornblende has resulted from one of augite, the two having the usual definite crystallographic relations. To this secondary hornblende the new hornblende has attached itself. There are here, then, two hornblendes, one of which is paramorphic to the augite, while the other is a new growth. The added hornblende has found room for itself, as in the case described by Becke, by penetrating the surrounding feldspars. Similar new hornblende is also found included in the partly decomposed feldspar in numerous small, fibrous, independent individuals. The new hornblende is of a pale green color; it is not strongly pleochroic; it shows often distinctly its intersecting prismatic cleavage. The crystallographic continuity of the paramorphic and new hornblendes, when the two are contiguous, is as plain as in the case described and figured by Becke, where, however, the first hornblende seems to have been original.

In other diabases from the same region the greater part of the augite is unaltered. Here nearly every individual of this mineral is surrounded by a sheath of hornblende. This hornblende has clearly formed subsequently to the consolidation of the rock, as is shown by the following facts: The hornblende cuts into the surrounding feldspar in the most irregular manner. The augite cores have the forms common in many diabases, being bounded by well-defined broken right lines, or lines somewhat curved, as the spaces left by the feldspars allowed.† Often the new growth has continued farther in places than in adjoining ones, and, as it went on, it has sometimes widened out, forming within the feldspar club-shaped protuberances of hornblende.

In longitudinal sections (fig. 3) the hornblende is more plentiful at the extremities of the individuals than at the sides.

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* R. D. Irving, this Journal, July, 1883, and Feb., 1884. Geology of Wisconsin, vol. iv, p. 663.

M. E. Wadsworth, Notes upon the Geology of the Iron and Copper Districts of Lake Superior.

G. H. Williams, this Journal, Oct. 1884, and Bull. U. S. G. S., No. 28.

Frederick H. Hatch, Min. und Petr. Mitth., vol. vii, pp. 75–87.

† In the greater number of these rocks the major part of the feldspar has crystallized prior to the augite, although in certain of them the augite and the feldspar mutually interfere to such an extent as to indicate that the augite began to crystallize before the feldspar had proceeded far in crystallization.

The terminations of these enlargements are sharply serrate. The constituent fibers at times are slightly divergent and usually cut deeply into the feldspar. Ordinarily the fine fibrous cleavage of the hornblende is coincident with the cleavage of the augite. However, the angles c : c in the augite and in the enveloping hornblende show their characteristic relations.

3

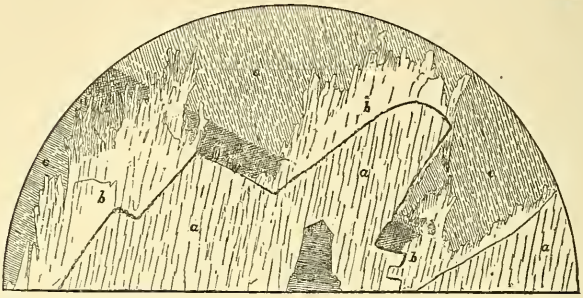

Fig. 3.—*a*, *a*, *a*, portion of an augite core; *b*, *b*, *b*, hornblende enlargements; *c*, *c*, *c*, feldspar.

4

In transverse sections (fig. 4) where the intersecting prismatic cleavages of the augite and hornblende are seen, their relations are such as to indicate that the ortho- and clino-pinacoids in the two minerals are parallel.

The crystallographic relations of the two minerals are, then, in both longitudinal and transverse sections, those well known to occur between augite and hornblende paramorphic after it.

University of Wisconsin, Madison, Feb., 1887.

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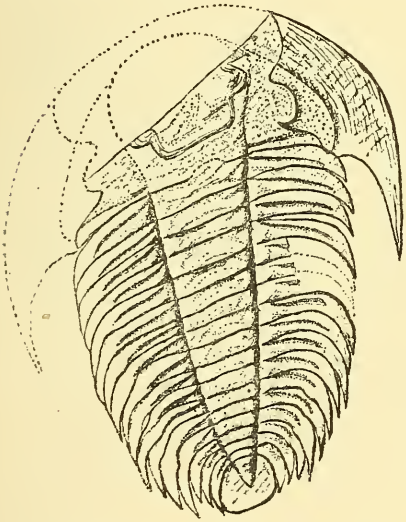
## Art. XLI.—*The great Acadian Paradoxides;* by G. F. Matthew.

In this Journal (vol. xxx, p. 73), the writer, in speaking of the occurrence of the great Welsh Paradoxides (*P. Davidis*) in the Cambrian rocks of Newfoundland, alluded to the fact that another gigantic species of this genus was present in the Cambrian basin at St. John. At the time when that communication was written, the St. John species was known only by fragments of the glabella, pleuræ and pygidium. An almost complete example has lately been found, from which it appears that the species differs from any hitherto described. Its nearest allies are *P. Bennettii* of Newfoundland and *P. Harlani* of Massachusetts, but it has not the "pendent ears" and abortive spine of the former, nor the long (sometimes extravagantly long) spine and round pygidium of the latter. It has a rather smooth test, and the eye-lobes are shortened and placed as in the two species named. It differs from *P. Bennettii* in being brachypleural in the adult stage, and from *P. Harlani* in having only seventeen segments in the thorax. It may be described as follows:—

### Paradoxides Regina.

A species of the largest size and having a very wide body.

*Head shield* greatly expanded, and having the genal angles produced into short spines; glabella broad and possessing two complete furrows; eyes rather short, situated opposite these furrows. *Thorax* with seventeen joints; having the axis very broad, and the ends of the pleura leaf-like, curved, but scarcely reflected, and having the three last joints shorter than the others. *Pygidium* subquadrate behind, with a small axis and with the lateral lobes expanded backward. *Hypostome* subquadrate behind, but having the posterior angles truncated, anterior lobe widely expanded laterally, and having the anterior margin expanded and widely extended.



The specimen is defective where the two anterior glabellar furrows would come, and so it is not known whether these are present or absent. The horizon is Band 1*c* of the St. John group. This species appears to be the largest trilobite which has so far been found in any country, being fifteen inches long and twelve inches across the cephalic shield. Professor W. C. Brögger calculated the length of an example of *Megalaspis acuticauda* found in Norway as sixteen inches (403$^{\mathrm{mm}}$), and the late M. Barrande gave the length of *Asaphus Barrandei*, found in France, as fifteen and a half inches (400$^{\mathrm{mm}}$), but these larger Asaphi are narrower in proportion than the Acadian trilobite.

Among Paradoxides the Acadian species is the largest known to the writer. With *P. Harlani* and *P. Bennettii* it constitutes a group of gigantic forms with more or less foliaceous, and curved rather than reflexed pleuræ, which the writer believes will be found to characterize elsewhere, as it does in Acadia, the Lower Paradoxides beds. From our present knowledge of these forms we indicate the two above named and *P. Regina* as independent species; but if connecting forms should be found, the Acadian and Newfoundland trilobites will stand as varieties of *Paradoxides Harlani*.

## ART. XLII.—*On the Kin of Paradoxides* (*Olenellus?*) *Kjerulfi*;[*] by G. F. MATTHEW.

THE following remarks are intended as a contribution to the discussion of the comparative age of the Paradoxides beds in Europe and America and the probable position of Olenellus in relation thereto. They are directed chiefly to the consideration of the allies of *Paradoxides Kjerulfi* Linrs., as upon the decision of this point partly depends the correlation of the Atlantic border Paradoxides beds with the Cambrian beds of the Hudson River and the more western part of America.

Mr. S. W. Ford, in an article "On the age of the Swedish Paradoxides Beds," in which he ably reviews the evidence as to the zoological position of *Paradoxides Kjerulfi*,[†] quotes the succession of the Swedish Paradoxides beds as given by Mr. Linnarsson in 1876, viz:

(6.) Strata with *Agnostus lævigatus*.
(5.) Strata with *Paradoxides Forchhammeri*.
(4.) Strata with *Paradoxides ölandicus*.
(3.) Strata with *Paradoxides Davidis*.
(2.) Strata with *Paradoxides Tessini*.
(1.) Strata with *Paradoxides Kjerulfi*.

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[*] In a communication published in this Journal. xxxi, 472, 1886, the writer stated that *P. Kjerulfi* occurred in Newfoundland, but on further examination of the material in which the trilobite so referred occurs, it seems doubtful if it is that species. The cheeks in the Newfoundland trilobite are free, whereas according to Dr. Brögger the cheeks of *P.* (*O.?*) *Kjerulfi* are soldered to the middle piece of the head shield; and there is no free cheek as in the typical Paradoxides. The example supposed to have been found at Kennebecasis River is, for the same reason, not *P. Kjerulfi*. Dr. Brögger has stated that the pygidium is unknown and probably small; but until this part is recovered and found to be of the same kind as that of the American Olenelli, we cannot with confidence speak of it as belonging to the genus Olenellus; I have therefore preferred to use in this article the generic name under which it was originally described. Dr. Brögger now gives *Wahlenbergi* as the specific name of this trilobite, but on referring to the place where this name is used it appears as one of a list of species, but is not accompanied by figure or description.

[†] This Journal, vol. xxxii, No. 192, Dec., 1886.

The position of No. 4, or the beds carrying *P. ölandicus*, was said to be doubtful, as not determined by observed sections of the Cambrian beds; it is however the horizon assigned by Mr. A. Sjögren the describer of the species.

Having observed the stratigraphical position of the Acadian representative of this species (*P. lamellatus* Hartt) to be below the beds which carry the Acadian species allied to *P. Tessini* the writer ventured to inquire of Professor Lindström of Stockholm what the position of *P. ölandicus* was, and by a letter lately received from that gentleman he learned that "in 1875 Professors Nathorst and Dames found the zone of *P. ölandicus* to be *older* than that of *P. Tessini.*"

The importance of this fact is the greater from the many points of affinity between this species (*P. ölandicus*) and *P. Kjerulfi.* Mr. Ford in his valuable article above referred to, speaks of "a number of strong points of resemblance" between these species, but does not specify the point wherein the relationship consists, but some of the more salient ones will appear from what follows.

If it could be shown that the lower part of the Paradoxides beds in America is characterized by a group of species which differ from the typical Paradoxides found higher up, an advance would be made in distinguishing the several parts of the Cambrian system on this side of the Atlantic. That there is such a group at the base of the Paradoxides zone in Europe and America is now I think sufficiently clear; and some of the points of structure which mark it are the following: *The test is granulated, the pleural grooves are short and strongly marked, the glabella and rachis are prominent, the fixed cheeks are narrow, the eyelobes are shortened and drawn in at the base, the genal spines are short (and channelled on the upper side?).**

In *P. Kjerulfi* the pygidium is not known; in *P. ölandicus* the pygidium has four points; in *P. lamellatus* the pygidium has two points.

In the second and third species the pygidium is that of Paradoxides, not of Olenellus, and it is a matter still to be determined whether the first named species is a true Olenellus in all respects, and especially as regards the pygidium.

In *Paradoxides Acadicus* we have another primitive type, but not of the same section in Paradoxides as those above named. The recovery of the parts show that it possesses the long sigmoid pleural furrow of the more typical forms of the genus and not the comma-shaped (almost pear-shaped) furrow of the three species above named. It has not yet been found so low down in the Acadian (Cambrian) measures as some other

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* They are channeled in *P. Kjerulfi* and *P. lamellatus.*

species; but its companion-form in Europe has been found to be associated with *P. ölandicus* whose place is next above *P. Kjerulfi.*

It is somewhat remarkable that *P. Eteminicus*, which is the American equivalent of *P. rugulosus*, should be one of the first species of Paradoxides to appear in the Acadian region, while in Scandinavia it is not known until after the appearance of *P. Tessini*, a species which is represented in Acadia at a higher level by *P. Abenacus;* possibly its later appearance in Europe is due to the higher measures presenting a more favorable habitat. In Acadia gray shales are followed by dark shales, but in Scandinavia the conditions were reversed, as the shales with black streak are the oldest.

The succession of the Paradoxides in the St. John Group, as far as it has been ascertained, is the following:

| | Division I. | | | | European Representative. |
|---|---|---|---|---|---|
| | Band *b* | Band *c* | | Band *d* | |
| | | 1 | 2 | | |
| Paradoxides Kjerulfi* | ? | — | — | — | P. Kjerulfi. |
| Paradoxides lamellatus | — | † | — | — | P. ölandicus. |
| Paradoxides Eteminicus | — | † | † | — | P. rugulosus. |
| Paradoxides Micmac | — | † | † | — | P. palpebrosus? |
| Paradoxides Acadicus | — | — | † | — | P. Sjögreni.<br>P. Harknessi? |
| Paradoxides Regina‡ | — | — | † | — | P. spinosus? |
| Paradoxides Abenacus | — | — | — | † | P. Tessini. |

Of the six divisions of the Paradoxides beds of Sweden, given by M. Linnarsson, the three oldest have been recognized in the St. John Group; the presence or absence of the three higher remains to be determined.

In regard to the form of the glabella in *P. Kjerulfi* there seems to be considerable diversity; in those from the green slate of Tomten in Norway figured by Linnarsson the front is wider than the base; but in those figured by Kjerulf the front lobe is as narrow or narrower than the rest of the glabella; one of Professor Kjerulf's figures show *P. Kjerulfi* to be brachypleural when half grown.‡

St. John, N. B., Dec., 1886.

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* Fragments have been found which may belong to this species.

† A gigantic species intermediate between *P. Bennettii* and *P. Harlani.*

‡ Om Skuringsmærker, etc., II. Sparagmitfjeldet (Christiania, 1873), p. 83, fig. 3.

## ART. XLIII.—*On Taconic Rocks and Stratigraphy, with a Geological Map of the Taconic region* (Plate XI); by JAMES D. DANA.

### Part II. The Middle and Northern Part.

(Continued from p. 276 of this volume.)

THE map of Middle and Northern Berkshire mentioned in the preceding part of this paper (p. 270 of this volume), is herewith published. For detailed explanations of the symbols and letters used on the map, the reader is referred to p. 206 of volume xxix (March, 1885) of this Journal.* The map illustrates fully the points presented on pages 271–276: (1) the eastern limestone with its intercalated and often isolated ridges of schist; (2) the passage of the eastern limestone belts into the western—as that of the Vermont through North Bennington, into the Hoosac and Petersburg area, that of the Vermont, through Williamstown and Hancock, into the Lebanon and Canaan area, and the near approach of the latter at Canaan to junction with the Stockbridge limestone in West Stockbridge; (3) the variations from normal directions and continuity in the belts, apparently due, for the most part at least, to earlier topographical conditions—exemplified (1) in the Williamstown and Clarksburg region; (2) in the town of Bennington; (3) in the

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* For the convenience of the reader, the following explanations of the lettering on the map and the symbols in the figures beyond, are here repeated in brief. Q, quartzyte; M, mica schist; M̶, (not used before) hydromica schist; Gn, gneiss; A, Archæan. In the figures, a dot stands for *quartz*, a hyphen for *mica*, and a cross (+) for *feldspar*, a *long hyphen* — for hydrous mica; dots for quartzyte; alternating dots and hyphens · - · - for mica schist; alternating dots and long hyphens · — · — for hydromica schists; and alternating dots, hyphens and crosses (· - +) for gneiss; alternation of four dots with a hyphen (· · · · · · · · · ·) for micaceous quartzyte; alternations of two or three dots with a hyphen (· · · · · -) for quartzytic mica schist; the lines alternate with a rule, for a bedded or schistose rock as mica schist, hydromica schist and bedded quartzyte; and groups of 3 or 4 lines with rule between, for gneiss or slightly bedded quartzyte. In the section the dip of the lines is the true dip; an unfilled space in the inner part of a figure of a section signifies that the dip was obtained from exposures over the surface, and not from an actual transverse section; while an unfilled interval between the lines indicates a concealment by soil, and the figures added, the width of the covered surface; the end of a figure to the right is always the eastern or northern end; a circle with a letter inside means a quarry or ore-bed, and the letter indicates the material afforded: Fe, the iron-ore, limonite; Q, quartzyte as hearthstone or sand. The map was plotted on the maps of Beers's Atlases, which, while of great value for the purpose, have not the accuracy of a thorough survey of the region; and hence some unavoidable errors are introduced which I could easily make right on a new map of equal size (mostly two inches to the mile), and having all of its details, including the positions and names of owners of all houses which aid in marking localities or as a base for measurements. Some of the areas, as the narrow one of schist in New Alford, might take a more probable form on such a map, since the roads have been the chief means of fixing the courses of the outlines. As in the map of Southern Berkshire, it was not possible to adjust to the Massachusetts map the lines on the portion of Connecticut added to it, so it is as regards the addition of Vermont. Scale ½ inch = 1 mile.

eastward extension of the Pittsfield limestone and the quartzyte south of it, and (4) in the Bear Mountain region with Monument Mountain west of it; the localities of Archæan being recognized by the presence of hornblendic rocks, sometimes zircon-bearing and chondroditic limestone, from eastern Tyringham northward and marked on the map by the letter A. The colored portion of the map is that covered by the limestone.

The next subject is:

### 2. *The Limestone and the conformably overlying strata.*

1. *Kinds of rocks and their distribution.*—The *kinds of rocks* observed in central and northern Berkshire, with the adjoining border of New York, are the same as in the southern portion, already considered, except that the mica schists north of the town of Sheffield have not yet been found to be staurolitic.

The limestone is mostly dolomitic, except to some extent (as made known by analyses in the Geological Report of Professor E. Hitchcock (1841, p. 80), in the more western towns of Berkshire. The same analyses show that the beds are rarely true dolomite, but partly calcite, by having a deficiency of magnesia, and that consecutive beds vary much in constitution. The subject needs investigation.

The rock varies in grade of crystallization, being coarsest (*a*) to the southward, and also (*b*) to the eastward. It varies in color, being usually white to the eastward, often gray in the more western belts of Berkshire, and generally gray west of Berkshire. It varies in impurity, being often very micaceous in the vicinity of the schist ridges, so as sometimes to be deceptive, and very quartzose near the quartzyte. Tremolite and white pyroxene, abundant minerals in the Sheffield limestone and its continuation southward, (to New York Island, if all is the same limestone, as is probable,) occur also in belts of Monterey, eastern Great Barrington, Tyringham and Lee; and minute tourmalines are occasionally present.

The schists are hydromica schists to the westward and mica schists to the eastward, along with indefinite intershadings through chloritic hydromica schists. Hydromica and chlorite are hydrous species, so that the difference in the metamorphic schists mentioned is largely a difference as to the presence of water; a hydromica containing 4 or 5 per cent (but like mica in other constituents), and chlorite containing 12 to 14 per cent. In the Greylock range the chloritic hydromica schist passes locally into a hydromica gneiss, which I designated in 1877 a protogine variety of gneiss.*

The more western schists west of Canaan, N. Y., are much like a glossy roofing slate, showing in the color no evidence of the presence of chlorite, though it may contain much of it.

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* This Journal, II, xiv, 258, 260.

In the main Taconic range, along the Massachusetts boundary, the schists are chloritic hydromica schists, and on the eastern sides often garnetiferous, especially to the southward. In an east and west line through South Williamstown and Greylock they continue to be chloritic hydromica schists from the New York boundary to the eastern slope of Greylock, or seven miles, where are some portions that might be designated true mica schist; a mile and a half east of Greylock summit, near the east foot of the Greylock mass, the rock would be ordinarily called mica schist; and this is true, also, farther north, abreast (west) of the village of North Adams, as seen at the little railroad tunnel, although the mica is slightly greasy to the touch.

The mica schist is sometimes muscovite schist, often biotite schist, but generally both micas are present.

Looking at Berkshire as a whole, in the part of it *east* of a straight line drawn through the county, southward, from Greylock to the northeastern corner of Mt. Washington in South Egremont, about S. 15° W. in course, the schists are nearly all mica schist, while to the *west* of the same line, they are nearly all chloritic hydromica schist. A ridge in Lanesboro (which is nearly on this line), has the schist intermediate between hydromica and mica schist, inclining most to the latter. This line throws to the *west* the high ridges, Tom Ball and Maple Hill, of West Stockbridge, which are of chloritic hydromica schist, and to the east, ridges near by on the east of these. But to one going over the region the transition would be found to be a very gradual shading from one to the other, some portions at the northeastern foot of Tom Ball almost meriting a place with the mica schist.

Fifteen miles south, in Canaan, N. Y. (nearly west of Pittsfield), the schist *west* of the limestone is a very thin, slaty, glossy roofing slate; that of the ridge east of it, north of Queechy Lake, a coarse chloritic hydromica schist, except near the boundary of Lebanon (at B, on the map, a high point called Douglass Knob) where it becomes quartzose, a very hard chloritic quartz rock, not schistose; the high knob is the source of the famous bowlder trains that cross Richmond into Lenox, first studied out by Dr. Stephen Reid, of Pittsfield.

East of the N. by E. and S. by W. line drawn from Greylock to the northeast base of Mt. Washington, the larger part of the mica schist is extremely arenaceous; and it often graduates imperceptibly into a bedded quartzyte, or alternates with strata of quartzyte, both that of the thin-bedded kind, and of the hard and massive, precisely as described in Part I of this paper for Southern Berkshire and the adjoining part of Connecticut; and, as there, the rock usually contains minute tourmalines. The narrow ridge entering the town of Great Barrington from Sheffield west of the railroad, consists of bedded quartzyte slightly micaceous. The ridge just north of this, situated to the west of the village of Great Barrington, consists partly of mica schists, of nearly normal type, though over-arenaceous, and largely of micaceous bedded quartzyte, with also much hard quartzyte especially to the north; and just northwest, a low quartzyte area extends to the base of Tom Ball; while northeast are others of quartzyte. North of Housatonic village quartzyte beds alternate with true mica schists. Monument Mountain has two strata of hard quartzyte with quartzytic mica schist between them; but the latter passes into a massive fine-grained micaceous rock, gneiss-like in aspect, which is calcareous (effervescing with acid). East of Great Barrington, a very similar gneissoid rock, somewhat calcareous, is the chief material of the lower part of a high ridge, and shows out gneiss-like in the great tumbled masses at the base of the bluff at the north end and where quarried; at the summit, the ridge is bedded micaceous quartzyte, passing into micaceous or quartzytic mica schist.

The quartzytic mica schists and micaceous quartzyte constitutes also Rattlesnake Mountain in Stockbridge and other ridges farther north to Adams. But for details I refer to the map.

A microscopic examination of thin slices of the gneissoid rock of the ridges east of Great Barrington, and of that in Monument Mountain, shows that, besides much quartz, considerable mica and a little calcite, it contains also considerable orthoclase, and merits the name of a quartzytic gneiss or a gneissic quartzyte.

In Tyringham there is a well characterized gneiss overlying the limestone.

The destructibility of the bedded quartzyte and the quartzytic mica schists is generally a marked peculiarity. It is very common to find decay extending down one or two hundred feet, concealing deeply the *solid* rock. The decay sometimes leaves a hillside covered with loose blocks of hard quartzyte, derived from harder layers, or isolated harder portions, in the strata. The porosity of the rock renders it permeable by waters to great depth; and then the presence of a little removable calcite or orthoclase makes destruction easy.

2. *Limits between the limestone and other areas.*—The approximate limits of the limestone areas are in general easily obtainable, as outcrops are numerous. But there are many regions where, owing to the covering of drift and the extensive decomposition of the rocks (the arenaceous schists and the bedded quartzytes), the uncertainties are great.

The first of these sources of doubt, as I have already said, affects widely the west sides of hills and mountains, the side that faced obliquely the moving glacier. The other may occur any where. Rattlesnake Mountain, in Stockbridge, is an example of an obscuring of the north, west and south sides by both causes. Maple Hill, in West Stockbridge, has much of its west and north sides under deep drift—250 feet at an ore-bed on its northwest slope. These are examples. Long experience in the region helps one to probable conclusions in many such cases, but in others, doubts will remain. In Adams the limit at the west foot of the Hoosac Range is one of the worst cases—a region of half a mile or more intervening without outcrops; and between the central quartzyte belt of the town and the range, it is still a question with me whether the quartzyte formation with its arenaceous mica schist may not extend for a considerable distance quite to the base of the mountain. The first rock encountered on the ascent of that part of the mountain is a light colored very arenaceous mica schist, like beds in the quartzyte area, and also like much of Hoosac Mountain elsewhere. The Clarksburgh region is one of much doubt on account of the few outcrops.

The quartzyte bowlders over a region are an assistance toward a knowledge of what is below, since they are often not drift bowlders, but, as explained above, masses left where they now are by decomposition. But again they are very deceptive evidence; for the region just mentioned, east and southeast of Adams, has striking examples of an abundance of quartzyte bowlders over the surface where the rock below is limestone.

### 3. *Stratigraphic relations.*

Limestone, hydromica schist, mica schist and quartzyte, and intermediate gradations between these, being the rocks within the limestone limits, the question is now as to their stratigraphical relations.

1. *No general overthrust faulting.*—The facts with respect to the relative positions of the rocks here set forth require no allowance for possible overturns except such as affect single or a few associated folds. That there has been no great overturn affecting the region as a whole, or over a large part, is proved by the following characteristics of the region and its rocks.

The gradual transition in *kinds* of rocks and in *grade of metamorphism* from east to west over the Taconic region; the like grade in the metamorphism of the limestone and the schist adjoining it, through all parts of the region; the absence of eastern rocks from the western part, and of western from the eastern; the gradual transitions in many cases from limestone to schist through impure micaceous and sandy limestones; these are all indubitable evidences on this point.

Not only are the transitions from limestone to schists marked by micaceous, arenaceous, and other similar impurities, but also in many places by ferriferous conditions in both the schist and limestone, and preëminently in the limestone which occurs adjoining the schist at intervals for long distances in western Berkshire (in Lanesborough, Richmond, and West Stockbridge and less abundantly in other towns), as well as in Vermont to the north and Connecticut and New York to the south—the limonite beds attesting to it. This is good evidence that the beds are natural in sequence; that there has been no great lateral move by a thrust-fault over the region of Berkshire and eastern New York, disturbing the order of stratification.

2. *The true stratification is not disguised by foliation, or slaty cleavage, or other effects of pressure.*—Questions as to slaty cleavage, foliation, schistosity, are not a source of serious difficulty in the Taconic region. If the rocks were all slates, all mica schist, all hornblende schist, or all limestone, that is, were wholly of one kind, the uncertainties as to bedding or not might be well-nigh insurmountable. But where the three kinds are together in alternating layers or strata, the doubts disappear, for there is then distinct stratification between layers or strata of different kinds in constitution, and the study of it is like the study of stratified rocks in non-metamorphic regions. If in such cases the schistosity of a schist is parallel to the planes of junction between the layers or strata of the different kinds, its planes are essentially those of bedding whatever their origin; and this is eminently manifest in Berkshire where one of the rocks is limestone. Alternation in strata or layers of different kinds of rocks cannot be a result of pressure. The principle presented is as true for Archæan rocks as for any others and affords a criterion which is of great value in their investigation.

For the reasons stated, the Taconic region is as much a region of stratified rocks as that of western New York. It has its *strata* of limestones, sandstone (quartzyte) and schist, the study of whose positions is stratigraphical study, far outside of microscopic investigation, though deriving great aid from such investigation as regards the constitution of the beds, metamorphic changes, and other points. The planes of junction between the strata are open to observation. And it is wonderful how very generally the planes of lamination in the schist correspond in position with these planes of junction. It is so general that the geologist of the region comes naturally to the opinion that it is exceptional for foliation to be any other than lamination conformable to the bedding. Stratification in the region stands out with the distinctness that characterizes ordinary regions of stratified rocks, and the anxious and sceptical petrographer has no occasion for his doubts, or for his expectation of settling all such cases with the microscope.

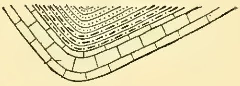
In many places, moreover, the strata are piled to mountain height while still nearly horizontal in the position of the beds. Such nearly horizontal lamination is not due to pressure attending uplift—the source of foliation or slaty cleavage; if to any pressure, it is to vertical, like that of the gravitating mass, or that pressure to which a shaly structure is attributed.

3. *Stratigraphy of the region.*—The question in this region of upturned, flexed and crystalline rocks, is, as in Part I—

Which is normally the upper stratum, the limestone, or the schist? Are the schist ridges usually synclinals or anticlinals? The fact that in the southern part of the Appalachians—the Alleghany Mountains—the *ridges* are usually synclinals shows that the view as to their being synclinals in the Taconic region, if it be sustained, is not exceptional.

*a. Characters of the flexures.*—The flexures over the area have usually the north-by-east direction or strike characterizing the main Taconic range. They generally, and probably always, have the axis inclined instead of horizontal—sometimes to the northward and as often to the southward, the two kinds being necessarily accompaniments in a complex system of warping (as not badly illustrated in the sleeve of a coat at the elbow-bend inside). The inclination is sometimes indicated by the form of the ground-plan of the schist ridges—that is by its widening from one end to the other. An example is seen on the map, west of the village of Great Barrington; the area narrows southward; and it necessarily follows that the axis of the flexure inclines to the southward if it is an anticlinal and to the northward, if a synclinal. Two similar areas occur in the town of West Stockbridge, those of Maple Hill and Tom Ball (the latter extending into the town of Great Barrington); others in Lee and Pittsfield.

1



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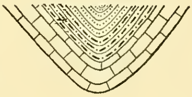

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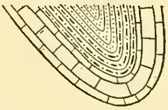

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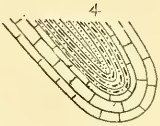

The dips, moreover, often indicate the precise kind of flexure. At the narrow end, they are usually eastward on both the east and west sides, as in a careened trough, as in the annexed (fig. 4); but at the other, while eastward on the west side, they are often *westward on the east* side, indicating a *tray-like synclinal* (fig. 1)—the whole fold being, therefore, an inclined tray-like synclinal with the narrower end of the synclinal, or that where the effects of pressure were greatest, careened or overthrust. The succession of figures 1, 2, 3, 4, represent sections of a mountain ridge having a broad tray-like synclinal structure (1) at one end and a careened synclinal (4) at the other, with two of the intermediate conditions in 2 and 3; and if the series of figures is viewed upside down, they then serve to illustrate the corresponding variations in an anticlinal flexure. (These figures are repeated on the map and numbered 52).

*b. Descriptions of Sections.*—The figures on the accompanying map of Berkshire and in the text beyond represent some of the many sections observed in the region: and, as already explained, they indicate also the kinds of rocks. The descriptions of the sections, as well as the numbering, here commences at the south. Numbers 1 to 21 are those already published in Part I. Of the 30 in this Part, figures 22 to 30 have appeared in my earlier papers on Berkshire, and are presented at this time only on the map; and I would refer to those papers for details with regard to the stratification.*

Section 22 (map). In the Konkaput Valley, on its northeast side, at the southwestern base of the high land from which Bear Mountain rises; part of the section is south of the road, and the rest north of it; the latter part terminates in "Devany's hearthstone quarry" (not now worked) which is situated a little to the eastward of the line. The several alternations of quartzyte and mica schist with limestone, the micaceous character of much of the quartzyte, and the small dip northeastward are the interesting points.

Sections 23, 24 (map). On the southwest side of the same Konkaput Valley opposite the locality of the preceding section, at the base of the high ridge. In section 23, the limestone does not appear at bottom, the soil covering it; but farther south, along the base of the same ridge, sections occur like 24, showing the true relations of the limestome to the quartzyte and the overlying mica schist; the rocks are like those of section 22, but the dip is reversed as if opposite parts of an anticlinal. The localities are in the southeastern part of the town of Great Barrington.

Section 25 (map). Just *east* of the Housatonic River at the village of Great Barrington, extending eastward from the limestone in the valley at the base of the high ridge (with a fault separating it from the rest), to the top; a gneiss-like rock below, a micaceous quartzyte at top.

Section 26 (map). *West* of the village of Great Barrington—a ridge consisting of arenaceous mica schist, micaceous quartzyte and bedded and non-bedded quartzyte. Limestone makes the western high part of the ridge opposite the village. Unfortunately, no section of the north end of the ridge is open to view.

Section 27 (map). Section 27 crosses a low N.-S. ridge just northwest of Vandeusenville (three miles north of Great Bar-

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* This Journal, vols. v and vi, 1873, and xiii and xiv, 1877. The locality of each section is marked on the map by large numerals corresponding with the numbering of the figures here used.

rington, and east of Long Lake Valley), which consists mostly of quartzyte, but has quartzytic limestone within it, and limestone on the west side and arenaceous mica schist near the east base in Williams River Valley. At the outcrop the limestone portion of the quartzyte, as developed by erosion, shows that the dip of the quartzyte is beyond question conformable to that of the limestone.

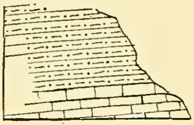
Sections 29, 30 (map). Section 29 crosses the northern part of the schist ridge Tom Ball, where it is a tray-like synclinal, and 30 the middle portion where, as farther south, it is a careened synclinal. The number 29 on the map (back of a house near the bridge over the river) shows where the westward dip of the limestone underneath the schist may be observed. At this place, on the *east* side of the river and railroad, the limestone dips eastward, indicating an anticlinal in it crossing the valley. The high ridge of West Stockbridge called Maple Hill commences with a high eastward dip just north of where Tom Ball ends, and widens northward.

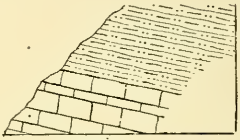
Section 31. On the north side of an east-and-west road a mile north of Housatonic Village (a road leaving the Housatonic Valley nearly opposite the "Old Furnace." It shows a low limestone anticlinal with mica schist covering either side. A short distance to the northward of the locality, the middle and eastern sides are cut away by denudation; the western continues northward as a ridge having a top of schist and a high base of limestone. both dipping westward as in the section. Southward the limestone disappears *beneath* the schist, the eastern part of which dips eastward toward Monument Mountain (only a mile distant on the east of the Housatonic) and becomes apparently the lower schist of the west end of the mountain with limestone beneath it.

To the southwestward of the above (see map) occurs a low narrow ridge which consists of quartzyte, and corresponds apparently to the overlying quartzyte of the same (west) part of Monument Mountain; and on its west side it is mica schist, answering to the schist of the mountain overlying the same quartzyte. The same rocks outcrop farther south through, and by the west side of Housatonic Village.

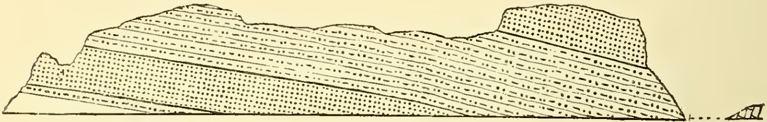
Sections 32, 33. On the road between Glendale and the Williams River Valley in North Stockbridge, and north side of road, at the south end of a spur of Lenox Mountain. Section 32 shows the very nearly horizontal position of the schist (a hydromica schist that approaches closely mica schist) and underlying limestone. Nearly the same dip may be seen farther west where the road descends into Williams River Valley. The limestone extends up 200 feet above the valley on the steep side of the mountain, and a railroad runs near the junction; and near the Fuarey quarry, section 33 was taken, showing the dip of the limestone under the schist. The synclinal character of Lenox Mountain, and the tray-like character at the south, is sustained by the sections; and this indicates that the limestone of West Stockbridge and Stockbridge are the same continuous stratum; a fact further apparent from their actual continuity to the northward in the town of Pittsfield.


31. 1 m. N. of Housatonic Village. W. of "Old Furnace"

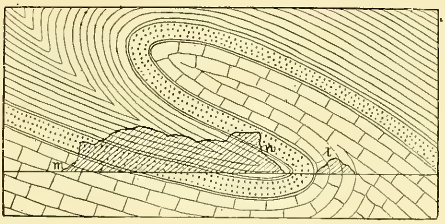

32. W. of Glendale.


33. W. Stockbridge, Fuarey's Q.

Section 34. Through Monument Mountain from the east side of the Housatonic River, at Housatonic village, in a southwest direction, nearly to the road from Great Barrington to Stockbridge. It gives the true dip at the east and west extremities of the section, and the mean dip of the intermediate portion; also the dip of the limestone at a quarry to the east of the eastern foot, near the Stockbridge road. It has two masses or strata of quartzyte with arenaceous or quartzytic mica schist between, and a thin bed of the same schist underneath the western quartzyte. No exposed section shows the rock underlying the western lower schist; but the dips of the schist to the westward of the river, with the underlying limestone, as explained above (p. 401), leave little doubt that the limestone passes beneath the mountain. The upper and lower quartzyte may be the same stratum in an overthrust fold as represented in the following figure. In that case, the limestone off the east end of the mountain is a part of the underlying limestone at the upward bend. The position of the quartzyte and mica schist strata west of the mountain and of the Housatonic River harmonizes with this view, as shown in the explanations already given (p. 401). A line drawn from the elevation


34. Across Monument Mtn., Southeastward from Housatonic Village to Stockbridge road.

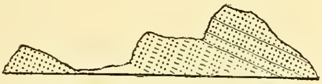
east of Great Barrington southeastward to the locality in the Konkaput valley affording section 23, is parallel to the Monument Mtn. section, and about three miles distant; it is similar in rocks and small dip, but reversed in dip, and in having the limestone at the *west* end nearly vertical in bedding. They seem to be counterparts, in the system of flexures of the same rock strata.



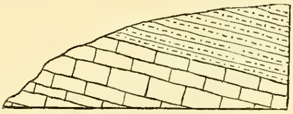
Monument Mtn: Ideal Section.

While the above view of the flexures affords a sufficient explanation of the stratification, it may not be the right one. There may be actually two distinct beds of quartzyte, as the figure represents; or possibly, the beds may be faulted at the middle of the section, and a displacement sufficient to make *apparently* two beds of quartzyte out of one; and this last view has in its favor the fact of much irregularity of dip on the line near the top. Again, there may be a reversal of the fold, making the quartzyte underlying quartzyte or Cambrian, and the schist of the mountain an *inferior stratum of the same formation*, with the limestone above the quartzyte and also an overlying stratum of schist.

Sections 35, 36. From the village of Lee. Section 35 runs eastward through the western and larger of two nearly parallel areas starting from a point near the M. E. church in the village. Hard quartzyte is overlaid by arenaceous or very quartzytic mica schist, and this again by quartzyte. Section 36 is from the western side of a more eastern ridge, just east of the village; it is remarkable for the absence of quartzyte, and the normal character of the mica schist, notwithstanding the nearness and close relations of the two areas. At the top of this ridge the schist bends over rather abruptly and becomes nearly vertical. It may be faulted.

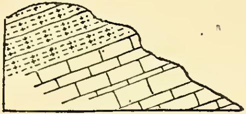


35. Village of Lee, E. of Meth. Church.



36. East of Lee

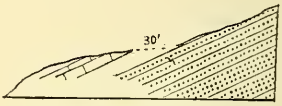
Sections 37–39 in Tyringham. Section 37 is on a line extending nearly westward from Tyringham village to the summit of "Cobble Hill" which stands in the valley near the village. Fig. 39 is a view up the valley, looking southward, showing the hill (at *c*) in the valley. The limestone dips beneath mica schist and gneiss, and the latter is the predominant rock.


37. Cobble Hill, Tyringham.


38. W. of Cobble Hill, Tyringham.

The limestone and schist of Cobble Hill extend westward, and are the rocks at a high level (300 feet or so) on the west side of the valley just south of an old Shaker establishment; and they extend from that place northward at about the same level all the way to South Lee, keeping nearly the same high level. At a point a few rods south of the Shaker establishment (now a summer boarding house) the limestone and schist outcrop on the road side, as in section 38, the former disappearing *underneath* the latter; but whether *normally* underlying or not is an undecided question.

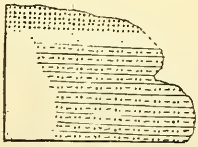
39 Tyringham

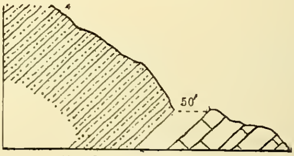


40. Southern part of Lee.

On the *east* side of the Tyringham valley the limestone *overlies* quartzyte or gneiss, and is not found anywhere much above the level of the valley plain.

Section 40. At the foot of the east slope of Tyringham valley, in South Lee, where bedded quartzyte dips westward at a small angle, crossing the road; but at one place, just south of this crossing, in the field, the limestone is seen overlying the quartzyte with similar westward dip and nearly the same angle.


41. E. p't of Wash., E. of Dewey's



43. S. Mountain, Pittsfield.

Section 41. On the western border of the town of Washington, west of the Hearthstone quarry, and south of the road from Dewey's Station.* A large outcrop of arenaceous mica schist

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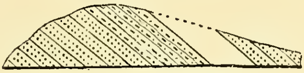
* On the map, fig. 41, the location of the section is wrongly stated to be *west* of Dewey's Station, instead of east.

with quartzyte, the rock of the region, above. Only a few feet without rock intervenes between the schist and quartzyte.

Section 42. In Washington, near Ashley Lake, quartzyte and mica schist in contact, with like dip.

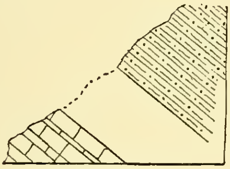


42. Ashley Lake, Washington.

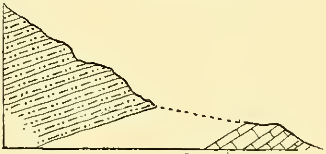
Section 43. At the north foot of South Mountain, south of Pittsfield, near the road, where there has been quarrying. The westward dip indicates the synclinal structure of the mountain.

Section 32 (page 402) represents well also a section at the southwest base of Sugar Loaf Mountain in New Ashford.

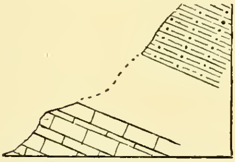
Sections 44–48. These sections in Adams, North Adams and Williamstown bear on the question as to the synclinal structure of Greylock. Section 44 represents the limestone and schist at the *east* base of Greylock, in Adams, showing the westward direction of dip and its small angle, sustaining the observations of Prof. Emmons and Prof. E. Hitchcock.



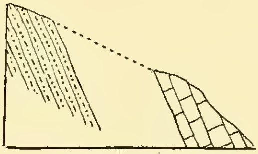
45. W. side of Graylock, at the Hopper, Williamstown.



44 E side of Graylock Section, W. of Adams.

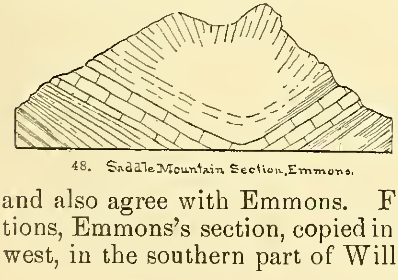


46. Same as 45, but S. of Entrance.

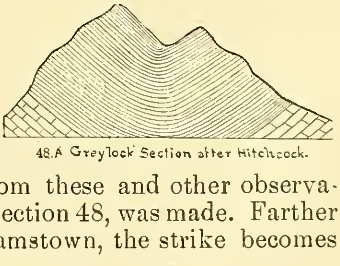


47. West of N. Adams.

Sections 45, 46 are from the western base of the Greylock Mountains, in Williamstown, at the entrance to the Hopper, and also agree with Emmons. From these and other observations, Emmons's section, copied in section 48, was made. Farther west, in the southern part of Williamstown, the strike becomes



48. Saddle Mountain Section, Emmons.



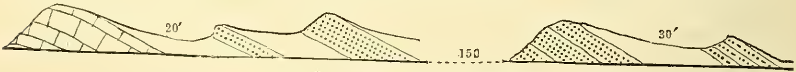
48.A Greylock Section after Hitchcock.

nearly east-and-west, and the dip southward; but this is true also of the schist, so that the conformability continues. This is true also to the north, as the T-shaped symbols on the map point out.

Abreast of North Adams, the dip of the limestone and schist is as given in section 48, the dip being eastward; and between this point and the locality of section 44, the dip varies to vertical and thence to westward as in that section. The facts make Greylock a broad tray-like synclinal at the south.

The synclinal character of the Greylock mass is manifest also from its high limestone basement which it has on both sides (except for half a mile, in the line of the range, between N. Adams and Williamstown), that is all the way from south of the Hopper, northward to within a short distance of the Notch road, nearly south of Braytonville; and then abreast of Adams for about three miles, the limestone has this great height above the valley, like a high substructure of 400 to 500 feet; southeast of Blackinton, by aneroid nearly 500 feet. The lower 400 to 500 feet of the Hoosac valley consequently were cut down through limestone. The upper limit of the limestone is, consequently, about 1150 feet above the sea-level; and this is nearly one-third of the whole altitude of Greylock—3,505 feet. The high limestone basement of Greylock in N. W. Massachusetts has its counterpart in the similar high basement of Mt. Washington in S. W. Massachusetts, and that of Mt. Anthony in Bennington, Vt.

Section 49 crosses the road on Stone Hill, Williamstown, where the limestone and quartzyte outcrop together. The limestone, quartzyte (the chief rock of the hill) and the black siliceous slate conform in angle of dip along the surface with only short intervals between the outcrops. Whether there is a fault or not between the limestone and quartzyte I found no section for determining. Deer Hill, south of Stone Hill, consists of arenaceous or quartzytic mica schist. Bald Mountain, between Williamstown and Clarkesburgh, is of quartzyte with some schist, as described by Emmons; and a prolongation of it appears to extend south of Braytonville into the north end of the Greylock mass, along the ascending road (but chiefly on its eastern side) for a mile.*



49. Across part of Stone Hill, S. of Williamstown.

Section 50. At the northwest base of Mt. Anthony, in Bennington, Vermont. At the eastern base I found the limestone and schist to dip westward corresponding in position

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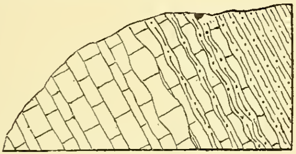
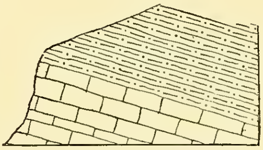
* The letter Q, which should be here on the map, is by oversight omitted.

very nearly with that of section 44 (Eastern Greylock). The synclinal character of the mountain, which is here sustained by my observations, was determined by the Vermont Geological Survey, one of whose sections passes through the mountain. An unpublished section by Prof. James Hall, made "about 1845," first described in 1854 (in this Journal, an engraved plate containing this among its sections having been sent by Mr. Hall to the writer) shows similar dips on the two sides. Mt. Anthony is, like Greylock and Mt. Washington, one of the more elevated summits of the Taconic range, the height being 2,606 feet. Mr. Hall's plate of sections also includes one of Mt. Washington, and sustains the synclinal character of this mountain. It is a further interesting fact that Mt. Anthony has on its north and east sides a similar high limestone basement; its height is about 400 feet by estimate above the valley at its east base.


51. Berlin, N.Y., East of river.


50. N.W. f't of Mt. Anthony, Bennington.

Section 51. The locality of this section is in Berlin at the west side of the Taconic range; it shows the slate and limestone in alternations at their junction, with the bedding somewhat contorted. The section conforms to all sections on the west side of the Taconic range in its eastward dip, and may be taken, with that at the western base of Mt. Washington, as a representative section. Other sections might be added from my note book from all parts of Berkshire; but the T-shaped symbols over the map make further additions unnecessary.

### 4. *Stratigraphic Conclusions.*

1. *Taconic schists and the limestone in the western half of the limestone region.*—From the sections through the higher points of the Taconic Mountains, Mt. Anthony, Greylock and Mt. Washington, the following conclusions are deduced.

(1.) The flexures in these three parts of the Taconic range are synclinal.

(2.) The limestone is the underlying rock.

(3.) The limestone lying along the eastern and the western sides of the range are continuous underneath the mountains and therefore one in mass,—a fact already proved for the western limestones and the eastern, by their continuity of mass at the surface. It follows, consequently, that—

(4.) The limestone must be the underlying rock in general, for the lower and narrower portions of the Taconic range—the schists of which are the same in kind and essentially continuous.

(5.) The above conclusions are, for like reasons, true for Tom Ball, Lenox Mountain, South Mountain and other minor ridges east of the main Taconic range in the western half of the Housatonic Valley, but not certainly of all. The hydromica schists and mica schists of these mountains are hence, for the most part, younger than the limestones.

2. *The quartzyte, quartzytic mica schists and limestones of the eastern half of the limestone region.*—In the *eastern* half of the Housatonic Valley, besides true or normal mica schist, there are, in alternating strata, as has been shown, arenaceous (quartzytic) mica schists, massive and bedded quartzytes, thinly bedded micaceous quartzytes, quartzytic gneiss or gneissic quartzyte. In the various sections that have been described, these rocks are shown to be conformable with one another and with the limestone; and this is the universal fact. Faults may occur besides those noted, and many of them not now exposed to view; but the conformability is a fact whatever their number.

With reference to these rocks, the question as to which is normally the underlying formation, the limestone or the schists with the associated quartzyte, is a different one from that above answered, and one not admitting in all cases of so positive an answer.

Some have an opinion ready in advance of investigation, knowing that typical Potsdam is sandstone or quartzyte, and assuming that the reverse is true,—that quartzyte is Potsdam positively. But such assumptions leave the question still for investigation since sand beds belong to all ages and times; and, further, with special pertinence here, they occur as an important part of the Hudson River formation in eastern New York at Chatham (Columbia County) and in other regions. The quartzytes graduate into mica schists; and so the sandstones of the Hudson River formation graduate into shales. Besides, the schists of the Taconic hills pass by gentle gradations eastward into the arenaceous mica schist and quartzyte, as explained for southern Berkshire and the adjoining towns of Connecticut, on page 437 of vol. xxix, 1885.

Many of the sections seem to leave little room for questioning the overlying position and Hudson River age of the quartzyte. In former papers,* I have presented, as evidence on this point, facts like those of sections 22 and 23, from opposite sides of the Konkaput Valley (see map); the rocks being there alike in kind, in stratigraphical relations, in small dip, but opposite in

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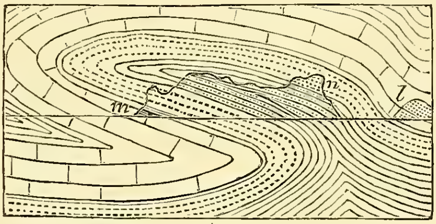
* This Journal, III, v, 33, 1873, and xiii, 45, 1877.

direction of dip, and all in harmony with the idea of an anticlinal (northward in dip of axis) spanning the valley, with limestone as the inferior rock. Farther north a section crossing the same valley continued across Monument Mountain (p. 402) presents a closely parallel case, leading to the same view of the stratigraphic relations. The quartzyte of the east end of the anticlinal over the valley covers the western flank of Bear Mountain from Devany's quarry nearly to Stockbridge.

Studying the facts connected with some of the other quartzytic ridges *within the limestone area* with an equal readiness for either conclusion under consideration, it is difficult to avoid the conclusion that the limestone is the older formation.

But doubts are introduced—not by the idea that Potsdam is sandstone or quartzyte and sandstone or quartzyte is Potsdam, but by the Berkshire fact that *some* of the quartzyte is unquestionably Potsdam or Cambrian. This appears to be true of the quartzyte of Bald Mountain between northern Williamstown and Clarksburg, as inferred from its position with reference to the Archæan mountain just eastward, and its connection with the great eastern range of quartzyte in Vermont. It is true of that of southeastern Pittsfield, eastern Lenox, eastern Lee, eastern Tyringham, in which cases Archæan rocks are near by, a little to the eastward, and the quartzyte usually dips westward toward the limestone as if passing underneath it, and at one locality has been observed to pass beneath it.

In the case of the quartzyte over the west slope and base of Bear Mountain, referred to above, the fact that Archæan probably makes the higher part of this mountain* is good reason for reconsidering the conclusion which has been drawn, and questioning whether the fold in Monument Mountain is not the reverse of that on page 403, as here figured. The question has



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* In my paper of 1873, in vol. v of this Journal, p. 367, and vi, p. 263, I describe a garnet rock consisting of garnet, quartz and some hornblende, as occurring near the summit of Bear Mountain; and as I have not found any similar rock elsewhere in the limestone series, and its aspect is Archæan, I have now little doubt of its Archæan relations. The loose mass of chondroditic limestone found on the south margin of the high region, as reported in the same paper, I believe to be further evidence for the same conclusion.

its two (or more) sides, and can be settled in this and other cases, only after a careful consideration of all the stratigraphic facts.

The quartzyte of Stone Hill and the quartzytic mica schist of Deer Hill, in Williamstown, may be either of the upper or lower quartzyte formation, if judged only by the facts the hill presents. But the position of these areas, in the Williamstown valley, between high ridges of hydromica schist suggest rather that it is the underlying Cambrian; and this is to be inferred also from the quartzyte spur of the Bennington range reaching toward it from the borders of Pownal.

The northern end of the Greylock range has an area of quartzyte as a continuation of that of Bald Mountain, as stated on page 406; and the mica schist near this quartzyte north and east of it may be Cambrian, as well as the quartzyte. The mica schist has much resemblance to that of the western part of Hoosac Mountain; and whatever the fact about the former, there is some reason for making Hoosac Mountain Cambrian. In its western part the mica schist is highly arenaceous, like much of the mica schist of the Quartzyte formation, and it is scarcely less destructible. I know of no evidence from my own observations, or from published accounts, that proves it to be Archæan. Prof. E. Hitchcock long since supposed a fault to separate it from the limestone formation of Adams; but the fault has not been proved to exist, and, if existing, it is no necessary evidence of true unconformability. Farther south, between the quartzyte of Cheshire and central Savoy (see map), the mica schist is probably, like the quartzyte, Cambrian.

This subject will be considered again in a following part of this memoir treating of the Lower Quartzyte formation.

### 5. *Conclusion as to the age of the Taconic Rocks.*

When the paper on southern Berkshire was published two years since, the evidence as to the age of the Taconic limestone and schists consisted in the occurrence of fossils in the eastern belt of limestone in Vermont, near Rutland and farther north, and in the western limestone and schists of Dutchess County, N. Y., near Poughkeepsie and elsewhere. Since then, as already reported in this Journal,* the discovery of Lower Silurian fossils in Canaan, N. York, has given additional proof from the limestone at the western base of the main Taconic Range —the localities found occurring within one to two miles of the schists of the range, and but ten miles west of Pittsfield, Mass. Professor W. B. Dwight joined me in the search there for fossils, but did all the finding. The first account of them, by

* Vol. xxxi, 241, 248, 1886.

Mr. S. W. Ford and himself appeared in this Journal for April, 1886,* and announced the existence of crinoidal joints, and probably a species of *Cleiocrinus*, of *Pleurotomaria*, and *Murchisonia;* and made the age to be probably, or perhaps, Trenton. The localities then known are the two more southern of the four marked by *o* in a circle on the map, the northern of these two being that at the railroad tunnel where the most of the specimens were obtained. At the meeting of the American Association in last August, Professor Dwight made known other fossils from a locality two miles north of the tunnel, at Mr. Hemmingway's, including species near *Ophileta*, one to nearly two inches in diameter, others related to *Holopea*, and numerous small crinoidal disks. Since then he has discovered, in the limestone 500 yards farther north (on the property of Prof. Drown) still other kinds, including a *brachiopod*, a *Lituites*, or related form, an inch and a quarter across, and *Orthocerata* nearly a foot long and two inches in diameter, remarkable for the closeness of their septa, with also Trilobites resembling the *Bathyuri*, and other kinds not yet determined. He has the fossils under investigation and will report on them before long. The age of the fossils at the last mentioned locality, he regards as either Calciferous or Chazy.

Whatever doubt may exist as to the particular periods to which the species collected should be referred, it is beyond doubt that all are Lower Silurian in age. Other fossils which are decisively Trenton in age, I have reported as occurring in loose masses of limestone in Canaan on the farm of Mr. E. S. Hall, not a mile from the schist of the Taconic range.† The masses consist largely of the minutely columnar coral, *Solenopora*, which occurs in small nodule-like forms and makes a limestone that looks like a limestone conglomerate. Along with this coral, occur crinoidal stems and other small fossils. The rock is nearly identical in species, and in aspect, with the Solenopora limestone found far to the southwest at Pleasant Valley, within eight miles of Poughkeepsie, and described by Professor Dwight. The loose masses are not worn, and this favors the view that they are from some underground ledge to the northward or northwestward, although none just like it occurs there in sight. Mr. Dwight in searching for an outcrop of such a Solenopora limestone in Canaan, found similar nodules in some of the limestone, but they failed of the columnar structure, and he is of the opinion, that the failure is due to incipient metamorphism; which is very probably the fact; for the first trace of metamorphic change would obliterate columns only 1-500th of an inch in diameter; and specimens thus changed he has found to be common near Poughkeepsie.

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* Ibid., p. 248.

† This Journal, xxxi, 241, 1886.

Adding the discoveries in Canaan (Columbia County, New York), on the western side of the Taconic Range, to those of Vermont on the eastern side, and in Dutchess County to the south, the facts are enough to demonstrate the Lower Silurian age of the Taconic limestone, the eastern and western. A Cambrian limestone is in places included in the formation, and when so it is conformably to the other strata except where faults occur. Mr. Wing announced the limestone of Vermont to be a combination of limestones from Potsdam to Trenton inclusive; and Prof. Dwight has found the same to be true near Poughkeepsie.

I have not felt at liberty to adduce as additional evidence to that from the Canaan limestone, the discovery of Lower Silurian fossils in the "Sparry" limestone of Hoosac, thirty miles north of Canaan, which Prof. Hall stated, at the meeting of the American Association in 1885,* that he made more than forty years since, because Prof. Hall has never mentioned this discovery in any of his published writings, and has not yet announced the kinds of species or the particular locality. Science cannot rightly use the facts before these details are made known. The existence of fossils in the Hoosac limestone is not at all improbable.

[To be continued.]

## *The Views of Prof. Emmons on the Taconic System.*

The announcement has been very recently made that Prof. Emmons admitted that the age of the western (Sparry) Taconic limestone was Lower Silurian in his second report on the Taconic System, that of 1844:—issued first in a quarto pamphlet, and in 1846 incorporated with his Report on the Agriculture of New York. Since my writings on the subject will need some correction in case this is a right interpretation of his report, I have been again over his statements, and give here the result.

The announcement appears in a paper by Dr. T. Sterry Hunt, in the February number (pp. 114–125) of the American Naturalist (issued near the close of March).† It is stated that Prof. Emmons in 1842, in his first detailed publication on the Taconic system (Report on the Geology of New York, 1842), pronounced the Transition or Sparry limestone, like the rest of the Taconic, to be older than the lowest member of the New York Lower Silurian (or Champlain Division), but that in 1844, 1846, "he made one important and significant change," "acquiescing in the judgment of Eaton" ['of 1832'] he "now declared that the upper portion of the Taconic system—namely, the great belt of slates with limestones, sandstones and conglomerates—designated by him in 1842 as the Taconic slate, and including both the Transition Greywacke and

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* This Journal, III, xxxi, 248, 1886.

† The title of the paper is, "The Taconic Question Restated."

the Sparry lime-rock of Eaton, was the stratigraphical equivalent of the lower part of the Champlain division, and in fact a thickened and modified form of the Calciferous sandrock, which was now said to be in its eastern extension 'protean' in its character and to include a great variety of rocks." Besides this, we find also in the same paper, the idea that Professor Emmons "came forward in 1842 as the champion of the views of Eaton," and this idea is repeated afterward in other championing words in which the first correct announcement of the age of the Taconic System is traced to Eaton.

Since it is established, by the facts already presented in this memoir, that Emmons's Sparry or western limestone, and his Stockbridge limestone (the eastern) are one in mass, any argument sustaining the Calciferous age of the Sparry limestone sustains the same for the Stockbridge limestone. But that Professor Emmons suggested the Calciferous as the age of either of these limestones, or of the "Taconic slate," in his memoir of 1844 and 1846, or was a "champion of the views of Eaton," I have been able to find no proof.

The "Champion of the views of Eaton," Professor Emmons, has these three sentences relating to Professor Eaton in his Report on the Geology of New York (1842).

On page 19, speaking of previous geological work in northern New York, he says: "Previous to the year 1837, nothing exact was known of the geology of the northern district. Mr. Eaton, who was the oldest laborer in geology in New York, had not extended his observations far into this field. He had, however, represented the McCombe Mountains as composed of ranges of gneiss, extending from the valley of the Mohawk to the Provincial line, and the intermediate valleys, of limestone extending along their bases and around their northern extremities; and the whole section as being composed of two principal formations, a Carboniferous slate, denominated Primary, and a calcareous formation, denominated Secondary. It is sufficiently evident that all this was imaginary; it is even difficult to conceive how imagination could have carried even a partial observer so far from the truth."*

Two lines below, on the same page, we have: "In this paper [by Mr. Finch] there is a brief account of the rocks of this county [St. Lawrence]; the Potsdam sandstone was spoken of as a Transition rock, and the Calciferous sand-rock of Eaton as a siliceous limestone."

On p. 280: "The mass of grit is the greywacke of authors; some portions are brecciated, or belong to that variety denominated *rubble* by the late Professor Eaton."

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* In this Journal, III, xix, 270, 1880, Dr. Hunt says that the lithological characters of the primary gneissic formation of northern New York "were clearly defined by Eaton, who under the name of the Macomb Mountains, described what have since been called the Adirondacks," etc.

These are all the sentences in the volume that contain the name of Eaton or relate to his views.

Professor Emmons, on the second page of his chapter VII on the TACONIC SYSTEM, has the heading, "*Persons who have Contributed to our Knowledge of the Taconic rocks*," and under it the "champion of the views of Eaton," should of course have something about the views of Eaton. The first two paragraphs are as follows:

Page 136. "By reference to the early numbers of the Journal of Science, it will be seen that Profs. Dewey and Hitchcock early turned their attention to the rocks under consideration. The former, distinguished for his scientific attainments, gave an elaborate essay, wherein the rocks were described as fully as was possible in the infancy of geology in this country; in fact, so far as mere description is concerned, very little remains to be added. In 1829, the history of Berkshire was published, the matter of which was contributed by the clergymen of the several parishes in the county. In this work an abridgment of Professor Dewey's former essay appeared, so that a general account of these rocks has been widely circulated. Prof. Hitchcock has at various times furnished many important facts in regard to the geology of Berkshire, but, as appears from his publications, has relied mainly upon the information derived from Professor Dewey's labors, especially in his elaborate and excellent work on the rocks of Massachusetts.* To these gentlemen, therefore, we are principally indebted for the facts which have been placed before the public."

Page 125. "The limestones of Berkshire have been fully and ably treated of by Professors Dewey and Hitchcock."

Page 151. Speaking of the Sparry limestone, he says: "This limestone is called Transition limestone upon the geological map contributed by Professor Dewey for illustrating the geology of Berkshire county, Massachusetts."†

In this mention of early workers, there is not a word about Eaton anywhere. Dewey made his investigations eight to fifteen years before Professor Eaton's work of 1832 was published. Eaton made no observations on the Taconic rocks, and honorably gave credit for all he knew (see page 270 of this volume) to Prof. Dewey. According to the facts, consequently, "the persistent war waged" against "the views of Amos Eaton" (p. 121 of the Naturalist) —till now an unheard of war—was begun by his pupil, Professor Emmons. Eaton was a man of great energy and enthusiasm; but his was the beginning-time in American geology; and little credit is to be given either to him or to Dewey for their adoption of the term Transition from European writers, or for any ideas on the age of the rocks.

Professor Emmons is charged (on p. 120 of the paper and be-

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* These remarks with reference to Professor Hitchcock relate evidently to his earlier report, that of 1835, on the Geology of Massachusetts, and not to his later quarto report of 1841.

† This Journal, vol. viii, 1824. Emmons dedicates his "American Geology" to Dr. Dewey.

yond) with "contradictions" and "perplexing discrepancies" in his volume of 1842; and in a note at the bottom of the page, "pages 121, 124, 125, 280–282, and further, p. 147," are referred to for testimony on this point. Only one of these pages is in the chapter on the Taconic system—the "and further p. 147." I find no "contradictions" or "perplexing discrepancies" in that chapter, or in anything relating to the Taconic system.

Professor Emmons does not merit the condemnation thus made; for he is clear and consistent throughout.

As to the change of opinion asserted, I find, as I had done before, that in 1842, Professor Emmons, contrary to the idea conveyed on page 123 of the paper in the Naturalist, made the Sparry or western limestone *older* than the Stockbridge limestone, because the western dipped eastward beneath it; he commences his paragraph on the subject of relative age (Rep. Geol. N. Y., "and further, p. 147,") with the sentence "there seems to be no valid reason against the opinion that the most western belt of limestone is, after all, the oldest of the Taconic limestones."

In 1844, 1846, speaking, in his Memoir, of the Taconic rocks, he says, p. 63 of the Agricultural Report and 19 of the 1844 pamphlet): "I shall describe the rocks in the *descending order*," and this is the order:

*First.* "The Black Slate" (on pp. 63–65), described as affording at Bald Mountain, Trilobites.

*Second:* "The Taconic Slate with its subordinate beds" (on pp. 65–72); of which he says: "Occupies almost the whole of Columbia, Rensselaer and Washington Counties" (p. 72); "extends from Lansingburgh to the Sparry limestone in the eastern part of Hoosic near the western bounds of Bennington in Vermont—at least 20 miles in a direct line" (p. 72); "It crosses the [Hudson] river near Poughkeepsie, ranging southward so as to underlie the belt of country to the west of Newburgh for six or eight miles" (p. 103). In these and other statements he gives the Taconic slate a wide range, and includes under it slates near Poughkeepsie that in recent years have afforded Hudson River brachiopods. He makes it older than the Black Slate.

*Third:* The "Sparry limestone (on pp. 72–74): of which he says, "Occupies the belt of country comprising the eastern part of Dutchess, Columbia, Rensselaer and Washington counties (p. 73); "not far west of the dividing line between Massachusetts, Vermont [on the east side] and New York [on the west]" (p. 74); "through Ancram, Hillsdale, Canaan, New Lebanon, Berlin, Petersburgh, Hoosic, Whitecreek," etc. (p. 74). In the account of this limestone I find nowhere, any more than in that of the Taconic slate, the slightest intimation of a change in his opinion as to its age. All the rocks of the Taconic series are made unequivocally older than the Potsdam sandstone.

As above indicated, Professor Emmons did make one change in 1844, and a wise one. In 1842 he argued from the eastward dip, as I have shown, that the Sparry limestone was the oldest of the

Taconic limestones. In 1844, 1846, he dropped the argument and the conclusion, and showed, by sections, how through flexures the order of original superposition might be reversed. This change left the Sparry limestone and Taconic slate older, as before, than the Potsdam. Further, he added the Black slate of Washington Co., N. Y., with its trilobites, and made this the *upper* or newer member of the series, on account of the fossils, with the other members following in the descending order above given,—the quartzyte at the bottom.

Professor Emmons was right in his Berkshire stratigraphical observations. He drew chronological conclusions on data that we now know to be too uncertain for any safe inference, and on lithological data extended his system beyond its true limits; but in those decisions at that early time there is nothing to his discredit, while his investigations are greatly to his honor.

It is a fact of historical importance in the Taconic controversy, that the writings, on the subject, by Professor Mather, the Professors Rogers, Dr. D. D. Owen and Professor E. Hitchcock, the early questioners or opponents of the Taconic system, do not contain a discourteous word. Their criticisms are such as give life and progress to the science. Professor James Hall, whatever opinions he may have had or may have orally expressed, has nowhere in his notes on the fossils of the Taconic slate (Black slate), an offensive remark; and these are all of his writings on the subject. Logan, after the Quebec discoveries of the Canada survey, put a few lines in his Canada Report—a very few, in all not over twenty; he did it courteously and not even controversially. He afterward made examinations in Vermont, Massachusetts and New York which gave him confirmatory conclusions, but personally he wrote nothing on these conclusions.

The writer's acquaintance with the subject began in 1843, after an absence abroad of four years; and for many years afterward he was learning, but published nothing. After the discoveries of fossils in Canada, and the announcements of the Canada Geological Survey, I adopted Logan's opinion; and this is presented in my Manual of Geology, published first in 1863. It appeared at the time to be the generally accepted opinion. My investigations in Berkshire were commenced in July of 1871, in order to get at the truth, without any feeling of opposition to Professor Emmons.

Dr. T. Sterry Hunt was one of the strong and active opponents of the Taconic system between the years 1849 and 1875. The Report of the American Association for 1850 has his decision that "The results of the [Canada] survey have shown, as I had the honor to state at the last annual meeting at Cambridge [in 1849], that the Green Mountain rocks are nothing else than the rocks of the Hudson River Group with the Shawangunk conglomerates, in a metamorphic condition;" and in his address before the same Association for 1871, he stated, as he had done many times in the interval, that the conclusion of Rogers and

Mather, referring the Taconic System to the "Champlain Division" of the New York rocks had been sustained by subsequent observations. Further, his "Chemical and Geological Essays" published in 1875 (see Title-page) contains the Association address of 1871, and the same remarks on the Taconic. Here are *twenty-five years* of opposition to Professor Emmons, in a number of papers, and never once a hint that Emmons agreed with him in the Calciferous age of either of the rocks. The account of the investigations of Logan and Hall in Dutchess County, New York and elsewhere, bearing against the Taconic system, as published in this Journal for 1865, has attached to it Dr. Hunt's name as he was the writer. Dr. Hunt's opinions were not always couched in courteous language. In 1861, he makes the Taconic, exclusive of the slates, equivalent of the Calciferous, adding: "It remains to be seen whether Dr. Emmons can retain, from the wreck of his system, the lower slates as a Taconic formation older than the Potsdam." This sounds like "persecution;" and the series of papers like "persistent war waged against Ebenezer Emmons." Now, the Restatement indicates for its author a return to the idea of the Calciferous age of some of the Taconic rocks.*

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* The continuation of the "Taconic Question Restated," to be found in the March number of the Naturalist (pp. 238–250), has been published since the above was put in type—the number having been received at New Haven April 13th. It calls for no further remarks. But as it will aid in clearing away doubts, and give a fuller view as to what have been, as the author expresses it (p. 248), "my own teachings," I cite a few more sentences from his papers during the 25-year period of *opposition*, and others from two of those of the subsequent period of *agreement.*

*Review of the Progress of American Geology*, in this Journal, II, xxxi, 402, 1861. "The Quebec group with its underlying shales is no other than the Taconic system of Emmons.

"*Review of Mr. Barrande, On the Primoridial Zone in North America*," in the Canadian Naturalist, 1861, and this Journal, II, xxxii, 427, 1861. "Dr. Emmons claims that the whole of his Taconic system is inferior to the Potsdam sandstone, which is the admitted base of the Champlain division, but we have already shown that the whole of his system, with the probable exception of these slates [the black slates] is of the age of the Calciferous sandrock, the second member of that division." "The fossils of the Quebec group show it to be the paleontological equivalent of the Calciferous sandrock. The Stockbridge and Sparry limestones with their accompanying slates (excepting only 7 and 8 [the Taconic slate and black slate]), we conceive to be no other than the Quebec group."

*Address to the American Association*, August, 1871. Salem, 1871.—p. 15, "The Taconic system, as defined by him [Emmons] may be briefly described as a series of uncrystalline fossiliferous sediments reposing unconformably on the crystalline schists of the Green Mountains, and partly made up of their ruins; while it is, at the same time *overlaid unconformably by the* Potsdam and Calciferous formations of the Champlain division, and constitutes the true base of the paleozoic column, —thus occupying the position of the British Cambrian." Hence in 1871 the author had not made the discovery that Professor Emmons referred any part of his Taconic system to the Calciferous.

*History of the Names Cambrian and Silurian in Geology;* published in the Canadian Naturalist, for April and July, 1872.—p. 36, "Emmons, misled by stratigraphical and lithological considerations, complicated the question in a singular manner, which scarcely finds a parallel except in the history of Murchison's Silu-

In view of these twenty-five years of opposition, and of present indications, it is of interest to read again (if already once read) the pathetic remark on page 122 of the paper in the Naturalist.

"There is a painful resemblance in many respects between the story of Emmons and of his opponents and that of the warfare waged against Sedgwick by Murchison and his allies in the famous Cambrian and Silurian controversy, as set forth by the present writer in 1874 in his Chemical and Geological Essays (pp. 364, 365):" the same volume that contains Dr. Hunt's Association Address.

A note to "opponents" in this sentence states a further incident in the "persecution" from a letter by Professor Emmons, in which Professor Emmons says, that "the *editor of the American Journal of Science* refused to publish my remarks upon Logan's Report when he [Logan] announced his Huronian System, though their tenor was courteous in the extreme; I claimed that the Huronian was only the Taconic System." The refusal was on the ground that the "remarks" contained no facts sustaining the opinion, and that opinions on such a point without facts were of no value to the science. The Huronian region and the Taconic were remote from one another, and Logan's discoveries of fossils in Canada seemed to be too decisive to be so set aside.

But this instance of "persecution" occurred far back in that

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rian sections. Completely inverting, as I have elsewhere shown, the order of succession in his Taconic system, estimated by him at 30,000 feet, he placed near the base of the lower division of the system, the Stockbridge or Eolian limestone, including the white marbles of Vermont, which by their organic remains have since been by Billings found to belong to the Levis formation [Quebec group].

The following are those on *the other side.*

*On the Azoic Rocks of Southeastern Pennsylvania*, Report E, of Geol. Survey 1878, pp. 206, 207. "We have given reasons for regarding the Lower Taconic, or the Primal and Auroral strata of the great Appalachian Valley as the equivalents of the similar series in southern N. Brunswick and of the Hastings series in Ontario with its Scolithus and Eozoon. While it has been shown, in a preceding chapter, that the Upper Taconic includes the organic remains of the European Cambrian at least as low as the Menevian, it is by no means certain whether the Lower Taconic series is to be regarded as the equivalent of the still lower beds of the Cambrian of Great Britain and Sweden. In this uncertainty it is deemed well to preserve for this series the original name of Taconic."

"*The Taconic Question.*" 84 pp. 4to, published in the volumes of the Transactions of the Royal Society of Canada for 1883 and 1884. In the "conclusions" the author says (pp. 149, 150): "There exists in eastern North America a great group of stratified rocks, consisting of quartzytes, limestones, argillites and soft crystalline schists, which have altogether a thickness of 4000 feet or more, and are found resting unconformably upon various more ancient crystalline rocks from the Laurentian to the Montalban inclusive. This series called Transition by Maclure . . . . is the Lower Taconic of Emmons." This series which I have preferred to call Taconian is essentially one of Transition crystalline rocks."—p. 151, "The Taconian, as I have suggested, may constitute a link between the older Eozoic groups and those of Paleozoic time."—p. 151, "the Upper Taconic group, the First Graywacke of Eaton, the Potsdam and Quebec groups of Logan (which include a large part of what was described by Mather and by Logan as Hudson River group) we have seen to be the Appalachian representative of the Cambrian group."

If any one doubts whether the author of the preceding extracts and of the article in the Naturalist is one and the same person he must investigate for himself.

interval of twenty-five years during which Dr. Hunt was one of the persecutors if there were any such—an interval, moreover, which was continued, without any abatement in the opposition on Dr. Hunt's part, for twelve years after Professor Emmons's decease.

I think I have stated facts enough to end the Taconic controversy. The work which Professor Emmons did in the stratigraphical geology of the Taconic region and his discoveries in Paleontology will in the main stand; while no effort can keep life in wrong conclusions, whatever the source.

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# SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *On the generation of Chlorine gas in Kipp's apparatus.*—The use of bromine in the laboratory would appear to be due in many cases to the inconveniences attending the ready preparation of the more active chlorine. WINKLER has sought to render the preparation of chlorine easier by suitably modifying the ordinary process of obtaining this gas from chloride of lime and hydrochloric acid. For this purpose the chloride of lime is mixed with about a fourth of its weight of calcined gypsum, and then so moistened with cold water as to form a crumbly semi-coherent mass. It is stirred in a mortar until entirely homogeneous and then is beaten with an iron mallet into a square iron frame ten or twelve millimeters thick, resting on an iron plate. When full the sides are covered with wax-cloth and the whole is submitted to the action of a strong press. The square cake thus obtained is then cut into smaller squares and dried at a temperature not exceeding 20°. The cubes thus obtained should be preserved in a well-closed vessel. When used they are placed in a well-made Kipp's gas-evolution apparatus, with hydrochloric acid of 1·124 specific gravity previously diluted with an equal volume of water. The preparation of chlorine in this way is as convenient and its evolution as constant as that of carbon dioxide by the use of marble. The author announces that Trommsdorff has agreed to keep these cubes already made, on hand for sale.—*Ber. Berl. Chem. Ges.*, xx, 184–5, Feb. 1887. G. F. B.

2. *On the action of Kaolin on the alkali-chlorides.*—In studying the action of kaolin on the halogen compounds of the alkalies, GORGEU has shown that when this substance is calcined with these compounds, double neutral silicates are formed, which themselves in some cases form direct combinations with the halogen salts. The sodium-aluminum silicate thus formed unites directly with sodium iodide to form a well crystallized compound. When the kaolin is calcined with sodium or potassium chloride,

hydrogen chloride gas is disengaged in abundance at a red heat; and if the action be continued in presence of water vapor, a considerable proportion of the chloride will be decomposed, depending on the amount of alumina in the kaolin. Bromides under these conditions evolve hydrogen bromide; but iodides evolve iodine, the hydrogen iodide being broken up by the heat. If the kaolin is anhydrous and the calcination is effected in a current of dry air, chlorine, bromine and iodine are evolved, but the action is much slower. By using kaolins free from carbonates, by mixing them thoroughly with the quantity of salt that they can completely decompose and by carrying the mixture in half an hour to a cherry-red and maintaining it there for three-quarters of an hour in a current of steam, 97 per cent of the chloride may be decomposed, yielding hydrogen chloride. With absolutely dry materials, heated in dry air to a bright cherry-red, about one-half of the chlorine contained in the salts is obtained free.—*Ann. Chim. Phys.*, VI, x, 145–170, Feb. 1887. G. F. B.

3. *On the Distribution in the Soil of the nitrifying organisms.*—In a paper published some years ago, WARINGTON gave an account of the experiments which he made at Rothamsted to ascertain to what depth the presence of the nitrifying organisms could be detected in the soil. From three series of experiments embracing 28 trials he concluded that "in our clay soils the nitrifying organism is not uniformly distributed much below 9 inches from the surface." Subsequently, further experiments in this direction were made, essentially similar to the others except that rather more soil was placed in the solution to be nitrified and to this solution a decigram of gypsum was added to each liter. The results were now in many respects entirely different. Not only was the process of nitrification more speedy but soil from very considerable depths was found capable of starting it. Soil from a fallow plot had this property uniformly to a depth of 2 feet and in some cases to 3 and even 4 feet. Soil from a white clover plot was all effective down to 3 feet, and one sample at 4 feet and one at 6 feet were found to be so. The lucerne plot produced nitrification with all samples down to 4 feet and one sample at 6 feet was active. A third series of experiments was made a year later, to see if these results could be due to the contamination of the solutions in the field by soil-dust from the surface. But the results confirmed those already obtained. No failure to produce nitrification was observed in samples of soil down to and including a depth of two feet from the surface. At 3 feet only one sample out of eleven failed. At 6 feet one-half the trials failed; and at 7 and 8 feet all failed. The failure in the earlier experiments was due the author thinks to the absence of gypsum from the test solutions. The final conclusion, therefore, is that the nitrifying organisms are practically confined to the surface soil; for although they may occur at considerable depths in a loam or clay subsoil, they occur there in small quantity and in feeble condition.—*J. Chem. Soc.*, li, 118, Feb. 1887. G. F. B.

4. *On the Absorption of Gases by Carbon.*—Though experiments have been frequently made to determine the volume of various gases which a unit volume of charcoal absorbs, there seem to have been very few attempts to determine the composition of the gas subsequently given up by the charcoal on heating. Baker has undertaken some experiments to ascertain the nature of the gas thus given up by charcoal when it has absorbed oxygen. The charcoal examined was that from boxwood and animal charcoal; but as the latter, especially after purification, absorbed a far larger volume of gas it was used by preference. Duplicate experiments were also made; the oxygen being dried in one series and saturated with moisture in the other. The carbon was contained in a cylindrical bulb one-quarter to one-third of an inch in internal diameter, drawn out to the size of a quill at one end. By means of a Sprengel pump the whole was exhausted, the bulb being heated to a high temperature. After cooling, it was attached to a gas pipette, oxygen was allowed to enter and to remain at the normal pressure until the absorption was complete, the bulb meanwhile being immersed in water or in a freezing mixture, at pleasure. The bulb was then exhausted. On heating it now to 100° and exhaustion, the gas obtained from it could be examined. The author finds: 1st, that moist oxygen absorbed at —15° by carbon, is not evolved free or combined at 12°; 2d, that ($\alpha$) the water-vapor and oxygen thus absorbed, when kept for a week at 100°, produce carbon dioxide, the charcoal giving up 7 times its volume, ($\beta$) water vapor and carbon kept at 100° for a week produce no carbon dioxide, and ($\gamma$) carbon and dry oxygen at 100° for a week produce no carbon monoxide; 3d, that ($\alpha$) a temperature of 450° is required to remove the dry oxygen retained by carbon, carbon monoxide being the chief product, ($\beta$) the more free from moisture the substances the less the oxidation, and hence ($\gamma$) carbon is burned directly to monoxide by the absorbed and firmly retained oxygen.—*J. Ch. Soc.*, li, 249, March 1887. G. F. B.

5. *On the Valence of Bismuth.*—The fact is well known that the organic compounds of the nitrogen group show in their trivalent combinations a greater intensity in the free bonds than the inorganic compounds. Thus while arsenous chloride $AsCl_3$ will not unite with more chlorine, methyl-arsenous chloride $CH_3AsCl_2$ forms a tetrachloride. Michaelis has sought to determine in this way the quinquivalence of bismuth. By adding bromine to a solution of bismuth-methyl in well-cooled petroleum-naphtha, no addition product was obtained. Nor was he able to add ethyl iodide to bismuth-methyl. But bismuth-phenyl thus treated gave at once triphenyl-bismuth dibromide $(C_6H_5)_3BiBr_2$ and chloride $(C_6H_5)_3BiCl_2$, as permanent and well defined compounds. In these bodies we have for the first time compounds in which five univalent atoms or atomic groups are united to a single atom of bismuth; and hence they establish the quinquivalence of bismuth as certainly as they did that of antimony.—*Ber. Berl. Chem. Ges.*, xx, 52, Jan , 1887. G. F. B.

6. *On the Action of Phosphoric chloride on Ethyl acetondicarbonate.*—In the hope of elucidating the constitution of certain unsaturated acids of the fatty series, Burton and von Pechmann have examined the product of the action of phosphoric chloride upon ethyl acetondicarbonate, as well as the two other bodies, acid in character, which are produced from this by the loss of hydrogen chloride. The first product of the above reaction is probably $CO_2C_2H_5.CH_2.CCl_2.CH_2.CO_2C_2H_5$; and this loses HCl spontaneously and becomes $CO_2H.CH.CCl.CH_2.CO_2H$, which because of its formation and analogies the authors call $\beta$-chlorglutaconic acid. By the further loss of HCl, a new dibasic acid is formed having the formula $C_5H_4O_4$, to which they give the name glutinic acid, and for which the constitutional formula $CO_2H.C{\equiv}C.CH_2.CO_2H$ appears most probable. The former acid is obtained in white crystals fusing at 129° and easily soluble in water. The latter acid crystallizes in white needles and fuses with decomposition at 145°–146°. It is easily soluble in water, alcohol and ether, insoluble in chloroform and in benzene.—*Ber. Berl. Chem. Ges.*, xx, 145, February, 1887. G. F. B.

7. *On the behavior of Iron and Steel under the operation of feeble magnetic forces.*—Lord Rayleigh discusses in this paper the question whether iron responds proportionally to feeble magnetic forces. This question is of practical interest in the working of telephonic instruments. The experiments of Ewing apparently prove that the hypothesis of Maxwell that when the molecular magnets of Weber are rotated they undergo first an elastic and then a partially non-elastic deflection, does not represent the actual phenomenon. They suffer instead a "kind of frictional retardation which must be overcome by the magnetizing force before deflection begins at all." The experiments of Rayleigh prove "that in any condition of force and magnetization, the susceptibility to small periodic changes of force is a definite and not very small quantity, independent of the magnitude of the small change. That the value of the susceptibility to small changes of force, is approximately independent of the initial condition as regards force and magnetization, until the region of saturation is approached."

In the course of his investigation the author experimented upon the construction of a sensitive galvanometer with a field strengthened by iron. The system of needles was astatic. The electro-magnet was of horseshoe form, with a core of hard Swedish iron wire $3{\cdot}3^{mm}$ in diameter. The electro-magnet was held so as to embrace the upper needle system. The experiments showed that a galvanometer of high sensitiveness could be thus constructed. The tendency to residual magnetism would, however, be troublesome.—*Phil. Mag.*, March, 1887, pp. 225–245. J. T.

8. *Movements of the Wings of Birds, represented according to three dimensional space.*—M. Marey, in a very interesting article illustrated by figures, represents the results obtained by instantaneous photographs of the flight of birds taken successively as if

the bird were projected on three planes. It is hoped that this new method of study of the flight of birds will add largely to our knowledge of the kinematics of flying."—*Comptes Rendus*, No. 6, Feb. 7, 1887, p. 323. J. T.

9. *Upon the Magnetic effect of Earthquakes.*—At various magnetic observatories on the continent of Europe, slight disturbances were registered which apparently were connected in time with the late earthquakes. M. Mascart believes that a more careful examination of the records of different observations will show the connection which may exist between the two disturbances.—*Comptes Rendus*, No. 10, March 7, 1887, p. 634. J. T.

10. *Heat of the Sun.*—FRÖLICH communicates the second portion of his voluminous paper on the measure of the sun's heat. In the course of the paper he examines Langley's hypothesis that the absorption of heat is proportional to pressure of air, and does not find a suitable agreement between his own observations and records of the barometer. He concludes, therefore, that the hypothesis is not true. The observations show that the heat of the sun is subject to important changes. The question whether an increase of the sun's heat follows a lessening of the sun's spots cannot be decided without a more careful study.—*Annalen der Physik und Chemie*, No. 4, 1887, pp. 582–620. J. T.

## II. GEOLOGY AND NATURAL HISTORY.

1. *Bulletin of the American Museum of Natural History, New York.*—No. 8, of vol. i, issued Dec. 28, contains a notice of investigations on Lower Silurian geology along the eastern shore of Lake Champlain, by Professor M. Seely and Pres. E. Brainerd of Middlebury, Vt., with a description of new fossils by R. P. Whitfield; and, by the same, a notice of a new fossil, probably a sponge related to Dictyophyton, from the slates at Kenwood, near Albany, N. Y.

2. *Brief notices of some recently described Minerals.* CARACOLITE.—This mineral was investigated by the late Professor Websky of Berlin, but was not announced until November, 1886, shortly after his sudden death. Its characters are as follows: Orthorhombic with pseudohexagonal symmetry due to twinning. The crystals appear as obtuse double hexagonal pyramids with prism, resembling witherite, to which it is also related in its axial relations, viz: $\breve{a}:\bar{b}:c = 0{\cdot}5843:1:0{\cdot}4213$. The colorless crystals of caracolite are associated with minute bright blue cubes of the rare species percylite, and the material analyzed consisted of a mixture of the two species in about the ratio of 6:1. The composition deduced for pure caracolite is expressed by the formula $PbHClO + Na_2SO_4$, requiring: Pb 51·56, Na 11·46, S 7·97, Cl 8·84, H 0·25, O 19·92=100. The mineral is named from the locality Caracoles, Chili.—*Ber. Ak. Berlin*, p. 1045, Nov., 1886.

KALIOPHILITE. In an extended article upon the ejected masses from Monte Somma, Mierisch describes a mineral allied to nephelite calling it kaliophilite, the name having reference to its high percentage of potash. It occurs in colorless prismatic or acicular crystals, which do not, however, show sufficient distinctness of form to allow of the system being determined to which they belong. They show basal cleavage, are optically uniaxial with negative double refraction; the specific gravity is 2·602. An analysis afforded:

| | $SiO_2$ | $Al_2O_3$ | CaO | $K_2O$ | $Na_2O$ |
|---|---|---|---|---|---|
| $\frac{2}{2}$ | 37·45 | 32·43 | 2·18 | 27·20 | 2·26=101·52 |

This corresponds to the formula, $K_2Al_2Si_2O_8$ which is that of an anhydrous muscovite, and is analogous to that of anorthite, nephelite and eucryptite in which calcium, sodium and lithium, respectively, enter in the place of the potassium here present.—*Min. petr. Mitth.*, viii, 160.

HARSTIGITE. Described by G. Flink of Stockholm. It occurs in prismatic orthorhombic crystals with an axial ratio of $\breve{a} : \bar{b} : c =$ 0·7141 : 1 : 1·01495. No cleavage was observed; fracture small conchoidal to splintery; hardness 5·5; specific gravity 3·049; colorless with vitreous luster. An analysis on 0·3 gram yielded:

| $SiO_2$ | $Al_2O_3$ | MnO | CaO | MgO | $K_2O$ | $Na_2O$ | $H_2O$ |
|---|---|---|---|---|---|---|---|
| 38·94 | 10·61 | 12·81 | 29·23 | 3·27 | 0·35 | 0·71 | 3·97=99·89 |

This does not lead to a satisfactory formula, and the composition must remain somewhat doubtful until more material is obtained for investigation. Obtained at the Harstig mine at Pajsberg, Sweden.—*Bihang Svensk. Vet.-Akad. Handl.*, xii, 1886.

SCHUNGITE. A name given by A. von Inostranzeff to a form of amorphous carbon occurring in the crystalline schists of Schunga in the Olenetz government, Russia. A similar form of carbon from the Saxon Erzgebirge was called graphitoid by Sauer. —*Jahrb. Min.*, 1886, i, 92.

3. *Materialien zur Mineralogie Russlands;* von N. VON KOKSCHAROW. Vol. ix, pp. 273–365. St. Petersburg, 1886.—This part forms the closing portion of the ninth volume of the great work on Russian Mineralogy by von Kokscharow. It contains a supplementary notice of the interesting variety of xanthophyllite called waluewite, giving a more exact determination of the crystalline form than has been obtained hitherto; also an extended review of papers on the topaz of Durango by N. von Kokscharow, Jr., and by DesCloizeaux, with an exhaustive list of calculated angles for the many new forms. A description is also given of the mineral MURSINSKITE, thus far known from two specimens only which were found more than thirty years ago. It occurs in minute crystals inclosed in large transparent topaz crystals from Alabaschka, near Mursinsk in the Ural. The form is that of a tetragonal pyramid with angles of 127° 31′ (terminal) and 77° 22½′ (basal); two pyramids of the second series and several zirconoids were also observed. The color is wine- to honey-yellow, transparent to semi-transpar-

ent; the hardness is six to seven and a determination of the specific gravity gave 4·149; this result has, however, no great claim to accuracy. Nothing is known about the chemical composition, so that its true relations must remain in doubt until additional material is obtained. The rarity of the species will be appreciated from the fact that in the past thirty-two years no additional specimens have been found, though often searched for.

4. *On the relation of Schorlomite to Garnet.*—Dr. König has recently published the following analysis of a massive titaniferous garnet from southwestern Colorado:

| | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $CO_2$ |
|---|---|---|---|---|---|---|---|
| G.=3·689 | 30·71 | 8·11 | 2·20 | 22·67 | 34·29 | 0·30 | 1·48=99·82 |

This result can be made to conform to the garnet formula only by assuming that part of the titanium replaces the alumina as $Ti_2O_3$ (3·64 p. c.). This garnet resembles the titaniferous melanites from the Kaiserstuhl described by Knop and the discussion has led König to the same conclusion in regard to schorlomite that Knop and Rammelsberg had reached on the basis of the Kaiserstuhl garnets, viz: that it is essentially a garnet containing $Ti_2O_3$ as well as $TiO_2$. An analysis of the Arkansas schorlomite gave König:

| | $SiO_2$ | $TiO_2$ | $Ti_2O_3$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | MnO |
|---|---|---|---|---|---|---|---|---|
| G.=3·876 | 25·80 | 12·46 | 4·44 | 1·00 | 23·20 | 31·40 | 1·22 | 0·46=99·98 |

This agrees approximately with the garnet formula; the general conclusion seems probably correct.—*Proc. Acad. Nat. Sci. Philad.*, 355, 1886.

## III. BOTANY.

BOTANICAL NOTES.—The numbers of this Journal for January, February, and March, 1886, contain an extended paper by Professor Penhallow of Montreal on "*Tendril Movements in Cucurbita maxima and C. Pepo.*" The author has recently sent us a copy of a quarto memoir, separately issued from the Transactions of the Royal Society of Canada, vol. iv, sect. iv, read May 27, 1886, on *Mechanism of movement in Cucurbita, Vitis, and Robinia;* also from the Canadian Record of Science, of Oct., 1886, *Additional notes upon the Tendrils of Cucurbitaceæ.* On looking over these two articles, the larger of which enters somewhat into the history of the subject and cites a good many publications, we find no reference whatever to his own papers published, at the author's particular desire in this Journal. This is the more remarkable as in them Professor Penhallow coins a new term, which he continues to make much use of; and an author generally likes to date his own discoveries as near to their inception as he can. [We learn that the omission was purely accidental, through forgetfulness.]

*A Redwood Reserve.*—We have received a copy of "An earnest appeal to the enlightened self-interest of California" for the preservation of a Redwood park in the Pescadero district, north of

Santa Cruz. It is earnestly hoped that the appeal which Mr. Ralph Sydney Smith very eloquently and sensibly makes may be successful. If nothing is done to preserve for posterity a specimen of Redwood forest, including, if possible, some of the large trees, future and not far distant generations of Californians will have cause to revile the memory of their forefathers. Time was when we had hoped for a government reservation of such forest, of ten miles square, in the northwestern part of the State, and it would have cost nothing. But the plan now broached, although it will cost something, has the great advantage of fairly securing this object and at the same time giving to San Francisco an unrivaled park quite within the reach of its citizens. Let us hope that the few great Redwoods which survive above Santa Cruz may form an annex to this reservation. Unless something of this kind is speedily done, one of the peculiar glories of the State of California will in the next century be only a tradition.

*Notes of a Naturalist in South America*, by John Ball, F.R.S., etc., is a duodecimo volume of 417 pages (London, Kegan, Paul & Co.), which we had hoped to give an account of. Especially one would wish to discuss the two appendices, viz: A. On the fall of temperature in ascending to heights above the sea-level, and B. Remarks on Mr. Croll's theory of secular changes of the earth's climate. We can only commend them to the consideration of those interested in terrestrial physics and meteorology.

*Pittonia, a Series of Botanical Papers*, by Edward L. Greene, Assistant Professor of Botany in the University of California. Vol. i, part 1. Berkeley, California, March, 1887.—An octavo of 48 pages. No preface or announcement is given. We may infer that Pittonia is in reference to the family name of Tournefort, and that the publication may have for its model the Adansonia of Baillon; but the ideas of genera and species are on quite another model. Perhaps the plan may be that of the Linnæa; for, as in that occasional rather than serial publication, a portion of the pages is given to reviews of recent botanical literature. Good botanists have followed Decaisne in referring the Big-roots to *Echinocystis;* but we suppose that the validity of the genus *Megarrhiza* may still be seriously defended. The various new species of *Trifolium*, *Zauschneria*, etc., and the recast of *Krynitzkya*, *Plagiobothrys*, etc., into new forms may be safely left to the final judgment of competent botanists. Professor Greene's judgment and ours are widely divergent.

Dr. August Gattinger has issued, in a thick and neatly printed pamphlet of 109 pages, 8vo, *The Tennessee Flora, with special reference to the Flora of Nashville; Phænogams and Vascular Cryptogams*, 1867.—The preface, full of pleasant personal details and grateful acknowledgments, is followed by a very interesting sketch of the general aspect of the flora of Tennessee and of its four natural floral arrondisements, which are graphically described, geographically, geologically and phytologically. We should be glad to quote the whole of it. Separate lists are given of the "Plants of the glades and bluffs, of calcareous soils;" of the "Oak barrens and highlands, siliceous and argillaceous soils;" and of "Plants peculiar to West Tennessee," the eastern part of Cretaceous, the western of Tertiary and Post-tertiary deposits. Then comes the systematic catalogue, in which the species occurring within thirty miles of Nashville are printed in full faced type. Recently published species are given with characters in foot-notes.

*Bulletin de la Société Botanique de France.*—In the 33d volume M. Franchet begins his *Plantæ Yunnanses*, an account of the collections from the interior Chinese province of Yun-nan. Beginning in the fifth fascicle, it is carried on in the sixth through the *Anacardiaceæ.* M. Clos, having proposed the term *pistillodium* as the analogue of *staminodium*, M. Cogniaux, on p. 470, calls attention to his use of it in the Flora Brasiliensis, in 1878, and thinks the term as needful as staminodium. That is not quite clear; the latter term is free from ambiguity. Pistilodium may be the homologue either of a carpel or of a circle of carpels. M. Hérail and Blottière have a paper on the histology of the *Lardizabaleæ.* They come to the conclusion that De Candolle was probably right in appending this group to the *Menispermaceæ*, that, in any case, they are not *Berberidaceæ.*

PROFESSOR A. W. EICHLER, Director of the Botanical Garden at Berlin (where he succeeded Alexander Braun), editor of the Flora Brasiliensis, a systematic botanist of the first class and a man most highly esteemed, died on the second of March, after a lingering illness. He was one of the foreign honorary members of the botanical section of the American Academy of Arts and Sciences.

M. Bornet delivered before the Academy of Sciences of the Institute of France, at the close of last year, a most appreciative notice of the late *L. R. Tulasne*, whose chair in the Academy he fills. It has now been published, and to it is appended a full list of Tulasne's publications.

*Botanical Contributions*, 1887 (a revision of some Polypetalous Genera and Orders, Sertum Chihuahuaense, Appendix, Miscellanea), by Asa Gray, are here mentioned only to state that a portion of the manuscript, accidentally omitted on p. 273, is supplied at the end, p. 314. Another grave oversight was not discovered in time. The paragraph in the middle of the page 299, beginning "*A. acerifolia*" was to have been erased from the printer's copy, being in fact replaced by the paragraph next below, beginning "*A. Thurberi.*" The lines printed by mistake have been cancelled by the pen in all or most of the distributed copies. A. G.

2. *Outlines of Classification and Special Morphology of Plants*, by Dr. K. GŒBEL, Professor in the University of Rostock; a new edition of *Sachs' Text-Book of Botany, Book II.* Authorized English translation, by HENRY E. F. GARNSEY, Fellow of Magdalen College, Oxford. Revised by ISAAC BAYLEY BALFOUR, M.A., M.D., F.R.S., Fellow of Magdalen College and

Sherardian Professor of Botany in the University of Oxford.—This work, published by the Clarendon Press, Oxford, in a large-paged octavo volume of 515 pages, is a great improvement upon the original of Sachs, not to speak of the advantage of having an independent volume apart from physiology and histology. Evidently the translator and reviser have done their part well. Perhaps it is too late to arrest such a misbegotten word as asexual meaning non-sexual; but Oxford University and the Clarendon Press might have lent a helping hand. The author himself, as appears from his introduction, was of doubtful mind as to the character, number and names of his primary group in the Vegetable Kingdom; so that his English representatives could not expect to help him. But he comes out essentially in a good old way with Thallophytes, Bryophytes, Pteriophytes or Vascular Cryptogams and Seed Plants (Spermaphytes). This, developed, recognizes a primary division into Phanerogams or Flowering and Cryptogams or Flowerless Plants; as to names, Flowering Plants is quite as good as Seed Plants, and long in use, and *Spermaphytes* is not such a name as the classical Endlicher would have made.

Coming to the classification of the Phanerogams, they are distributed, first into those without an ovary, *Gymnospermæ*, the third group of which, *Gnetaceæ* is said to have "flowers in many respects like those of Angiosperms," which is true and pertinent; second, Phanerogams with ovaries, *Angiospermæ*, A. *Monocotyledons*, B. *Dicotyledons*. Thus the Gymnosperms are taken to be what they are, whatever they may have come from, part and parcel of Phanerogamous plants; and, if the *Gnetaceæ* be of them, strictly connected with the Dicotyledons.

Finally, names and terms have some rights which ought to be respected. So we may protest against the present but probably fleeting fancy of imposing cryptogamous terminology upon phanerogamous botany, the new and ill-defined upon the old and well-settled. If all homologues must needs have the same name, why not call microspores "pollen," rather than pollen grains "spores?" This translation reads remarkably well; for the German has really been turned into English. It is not the translator's fault that we read that in the Cycads, "the branching of the primary root is monopodial," which is one way of saying that the branching is no branching at all. A plain writer would simply say such roots do not branch. A. G.

## III. ASTRONOMY.

1. *The Astronomical Journal.*—Eleven numbers of Dr. Gould's Journal have appeared since its resumption last autumn. It maintains the high character of the earlier volumes.

2. *Comets in* 1886.—In the tenth number of the *Astr. Jour.*, is given the following table:

## COMETS OF THE YEAR 1886.

The dates are in Greenwich M. T., and the elements only approximate.

| Designation. | Discoverer. | Perihelion 1886. | Ω | ω | *i* | *q* | Discovery. | Synonym. | |
|---|---|---|---|---|---|---|---|---|---|
| I | Fabry | Apr. 5·96 | 36°23′ | 126°36′ | 82°37′ | 0·642 | '85 Dec. 1 | 1885 *d* | |
| II | Barnard | May 3·28 | 68 19 | 119 36 | 84 25 | 0·479 | Dec. 3 | 1885 *e* | |
| III | Brooks | May 4·67 | 288 6 | 39 1 | 100 33 | 0·842 | '86 Apr. 30 | 1886 *b* | |
| IV | " | June 6·78 | 52 6 | 176 50 | 13 24 | 1·360 | May 22 | 1886 *c* | periodic. |
| V | " | June 7·40 | 192 42 | 201 13 | 87 44 | 0·270 | Apr. 27 | 1886 *a* | |
| VI | Finlay | Aug. 19· | 101 56 | 174 8 | 14 27 | 0·883 | Aug. 19 | 1886 *d* | Winnecke |
| VII | " | Nov. 22·39 | 52 26 | 315 7 | 3 2 | 0·998 | Sept. 26 | 1886 *e* | periodic. |
| VIII | Barnard | Nov. 28·22 | 258 13 | 31 46 | 85 35 | 1·479 | '87 Jan. 23 | 1887 *c* | |
| IX | " | Dec. 16·54 | 137 23 | 86 22 | 101 37 | 0·663 | '86 Oct. 4 | 1886 *f* | |

3. *Comets in* 1887.—The following are the comets discovered thus far in the present year:

Comet 1887*a*, discovered January 18th by Thome.
" 1887*b*, " January 23d by Brooks.
" 1887*c*, " January 23d by Barnard.
" 1887*d*, " February 16th by Barnard.

H. A. N.

4. In the same number of the *Astr. Jour.*, Professor Hall gives the result of his measurements of 63 small stars in the Pleiades. The probability that the stars of such a group have a common proper-motion, and that the small stars are connected physically with the larger ones, together with the importance of being able at some future time to test the motion of the brighter stars relative to the neighboring faint ones, led Professor Hall to undertake this series of observations. The triangulation of the bright stars of the Pleiades by Dr. Elkin, recently finished, made the present a favorable time for such measurements.

The improvement of the photographic processes is such, however, as to make it seem best for the present to discontinue these measurements and to wait to see what the photographic methods will furnish. H. A. N.

5. *Henry Draper Memorial.*—Professor PICKERING has issued his first annual report of the photographic study of stellar spectra made at the Harvard College Observatory under the very liberal provision of Mrs. Draper as a memorial to her husband. The various investigations begun or devised are: 1. A catalogue of spectra of bright stars; 2. Catalogue of spectra of faint stars; 3. Detailed study of the spectra of bright stars; 4. Faint stellar spectra; 5. Absorption spectra; 6. Wave lengths. The progress already made in spectral photography is vividly illustrated by the plate which accompanies the Report. H. A. N.

6. *U. S. Coast and Geodetic Survey, for the year ending with June*, 1885. Washington, 1886.—This report contains, among the results of work accomplished, papers by C. A. SCHOTT on the magnetic dip and intensity with their secular variation and geographical distribution in the United States, with three maps and

three plates; George Davidson, collection of some magnetic variations off the coast of California and Mexico, observed by Spanish Navigators in the last quarter of the 18th century; Wm. Ferrel, on the harmonic analysis of the tides at Governor's Island, New York Harbor; Lieut. J. E. Pillsbury, U. S. N., on deep-sea current work in the Gulf Stream; C. S. Peirce, on the influence of a noddy on the period of a pendulum, and on the effect of unequal temperature upon a reversible pendulum.

*Magnetic dip in North America.*—Mr. Schott, in Part II of his paper, mentions Prof. Loomis's deduction as to the diminution of magnetic dip based on observations from 1819 to 1839, making it 1·5′ per year; and again, "comparing the dips in N. York by Sir E. Sabine and Sir J. Franklin (1822 to 1825) with his own and others about the epoch 1835, deducing the rate of 2·1′ per year, and thence, including also the earlier observations, a rate of 1·8′ as the annual diminution of dip in the Eastern United States. Mr. Schott then observes that in 1856 he showed that in the northeastern part of the country the dip continued to decrease till about the year 1843, when it became stationary, 1842·7±0·7, being deduced as the period of the minimum; that from that date to 1856, the increase had been 2·7′. But unexpectedly the increasing of the dip stopped about 1859 in the Eastern United States, and that since about 1860, a decrease has been in progress "thus suggesting the idea of a secondary motion or wave of comparatively short duration, and of a character opposite to the general motion in the variation of the dip as it existed before and after this temporary interruption." The time was the same at Toronto and Washington, but much later on the Pacific in Southern California. After a further discussion of the subject, Mr. Schott gives as the annual decrease in seconds for Cambridge and Boston, 7·5; New Haven, 5·6; Albany and Greenwich, 6·6; New York, 5·4; Philadelphia, 5·5; Baltimore, 4·8; Washington, 3·5; Toronto, 2·5; Cleveland, 3·6; Detroit 2·8; Saint Louis, 5·0, "which values, in the absence of any additional observations, may be used for a few years to come."

At Rio de Janeiro there has been a steady increase of north dip between La Caille's observation in 1751 (dip = −20° 0′) and Harkness's observation in 1866 (−11° 47′). The same is noted in Valparaiso, between the observations of Malaspina in 1793 (dip = −44° 58′), and Harkness's observation in 1866 (−35° 23′). In contrast with this, at Havana the present annual change is probably less than +0·8′: at Acapulco about +1·0′; at Mexico and San Blas, perhaps, +1·5′ to +2·0′. "At Magdalena Bay, Lower California, the annual change seems to have become zero at present."

In British N. America, North of Dakota over the Lake Winnipeg region to Hudson's Bay, it is not now very different from what it was forty years ago; farther west at Fort Chipewyan, Fort Edmonton, it may be about −0·5′; at Nootka Sound, Vancouver Island, about −0·7′; at Port Simpson, −1·5′; in Alaska, decreasing since (about) 1852, with an annual rate between −2·2′ at Sitka, −1·5′ at Unalashka, 1·0′ at Port Clarence near Bering Strait, and 1·2′ at Point Barrow. Crossing to Asia, the dips indicate a maximum about 1854, which appears to be supported by the dips at Port Clarence, and has been conjectured for Unalashka.

The position of the pole of the vertical dip was deduced by Ross, as follows: in June, 1831 in $\varphi$ 70° 05·3′, $\lambda = -96°$ 45·8′. Mr. Schott observes, "It seems perhaps more reasonable to suppose its range of displacement to be quite limited than to assign to it, as has been done, a path surrounding the geographical pole, and to be described in several centuries." "Observations on H. M. S. Brazen in 1813 point to approaching verticality in $\varphi = 69°$ and $\lambda = -92°$;" and "Lieut. Schwatka supposes the pole in 1879 to have shifted to $\lambda = -99°$ 35′, while he leaves any change in its latitude undecided." Mr. Schott adds, "If the secular diminution extends to this northern region, the pole would now be found in a higher latitude than that given by Ross, but of this we are not certain. It is to be regretted that no steps were taken toward its solution in connection with the late international circumpolar explorations."

The first 125 pages of Mr. Schott's able paper are occupied with a tabulation and discussion of observations; and Part third treats of the secular variations of the horizontal component of the magnetic force and of the total intensity in the United States, and contains a table of the annual value of observed magnetic horizontal force at prominent stations.

## IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Die Hochseen der Ostalpen.*—Dr. AUGUST BÖHM has given in a recent publication of the Vienna Geographical Society an interesting discussion of the distribution of lakes on the earth's surface. Alluding to the recognized fact that lakes occur for the most part in groups and as connected with glacial phenomena, he goes on to show that there is a connection between their situation and their altitude. In other words, it may be shown that the height of the mountain lakes above the sea, in general, increases as we go from the pole toward the equator, somewhat as the snow level rises. The Alpine lakes, which give the data for this discussion, are divided into two groups, the valley and mountain lakes. The former are in general large and occupy the valley bottoms, forming a horizontal zone among themselves; they lie on the circumference of the former glacial region, where the ice streams at the time of maximum glaciation could exert their greatest force. The latter are generally small and are situated high up in the heart of the mountain region, but they also occur in greatest abundance at a definite altitude in each mountain chain, marking the last phase of the retreat of the shrinking glaciers. These mountain lakes are regarded as having but an ephemeral nature; the filling of the lake with detritus and the

deepening of its outflow channel so as to drain it being the two causes at work to destroy these bodies of water. Attention is called to the fact that within the last century 100 lakes have disappeared in Tyrol. With the retreat of the glaciers the upper lake zone also retreats to a continually higher level, until a limit is reached as determined by the precipitous character of the mountains. The rise in altitude of the present lake-zone from pole to equator is connected with the fact that glaciation has been more marked in higher latitudes. The author discusses in detail the distribution of the lakes and their character in the Eastern Alps, and then gives a tabulated list of them arranged according to their vertical distribution at intervals of 100 meters. This brings out clearly the concentration of these lakes at certain levels, and this is made still more striking in a graphical chart. The following table gives some of the facts in condensed form :

| | 3000 | 3000-2500 | 2500-2000 | 2000-1500 | 1500-1000 | 1000-500 | 500-0 |
|---|---|---|---|---|---|---|---|
| Limestone Alps—North, | 0 | 2 | 36 | 84 | 71 | 122 | 5 |
| Schist Alps—North, | 0 | 6 | 46 | 27 | 2 | 7 | 0 |
| Gneiss Alps—Cent. chain, | 1 | 372 | 771 | 312 | 38 | 21 | 1 |
| Limestone Alps—South, | 0 | 8 | 100 | 71 | 41 | 28 | 21 |

2. *American Association.*—It has been decided to hold the meeting of the American Association for the Advancement of Science, for this year at New York, commencing on August 10th.

3. *Agriculture in some of its relations with Chemistry ;* by F. H. Storer, S.B., A.M., Prof. Agric. Chem. Harvard Univ. 2 vols. 8vo. New York, 1887. (Charles Scribner's Sons).—A notice of this excellent work by the able chemist of the Harvard Agricultural School is deferred to another number.

4. *National Academy of Sciences.*—The following papers were entered to be read at the meeting held at Washington, April 19–22 :

T. Sterry Hunt : On Chemical Integration.

C. E. Dutton and E. Hayden : Results of the Investigation of the Charleston Earthquake.

Joseph LeConte : On some Phenomena of Binocular Vision.

W. G. Farlow : The Vegetation of the Hot Springs of the Yellowstone Park.

E. D. Cope : On the Fore Limb and Shoulder Girdle of Eryops, and on the Vertebrates of the Triassic.

Elias Loomis : Rainless character of the Sahara.

S. P. Langley : The Color of the Sun ; a new Map of the Spectrum.

Ira Remsen : Chemical Constitution and Taste ; On a New Class of Compounds analogous to the Phthaleins ; On the Decomposition of Diazo Compounds by Alcohol.

A. G. Bell : On the Ancestry of the Deaf ; On the Notation of Kinship.

J. W. Gibbs : On the Determination of Orbits of Planets and Comets.

G. H. Williams : On the Serpentine of Syracuse, New York.

A. W. Greely : On the Barometric Oscillation—Diurnal and Annual.

W. H. Dall : On Floridian Geology.

C. D. Walcott : On the Taconic System of Emmons.

R. D. Irving : Is there a Huronian Group ?

B. G. Wilder : On the Brain of the Ceratodus, with Remarks on the General Morphology of the Vertebrate Brain.

Theodore Gill : Outline of the Ichthyological System.

A. W. Wright : The effect of Magnetization on the Electrical Resistance of Metals.

# SCIENTIFIC AND MEDICAL BOOKS, MINERALS,

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## A. E. FOOTE, M. D.,

### No. 1223 Belmont Avenue, Philadelphia, Penna.

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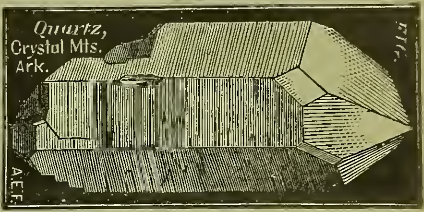

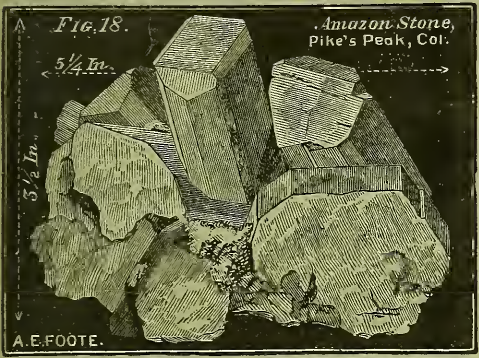

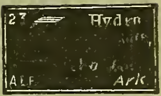

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## SCIENTIFIC INTELLIGENCE.

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ERRATUM.

Vol. xxxiii, p. 291, in foot-note, Jahrb. Berg-Hütt., for "1877" read "1887."

No. 198. VOL. XXXIII. JUNE, 1887.

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WITH PLATES XII AND XIII.

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## ART. XLIV.—*History of the Changes in the Mt. Loa Craters, on Hawaii;* by JAMES D. DANA. With Plate XII.

THE instructive papers of Messrs. Emerson, Van Slyke and Dodge (p. 87) are a good beginning for a future history of the Hawaiian volcanoes. The earlier history, for sixty-five years back, has a source of material in three scientific reports: that of Captain C. E. Dutton (1883),* the memoir of Mr. Wm. T. Brigham, who visited the region in 1864 and 1865,† and the report of the writer,‡ after an examination in 1840, each of which may be assumed to give the facts as they were observed, whatever the value of the explanations offered. In connection with these should be mentioned the descriptions and illustrations in the Narrative of the Exploring Expedition by Captain Wilkes.§ There are also accounts from various other sources which, although in many cases overdrawn, contain information of

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* In the Fourth Annual Report of the Director of the U. S. Geol. Survey, 1882–'83, 140 pp. roy. 8vo, with maps and plates of Kilauea, the Mt. Loa crater, etc.

† Notes on the volcanoes of the Hawaiian Islands, with a history of their various eruptions, by Wm. T. Brigham, A.M., Mem. Boston Soc. Nat. Hist., vol. i, Part ii. 126 pp. 4to, with four plates (including a new map of Kilauea) and several woodcuts. 1868. Mr. Brigham's map is reproduced in Captain Dutton's Report, but without explanation or remark.

‡ Report Geol. Wilkes Expl. Exped., 756 pp., 4to, with folio atlas, 1849.

§ Narrative of the Expl. Exped., by Charles Wilkes, U. S. N., Commander of the Expedition, 1838–1842. 5 vols. roy. 8vo, with an atlas. 1845. The account of the volcanoes of Hawaii is in vol. iv. Captain Wilkes required his officers to keep journals, and used them as a source for part of the material for his Narrative.

AM. JOUR. SCI.—THIRD SERIES, VOL. XXXIII, NO. 198.—JUNE, 1887.

much importance. In my Geological Report I endeavored to bring the history in a brief way down to 1849, the time of its publication. Mr. Brigham reviewed the same to the date of his last examination in 1865.

Captain Dutton gives his own observations in 1882, and his conclusions, with a few citations from other accounts; but the condition of the crater at the time of the visit was not favorable for an appreciation of the phases of the volcano or for an understanding of all its phenomena; and he is led to doubt much that was well reported before him, very much more than appears, in the light of the facts presented beyond, to be reasonable.

The conclusions he gathers from the accounts, as stated on pp. 117, 118 of his Report, are the following:

> "At the present time [1882] the liquid lava columns stand about 435 feet higher than they did forty years ago. No record has ever been kept of the progressive action by which these changes have been brought about. Nothing remains to show the successive steps in the accretion of lavas which gradually filled up the interior pit. The only guides we have are the fragmentary accounts of numberless visitors describing the condition of Kilauea from time to time. These are all so incoherent, and so grossly wanting in precision, that it is impossible to frame a connected account of the process.
>
> "There are, however, a few general features of the process which appear, and these may be briefly summarized. All accounts go to show that the height of the liquid column oscillates in an irregular manner; and while most of these oscillations are small, usually not exceeding ten to fifteen feet, yet in exceptional cases they are very much greater. Whenever the liquid column rises there is a tendency to overflow the margin of the pool which surrounds it, and this frequently happens. The quantities of lava thus outflowing and spreading out over a considerable area vary extremely, being sufficient sometimes to cover no more than a few acres to the thickness of a very few feet, while on rare occasions a square mile or two may be overflowed with a considerable body. The duration of these overflows is also extremely variable. Sometimes it is a single belch or surge lasting but a few minutes. It is quite common for the lava to run in this way for a whole day, and in large outflows it may run for two or three weeks without interruption. Sooner or later the liquid column sinks and the overflow ceases. The eruptions are not by any means confined to the lakes, but break out at unexpected places. One of the most favored spots for this action is the former focus of the Old South Lake, which for several years has been completely frozen over. The cooling lava invariably takes the form of pahoehoe."

The above meagre summary, which Captain Dutton's facts, and his knowledge of the descriptions of earlier "visitors," have enabled him to present, contains little, it is true, that is important to the science of volcanoes. After a careful sifting of all the earlier accounts with reference to statements bearing on the progressive changes in the craters of Kilauea and Mt. Loa, I have found that very much more is taught. What, and of what significance, the following pages aim to show.

## I. KILAUEA.

Besides the publications already mentioned, the following, relating to Kilauea prior to 1841, are cited from beyond, and referred to by means of the Roman numerals here prefixed. I add some descriptive and critical notes that the facts reported may be received with proper discrimination.

I. *a.* Journal of a Tour around Hawaii [in August, 1823] by a Deputation from the Mission of the Sandwich Islands. 264 pp. 8vo, with six plates. Boston, 1825 (Crocker & Brewster). "Drawn up by the Rev. Wm. Ellis," of England, one of the party, "from minutes kept by himself and by his associates on the tour, who subsequently gave it their approbation." Contains, facing p. 136, a night-view of "the south end of Kilauea," from a sketch taken by Mr. Ellis, looking southwestward,* engraved by S. S. Jocelyn, of New Haven, Ct. See also Missionary Herald, xxii, 25, 1826. *b.* London edition, "with large additions," 1826, under the title, "Narrative of a Tour through Hawaii;" 3d edit., March, 1827, 480 pp. 8vo. Contains, facing p. 226, a day-view of the "southwest end" of Kilauea, engraved, from the same sketch, in England; but a large cone stands where was the foot of a lava-stream descending the west wall; two cones are omitted; the active cones give out steam quietly. See p. 438.

II. Polynesian Researches, by Rev. Wm. Ellis, 2d edition, 4 vols. 12mo, London, 1831. The first edition, 2 vols. 8vo, published in 1829, contains nothing about Hawaii. In preparing for a second edition, the Narrative (I *b*) was added (as the fourth vol.); and, for a frontispiece to this volume, a new engraving of Kilauea (from a painting—a night-view) was introduced, having the subscript, "The volcano of Kilauea in Hawaii. Sketched by W. Ellis. Painted by E. Howard, Jr. . . . London, 1831." A copy of this plate, with the subscript, "Blowing Cones. Reproduced from Ellis' Polynesian Research, 1823," is contained in the Report of Captain Dutton. An outline copy is introduced beyond, on p. 441. The plate differs widely from those of 1825 and 1826;

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* Leaving the north end of the crater, says the "Journal," p. 145 (and "Narrative," p. 247) "we passed along to the east side, where Mr. Ellis took a sketch of the southwest end of the crater." And then, in the next sentence, "As we travelled from this spot we unexpectedly came to another crater" nearly half as large as the former. The native name of it is Kirauea-iti [Kilauea-Iki, as now written]; "it is separated from the large crater by an isthmus nearly 100 yards wide." The position from which the view was taken was hence north of Byron's hut (p. 440), either on the isthmus referred to or farther north on the bluff adjacent.

and since the text (Polyn. Res., vol. iv, p. 266) gives the same statement as the Narrative as to where the sketch was taken, the artist's fancy is evidently the chief source of the differences. The cones are fewer, but they are as active; and one, placed out in the front, is a grand high shooter, far outdoing any of those on the other plates. Further, the features of the black ledge and the wall above are changed on both sides of the pit, and the Great South Lake is put in a *southeast* recess instead of to the southwest. Mr. Ellis was a second time at Kilauea, but this was before 1826. He then found the crater much more quiet, and "the fires in the south and west burning but feebly."

III. Journal of a voyage to the Pacific Ocean and residence at the Sandwich Islands, 1822–1825; by Rev. C. S. Stewart. 8vo. New York, 1828. Contains an account of a visit to Kilauea, made on July 2, 1825. Am. J. Sci., xi, 363, 1826.

IV. Visit to the South Seas, by C. S. Stewart. 2 vols. 12mo. New York, 1831. In vol. ii, an account of Kilauea after a visit Oct. 9, 1829, not overdrawn like that in the preceding work. Am. J. Sci., xx, 229, 1831.

V. Voyage of H. M. S. Blonde to the Sandwich Islands in the years 1824, 1825, by Right Hon. Lord Byron, Commander. 260 pp. 4to, with plates. London, 1826. Contains an account of a visit to Kilauea on June 28, 29 (29, 30, American time), illustrated by a folded plate presenting a view of the volcano, by R. Dampier, in which the many cones give out vapors quietly, and a map of the crater by Lieut. Malden, R. N. (see p. 441 beyond).

VI. Letters of Rev. Joseph Goodrich: *a*, Am. J. Sci., xi, 2, 1826, letter of April 20, 1825; *b*, ibid., xvi, 345, 1829, letter of Oct. 25, 1828; *c*, ibid., xvi, 346, letter of June 12, 1828; *d*, ibid., xxv, 199, 1834, letter of Nov. 17, 1832.

VII. Letter of Rev. A. Bishop, Missionary Herald, xxiii, 53, 1827, after a visit to Kilauea, Jan. 3, 1826.

VIII. Note of Rev. L. Chamberlain, after a visit to Kilauea with J. Goodrich, Dec., 1824, Missionary Herald, xxii, 42, 1826; also in Ellis's Pol. Res., iv. 253, and Phil. Mag., Sept., 1826.

IX. *a*. Memoir of David Douglas, by Dr. W. J. Hooker, with portrait, letters and Journal, Companion of the Bot. Mag., ii, 79–182, 1836; the part on Hawaii, pp. 158–177. The visit to Kilauea was on Jan. 23–25, 1834, and to top of Mauna Loa, on Jan. 29; the account of the latter in his Journal, p. 175, and that in a letter to Dr. Hooker, p. 158.—*b*. Letter to Capt. Sabine, dated Oahu, May 3, 1834, partly from his Journal, but with additional material on his barometric, hygrometric, thermometric and hypsometric observations, Journal Royal Geogr. Soc., iv, 333–334, 1834. —*c*. Extracts from the Journal of Mr. Douglas, Mag. Zool. and Bot., i, 582, 1837, and including the letter to Dr. Hooker which describes Mt. Loa.

Mr. Douglas spent a dozen years in travels over N. America (Oregon, California, Hudson's Bay region, etc.) as an exploring naturalist, and twice visited the Sandwich Islands, making collections and observations in botany, zoology, etc., part of the time under the auspices of the Horticultural Society of London. His instruments included a barometer, chronometers, a reflecting circle, large dipping needle, etc. While on an excursion over Hawaii in July, 1834 (then 35 years old), he fell into a pit made to entrap wild cattle and was gored to death.

X. Account, by E. G. KELLEY, of observations made at Kilauea by Captains CHASE and PARKER, on the 8th of May, 1838, and published, after submission to Capts. C. and P., in this Journal, xl, 117, 1841, with a map of the crater (see p. 448).

XI. Notes of Count Strzlecki, after a visit to Kilauea in 1838, in his "New South Wales and Van Diemens Land," 8vo, London, 1845, and cited in quotation marks from, he says, his "manuscript notes." Also a note in the Hawaiian Spectator, i, 436, but the facts differently stated—see note, p. 449.

XII. Account, by Captain JOHN SHEPHERD, R. N., after a visit, Sept. 16, 1839, contained in the London Athenæum of Nov. 14, 1840, p. 909.

XIII. Account, by Rev. TITUS COAN, dated September, 1840, Missionary Herald, xxxvii, 283.

XIV. Rev. H. Bingham's Residence of thirty-one years in the Sandwich Islands, 1847.

## 1. KILAUEA FROM JAN. 1823 TO JAN. 1841.

For convenient reference in describing the varying phases of the volcano, I introduce (see Plate XII) a view of the crater of Kilauea from its north side, as it appeared in December, 1840,* when it had, as a consequence of the eruption about six months before, a lower pit, and a "black ledge," besides the great southern lake of lavas, Halema'uma'u, all well defined. The artist of the expedition, Mr. J. Drayton, has, with the aid of his camera lucida, brought out well the features of the scene. The more distant wall is about 14,000 feet from the near side, and this is not far from the idea the view conveys, quite as nearly so as it appears to be in the actual scene. But one or two points of geological importance have been overlooked which should be mentioned to forestall wrong inferences; one is, the omission of the stratification of the wall, which is a marked feature; and another is the giving a slight concavity to the floor of the crater in the northern or near part, which was not a fact. The small jets of vapor over the bottom arise, with a single exception, from fissures or cavern-like openings; and such escapes of vapor are greatly multiplied by a rain. The exception was that of a lava-lake, about 200 feet in diameter, named Judd's Lake in the "Narrative," which was the

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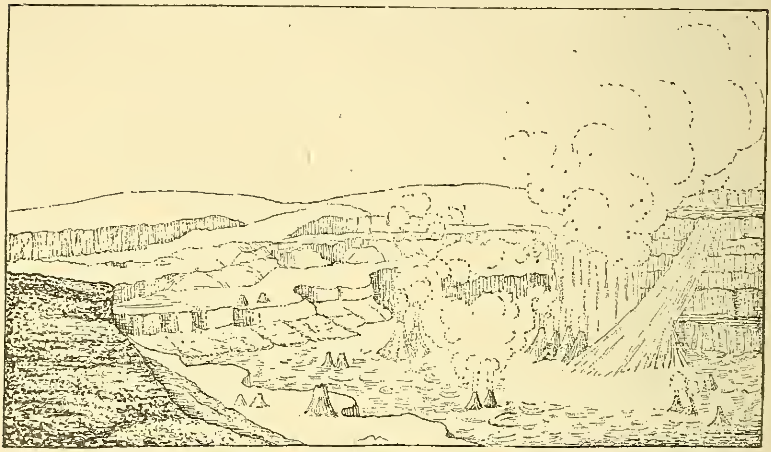
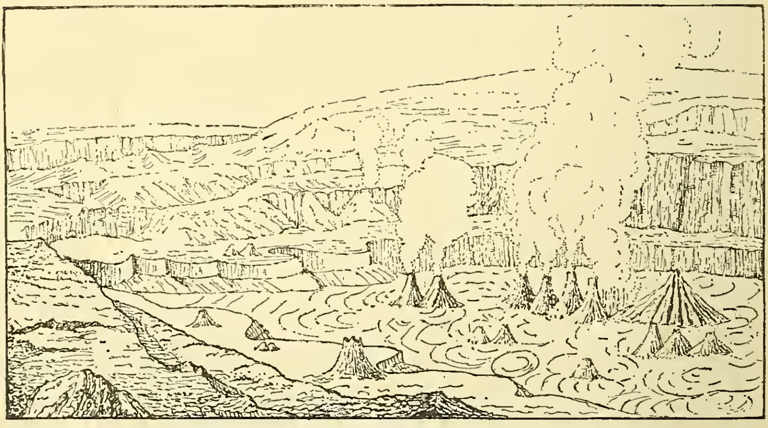
* Copied from the plate facing page 125, in the 4th volume of Wilkes's Narrative.

larger of two small lakes that were active in November, at the time of my visit.

1. Before the Eruption of 1823.—The condition of Kilauea prior to the eruption of 1823 is known only from statements in the "Journal of the Deputation of the Mission" (I*a*), or the "Narrative" (I*b*), and in a letter of Rev. Joseph Goodrich (VI*a*), both made after the visit of August 23, and based on evidence, seen by each of the party, that a high-level mark existed in a "black ledge," as it was then called, running like a terrace-plain around the interior, some hundreds of feet above the bottom. "It was evident," says the Journal, "that



1. "The south end of Kilauea." Sketched by W. Ellis.



2. "The southwest end of Kilauea." W. Ellis, del.

the crater had been recently filled with lavas up to the black ledge;" and Mr. Goodrich remarks that "the black ledge was made by the crater's being filled to that level" (VI*a*). This conclusion was evidently derived from the features of the ledge; for this was the first visit of foreigners. Still they may have had a hint from the islanders, one of whom in 1826, told the Rev. Mr. Bishop that "after rising a little higher the lava would discharge itself toward the sea as formerly by an underground way." I introduce here (fig. 1) an outline copy of the plate in the Journal (I*a*), and also (fig. 2) of that in the Narrative (I*b*), both reduced. They corroborate one another in all the main points, though having differences due either to corrections in England, or to changes suggested by Mr. Ellis. The black ledge borders the lower pit around, as in 1840, but is very narrow.

The eruption probably took place between the preceding months of March and June. At Ponahohoa in Kapapala, they saw (I*a*, p. 117) a large sunken area, 50 feet deep, fissured in all directions, besides steaming chasms, and ejections of fresh lava, which they were told by the natives of the place were made by Pele two moons before; and by natives of Kearakomo, five moons before (p. 151). It is added: "Perhaps the body of the lava that had filled Kilauea up to the black ledge" "had been drawn off by this subterranean channel."*

2. AFTER THE ERUPTION OF 1823. *a. Size of the Crater.*—The discharge, wherever it took place, was followed in the crater by a down plunge of part of the floor, giving Kilauea its lower pit and "black ledge." The depth of the lower pit was estimated by the Mission party at 300 or 400 feet; and the total depth of the crater, 700 to 800, making the former nearly or quite half the latter. Mr. Goodrich, who was at the crater with the party, and three times afterward before April, 1825, estimated the whole depth at over 1000 feet, and that of the lower pit at 500 (VI*a*), the latter again half the former.

Lieut. Malden, R. N., of the Blonde (V, p. 184) made a map of the crater (of which the following is a copy reduced one-third),† and measured the height of the high northwest wall above the black ledge. He states, in a note to Lord Byron's work, that he obtained by triangulation, 8209 feet for the distance across from the "Hut," the place of encampment, to the

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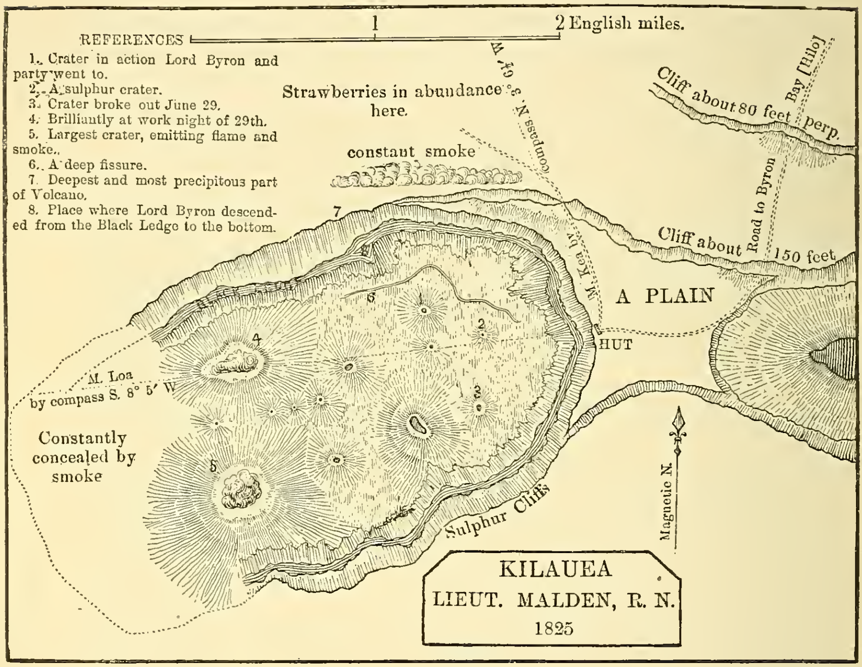
* It is a favoring fact that Mr. David Douglas in January, 1834, had information from the natives that in 1822 there was a great discharge in the Kapapala direction (IX*b*, p. 170). The same region was fissured and had its small ejections of lava at the eruption of Kilauea in 1868, and probably a large outflow off the coast.

† This copy has the lettering of the original, excepting the title, which is "A plan of the Volcano Peli, in the island of Owhyhee, by Lieut. Malden, R.N., 1825;" also the east half of Kilauea Iki is omitted.

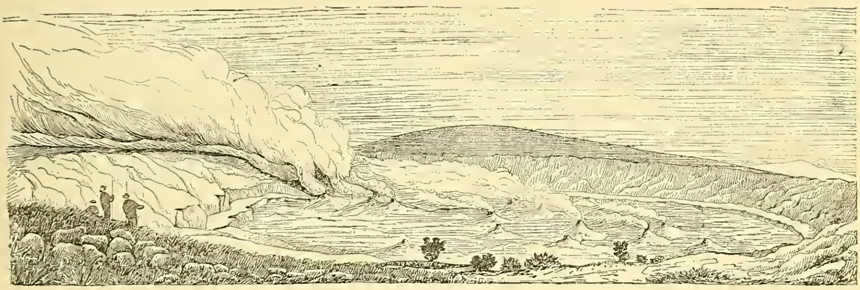
highest part of the western wall, a point numbered 7 on his map, which is, in all probability, Kamohoalii of Mr. Dodge's map (Plate II of this volume), and 5° 55′ for the angle subtended by the wall between its summit and the black ledge; and that he thus made the height of the wall, 932 feet. There is here a slip, for the data give 851 in place of 932. The most recent survey makes that distance 8750 feet, using which number in the calculation we get 907 for the height of the wall. It is therefore probable that 900 feet is not far from right.



KILAUEA
LIEUT. MALDEN, R. N.
1825

Lieut. Malden *estimated* the depth of the lower pit at 400 feet (and Dampier's sketch beyond accords with this); but he saw it only from above (illness preventing his descent), and more than two years after the eruption. The observers of August, 1823, and Rev. Mr. Stewart in 1825, made it nearly or quite half of the total depth (giving for the total 1700 or 1800), and this is assumed by Mr. Goodrich in his later letters.

All accounts and pictures, together with Lieut. Malden's map, make the black ledge narrow. The plates from Ellis's sketch in the "Journal" and "Narrative" (p. 438) make the eastern side of it the broader; but the part shown is really the southeastern, toward the sulphur banks; and there Rev. E. Loomis, in June, 1824, found it by measurement to be "nearly fifteen rods" wide.* Lord Byron, on his descent into the pit, went from the northeast to the northwest side, and says: the width (referring probably to the north side) varies from four or five feet to upwards of twenty. The annexed sketch, which is a copy (reduced one-third) of the plate by R. Dampier, making the frontispiece to Lord Byron's "Voyage" (V), has the ledge very narrow.† It is not quite certain what part of the crater the view represents. Mts. Loa and Kea are in the



4. Kilauea. Drawn by R. Dampier.

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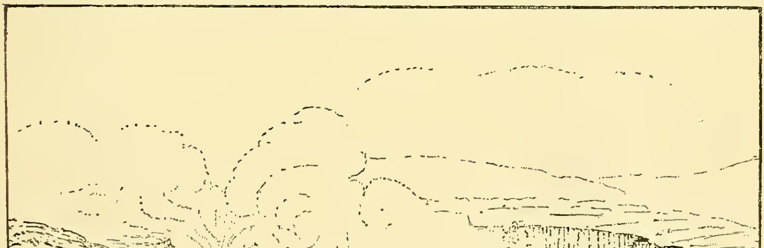
* Memoir of Wm. T. Brigham, p. 407.

† The plate in Ellis's Polynesian Researches makes the breadth about the same on the two sides, as the following outline copy (reduced a sixth) shows; but, as has been explained (p. 436) it has little value as to details. In the relative depths, however, of the lower pit and upper portion it agrees better with the several descriptions than the other plates.



Painted by E. Howard. Sketched by W. Ellis.

5. The Volcano of Kilauea, in Hawaii.

distance and the chief seat of fires is to the left, and by comparing with Lieut. Malden's map and Drayton's plates the position required for such a view can be ascertained. Rev. C. S. Stewart describes the ledge as in some places many rods, in others a few feet wide. Mr. Goodrich (VI*a*), after having measured the whole length of one side, remarks that "it is like a stair, although it is half a mile wide some part of the way"—which part he does not say.

On the 22d of December, 1824, Mr. Goodrich (VI*a*), with Mr. Chamberlain (VIII), measured the circumference of Kilauea at the top *with a line*, and made it 7½ miles; which is the length it has on Mr. Dodge's map, the scale of which is 500 feet to the inch. They measured the crater also on the black ledge, going half way around it and estimating for the rest, and obtained, as the result, 5½ miles for the circumference of the lower pit, which I find to be probably nearly right.

*b. Condition of the crater after the eruption.*—The "Journal" (I*a*) says, on page 131, "the southwest and northern parts of the crater were one vast flood of liquid fire, in a state of terrific ebullition." "Fifty-one craters, of varied form and size, rose like so many conical islands, from the surface of the burning lake. Twenty-two constantly emitted columns of gray smoke or pyramids of brilliant flame [lava-jets?], and many of them at the same time vomited from their ignited mouths streams of florid lava which rolled in blazing torrents down their black, indented sides into the boiling mass below." In a night scene, p. 136, "the agitated mass of liquid lava, like a flood of metal, raged with tumultuous whirl," and "at frequent intervals shot up, with loudest detonations, spherical masses of fusing lava or bright ignited stones"*

Descending to the black ledge (Journal, p. 144) they "entered several small craters," "bearing marks of very recent fusion," "and many which from the top had appeared insignificant as mole-hills" proved to be "12 or 20 feet high." They also collected the "hair of Pele," and afterwards found it seven miles south of the crater, "where it had been wafted by the winds."

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* The plate in the "Journal" of the "south end" represents "one" continuous area of lavas in "tumultuous whirl," in accord with the text, and that in the "Narrative" is similar, but with more extravagant whirls, for they are hundreds of feet in diameter, and even the black ledge is covered by them. The engraver has apparently tried to conform to the description. In the plate of the Polynesian Researches, the liquid surface is confined to the great South Lake, and a separate large area (or two of them), and nothing of the "tumultuous whirl" is represented, although the expression remains in the text (p. 245). It seems probable from the description that the party saw only "one" great lake, that of the South end, and that great overflowings sent streams far northward. The height of the throw of stones (see plates) is evidently an exaggeration, as it is inconsistent with the condition of "ebullition" at the time, and with all that has been said of Kilauea since. The text says "shot up," but does not say how high.

Mr. Ellis argues from the "conical islands" (I*b*, p. 226, and II, iv, p. 237) that the boiling caldron of melted lava "was comparatively shallow," implying that the cones stood on the solid bottom of the lake. He also noticed that the walls of Kilauea were "composed of different strata of ancient lava."

On page 144, the Journal (I*a*), after describing long, covered, tunnel-like chambers occupying the emptied interiors of lava streams, the upper surface rippled, the roof "hung with red and brown stalactitic lava," and "the bottom one continued glassy stream," says that they followed one such covered way "to the edge of the precipice that bounds the great crater, and looked over the fearful steep down which the fiery cascade had rushed, the fall "several hundred feet." The plate in the "Journal" (p. 438) represents rudely such a stream descending the *west* wall (like that of 1832, on the opposite side of the crater); but it is strangely (perhaps because badly drawn) omitted from the plate in the "Narrative."

Mr. Goodrich's letter on April, 1825 (VI*a*), does not distinguish the events of his first four visits. He observes that in February, 1825, he counted twelve places where the lava was red hot, and three or four where it was "spouting up lava 30 or 40 feet"; and mentions the escape of vapors in many places, making "a tremendous roaring." On December 22, 1824, a crater opened in the bottom where the lavas boiled like a fountain, with jets 40 to 50 feet high, and flowed off 50 or 60 rods.

Lord Byron's "Voyage" states (p. 184) that on June 30th, 1825, "fifty cones of various height appeared below," at least "one-half of these in activity"; and Mr. R. Dampier's sketch represents such a scene. Lieut. Malden's map makes the cones fewer and very broad, unlike the descriptions; crater No. 5 (p. 440) is probably Halema'uma'u, for the distance from the hut is right for it, and if so the part "concealed by smoke" was of much less extent than was supposed by the party.

Rev. C. S. Stewart, who was with the party from the Blonde, makes the same statement (III) as to the number of "conical craters," and the position of the great seat of action in the southwest. He describes (p. 298) the black ledge as covered with tortuous streams of shining lava bearing "incontestible evidence of once having been the level of the fiery flood," and adds that "a subduction of lava" had "sunk the abyss many hundreds of feet to its present depth." A cone on the bottom, visited by the party, spoken of as "one of the largest," "whose laborious action" had attracted attention during the night (p. 304 and No. 1 on the map), was judged to be 150 feet high "a huge, irregularly shapen, inverted funnel of lava, covered with clefts and orifices, from which bodies of steam escaped with deafening explosions, while pale flames, ashes, stones and lava were propelled with equal force and noise from its ragged yawning mouth." The following night, crater No. 3 (Malden's map) became suddenly eruptive, and a lake of fire (No. 4?), perhaps two miles in circumference, opened in the more distant part.

Mr. Bishop, after a visit, Jan. 3, 1826, reported (VII) a similar condition of the crater; and also the filling up of the lower pit since August, 1823, of 400 feet—probably on the view that the original depth was 900 feet.

It will be observed that the above citations from Mr. Ellis and other early writers on Kilauea contain no mention of "blowing cones," except what is implied in the general descriptions. This is true of other later reports, including that of Captain Wilkes, who saw no cone in action. Further, it appears that the blowing described was done partly by the small cones, and partly by openings or oven-shaped places over the floor of the crater, as implied in the statement of Mr. Goodrich (p. 443), just as was true in 1886. They blow violently because they are small, or have relatively small apertures, so that the imprisoned vapors, on bursting the envelope of liquid or semi-liquid lava, go out with a rush and a roar. The only heights of ejections of lava mentioned are 30 to 40 and 50 feet; and the heights of cones 12, 20, and, for "one of the largest cones," 150 feet; which are common facts of later time down to the present.*

The close correspondence between the heights and character of ejections given in the earlier accounts, and those of recent years, is interesting as proving long-continued uniformity as to kind and quality of work even to the blowholes. The activity was however greater and more general than has been witnessed for many years. There are exaggerations, but they are mostly confined to the pictures, and to some of the general descriptions. The *estimates* made were usually below the truth, from honest caution.

Further, Mr. Ellis guards the reader, as has been shown, against the inference, from the island-like position of the cones in the region of liquid lavas, that they were floating-cones.†

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* It is obvious that the high-shooting cone in the plate of Ellis's Polynesian Researches (II), blowing to a height of 700 or 800 feet (measuring it by the height of the upper wall), is the artist's fancy sketch, as suggested on page 436. It is wholly un-Kilauean and fundamentally out of place. The earlier plate from Mr. Ellis's sketch in the 'Journal' (I), also exaggerates, but only a third as much except over the South Lake.

† On page 111 of Captain Dutton's Report, the author presents the case differently, as follows.—"The earlier visitors to Kilauea whose accounts of it are now accessible speak of a phenomenon which did not exist at the time of my visit. I refer here to what has been termed 'blowing cones' within the lake. Ellis, in his account of Kilauea in 1823, described them as 'conical inverted funnels' rising to heights varying from twenty to forty, or even fifty feet above the surface

*c. Progress in the filling of the lower pit.*—As early as February, 1825, Mr. Goodrich stated, in view of the overflows he had observed, and the making of a "mound" over 60 feet high in six weeks, that the pit had begun to fill up (VI*a*); and in his letter of October 25, 1828, (VI*b*) he made the pit to have diminished in depth since August, 1823, by 300 or 400 feet. A year later, Oct. 25, 1829, Mr. Stewart (VI) described the lavas as still 200 feet below the level of the black ledge—which implies a filling of 400 feet, if the depth in 1823 was 600 feet, and of 600 if 800 feet deep. He states that although the crater was comparatively quiet, the bottom was crossed by a chain of lava-lakes, one of them a mile wide, throwing up masses of lava 15 to 20 feet; and that there were also six cones in action in the lower pit and one on the black ledge. Here again the height of the ejections mentioned is small. In October, 1830, the black ledge was still distinct (XIV, p. 387.)

3. Before the eruption of 1832.—Before the eruption of 1832, as Mr. Goodrich states, after a visit to Kilauea "about the 1st of September" of that year (VI*d*), "the crater had been filled up to the black ledge and about fifty feet above, about 900 feet in the whole since I first visited it, and it had now again sunk down to nearly the same depth as at first (in 1823), leaving as usual a boiling caldron at the south end." The precise time of the discharge and down-plunge is not stated. He adds, "The earthquake of January last had rent in twain the walls of the crater on the east side, from the top to the bottom, producing seams from a few inches to several yards in width, from which the region around was deluged with lava." "The chasms passed within a few yards of where Mr. Stewart, Lord Byron, myself and others had slept," "so that the very spot where I have lain quietly many times is entirely overrun with lava." (See map, p. 440). This outflow is stated by Mr. David Douglas (IX*b*) to have occurred in June, 1832. We may conclude, therefore, that the time of eruption was probably in January, but perhaps in June of 1832; certainly before September 1832, the time of Mr. Goodrich's visit.

4. After the eruption.—*a. Size of the crater after the eruption.*—As to the new depth of the lower pit, we have first Mr.

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of the lake, with openings at the top from which jets of vapor and sometimes spouts of lava were thrown out. As many as fifty were seen at one time within the great lava lake then existing, and most of them were simultaneously active. The same phenomenon was described in 1825 by parties from H. B. M. frigate Blonde. They were also observed by Wilkes in 1841, and have frequently been seen within the last ten or fifteen years by many other visitors. They appear to have been composed of solidified but very hot lava. None of them were permanent, but after a short period of activity they were either melted down, or shifted their positions. Ultimately, no doubt, they were remelted. That they shifted their positions is fully attested by many observers. Most probably they were masses of solidified lava floating like bergs in the lake."

Goodrich's statement above cited, "the same depth as at first," and the additional remark that the filling amounted to "about 900 feet"; which statement would make the depth of the lower pit after the eruption of 1832 nearly 900 feet, and of the crater from top to bottom 1750 feet. This estimate of the original depth accords with his view in 1825 that the upper and lower walls were of nearly equal height, and that Lieut. Malden's measurement was therefore good for both. There is no published account furnishing data for correcting this estimate.

By letter from Mr. W. D. Alexander, Surveyor General of the Hawaiian Islands, dated March 2, 1887, I learn that his father, Rev. Wm. C. Alexander (who arrived at the Sandwich Islands in 1832) visited the crater on the 12th of January, 1833, four months after Mr. Goodrich's visit, and in his private diary gives the depth of the crater as 2000 feet. This tends to confirm Mr. Goodrich's numbers, although only a rough estimate. He says nothing of any black ledge, except of that at the bottom of the 2,000 feet; and this leads to the inference that the ledge was quite narrow, as in 1823.

On the 22nd of January, 1834, Mr. David Douglas, of Scotland (XI), made careful barometric measurements of the crater, (all the details of which, with the calculation, are given in his letter to Captain Sabine, IX*b*). He obtained for the depth to the black ledge, on the highest northwest side, 715 feet; and to the bottom of the lower pit, 1,077 feet, (mean of two calculations). This makes the depth of the lower pit at that date 362 feet; in addition to which he says that there were 43 feet more to the surface of the liquid lavas.

We thus know that the down-plunge was a fact; and using as evidence only the measurements of Mr. Douglas, and noting that they were made at least a year and a half after the eruption, it was larger both as to depth and breadth than that of 1840. Hence the eruption of 1832—instead of being "a very small one, only remarkable from the fact that the fissure from which it emanated opens at a level of more than 400 feet above the present lava-lakes" with, "so far as known," "no sympathy" "within the lavas of Kilauea"*—was one of Kilauea's greatest, although not registered, so far as known, in any outside stream of lava.

*b. Condition after the eruption.*—Mr. Goodrich describes the Great Lake at the south end as "60 or 80 rods long, and 20 or 30 rods wide," about 20 feet below the brim; "the whole mass of liquid and semi-fluid lava was boiling, foaming and dashing its fiery bellows against the rocky shore; the mass was in motion, running from north to south, at the rate of two or

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* Report of Captain Dutton, p. 124, referring to the eruption near Lord Byron's Hut.

three miles an hour, boiling up as a spring at one end and running to the other." Mr. Alexander, while in the crater four months later, found this lake, "the principal furnace, not in lively action," and ascended, much disappointed; but by the time he had reached the summit, "the grand crater commenced furious action, spouting with a roaring sound, streams of melted lava far into the air." The next day he went again to the bottom, and direct to the great boiling caldron two and a half miles distant," and found it "3000 feet long and 1000 feet wide, tossing its fiery surges 40 or 50 feet into the air." He went to the brink of the lake, but left it on account of the fumes, and three minutes afterward the spot was covered with the lavas of an overflow, "which," he says, "seemed to pursue us as we hastened away." It is important to observe that uniformly the "far into the air" and similar expressions in the general descriptions of travelers become, when put in figures, not far from 30, 40 or 50 feet of actual height.

Mr. Douglas, whose visit was in 1834, reports (XI) that he found two great boiling lakes in the crater, a northern 319 yards in diameter, and a southern 1190 by 700 yards in area, heart-shaped in form. The great southern lake was "at times calm and level, the numerous fiery-red streaks on its surface alone attesting its state of ebullition, when again the red hot lavas would dart upwards and boil with terrific grandeur, spouting to a height which from the distance at which I stood (on the west wall) I calculated to be from 20 to 70 feet. Close by stood a chimney above 40 feet high which occasionally discharged its steam as if all the steam engines in the world were concentrated in it." There were other chimneys over the bottom, some active and others comparatively quiet. In each of the large lakes the lavas had an apparent movement southward, the velocity of which Mr. Douglas measured (by throwing on a block of lava and seeing how long it took to go 100 yards) making it nearly 3¼ miles an hour.*

*c. Filling of the pit after the eruption of* 1832.—On the 8th of

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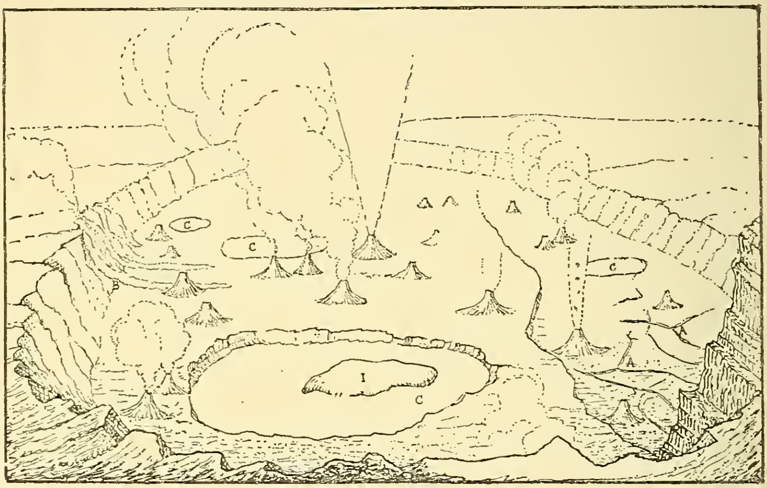
* Mr. Douglas's testimony with regard to the Hawaiian volcanoes has been doubted because of his incredible account of what he saw at the summit crater in a letter to the eminent botanist, Dr. Hooker. But I find that injustice has been done him. His *Journal* of his visit to the summit (IX*a*), evidently written by him at the time of his observations, represents the crater as having been long quiet. While at Honolulu, over three months later (May 3), he wrote Capt. Sabine on his various physical investigations and barometric measurements, and gave him the same facts as to the summit crater that he has in his Journal, and partly in the same words. Only three days later (May 6) he wrote his letter to Dr. Hooker—a reasonable letter in all parts excepting its description of the terrific activity and immense size of the Mt. Loa crater. His words indicate a mixing up and magnifying of what he had seen at the Kilauea and summit craters, which can be explained only on the ground of temporary hallucination. Mr. Douglas was an excellent Scotchman, and all the rest of his writings are beyond questioning.

May, 1838, about six years after the eruption, Captains Chase and Parker were at Kilauea. An account of what they saw was written by Mr. E. G. Kelley from their statements, submitted to them for approval, and afterward published in this Journal (X), with a plate from their sketches, but redrawn unfortunately by a New Haven artist who evidently had Vesuvius in his thoughts. An outline copy is here introduced. It was taken at the south end looking northeastward, and has the Great South Lake in the foreground. There is no black ledge on the west or north side; and to the left instead of a black ledge there is a depressed plain, 40 feet below the general level; the part of it AA was flooded by lavas after having been passed over by the party. The crater was unusually active; there were 26 volcanic cones, 20 to 60 feet high, eight of them throwing out cinders, red hot lava and steam, and six lakes of lava (*c*), including the Great Lake "occupying more space than all the rest."



Kilauea, from the south end.

Not far from the center of the Great Lake there was an island, I, of black solid lava which "heaved up and down in the liquid mass" and "rocked like a ship on a stormy sea." This is the first mention of a "floating island." The descending streams at B are described as streams of sulphur, but as this is not possible they were probably lava-streams in part colored yellow.

The same year, in August or September, Count Strzelecki (who later visited New South Wales), was at the crater (XI). He made some barometric measurements over the region, and determined the height of the north-northeast wall down to the "boiling surface of igneous matter" to be 600 feet, and makes no mention of a black ledge. He describes six craters with boiling lavas, four of which were only 3 or 4 feet high, a fifth, 40 feet, the sixth 150; the first five as containing 12,000 square feet each, while the sixth—which he says is called "Hau-mau-mau"—contained nearly a million. He alludes plainly to the ebullition over this great lake in the expression "ceaseless impetuosity and fury." He states that the lava sank and rose in all the lakes simultaneously; which is not always true.*

On the 16th of September, 1839, Captain John Shepherd, R. N., visited Kilauea (XII). He speaks of the black ledge as "obliterated;" of cones 20 to 30 feet high, whence issued vapors and lava with loud detonations; of a lake of lava toward the *east* side one mile long and half a mile wide within a cone 100 feet high, from the summit of which he saw the expanse of liquid lava in violent ebullition. He also mentions that the lavas had an apparent flow from south to north, and adds, "caused by the escape of elastic fluids, throwing up the spray in many parts 30 to 40 feet."

5. BEFORE THE ERUPTION OF 1840.—Mr. Coan states (XIII) "on the testimony of many natives" that in the latter part of May, for a week previous to the eruption, the interior of Kilauea was "one great sea of liquid lavas;" which signifies the existence of many active cones and boiling lakes over the bottom and extensive outflows from the lakes and from opened fissures. He remarks, further, that the ground about Kilauea so trembled from the action below that the islanders avoided the path along the verge of the crater.

There was indubitable evidence at the time of my visit, in November, five months after the eruption, of a recent flooding of the black ledge with lavas, in the tortuous scoria-covered streams of cooled lava that covered it.

6. THE ERUPTION OF 1840.—No intelligent observer was present at the eruption. Mr. Coan, then a resident of Hilo, returned home from Oahu in July, and his first account of it appeared in September of that year. He found that, through

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* Count Strzelecki's note in the Hawaian Spectator occurs in the number for October, 1838, which number also states that he was visiting various portions of the Pacific in H. B. M. S. Fly. It differs widely from the report in his own work, in making the area of the largest lake 300,000 square yards, and those of the smaller "about 5,700 square yards each." His volume is the later publication, and should set aside the newspaper note. Count Strzelecki, in this volume, describes the terraces around the Kilauea crater as vast platforms; makes the height above the sea-level of the north-northeast side of Kilauea two paces from the edge of the precipice 4,109 feet and 600 feet above the fires below; and observes that this is 950 below the brim of the *ancient* crater, the highest point of which he made 5,054 feet, and its circuit 24 miles. He thought he saw evidence that this greater crater was formerly brimfull of molten lava.

the discharge of lavas and a consequent down-plunge in the crater, there was again a lower pit with a black ledge. He gathered facts showing that the eruption began on the 30th of May, made itself apparent at intervals down the eastern slopes of the mountain, finally broke out as a stream twelve miles from the coast and flowed into the sea just south of Nanawale; and that the flowing continued for three weeks. The condition of the crater in November, the time of my visit, agrees well with the view in the accompanying Plate (Pl. XII) which was taken two months later. The route to the seashore was surveyed by the officers of the Expedition in January, and less perfectly by myself in November.

My failure to survey the whole route of the lavas to the seacoast and investigate other parts of Hawaii was in obedience to orders. The vessel of the Expedition to which I was attached—the sloop-of-war "Peacock"—was at the time already under sailing orders for hydrographic work in the equatorial regions of the Pacific; and, although the geologist of the Expedition, I was required to go off with her, away from the most important field of geological investigation in the ocean. Only a week was allowed me for Hawaii. I left the region of volcanoes with a silent protest—the only safe kind—but found compensation through work in another field; and though an old field to me, it was one of unexhausted delight and instruction—the coral islands of the central Pacific. I was enabled to add much to the knowledge of reefs, corals and crustaceans which I had gathered during the preceding season in the Paumotu, Society, Samoan, Friendly and Fejee Islands, by excursions and studies in the Union Group of atolls, the Phœnix Group, the Kingsmill or Gilbert islands, and others. Captain Wilkes had once (while we were off Patagonia) sent me word, when I was seeking information from the log-book of his vessel as to the winds of a Cape Horn gale, that he had that department in charge. At the Hawaiian Islands it was made to appear that at his pleasure, he had the geological department also in charge, although he knew nothing of the subject. The "Narrative," however, was intended to include all departments; and the energetic commander was never conscious of incapacity in any direction.

7. AFTER THE ERUPTION OF 1840.—*Size of the Crater.*—Capt. Wilkes states, on page 123 of the 4th volume of the Narrative, that the "black ledge surrounds it [the crater] at the depth of 660 feet, and thence to the bottom is 384 feet;" and four pages beyond: "the black ledge is of various widths, from 600 to 2,000 feet." The black ledge "was found [to be] 660 feet below the rim." The floor of the crater "was afterwards found to be 384 feet below the black ledge, making the whole depth 987 [1,044 ?] feet below the northern rim."

The observations here reported were made in December, 1840, the party leaving on the 18th for the top of Mt. Loa. Other observations on Kilauea were made by Capt. Wilkes and his officers just a month later, in January; and these include a topographic survey of the crater by Capt. Wilkes, who says: "I measured my base and visited all the stations around the crater in their turn." On page 175 it is stated that the observations of one of the officers of the expedition, Lieut. Budd, made the depth to the black ledge 650 feet, and thence to the bottom 342 feet, whence "the total depth 992 feet." On page 179, we learn that Lieut. Eld was instructed to make the measurement of the depth, "as I was desirous of proving *my own* as well as Lieut. Budd's observations;" and then follows the remark, "The measurements coincided within a few feet of each other." Had the precise numbers obtained by Lieut. Eld been reported we might be able to remove the doubts left by the varying statements. But the fact that Lieut. Budd's results are inserted by Capt. Wilkes on his own map of the crater is a strong reason for believing that the coincidence was between the results obtained by the two Lieutenants.

I add here a few words from my own report, on the surface about Kilauea, on the stratification and rock of the walls and the absence from them of scoria, and on the escaping vapors of the Great Lake. "The country around [Kilauea] is slightly raised above the general level, as if by former eruptions over the surface." The walls "consist of naked rock in successive layers" "and look in the distance like cliffs of stratified limestone." The rock is a heavy compact dark gray to grayish black lava [basalt] containing usually fine grains of chrysolite; and no layers of scoria like that making a crust of two to four inches over the solidified lavas from the lava-lakes, intervene even in the walls of the lower pit, each new stream having apparently melted the scoria-crust of the layer it flowed over. While the cooled lava-streams over the bottom were of the smooth-surfaced kind [and would be called pahoehoe] there was the important distinction into streams having the scoria-crust just mentioned, and those having a solid exterior and no separable crust, pointing to some marked difference in conditions of origin. "The vapors rising from the surface of the Great Lake were quite invisible until reaching an elevation where part became condensed by heat" (p. 179); here began "a column of wreaths and curling heaps" and upon this column, "the broad canopy of clouds above the pit seemed to rest" (p. 172).

[To be continued.]

## ART. XLV.—*Special Processes of Research*; by G. K. GILBERT.

[Presidential Address read before the American Society of Naturalists at Philadelphia, December 28, 1886.]

MR. PRESIDENT AND GENTLEMEN:—A year ago your suffrages made me my own successor in office. To that fact is due our present relation of audience and speaker, and to that fact is also due the subject of my discourse. My re-election was a phenomenon of so surprising nature that I have only recently ceased to frame explanatory hypotheses. One theory after another was subjected to such tests as were available, and was proved to be untenable—until finally it occurred to me that my address last year was not thrown open to debate, and that the nomination of officers came soon after it. It was then evident that the treatment of the subject of the address had not been so clear and convincing as was desirable, and that you had delicately given me an opportunity to supplement it. I embrace the opportunity.

Our subject last year included the general process of scientific research.* To-day endeavor will be made to illustrate the general process by a description of certain special methods of its application.

When one of our citizens first comes into relation with the Chinese, he finds great difficulty in distinguishing and recognizing individuals. This is not because marks of discrimination are wanting—the Chinaman from a different province has no such trouble,—it is merely that he unconsciously groups together all the features of face and costume as strange. The *common* features by their strangeness hold his attention, and until this strangeness has passsd away, he does not automatically catch the *individual* features. A year ago we gave attention to the common features of research and saw it as a unit. If now we should attend instead to the features of difference, we would find an immense assemblage of individual operations, devices, and other details, a limited number of formulated procedures applicable to groups of special cases, and a great organized, though ever enlarging, system of research, in which each special procedure assumes its proper coöperative function. I shall attempt neither the enumeration of the details, nor the characterization of their groups, nor the demonstration of the organized system. I could not if I would, and if I could, time would not permit. What I shall attempt is this: first, to follow for a time the course of an elaborate, carefully planned investigation of a complex subject, analyzing its

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* This Journal, vol. xxxi, p. 284, April, 1886.

methods by the way; and second, to describe a special system of procedure which, like the rule of three, stands ready to assist the student whenever a suitable occasion arises.

The investigation chosen for my first purpose is that of thunderstorms, as undertaken by the New England Meteorological Society. It is planned by the society in a broad way and has among its objects the classification of the storms (provided the discrimination of distinct types is possible), the determination of their mechanism, the discovery of their causes, and the prediction of their occurrence. An account of the work, a summary of the first season's observations, and an outline of the conclusions deduced therefrom have been published by Professor Davis. I have selected this research as an illustration of my theme, partly because it belongs to the living present and is somewhat familiar to most of my audience, and partly because the methods employed and the reasons for their adoption have been set forth by Professor Davis with exceptional fullness and clearness.*

You are not to expect an abstract of his papers, but only of such passages as are necessary to an understanding of the general nature of the considerations determining, first, the formulation of the scheme of observations, and, second, the methods of classifying the observations after they had been made. My discussion of the scheme of observations will be introduced by a general account of the factors determining its principal features, and by an account of the features themselves, after which an analysis will be attempted of the logical relations of the two.

The system of atmospheric phenomena which centers about a large area of low pressure is called a cyclonic storm. One of these storms usually has a diameter of several hundred miles, and moves across the country so slowly that an entire day is spent in passing a single point. Their nature was discovered by comparing together simultaneous observations of atmospheric phenomena made at numerous stations scattered over a large area; and a knowledge of this character is utilized, as you all know, by the national weather bureau in the prediction of storms and other weather features from day to day. To obtain the data necessary for prediction, observers are stationed at a large number of points distributed at intervals throughout the United States; and it is arranged that they record a certain set of atmospheric phenomena at three concerted times in each 24 hours. Before the New England society began its

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* On the methods of study of Thunder-storms; by W. M. Davis. Proc. Am. Acad. Arts and Sci., vol. xxi, p. 336.

Thunder-storms in New England in the summer of 1885; by William Morris Davis. Proc. Am. Acad. Arts and Sci, vol. xxii, p. 14.

work, it was known that thunderstorms, although too large to be fully observed from a single station, are too small to be investigated by means of so coarse a mesh of stations as that of the national weather bureau. A thunderstorm observed at one of these stations frequently escapes notice at the other stations of the vicinity, while many of them occur between stations and are thus entirely omitted from their records. It was known that the local phenomena of a thunderstorm are of comparatively brief duration, so that the tri-daily observations do not afford a complete record of their occurrence. It was known that some thunderstorms move across the country, appearing successively at different points. It was known that they are characterized by electric discharges as well as by rain, wind and temperature change, and it was known that their occurrence is more frequent in summer than in other seasons of the year. It was believed or hoped that some conspicuous, readily observed feature of their transit might be found so persistent and constant in its relation to the aggregation of phenomena constituting the storm that it could be used for the purpose of tracing out the path and general form of the meteor. The society was unable to pay its observers for their services, and it recognized the fact that those who might voluntarily coöperate with it must not be overtaxed, or they would withdraw their aid.

With these considerations, and doubtless many others, in view, the work was planned and organized. The initial steps were the arrangement of a system of stations for observation, and the preparation of schedules of phenomena to be observed. A large number of resident observers were engaged, so distributed that the interspaces between stations were much smaller that in the system of the Signal Service. Provision was made for observations at very short intervals of time during the approach and passage of thunderstorms, but no record whatever was required, except a general negation, on days when no thunderstorms occurred. The work was restricted to the summer months. The observers were classified in such way that the greater number were called upon to record but few features of the storm, while a few who were able and willing to bestow much time and attention were instructed to make very full and minute records. The schedule of observations included, besides numerous other features, a number of definite events, namely, the time of the first rainfall, of the last rainfall and of the heaviest rainfall, the time of the first thunder heard, and of the loudest thunder.

Looking at this organization for observation from our special point of view, we are able to group the considerations determining its details in four categories. In the first place, there was a certain amount of antecedent knowledge with respect to the subject of investigation, and this determined a large portion of the scheme; thus the nearness of the stations was dictated by approximate knowledge of the size of the storms to be observed. In the second place, certain hypotheses were entertained in regard to the phenomena, and these had their influence; for example, it was tentatively postulated that the beginning of rainfall bore such a constant relation to the storm as a whole that the timing of it would afford a record of the progress of the storm. In the third place, analogy with other researches had its influence; a certain resemblance was recognized between thunderstorms and cyclonic storms, and the general system of investigation was modeled upon that which had proved successful in the study of the larger meteors. Finally, numerous features of the system were determined by what may be regarded as obstacles to observation. The limited endowment of the investigation was such an obstacle and occasioned the restriction of observation to a certain season, the further restriction to the actual period of storm occurrence, and also the classification of observers.

This classification of considerations controlling the organization of the research is believed to be comprehensive, and applicable to any other systematic research, but it will not serve the purpose of dividing into groups the details of working plan to which the considerations give rise, because nearly every detail is the joint product of considerations falling in two or more categories; and it should be observed also that its categories are not mutually exclusive. The consideration of obstacles—or practical limitations—never occurs alone, but merely modifies the procedure indicated by other considerations. The consideration of analogy cannot stand alone, because analogy exists only in virtue of some knowledge or supposed knowledge or hypothesis with reference to the nature of the subject of research. And again, considerations of antecedent knowledge and of hypothesis have no clear line of demarcation, for the practical discrimination of knowledge and hypothesis, however sharply they may be divided in thought, is beset with insuperable difficulties.

Returning to our illustration, we note that the published plan of observation includes no mention of barometric pressure; and that the only observations touching the electric condition of the atmosphere are those on lightning and thunder. It is easy to understand that these omissions are referable to the obstacle of expense, and we may also assume, although we have no warrant in the publications of the society, that such observations will be made at some future stage of the investigation, when accumulation of knowledge and hypothesis has made it possible to develop a plan whereby a small number of the necessary instruments can be so distributed as to perform their work effectively and economically. This assumption of our own is based on the analogy of other investigations, for it is a common feature of researches that the preliminary results determine the scope and field of subsequent observation. A research is the exploration of an unknown land, and neither the route nor the goal can be foreseen. The explorer climbs the hill before him, and from the vantage of its summit selects the most promising course for the next stage of his journey.

One of the most important obstacles encountered in the work of the society arises from the difficulty of making observations at a distance from the surface of the earth. A thunderstorm involves a mass of air of very considerable vertical dimension, and the ideally complete system of stations would include many more points in mid-air than upon the ground. Observations from balloons, though within the range of possibility, are limited by expense and danger, and would moreover be conditioned by uncertainty as to location at all points within the storm cloud. The society has thus far attempted only terrestrial stations, but it endeavors by indirect methods to learn something of what is taking place at greater altitudes. The wind cannot be directly observed there, but floating objects can, and observers are therefore instructed to watch the motions and observe the positions of clouds. Temperature and moisture cannot be directly measured, but advantage is taken of the fact that a certain combination of temperature and moisture produces condensation, so that the boundary of a cloud is the locus of a certain atmospheric condition which is a joint function of temperature and moisture. The configuration of the storm cloud therefore has a certain value, and is the subject of study. It was also known antecedently that as the domain of saturation advances in the air, the resultant cloud grows, while its recession is characterized by the dissipation of the cloud. Observers are therefore instructed to record cloud formation and cloud dissipation.

The preliminaries having been arranged, observations were made during the summer of 1885, and the records of observation were placed in the hands of Professor Davis for the purpose of what is variously called "reduction," or "working up," or "digestion," or "discussion." What he did was to classify them in various ways, and observe the relations brought to light by the classification. But before he made a classification, it was necessary to select its basis. The particulars of observation were numerous. They included the intensity of the storm, the first thunder heard and its direction, the loudest thunder and its direction, lightning strokes, the first rain, the heaviest rain, the last rain, the total rainfall, hail, the temperature of the air, the moisture of the air, the direction of the wind, the force of wind, cloud form, cloud motion, cloud height, cloud growth, and cloud dissipation; in all no less than twenty categories of items, and each item connected with a place and a time. The number of possible arrangements was indefinitely large. Any one of these particulars might be assumed as basis for the classification of any other one; or two might be assumed as joint basis, or finally the basis of classification might be some very different phenomenon, either occurring at the same time, or belonging to the same region. From this bewildering array of possibilities it was necessary to make a selection, and there was small probability that a random choice would lead to a profitable result. Considering the selection or rather the series of selections which he actually made, we are compelled to believe that they were not accidentally determined, but it is proper that I should admit in advance that the considerations I have assigned are chiefly based upon my own inference, rather than his statement.

The basis of the first classification was time, but this was merely a stepping stone to the accomplishment of a classification based on the individual storm. It was known or postulated that each storm was so short-lived that its record would be comprised in a single day, if not within a few hours. The reports were therefore sorted by days, and then examined more closely to see whether the storm records of a single day fell naturally into two or more groups.

The next classification depended, in part at least, on the hypothesis that the individual storm moves bodily across the country. Its bases were time and place jointly, and its method was graphic. Place was introduced by the employment of a map of the district; time was introduced by platting upon this map certain classes of data with reference to the times of their occurrence. By this classification different particulars of observation were tested as to their value in determining the bodily motion of the storm. For example, there was marked upon a map at the locality of each observer's station the time at which the rain of the particular storm began. Then lines were drawn connecting points characterized by the same time, or more precisely, a line was drawn for each quarter hour, the line being made to intersect all points marked with its particular time, and being interpolated among points marked with times a little earlier and later. The result was a system of lines representing the position of the rain front at equidistant times (fig. 1). The lines also showed the form of the rain front, and their order served to indicate its direction and rate of progress across the district, while the space they collectively covered marked out the path of the rainstorm. When the times of the loudest thunder, and the times of certain other events of the storm had been similarly tested, a comparison of the results showed that the observations on the times of first rain produced the most orderly system of lines, and the rain front was therefore selected as one of the bases for the next classification.

It will be observed that the second classification, by place and time, was superposed on the first classification, by storms. The third classification was likewise superposed on the first, but not on the second, except in the sense that it used its results; that is to say, the third classification was applied to the individual storm, and substituted new bases in lieu of place and time. These bases, which may be called the horizontal axes of the storm, were the middle path and the rain front. The classification was once more graphic, and was accomplished in essentially the following manner. A straight line drawn on a sheet of paper represented for any and every instant of the history of the storm, the portion of the middle line of its path momentarily included in the storm area. A curved line transverse to this represented with its proper form the line of first rain or the rain-front (fig. 2). Then observations of thunder, of heaviest rain, of temperature, of lightning strokes, etc., were platted on the same sheet, the position of each observation being determined by measurement from the axes. Its distance from the middle path axis was made equal to its distance from that path on the map showing the storm track; its distance from the rain-front axis was determined by a computation based on the velocity of the storm and the time elapsed before or after the rain-front passed the same station. If for a given instant of time a chart were prepared, showing, in their proper place relations, all the features of the storm observed at that

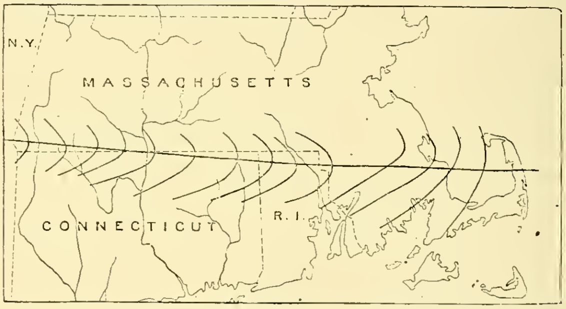

Fig. 1. Lines of synchronous rain-front, storm of July 21, 1881.

instant; if similar charts were prepared for all other instants of the storm's life; and if these were superposed on each other so as to bring common features together, the result would be the same as by the process just described, and this result has therefore been compared by Davis with Galton's photographic overprinting and aptly called a "composite portrait" of the storm. This composite (of which my diagram is a mere abstract) was explained and illustrated to the Society at its Boston meeting, and you will recall what an orderly presentation it gave of the complex congeries of phenomena. Its inspection afforded at once to the investigator a large body of generalizations concerning the individual storm and of hypotheses concerning thunderstorms in general.

If now we examine these three processes of classification in their relations to each other and in relation to the purposes of the investigation, I think we shall be able to perceive the considerations which led to their employment. One of the primary objects of the research was the determination of the mechanism of the thunderstorm, and this object manifestly required the study of the simultaneous phenomena of the storm. The first effort in classification was therefore the isolation of the individual storm. A natural second step would have been the selection of some moment of the storm's life for special examination, but if such examination was attempted, it met with an obstacle arising from the fact that the simultaneous observations at any one moment were so few as to be quite inadequate to the purpose. The analogy of other investigations suggested that the desired result might be accomplished by combining the observations on the individual storm without reference to time or place, but with reference to some central feature or features

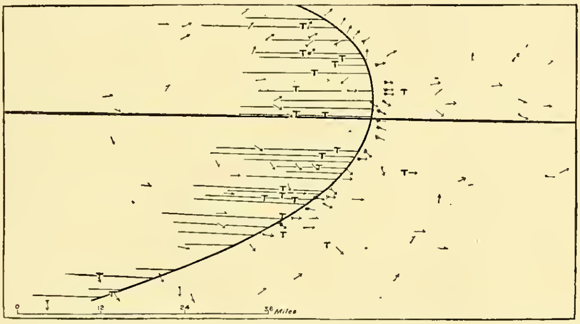

Fig. 2.—Composite portrait of thunderstorm; arrows and the number of their feathers show direction and force of wind. T, T, observation of loudest thunder. Straight lines mark observations on the width of rain area.

of the storm itself. In the case of cyclonic storms the area of lowest pressure has been thus used, its terrestrial meridian serving as an axis of orientation. In the case of thunderstorms no such area of lowest pressure had been determined, and it was necessary to select some other feature or features to serve the same purpose. The second classification was therefore made as a means of overcoming a practical obstacle to the accomplishment of the desired classification.

The preliminary classification, or more exactly group of classifications, having been decided upon, its particular nature was determined by the antecedent knowledge that thunderstorms ordinarily move across the country, and by the hypotheses that the first rain, or the heaviest rain, or the loudest thunder, or some other definite event might be found to be so constant in its relation to the storm as to constitute a suitable basis for the third classification.

The change of basis in classification, whether it belonged to the original plan of the investigation or was devised under the stimulus of a discovered obstacle, finds its analogues not only in other researches but in other departments of human experience. The quarryman who wishes to overturn a heavy block inserts his bar beneath it wherever it finds a crevice, even though the point of insertion be not the most advantageous for his general purpose. Having done so, he lifts until there is room for the lever at the point of vantage, and then shifts his position. The algebraist by premeditation eliminates from his equations all but one of the quantities whose values he seeks, and having determined that one, undertakes with its aid the solution of one of the original or intermediate equations.

If then our interpretations are correct, the bases of clasification, like the methods of observation, sprang from analogy with other researches, from previous knowledge of the subject in hand, and from hypotheses in regard to the results, and were conditioned by obstacles.

As already remarked, the basis of classification need not itself belong to the subject under investigation. The phenomena of the New England thunderstorms may be compared with respect to distribution in time with any other phenomena or events occurring in the same time, or they may be compared with respect to distribution in place with any feature of their district. Thus it is entirely possible to group any of the thunderstorm phenomena according to the days of the week, or with reference to the daily records of marriages in London, or the fluctuations of a mining stock, or the success of the Philadelphia base ball nine, and it is equally possible to compare their distribution with the topographic relief of the country, with the density of population, with the distribution of forests, of geologic formation, or of railroads and telegraph lines. There is in fact no limit whatever to the number of possible classifications of this nature, and as very few of them can yield other than negative results, it is evident that the investigator cannot afford to take them at random. Some criterion of discrimination is necessary, and this he finds in the employment of hypotheses. The only bases of classification affording him results of positive value are the phenomena which are connected in a necessary or causative way with the phenomena under investigation, and the only bases he can afford to test are those which hypothetically have such connection. If he entertains the hypothesis for example that arboreal vegetation induces precipitation, he will classify the rainfall with reference to the distribution of forests; and if he finds a general correspondence but suspects that it may be deceptively produced through the influence of altitude on both rainfall and forest preservation, then he will also classify both rainfall and the distribution of forests with respect to altitude. If he entertains the theory that the moon is concerned in the generation of storms, he will group his phenomena according to the phases of the moon.

We find from the record that Prof. Davis employs successively two external bases of classification. On the hypothesis that solar heat is directly concerned in the production of the storms, he groups them with reference to the hours of the day, finding a well marked correspondence. On the hypothesis that the conditions of their occurrence are produced by the more general movements of the atmosphere, he groups them with reference to cyclonic storms traversing the same district, and here again he finds a correspondence. In each case the correspondence is of such nature as to suggest other hypotheses and lead to other classifications.

In platting the data concerning rain-front on the map of the district, and in the preparation of the composite portrait of the storm Professor Davis employed what are called graphic processes; and the general graphic method to which these processes belong is of such importance in research that no apology is needed for devoting the remainder of my time to its consideration.

It is a familiar principle of analytic geometry that every equation involving two variables may, through a process of construction, be represented by a line on a plane surface. The values of the two variables are referred each to an axis, or origin of distances, and each pair of corresponding values determines the position of a point. The line drawn through or constituted by all the points is then a graphic expression of the equation. It has many of the properties of an equation and may be discussed in a similar manner.

The subsidiary or dependent laws deduced algebraically from the written equation have a quantitative definiteness to which the platted curve can afford only approximations, but the curve yields to the minds of most men a clearer conception of the nature of the relation of the two variables than is conveyed by the equation. Its advantage is that it appeals to the eye, and thus brings a sense impression to the aid of the imagination. This however is by the way, for the application of the platted curve in research is somewhat different.

When the investigator, suspecting that two phenomena are mutually related in a constant and necessary manner, has made a series of observations affording him simultaneous quantitative values of the phenomena, there are open to him two general ways for the classification of his observations and the drawing of the proper inferences. Pursuing what may be called the written or mathematical method, he writes the observed quantitative values of one phenomenon in a column in the order of their magnitude, and the corresponding quantities expressing the other phenomenon in a parallel column. He then inspects the numbers of the second column to see whether they constitute a series. If their arrangement is quite irregular, he infers that the two phenomena have no constant relation; but if he detects a greater or less amount of order among the numbers, he assumes the existence of a law, and endeavors to ascertain its nature by discovering its mathematical expression. He first assumes more or less arbitrarily or hypothetically the general form of the equation expressing the relation of the phenomena, and by substituting the observational values successively in this formal equation, he obtains a number of numerical equations from which a single one is deduced by the method of least squares. The resulting formula expresses the law connecting the phenomena with a degree of precision which depends on the consistency of the observations; and by another mathematical process he can obtain a numerical expression representing this degree of precision. The two expressions will enable him for any given value of one variable or phenomenon to compute the corresponding value of the other, and also to compute the probable error of this value.

If on the other hand he employs the graphic method, his procedure is ordinarily as follows: Upon a sheet of cross-barred paper he assumes the lines running in one direction to represent equidistant values of one of the observed phenomena, and the lines running in the transverse direction to represent equidistant values of the other phenomenon. The scale assigned upon the page to the numerical values is unessential, and is adjusted purely to considerations of convenience. Then for each pair of simultaneous values of the phenomena he finds the intersection of the corresponding lines and marks the point with a dot. If the value of either phenomenon falls between the numbers represented by two adjacent lines, the position of the dot is correspondingly interpolated. The relations of the dots to each other are then considered by inspection. If they are irregularly scattered over the sheet, the absence of a law is inferred. If they fall in line, either accurately or approximately, the existence of a law is demonstrated. In that case a line is drawn through or among the platted points, and this line is an expression of the law or relation sought. The investigator may or may not proceed to the computation of the algebraic equation. As a rule such procedure is profitable only when the platted points fall well in line, for it is only then that the proper form of equation can be selected with confidence, and without a knowledge of that form extrapolation is hazardous. For purposes of interpolation the free hand curve drawn among the platted points is practically as serviceable as the algebraic equation.

Ordinarily, as in the employment of section paper, the lines used to represent numerical values are straight, parallel and equidistant, and the two sets intersect at right angles, but none of these characters are essential to the graphic method. The lines may be curved, they may converge, their interspaces may follow any law of increase or decrease, and the two sets may intersect at any angle. Nor is it essential that more than one line of each set be drawn—indeed, in a large group of practical examples even these are omitted, the edges of the paper standing for them. The graphic notation is thus highly elastic, adjusting itself freely to the convenience of the investigator.

It is equally versatile in the character of the results it attains. Even when the phenomena do not practically admit of algebraic expression, and no representative line can be drawn upon the graphic chart, the form of the area occupied by the dots, or some other feature of their distribution may convey a meaning. If one in ignorance of the principle of the psychrometer should plat upon a sheet the simultaneous observations with a dry bulb thermometer and a wet bulb thermometer, representing the dry-bulb readings by abscissas and the wet-bulb by ordinates, he would find that the group of determined points could not be connected or generalized with any degree of approximation by a line, but if the number of his observations was large, he could not fail to perceive that the area occupied by the dots was definitely limited above by a diagonal straight line passing through the points of intersection of the lines representing equal temperatures on the two thermometers. He would thence legitimately infer that the wet bulb temperature is never higher than the coincident dry-bulb temperature.

Diagram No. 3 is copied from one prepared by Professor Call to illustrate the relations of size exhibited by certain collections of the shell *Helisoma trivolvis.** The ordinates represent lengths in millimeters, the abscissas, which have the same scale, represent breadths; each circular dot shows the length and breadth, and thus stands for, an adult individual collected from a small lake in Utah; each square dot represents an adult individual collected from a late Quaternary deposit in Nevada. Now it is evident by inspection that these dots do not form even approximately a straight line, and we therefore infer that in this species the length does not bear a constant ratio to the breadth. It is further evident that the area covered by the circular dots is quite distinct from that covered by the square, and that it is farther from the origin. The modern specimens are therefore distinctly larger than the fossil, and this difference is, for the two localities in question, of a constant nature. Thirdly, each group of dots is horizontally elongate, the distal end of the group being slightly—and only slightly—higher than the proximal, and from this we learn that at each locality the length is more constant than the breadth, variation of size being chiefly, though not entirely, confined to the lateral dimension. Now there can be no question that all of these results might have been obtained by mathematical methods, provided they had been suspected in advance, but without antecedent hypothesis they would never have been discovered, while the graphic method furnishes the information without the aid of leading questions.

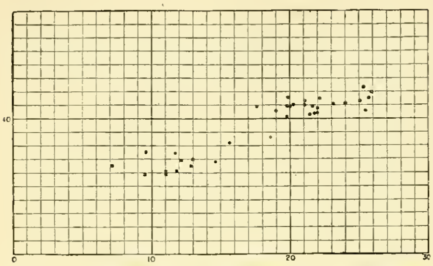

FIG. 3.—Length and breadth of *Helisoma trivolvis.*

This example illustrates also a second and higher office of the graphic method, for it essentially involves more than two variable phenomena. It not only shows the relation between the length and the breadth of this shell, but the variation of this relation with geologic horizon. In the black dots are compared the length and breadth of the round *Helisoma trivolvis,* in the square dots the corresponding dimensions of the same

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* On the Quaternary and recent mollusca of the Great Basin; by R. Ellsworth Call. Bul. No. 11, U. S. Geol. Survey, Pl. III, Diagram II.

shell from the geologic deposit. The two relations might have been exhibited upon separate sheets, but as they are relations between similar quantities, we can by employing the same scale plat them upon the same sheet, and thus platted, we are enabled to compare them with each other.

It is a general principle that if we have a series of observations showing the relations of phenomena A and B and another series showing the relations of A and C, we may by platting them upon the same sheet and employing the same scale in the representation of the values of the common phenomenon, A, make a sort of comparison between B and C. The units of measurement for B and C may be of different kinds, and even if of the same kind, may be of different orders of magnitude, and it is not ordinarily necessary to establish any correspondence in their scales. Neither is it necessary that the zeros of their scales have the same position.

In this manner Professor Loomis has compared the mean daily range of the magnetic declination with the relative extent of dark spots on the surface of the sun by the aid of their common relation to time;* that is to say, using time for his scale of abscissas and the relative extent of spots as a scale of ordinates, he has platted a curve showing the relation of spot extent to time. Then upon the same sheet and with the same scale of abscissas he has platted a curve in which the ordinates represent the daily range of magnetic declination. The second curve shows the relation of magnetic declination to time, and the two curves exhibit to the eye whatever correspondence or discordance there may be between the time relation of the magnetic declination, and the time relation of the extent of sunspots. Again he has made the ordinates represent frequency of auroral displays, and has thus produced a curve showing the relation of auroral frequency to time, and this curve he is able to compare with each of the others. There is indeed no limit to the number of relations which may be compared in this way, provided only that one system of coördinates, either abscissas or ordinates, remains unchanged in meaning and scale. Mr. Schott in his discussion of the temperatures of the United States has compared the sun-spot curve with four curves representing secular changes of temperature at as many stations, the abscissas representing the common factor time, and the ordinates standing for temperatures in the case of four of the curves, and for relative frequency in the case of the other.†

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* This Journal, III, vol. v, p. 346.

† Tables, distribution, and variations of the atmospheric temperature in the United States, etc.; by Charles A. Schott. Smithsonian Contributions. Plate facing p. 310.

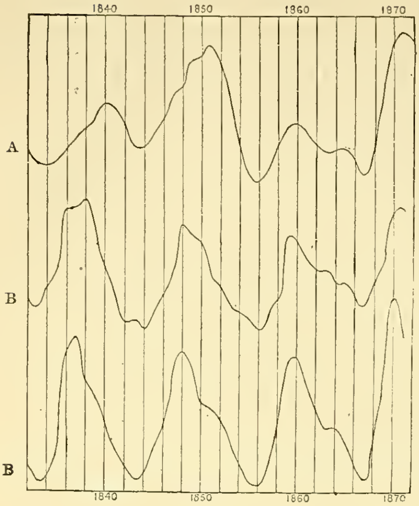

Fig. 4.—*A*, number of auroras. *B*, range of magnetic declination. *C*, relative extent of spots on the surface of the sun.

Looking at these curves from the algebraic standpoint, we see that they do not correspond to a single equation between three or more variables, but to a group of equations with one variable in common, and with one other variable in each equation. If we combine two of the equations or curves in such way as to eliminate the common variable, we obtain an equation or curve showing the relation between the two other variables. It is frequently advantageous to do this, but not always; and it is not ordinarily advantageous to do it when the common variable is time. I have copied in fig. 4 a portion of Professor Loomis' curves, and it is evident by inspection that there is a marked correspondence between the maxima and minima of the three curves. I have also combined the data employed in the construction of the upper curve (auroral frequency) and the lower curve (extent of sun-spots) in such way as to eliminate the common element of time, that is to say, I have (in fig. 5) platted for each year the relation of auroral display to extent of sun-spots, the ordinates representing frequency of auroras, the abscissas the extent of solar spotting. It would hardly be suspected from the arrangement of these dots that the two phenomena are in accord.* Looking again at fig. 4, we see that while the minima of the upper curve correspond very closely with the minima of the lower, the maxima lie farther to the right. If the phenomena are really connected in a causal way, it would seem that the auroras are the effect, and that they are brought about by some chain of causation involving time.

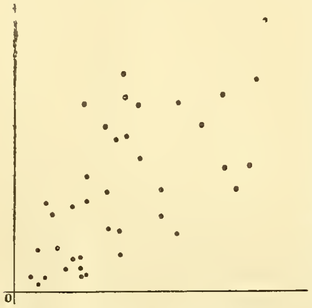

Fig. 5.—Direct comparison of auroras with sun-spots.

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* My illustration is subject to a qualification, which, though unessential, should be stated. In fig. 5 each ordinate represents the number of auroras observed

The next higher division of the graphic method is homologous with the algebraic equation containing three unknown quantities, and is employed in the discussion of a phenomenon with reference to its simultaneous relations to two other phenomena. If in an equation between three variables we make one of the variables successively equal to 0, 1, 2, 3, etc., we obtain a series of equations between the remaining two variables. Each of these equations is the equivalent of a curve, and we may plat the equivalent curves upon the same sheet of paper, referring them to the same coördinate axes. They constitute a system, and they collectively express, in connection with the other systems of lines on the paper, the original equation between three variables. If the sheet upon which they are platted is ordinary engineer's section paper, then we may say that the vertical lines of the paper represent equidistant values of one variable, the horizontal lines equidistant values of a second, and the system of curves equidistant values of the third. Definite values being assigned to either two of the variables, the corresponding value of the third may be found by inspection. This principle is extensively applied in abridging the labor of computation where a large number of results are to be derived by means of the same formula.

It is possible that the nature of this system of curves will be more clearly apprehended if we approach it by a route involving more of geometry and less of algebra. An equation between three variables is the algebraic equivalent of a surface, either plane or curved. Let us think of such a surface as forming the uneven top of a solid body whose base is flat and square, and whose sides are vertical. Horizontal distances along the sides in one direction correspond to values of one variable, and in the transverse direction to those of another, while vertical distances correspond to values of the third. Now intersect the solid by a system of horizontal planes, each one at a height above the base determined by an integral value of the third variable. Each plane will cut the upper surface in a different curved line, and each of these lines will be a contour of the surface. Now move all these lines vertically downward to the basal plane, and there is formed on that plane a contour map of the upper surface of the solid. This contour map is identical with the system of curves obtained through the algebraic manipulation of the equation. The relation between the three variables has thus three separate but equivalent expressions

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(from a certain system of stations) in a single year. In fig. 4, curve A, each ordinate represents the mean of the numbers observed in three consecutive years. That is to say, Professor Loomis "smoothed" the curve by a process making each ordinate an equal function of the observations of the corresponding year, the preceding year and the following year, while I employed the unadjusted data of observation.

besides its verbal statement. It is expressed by the equation, by the curved surface, and by the system of plane curves, or the projection on a plane of the contours of the curved surface.

The allied process in the conduct of research is as follows: Upon a sheet of paper two systems of lines representing equidistant values of two variable phenomena are drawn or conceived to be drawn. Points representing observations are then added, their positions with reference to the two systems of lines being made to indicate the quantitative observations of the two phenomena, and figures, or other equivalent notation, being employed to indicate the simultaneous quantitative observations of the third phenomenon. Lines are then drawn connecting those dots which bear the same figures, and it is arranged, by the aid of interpolation, that these lines represent equidistant values of the third variable. The chart thus prepared shows by inspection the relations of the third phenomenon to the other two. The isobars on our weather maps are of this nature. Space in two of its dimensions constitute in this case two of the variables; we may say for convenience that one variable is latitude and the other longitude. The third variable is barometric pressure. The lines representing meridians and parallels may or may not be drawn upon the map, and if they are drawn, their character, as straight or curved, will depend upon the nature of the projection of the map. Another illustration is found in Davis's rain-front map, (fig. 1.)

It will be convenient to have distinctive terms for the line, corresponding to two variables and for the system of lines corresponding to three, and I venture to propose for the first the name *nomogram*, or line representing a law, and for the second *isogram*, a title connecting it with its familiar examples in the isobaric, the isothermal and the isohyetal curves.

Isograms admit of combination in the same manner as nomograms, but in their case it is essential that *two* of the variables be common to all. Upon our daily weather maps the isobars and isotherms are both platted with reference to latitude and longitude, and we are thus enabled to compare in a direct and simple manner the areal phenomena of temperature with the areal phenomena of pressure. The weather map is the logical equivalent of two equations, each including three variables, the equations agreeing in two variables and differing in a third.

The general case of an equation of four variables has not yet found graphic expression, although some special formulæ with four or even five variables have been reduced to graphic form for the purposes of the computer.

I am not aware that the graphic method has been used in research to express a relation involving more than three independent variables. In an investigation by Prof. Thurston into the comparative strength of the different members of a certain group of alloys, he has platted the strength by means of an isogram whose points are fixed by three coördinate lines, each representing the ratio in which an ingredient enters into the alloy.* But the ratios of the three ingredients are not independent variables, since any two being known, the third may be determined. His method of platting employs three coördinate axes arranged in the form of an equilateral triangle, but one is redundant; the same result would be attained if the ratio of one ingredient were ignored and the ratios of the other two were referred to two coördinate axes intersecting at an angle of sixty degrees. I would not be understood to criticize this method of projection unfavorably—it is a singularly happy adaptation of a general method to a special case; I merely claim it as essentially a normal isogram. It may be added that in the general theory of projection by trilinear coördinates the redundancy of one set of coördinates is recognized by mathematicians.

Prof. Davis's composite portrait (fig. 2) is the rational equivalent of a group of equations, each containing three variables, and all agreeing in two variables which they hold in common. It differs from the normal isogram in that the lines representing the third variables of the several equations are undrawn. One of the common variables is distance from the middle path of the storm, the other is distance from the line of rain-front; the remaining variables, which are severally functions of these two, are the phenomena of wind, temperature, thunder, lightning stroke, etc.

The composite photograph devised by Galton also finds place here. In his method a number of pictures, over-printed on the same sheet of paper, have two points in common. This is equivalent to giving them the same origin of coördinates, the same directions of coördinate axes, and the same scale.

There is also a type of graphics bearing the same relation to the isogram that Prof. Call's group of points bears to the nomogram. It is illustrated by charts of geographic distribution in which the data platted either do not admit of, or are not subjected to, quantitative gradation. Of this nature is a chart showing the positions of the volcanoes of the world.

The graphic processes thus outlined and classified constitute essentially the graphic method as employed in research, but there are numberless details and devices, having the general nature of short cuts, in the invention of which any one will become fertile who makes extensive use of the general method.

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* The strongest of the bronzes, a newly discovered alloy of maximum strength. By Robert H. Thurston. In Rept. U. S. Board appointed to test iron, steel and other metals. Vol. ii, p. 133.

For example, in describing Prof. Davis's preparation of the composite portrait, I have represented him as computing certain distances from knowledge of the corresponding times; but in point of fact he saved himself that labor by a very simple graphic expedient. The velocity of the storm being approximately uniform, distances in the direction of motion were proportional to times; and as distances on the composite were proportional to distances on the ground, they were likewise proportional to times. He therefore graduated a time scale on a strip of paper, laid it on the composite sheet parallel to the storm-track axis and at the distance corresponding to a particular station, slid it along until the graduation for the time of first rain at that station was over the rain-front axis, and then marked on the composite opposite the proper time graduations all the other observations made at that station.

Another of these special devices it has fallen in my own way to employ, and I will take the liberty to describe it, for while its field of application is narrow, it was found exceedingly useful within that field. Whether it is novel, I am not informed. It is a method of graphic integration allied in principle to the algebraic process known as mechanical quadrature.

Of the many variations to which the pressure of the atmosphere upon the barometer is subject, there is one having a daily period. Early in the morning the barometer rises, then during the middle of the day it falls, reaching a minimum in the afternoon, and there follow during the night one or more minor undulations. This oscillation was recognized long ago, and it is the subject of an extensive literature, and many theories have been framed to explain it. One of these, proposed by Espy,* appeared to me so plausible as well as simple that I undertook some years ago to test it. The theory is this: During the day the atmosphere, being warmed by the sun, is expanded and made to occupy greater space. Every stratum except the lowest is thus moved upward, and as the air is endowed with mass, time is consumed in putting it in motion. While the expansive force is acting, and so long as fully equivalent motion has not been produced, there is a reaction downward, causing a rise of the barometer. Conversely, when the rate of heating or the rate of expansion diminishes, the upward momentum of the air produces the reverse effect, a defect of pressure on the barometer. The addition to the normal pressure of the barometer is greatest, not in the afternoon when the temperature of the air is highest, nor yet at noon when the heating of the air is most rapid, but in the morning when the increment to the rate of heating is greatest. Now the momen-

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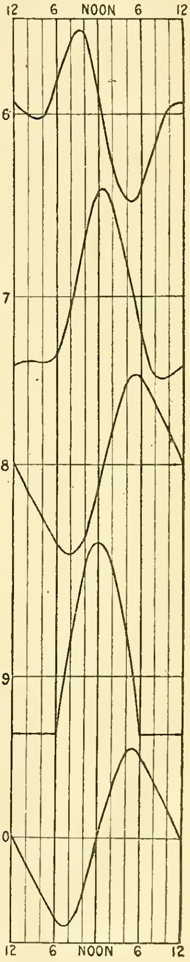
* Fourth Meteorological Report. Foot note to p. 11.

tary rate of heating is the differential of the temperature, and the momentary increment to the rate of heating is the differential of the rate of the heating, or the second differential of the temperature. If then the variation of pressure is proportional to the increment of the rate of heating, it is also proportional to the second differential of the temperature; and an equation or curve expressing the law of the diurnal oscillation of pressure should by a double integration yield the equation or curve expressing the law of the diurnal oscillation of temperature. This being the theory, I sought to test it by twice integrating an expression for the observed law of pressure change.



Thinking to diminish the disturbing effect of local conditions, I combined for my test observations made at San Francisco and Girard College. To avoid complication from the annual variation in the character of the diurnal oscillation, I used only the observations for the equinoctial months of March and September. Making the combination and giving it graphic expression, there resulted the curve shown in figure 6. This curve I undertook to integrate, and wishing to avoid the labor of converting it into an equation, I devised a graphic method of performing the operation. It is evident that, regarding the curve as an equation, the area contained between any two of its ordinates is the definite integral beween the limiting values represented by the corresponding abscissas. On cross section paper it is easy to estimate such an area by the counting of squares. Selecting twenty-four equidistant ordinates I ascertained the definite integrals contained between the first of these and each of the others severally, and this gave me twenty-four equidistant values of the integrated function. Assuming an arbitrary scale, I platted them as the ordinates of the integrated curve, obtaining figure 7 as the result. A repetition of the process produced the curve in figure 8, which, if the theory was correct, should express the diurnal variation of the temperature of the atmosphere. It has the general form of a temperature curve, but its maximum is several hours later than the maxima shown by the observations at San Francisco and Philadelphia.

This difference appeared to be susceptible of explanation, for the part of the atmosphere heated most rapidly is that in contact with the earth, and in the later part of the day the lower strata become so much warmer than the upper that a vertical circulation is produced, whereby cooler air is brought down and the rise of temperature near the ground somewhat checked. Thermometric observations near the ground therefore fail to exhibit the variations in the amount of heat contained in the atmospheric column as a whole.

To escape this difficulty I tried to discover the temperature of the air column as a joint function of insolation and radiation. Radiation to space was assumed to be at a constant rate. The rate of heating by the sun was assumed to be proportional to the sine of the angular height of the sun above the horizon. On these postulates the law of temperature increment for the equinoctial day in the latitude of Philadelphia is expressed by the curve in figure 9. Integrating this, I obtained as the diurnal law of temperature variation the curve in figure 10. This curve resembles very closely the one obtained from the curve of barometric oscillation (8), differing by less than an hour in the epochs of maximum and minimum. The theoretic curve of temperature increment (9) moreover possesses a general resemblance to that derived by one integration from the barometric curve (7).

If no other test had been possible, I should have regarded the hypothesis as well sustained, but unfortunately for it there are widely different types of barometric oscillation in different parts of the world, and when the same integration was applied to curves of other types, the results were found to have little or no resemblance to temperature curves. I was compelled therefore to believe that either the theory or the method of testing it was inadequate; and I may add that I have since satisfied myself by independent reasoning that the relation of the temperature oscillation to the pressure oscillation is less simple than the one suggested by Espy.

I have pursued the subject farther than was warranted by its use in illustration of graphic method, and I have done this for the sake of a moral, with which I will close. The sun is the creator of the day. By alternately giving and withholding his light and heat he brings to pass an infinite series of events which agree in having a diurnal period of wax and wane. Were we to ascertain the quantitative elements in these cycles of events, and picture them by curves, it is to be anticipated that these curves, representing as they would a series of functions of the same periodic flux, would include a large number of close coincidences. For this reason the test I applied, though by no means a waste of energy, could not by itself demonstrate the assumed dependence of pressure on temperature. The pressure and temperature cycles, belonging both to the diurnal family of the sun, might perhaps trace their relationship to their common ancestor through separate lines of descent and neither acknowledge the other as parent. It is unsafe to infer because two currents have a common rhythm that one has borrowed it from the other; it is always possible that they flow by independent courses from a common source.

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## Art. XLVI.—*Geology of the Rainy Lake Region, with remarks on the classification of the Crystalline Rocks west of Lake Superior. Preliminary note;* by Andrew C. Lawson.

In the Rainy Lake Region there can be distinguished five groups of rock formations which are geologically distinct from one another. The petrographical characters of each group are peculiar to itself to a great degree; so that a scheme of classification which takes into account only those conditions of mutual relationship, as observed in the field, that serve to distinguish the different groups with respect to their stratigraphical position, age and genesis is at the same time probably the best that could be adopted for considering systematically the purely petrographical characters of the rocks of this field by laboratory methods. The rocks comprised in the first of these groups may be arranged in the following scheme in which Rosenbusch's nomenclature is employed for the non-foliated varieties. With regard to the foliated varieties it will be observed that the word "gneiss" is used simply with reference to the structure of the rock independently of its mineral composition.

| Type. | Non-Foliated. | Foliated. | Texture. |
|---|---|---|---|
| Granite, (quartzose). | True granite.<br>Granitite. | Granite-gneiss. | Medium grained, or fine grained. |
| | Amphibole Granite. | Amphibole-granite-gneiss. | |
| Syenite. (quartz absent or only sparingly present). | Hornblende syenite. | Hornblende-syenite-gneiss. | Usually very coarse grained and in micaceous varieties of porphyritic aspect. |
| | Mica syenite. | Mica-syenite-gneiss. | |
| | Augite syenite. | Augite-syenite-gneiss. | |

The rocks classified thus under two main types, the granitic and the syenitic, cannot as yet be separated in the field in such a way as to afford a definite suggestion as to their mutual geological relations. Geographically it is frequently possible to map off the quartzose, usually finer grained: rocks included in the two parallel series of the granitic type from the very slightly quartzose, coarse-grained members of the syenitic type. But what this geographical separation means, whether the one is earlier or later than, above or below, the other, or what other geognostical relation exists between them. either in space or in time, the meagre amount of field work that has yet been done, relatively to the magnitude of the units with which we have to deal, leaves still an unsettled question. Such feeble suggestions of possible relations as have been received will be set forth in another place.

The granites and the foliated rocks of similar composition and habit, which are classed with them in parallel series, are genetically the same, the latter owing their distinctive characters to a differentiation in structure due to the influence of certain conditions affecting portions of a more or less homogeneous magmatic mass at the time of its solidification. The field evidence establishing the common genesis of the granite and gneiss is so strong that there is no room for doubt in the matter to one who has carefully studied their occurrence in nature. It is of course possible for geologists who are wedded to extreme metamorphic views to regard these rocks, even granting their sometime magmatic condition, as fused sedimentary strata; and they are at perfect liberty to do so, but so far as evidence goes the supposition is purely gratuitous and cannot in the absence of facts to support it be entertainted as a very probable hypothesis. The evidence in favor of such a supposition is, so far as can be gathered from a study of the region under consideration, very speculative. What is said of the granites and granite gneisses is also true of the syenites and their foliated varieties. The identity and igneous origin of the foliated and non-foliated series is shown by (1) the direct traceable passage from the granitic to the gneissic phase in a rock mass which must be regarded as a geological unit; (2) by the identical nature of their contact relations to other series of rocks to be mentioned, viz: the igneous, brecciated nature of the contact, the gneiss or granite holding angular fragments of the rock through which it breaks, and sending apophyses into it, which, where the rock is gneissic are often distinctly foliated; (3) the identity, as revealed by the microscope, of the mineral composition and structure of two varieties of the same mass.

This group of crystalline rocks, granites and syenites, foliated and non-foliated, forms the floor of the region upon which rest all other formations that are not in the condition of dykes or intrusive bosses. Regarded as a geological system of rocks it occupies an apparently paradoxical and anomalous place in any scheme of classification. As the floor or basis upon which the geological column of stratiform rocks rests it must be regarded as the first or fundamental system of rocks of which we have any cognizance. If, however, we inquire as to the age of these rocks we are forced by the direct application of the simplest principles of geological science to look upon them as of later age than certain of the series which overlie them. We do not yet know their original condition prior to the fusion from which they solidified into granites, syenites and gneisses. They may have been sedimentary; they may have been the original crust of the earth. The abstract speculations that are so often indulged in on this and similar questions have not decided the facts of the matter. There is as yet no sufficient ground for a just opinion upon it. But whatever may have been that original condition the evidence is clear on this point, viz: that the fusion and solidification, whereby they were brought into their present condition as firm crystalline rocks, took place at a period subsequent to the existence, in a hard, brittle condition, of the stratiform and often very distinctly clastic rocks which occupy a higher place in the column. Therefore, as rocks, the members of this fundamental system are of younger age than that of the nearest overlying formations. An analogous case with which every geologist is familiar is that of dykes. These are of younger age than the strata they cut, although the main mass, of which they are merely the apophyses, is far inferior to those strata and may form the base upon which they rest. These apparently paradoxical but naturally quite consistent attributes of absolute inferiority of position with reference to all observable stratiform systems or series, and an age younger than part of the latter, places a classification of these Archæan formations based on age at variance with that which has reference to stratigraphical position. This is not usual in geology, except in the case of intrusive sheets of trap, and raises the question of which method should be adopted. The classification according to age is the usual one, but although this is facilitated in the post-Archæan formations by a knowledge of the laws governing the distribution in time of organic forms, it is primarily based upon the relative position of strata. The most prominent idea associated with these granites and syenites and their gneissic modifications is their basal or fundamental relation to all stratiform rocks. The formations of the region are, therefore, considered in their natural ascending order, in so far as they are stratiform, while dykes and intrusive bosses are taken in order of their age.

The group of rocks comprised in the table given above is designated geologically as the Laurentian System in accordance with the practice in vogue among geologists of so naming the lowest well-defined system of crystalline rocks which is clearly separable from overlying strata. It is not intended by the use of this term to imply that the rocks are necessarily of the same age as those described as the typical Laurentian by Logan, or as those named Laurentian in any other part of the world. For it is manifestly at variance with scientific methods to definitely correlate, with reference to age, rocks in which there are no criteria for comparison other than their petrographical characters. That the rocks considered have passed through a period of fusion and solidification is a palpable fact in the Rainy Lake Region, and will probably be also established beyond question in other regions when they come to be carefully studied.*

But to assume that the period of solidification, which defines the age of the rock, was the same the world over, is as yet unwarranted. If prior to fusion the material was in form of stratiform sediments, these may have been of many different ages, and may have been fused in different parts of the earth at very diverse periods anterior to the deposition of fossiliferous strata. If it constituted, prior to fusion, the first formed crust of the globe, the period of fusion might, as before, be very different in different regions before the advent of life upon the surface of the earth. The loose way in which the term Laurentian is used is convenient in the present state of science, but let it be clearly understood—as it is not generally—that the usage is different from that familiar in the fossiliferous formations. It is in this loose sense—the strictest permissible in the present state of science—that these rocks are referred to the Laurentian.

Superimposed upon the rocks thus referred to the Laurentian system, the splendid exposures of the shores of Rainy Lake reveal as the next geological group a thick series of very distinctly stratiform mica schists and fine grained, gray, evenly bedded, often garnetiferous, very quartzose granulitic-gneisses. The use of the same term "gneiss" both for the foliated modifications of granites and syenites which are clearly of igneous origin, and for bedded rocks of similar composition to the granites, but whose natural history has evidently been very different, is very confusing. The lack of distinction in terms has been fruitful of much error. The term gneiss is coming more and more to be used by geologists to describe a certain phase of structure independent of composition. The fine-grained bedded gneisses often have the character of granulites when exam-

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* Wadsworth has already called attention to the fact that the foliated granite of the Marquette district, described by Brooks and other geologists as Laurentian, is of more recent age than the rocks there referred to the Huronian and the intrusive nature of the contact is described. Vide Notes on the Geology of the Iron and Copper Districts of Lake Superior, Bull. Mus. Comp. Zöol., Harvard, 1880, p. 52 et seq., p. 70 et seq. The work was not known to me when I described the Contact of the Laurentian and Keewatin of the Lake of the Woods, Annual Report, Geol. Survey of Canada, 1885.

ined under the microscope, and the term "granulite-gneiss" might be useful as a distinguishing term if the granulitic character can by more extensive study be shown to be a common one. For the present it will be used provisionally as one that suggests the contrast that exists between them and the granite-gneisses.

This thick series of mica schists and granulitic gneisses attains its greatest development so far as has yet been observed in the southern part of Rainy Lake, where its thickness in continuous exposure, with the strata at low angles which preclude the idea of reversed dips, can be measured for a thickness of over two miles in a low anticlinal. The series is for convenience designated the Coutchiching series, from the Coutchiching Rapids at the head of Rainy River where the rocks are first met with on entering Rainy Lake from the west. They are very sharply and distinctly marked off from the lower granites and gneisses of the Laurentian. The geological contact between the Coutchiching series and the Laurentian system is one of neither conformity nor unconformity. The break is of an entirely different order, and the contact is eminently that of an igneous injection or intrusion of the lower through the upper rocks. This series appears to thin out rapidly toward the north, and on the north shores of the southern part of Rainy Lake, in the neighborhood of Seine, Swell, Red-gut and Rocky Islet Bays, and on the islands of the lake, it is seen to form a trough in which lies folded another higher series of entirely different characters. The rocks comprising it are for the most part of volcanic origin. They are chiefly black-green, compact, hornblende schists; softer, less compact, and more fissile green schists in which hornblende is the prevailing constituent, but with chlorite, calcite, epidote and other decomposition minerals well represented in them; and, in intimate association with these schists and interbedded with them, great sheets of 'trap' comprising uralitic diabases and gabbros (often called diorites) and other massive altered basic volcanic rocks of less determinate characters. These altered traps are sometimes quite massive and sometimes schistose to a varying extent, in which case the crushed or stretched condition of the rock is so clearly displayed in microscopic sections as to leave no doubt that the schistosity is due to pressure and to stretching or pulling forces upon the rock after the assumption of a firm crystalline condition. When the crushing has been excessive the original character is often almost or completely obliterated, particularly as the comminution of the rock under such forces is accompanied by the development of secondary minerals like quartz, calcite, epidote, zoisite, chlorite and albite. Included also in this series are dark green, very fissile glossy schists holding water-worn pebbles; green volcanic breccias; finer textured clastic rocks or 'graywackes'; sericitic schistose quartz-porphyries and regular porphyroids; and soft, fissile, nearly always much decomposed hydromicaceous schists with which are associated yellowish dolomitic segregations.

The breccias, graywackes and hydromica schists are more commonly met with in the northern part of the Rainy Lake Region than on Rainy Lake itself. This group of rocks is the same as a large portion of the series described in my report on the Lake of the Woods Region as the Keewatin series, and in the northern part of the Rainy Lake Region can be traced in direct continuity with that series. They will therefore be referred to as the Keewatin series of rocks. Concerning the geological relations of the Coutchiching and Keewatin series it is not possible to make any sweeping statement as to their conformity or unconformity. The Coutchiching rocks do not appear to have been at all disturbed prior to the deposition of the Keewatin, and the parallelism of the strike and dip of the strata or beds of the two series is often seen to be perfect. But as Geikie points out the geological conformity or unconformity of two sets of strata implies a broader question than the mere relations in space of their contiguous portions. Strata which are in close contact and show at certain places perfect parallelism may sometimes be separated by ages. The appearance of parallelism is often simulated by pressure and folding so that it is not always a criterion of continuity of geological history. The very diverse character of the two series, the Coutchiching and the Keewatin, is proof of a profound alteration in the conditions of rock formation, which implies a geological break, though it does not indicate its duration. The Coutchiching series is seen occasionally to be cut by intrusions of a certain character which have not been detected traversing the Keewatin rocks. These may possibly be instances of vents from which the traps of the Keewatin series were extravasated. In the northern part of the Rainy Lake Region the Keewatin series comes into direct contact with the Laurentian without the intervention of the Coutchiching series, and the conditions of contact are those which have been described as obtaining in the Lake of the Woods Region. The contact of the hornblende schists and altered traps with the Laurentian rocks is of the same igneous or brecciated character as that observed on the Rainy Lake between the Coutchiching and the Laurentian, the direct inference being, of course, that the Laurentian rocks are of more recent age as such than either the Coutchiching or Keewatin, although stratigraphically they are inferior to both.

Of later age than Laurentian, Keewatin or Coutchiching is a system of dykes and bosses of red granite, in which there has never been detected the slightest tendency to gneissic foliation. This granite is found cutting the Laurentian gneiss in sharply defined but irregular dykes in certain parts of the region, particularly in the Northwest Bay of Rainy Lake. These dykes are very frequently associated with "veins" of pegmatite. Where exposures are few and isolated there is danger of confusing these granites with the older granites of the Laurentian; where the country is well uncovered, however, the different relationships of the two are quite apparent.

Of still later age is a system of strong, well-defined dykes of diabase cutting the Laurentian, Coutchiching and Keewatin rocks and the post-Laurentian granites. These, wherever observed in various parts of the region have a strike of N.W. to N.N.W. Their width is generally from 60 to 150 ft., and they are sometimes traceable for miles. These dykes have been studied microscopically, as have all the chief types of rocks occurring throughout the region, and some interesting features have been brought to light concerning them which will be found described elsewhere. Besides these dykes there occurs between Seine River and Turtle Lake, east of Rainy Lake, a somewhat extensive mass or boss of very coarse grained saussurite gabbro, concerning the age of which it is only known that it cuts the Keewatin rocks, and is therefore younger than them. It is not improbable that it is of synchronous origin with the diabase dykes, possibly the plutonic facies of the same rock. These later diabases and gabbro have an interesting possible or problematic relationship to the trap flows which form so large a part of the Animikie and Keweenawan series.

The rocks of the region or their equivalents appear in their eastward geographical distribution in the neighborhood of Lake Superior to pass in a folded state under the flat lying beds of the Animikie series, the contact being one of marked unconformity. The Animikie is, according to the prolonged and valuable researches of Prof. R. D. Irving, of the United States Geological Survey, the geological equivalent of the typical Huronian of Logan.* The Animikie or Huronian is, according to the same eminent authority,† distinct from and underlies the Keweenawan (Nipigon). Hence the classification of the various geological systems or series of rocks in the country west of Lake Superior, so far as our present knowledge goes, is with reference to their place in the ideal geological column, as follows:

Keweenawan (Nipigon).
Huronian (Animikie).
Keewatin.

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* Monograph V, United States Geol. Survey, pp. 367–386, p. 390.
† Op. cit., pp. ibid.

Coutchiching.
Laurentian.

With reference to their age, as follows:

Keweenawan (Nipigon).
Huronian (Animikie).
Diabase dykes and gabbro.
Granite, post-Laurentian.
Laurentian.
Keewatin.
Coutchiching.

Petrographical Laboratory, Johns Hopkins University, March, 1887.

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## ART. XLVII.—*Identity of the Photosalts of Silver with the Material of the Latent Photographic Image*; by M. CAREY LEA, Philadelphia.

IN the first part of this paper I described certain strongly colored forms of silver chloride, bromide and iodide, obtained independently of any action of light, for which I proposed the name of photosalts, by reason of their identity with the products of the action of light on the normal silver haloids; both with the substance of the latent image itself and also with the principal results of the continued action of light on these haloids. It remains to prove this identity.

First as to identity with the product of the continued action of light.

If we expose silver chloride precipitated with excess of HCl to light, we get a deep purple black substance which boiled with dilute nitric acid gives up a little silver, at the same time somewhat lightening in color and forming a dull purple material which closely resembles some of the forms of photochloride described in the first part of this paper, most those produced by the action of sodic hypochlorite or of ferric chloride on metallic silver: it shows the same reactions with ammonia that they do. The brighter colored photochlorides are not formed by the action of light on silver chloride.

But these brighter colored chlorides can also be shown to be formed through the action of light. Most salts of silver darken by exposure, and when these dark products are treated, first with HCl, and then after thorough washing, are boiled with dilute nitric acid, we can obtain results perhaps as varied as those which I described in the former part of this paper as arising from purely chemical action.

*Silver oxalate* exposed for two days to sunshine, covered with water and with frequent agitation, changed to a deep brownish black which by treatment with HCl became a little lighter. When this product was washed and boiled with strong nitric acid, it acquired a fine deep copper red color, the acid taking up silver. This red substance dissolved in ammonia readily, leaving a small amount of black residue; the same with sodium hyposulphite.

(This examination, made a year ago, has recently been repeated with a view to obtaining a quantitative determination of the proportion of $Ag_2Cl$ contained in the red product. The exposure was for about a day, the oxalate at the end of the exposure seemed absolutely black. After treatment with HCl it assumed a purple black shade. After thorough washing and boiling with dilute nitric acid, which removed a large quantity of silver, perhaps 12 or 15 per cent of the entire quantity, it had a fine lilac purple color. Analysis showed that it contained about one-half of one per cent of subchloride, or more exactly, 0·45 per cent $Ag_2Cl$ was found).

The red chloride thus obtained from silver oxalate, not only closely resembles the red chloride obtained by means exclusively chemical, but shows the same behavior to reagents.

Treated with ammonia it dissolves leaving a black residue. The formation of this residue takes place precisely in the same manner with both substances. As fast as the material dissolves the liquid becomes clouded and an extremely fine black substance seems to form within it, which gradually falls to the bottom.

Treated with solutions of the alkaline haloids, the red chloride derived from exposed silver oxalate remains unchanged after 24 hours contact with potassic chloride and becomes paler and more lilac under potassic bromide; under potassic iodide becomes gray. These reactions correspond with those of the photochloride.

*Silver phosphate* belongs to the more sensitive silver salts and easily darkens in sunlight. In a few hours it becomes greenish all through, after which further exposure produces little visible effect. This product becomes with HCl quickly gray, and by treatment with nitric acid after washing, light pink.

*Silver tartrate* by exposure to sun became quite black. With HCl this changed to reddish gray or dull pink. This product well washed and let stand with cold nitric acid 1·36 became first lavender and then light pink.

*Silver carbonate* by prolonged exposure became greenish black, and with the above treatment yielded a dull pink photochloride.

*Silver pyrophosphate* even by several days' exposure to winter sun did not blacken, but assumed an ochreous or buff shade. With HCl this passed to a sort of salmon pink and by heating a few minutes with dilute nitric acid, to a beautiful copper shade.

*Silver acetate* was singularly little affected by sunlight, it looked blackish, but on closer inspection was found to be very little altered. By the same treatment as above it yielded a pale pink photochloride.

So far as examined, all silver salts thus treated yielded pink or red photochloride.

These facts may serve to show the identity of the photochloride with the principal product of the continued action of light on silver chloride and on other salts of silver, subsequently converted into chloride. I should wish, however, to use this word identity in a somewhat limited sense. When the photochlorides are formed by different methods without the aid of light hardly any two forms can be considered absolutely identical: they differ in color and in proportion of subchloride, as already often mentioned, but they also differ in other respects, especially in resistance to reagents. Some forms are far more easily destroyed by nitric acid: those obtained by the action of sodium hypophosphite (as presently to be described) are amongst the most easily destroyed by nitric acid. There is variation, too, in the degree of their resistance to ammonia.

Very similar differences are found in the stability of the photochlorides obtained by the action of light: some are much more readily attacked by nitric acid than others. The product obtained by the action of light on silver chloride resists ammonia more strongly than that obtained by the action of HCl on exposed silver oxalate. This last is quickly attacked. Generally, I think the dark colored forms are the most stable.

At a future time it may perhaps be possible to distinguish more exactly between these varieties.

I next pass to the consideration of the identity existing between the photosalts and the material of the latent image. Before entering, however, on that matter, it is necessary to describe a reaction leading to the formation of these photosalts, somewhat differing from the reactions already mentioned, and which has important bearing on the subject.

The remarkable action which an alkaline hypophosphite exerts on salts of copper was described many years ago by M. Wurtz. Its action on silver salts, though there is no parallelism between the two, has enabled me to find a key to some of the great difficulties of the latent image.

A dilute solution of sodium hypophosphite if poured over a mass of chloride, bromide or iodide of silver formed in the absence of light, produces no visible effect, but has the property of bringing those substances into the condition in which they exist in the latent image. Applied in strong solution and with the aid of heat, it produces brown purple photochloride, bromide and iodide of silver. I will here briefly describe the first of these compounds in order to continue the series of photochlorides, and then pass to the consideration of the latent image.

### *Photochloride of Silver by Sodium Hypophosphite.*

Silver chloride freshly precipitated with excess of HCl and well washed, placed in a flask with a strong solution of sodium hypophosphite and heat applied begins to darken before the boiling point is reached. Actual boiling for ten or fifteen minutes gives a deep chocolate color. This product well washed and freed from traces of metallic silver by cautious boiling with very dilute nitric acid has a pink, red or brown color varying in intensity according to the length of the action. Sometimes a lavender shade is produced, and this is more apt to be the case when the silver chloride has been precipitated with excess of silver nitrate instead of excess of HCl.

Silver determinations of two specimens of the purified product were made, indicating the presence in one specimen of 1·77 per cent of subchloride, in the other of 3·53.

By the continued action of heat for many hours a complete reduction to metallic silver takes place.

Photochloride obtained in this way has generally a brown or dull purple color. Boiled with nitric acid it is apt to break up in as many minutes as some other forms would require hours for decomposition, yielding white chloride, whilst the nitric acid takes up small quantities of silver.

## IDENTITY OF PHOTOSALTS WITH THE MATERIAL OF THE LATENT IMAGE.

It is proposed here to show:

1st. That in the entire absence of light, sodium hypophosphite is able to affect a sensitive film of silver haloid exactly in the same way as does light, *producing a result equivalent to a latent image formed by light* and capable of development in the same way as an actual impression of light.

2d. That these two effects, the impression produced by hypophosphite and that by light, comport themselves to reagents exactly the same way and seem every way identical.

3d. That the image produced by hypophosphite on silver chloride always gives rise to a positive development, but on silver bromide may give rise either to a direct or to a reverse image, *both of these effects corresponding exactly with those of light.* More than this, sodium hypophosphite may be made to reverse the image produced by light on silver bromide and conversely light may be made to reverse the action of hypophosphite. So exact a correspondence in these remarkable properties can scarcely be fortuitous.

## I.

A silver haloid formed in the absence of light and subjected to the action of sodium hypophosphite gives rise to the gradual formation of subsalt, which combines with the normal salt in the manner described in the previous part of this paper. This action of the hypophosphite closely corresponds with that of light. In its initial stages it is invisible, but can be brought out, in both cases by development.

If we form a film of chloride, bromide or iodide of silver and with a glass rod dipped in solution of hypophosphite, make marks upon it, these marks can with the utmost ease be developed in precisely the same way as an image produced by exposure to light.

A very simple mode of operating consists in imbibing photographic paper with a solution of an alkaline haloid, drying, applying a silver solution and then thoroughly washing, all of course with careful exclusion of active light. If the silver solution is acidulated with nitric acid, a drop to the ounce, the result is brighter, but this is not important. In any case the washing must be thorough.

Marks made on this paper can be developed with the oxalate developer with the utmost facility. If a strong solution of hypophosphite is applied cold, it may be washed off at the end of a minute, but a stronger impression is obtained by allowing it to wait a half an hour before developing. Or the action may be accelerated and increased in strength by laying the freshly marked paper on a hot surface, or better, by steaming it, before applying the developer. A convenient mode of steaming is to lay two pieces of glass on a small water bath kept boiling, with a space between them. Over this space the paper is rested for two or three minutes. Paper prepared with a solution of KCl, KBr, or KI, dried and floated on acidulated solution of silver nitrate and well washed, if marked with strong solution of hypophosphite and steamed for two or three minutes, will develop the marks as black as ink on a white ground. The use of heat simply gives a blacker development, but a very vigorous image may be got without.

(A similar result may be obtained by substituting for the hypophosphite a dilute solution of potash and an oxidable organic substance. With milk sugar the action is very energetic and heat is quite superfluous).

Both these are the initial steps of reactions which when prolonged result in the visible formation of the colored photosalts.

It is a matter of interest that sodium hypophosphite which produces the above described effects, has no developing power whatever.

## II.

The two impressions, that formed by light and that by hypophosphite, are similarly affected by reagents

As an example of this identity of effect produced on the two impressions, I first take the action of nitric acid.

Chloride, bromide and iodide papers were exposed to moderate diffuse light under a screen with openings, for a proper time to form a latent image, the chloride and bromide for four or five seconds, the iodide for twenty or twenty-five. They were then cut into halves and one half of each was soaked in strong nitric acid for five minutes. These halves were then washed for some hours and were developed along with the halves not so treated. Result was, latent image on silver chloride almost if not quite uninjured; on silver bromide, somewhat affected but still strong; on silver iodide entirely destroyed.

Similar portions of the same papers were then marked with hypophosphite and were cut into halves and one-half was subjected to the action of nitric acid in exactly the same way as the previous. The result was exactly as before. The hypophosphite marks on the half of the chloride paper that had been treated with acid came out in development as vigorously as on the half that had not been treated. The bromide paper showed the marks weakened by the acid but still strong; on the iodide not a trace appeared. In all respects the result was the same, what the one resisted, the other resisted, what destroyed the one destroyed the other.

Another confirmation is presented by the action of the alkaline haloids upon the latent image.

The latent images produced by light on chloride, bromide and iodide of silver were all treated with cold and moderately strong solutions of potassic chloride, bromide and iodide for half an hour, and were then subjected to development. It was found that all three silver salts bore the action of potassic chloride and bromide fairly well, the images were somewhat weakened but strong developments were obtained without difficulty. But when potassic iodide was applied the latent image was totally destroyed.

The visible effect of the alkaline haloids on the photosalts exactly corresponds with their action on the latent image. Potassic chloride and bromide, applied in moderately strong solution and cold have little effect, but potassic iodide quickly destroys them.

Therefore the action as well of nitric acid as of KCl, KBr and

KI is exactly the same on the latent image impressed by light on AgCl, AgBr and AgI as it is on the corresponding photosalts.

## III.

The impressions produced by alkaline hypophosphite upon silver chloride always give rise to direct images, darker than the ground on which they are formed. The same substance produces an impression on silver bromide which may by development produce either a direct or a reverse image. So that there is a perfect parallelism with the action of light.

The reverse action of light, sometimes called solarization, shows itself as follows. A film of bromide being exposed to light, part covered by an opaque screen, the exposed portion receives an impression capable of development, and this impression grows in strength to a certain point, then recedes and reaches a condition in which it is less susceptible of development than before exposure. All bromide films, even unexposed to light, will darken in a developing solution in time. The portion that under the action of light has reached the reverse stage resists the reducing action of the developer better than that which was not exposed at all, and consequently appears after development as light on a dark ground and is therefore a reverse image. As to the cause of this action we are as yet wholly in the dark. If the continued effect of light was simply to restore the affected part to its original state we might attempt an explanation by affirming that the continued action of light undid its own work. But the fact of the resistance to reduction being greater than before exposure shows that some as yet unknown action of light is in play. The reverse action cannot be due to oxidation as has been suggested, because hypophosphite reverses and certainly cannot oxidize.

The reversing action of light on silver bromide finds its counterpart in the action of sodium hypophosphite.

If we take bromide paper (it is immaterial whether in making it the bromide or the silver solution be applied first, but for these experiments on the reversal of the image it is essential that a pure neutral silver solution be employed and that after the second solution has been applied, the paper should be thoroughly washed, all the operations being of course performed by inactive light):—if we take such paper and make marks on it with a strong solution of hypophosphite, and then throw the paper into potassio-ferrous oxalate, we shall get a direct development; the marks will be stronger than the ground. If now we continually weaken the hypophosphite solution, we shall presently reach a point at which these marks are in development almost wholly indistinguishable from the ground on which they were made. But continuing the dilution still further we presently reach a point at which the marks reappear, but this time reversely; as lighter marks on a darker ground. This result is obtained with about a two per cent solution; the first mentioned effect comes with a solution of 25 or 30 per cent. So that according as we use the hypophosphite solution stronger or weaker we obtain exactly opposite effects. Here the parallelism is striking but not perfect, at least it remains to be explained why the action in the two cases proceeds in a reverse order. All the other reactions show a perfect identity.

Time will also sometimes produce the same effect as dilution. Paper marked and put away for 24 or 48 hours, giving at first a direct image may after that time give a reverse one. This effect is extremely uncertain and I think, exceptional. I have kept very many pieces for periods from a few hours to several weeks, which first and last gave direct images only; a few became reversed. But the experiment itself, the opposite effect of strong and weak solutions, is liable to no such uncertainty.

Again, we may make light and hypophosphite interact and each reverse the other's action.

To make hypophosphite reverse the action of light, I take a piece of silver bromide paper, expose it to the action of diffuse daylight for a few seconds, then taking it to the dark room, make marks upon it with a glass rod dipped in solution of hypophosphite. On developing with potassio-ferrous oxalate the marks appear lighter than the ground. Or what is perhaps more striking, we take two pieces of such paper, retain one in the dark room and expose the other from 5 to 20 seconds to diffuse light, then make marks on both with a glass rod dipped in strong solution of hypophosphite, and then, after allowing a few minutes for the hypophosphite to act, place them both in a solution of potassio-ferrous oxalate. The marks will develop, in the one case, as dark on a light ground, in the other (that exposed to daylight) as light on a dark ground.

We have here made the hypophosphite imitate the action of light: it has reversed the image in the same way as would result from a prolonged exposure to light. It will next be shown that light may be made to imitate the action of hypophosphite and reverse the effect already produced by that or other reducing agent.

If we take the red or purple silver bromide, preparing it with exclusion of light and the same precaution as in the case of a dry plate and extend it over paper (it is best though not essential, to mix it with a little gelatine to enable it to retain its hold on the paper in the subsequent treatment) dry it and expose it to light under a screen such as a piece of opaque stiff pasteboard with openings cut in it: then apply potassio-ferrous oxalate, we shall obtain a very remarkable effect: all the parts exposed to light take a reversed development and appear as lighter spaces on a dark ground. And this goes so far that we may expose till we get a visible and quite strong image, darker than the ground and yet in development this darker portion will come out lighter than the ground. Indeed I have one specimen which shows almost white figures on an intensely black ground. Before development these light figures were brown, by exposure to light, on a rose-purple ground. I have seen few more curious results than this.

From the foregoing it follows that red bromide, notwithstanding its intense coloration is in the same condition respecting light as normal silver bromide that has received an impression of light so strong that any further influence of light would cause reverse action, only that a vastly larger proportion of its molecules are affected. In the case of the latent image formed by light on normal bromide it would seem that the particles affected, although numerous enough to serve as a basis of development are still too few and too scattered to be visible or affect the color. The photobromide on the contrary has its mass made up of them. Then if exposed to light, the light carries them a stage farther—brings them to the reverse or "solarized" condition and the parts affected by light develop less strongly than those not exposed.

So light can act the part of hypophosphite and hypophosphite that of light, interchangeably; each can produce a direct action, each a reverse and each can reverse the other.

It then appears that in all the numerous ways in which it is possible to compare the photosalts with the material of the latent image they are found to be identical. The proofs based on development generally, and especially on the reversal of the latent image seem very strong and these receive additional support from the exact identity of reactions shown by the photosalts and by the material of the latent image.

The question of the identity of the photosalts with the products of light on the silver haloids might perhaps be left with some confidence to the cumulative proofs here offered. But I hope to be prepared to give in the next number of this Journal additional evidence from a new direction.

Philadelphia, March 21, 1887.

## Art. XLVIII.—*On Photobromide and Photoiodide of Silver;* by M. Carey Lea, Philadelphia.

### *Photobromide of Silver.*

This substance is formed for the most part by the same reactions as the corresponding chlorine salt.

It is not however to be supposed that all reddish-brown substances resulting from the action of reducing agents on silver bromide are the photosalt. By reduction, AgBr may yield a brownish colored form of silver, which, mixed with unreduced AgBr may form a substance resembling the photosalt, but having none of its properties. The two are easily distinguished by the action of cold nitric acid which added to a brown mixture of AgBr and Ag quickly dissolves the silver leaving AgBr. On the photosalt it has no action.

A beautiful variety of photobromide is easily obtained by dissolving silver nitrate in ammonia and adding it to ferrous sulphate previously mixed with solution of soda. Then KBr is added dissolved in dilute sulphuric acid, until the mixture has a strong acid reaction.

Sometimes this method gives immediately a fine purple, sometimes a brown product. But in either case, after washing and cautiously heating with dilute nitric acid, a beautiful purple results. Much care is needed in the nitric acid treatment or particles of yellow bromide will form.

A specimen obtained in this way gave figures indicating 7·25 per cent of subbromide. Each specimen however varies in composition, often very materially.

I subsequently found it desirable in some degree to vary the method and to determine the best proportions in which the materials were used, to obtain a constant product. That which I prefer to use is as follows:

Six grams of silver nitrate are to be dissolved in 200 centimeters cube of water and ammonia added until the precipitated oxide re-dissolves easily. Twelve grams of ferrous sulphate are dissolved in 200 c. c. of water and the silver solution is poured into this. Then four grams pure caustic soda dissolved in 50 c. c. of water are added, let stand a few minutes, then five grams of KBr dissolved in a little water. Finally, dilute sulphuric acid until the whole has a strong acid reaction.

This product, well washed and then heated cautiously with nitric acid 1·36 diluted with five times its bulk of water, gives photobromide of a shade of royal purple, extremely beautiful.

Notwithstanding its fine color it proved to contain but little subbromide, not quite one per cent (0·98 p. c.).

Various other methods may be employed. Silver bromide may be dissolved in ammonia and be treated first with ferrous sulphate and then with dilute sulphuric acid. This method, which is very good with the chloride, is less available for the bromide because of the less solubility of the normal bromide in ammonia, so that although the product is good it is small in quantity.

Very good results are obtained by dissolving silver phosphate, nitrate and probably almost any other salt of silver in ammonia, adding ferrous sulphate and after two or three minutes, hydrobromic acid.

Potash bromide and cupric sulphate may be made to act on metallic silver in fine powder, but the product is contaminated with much copper, difficult to get rid of.

When AgBr is treated with sodium hypophosphite a brown or brownish purple form of photobromide is obtained which seems to be more easily decomposed by nitric acid than most other forms of this substance.

Potash or soda with oxidable organic substances, made to react on silver nitrate and then treated with HBr gives the photobromide. With soda and milk sugar or aldehyde a rose-colored or pink product is generally obtained.

*Reactions.*—In strong solution of potassic iodide it dissolves and this solution by dilution lets fall pale yellow normal bromide. With a weaker solution it becomes somewhat lighter in color.

With acid ferric sulphate there is no action in the cold, but with a few minutes boiling the photobromide is converted into bright colored normal bromide.

In sodium hyposulphite it dissolves, leaving a little black residue of silver.

With ammonia the action at first seems slower than is the case of the corresponding chloride and if the ammonia is poured over the photobromide in small quantity, it may seem to be without effect. But the photobromide shaken well up in a test tube with a large excess of ammonia is almost instantly blackened.

Exposed to light, the red shades of photobromide darken with great rapidity. Placed along side of the corresponding chloride, the contrast is very striking:—a strong image forms on the bromide long before anything appears on the chloride; nevertheless, if these two films are thrown into a developing solution, the chloride on which nothing could be seen, gives a vigorous positive development, while the bromide which already showed a strong positive image develops a negative one. The details of this reverse development have been already considered in another paper.

As respects the direct effect of light unaided by development, the contrast between its action on the normal haloids and on the photosalts is very striking. If a rose-colored photobromide and some normal bromide are exposed side by side the normal bromide (formed in presence of excess of alkaline bromide) darkens but very slowly while the photobromide is quickly acted on. I have seen deep purple photobromide change to brown all over its surface with less than five minutes' exposure to diffuse light in the middle of a room, an amount of exposure which would scarcely have produced a visible effect on normal bromide formed in presence of excess of KBr.

When photobromide is exposed to the spectrum, it shows the same difference in sensitiveness and darkens more rapidly than photochloride. But it gives little indication of color.

When exposed under colored glass photobromide gave distinct indications of reproducing colors, but much less favorably than photochloride. Under green glass it became bluish, under blue greenish, under yellow glass it bleached and under red glass the red of the photobromide remained unchanged.

### *Photoiodide of Silver.*

The most characteristic color of this substance seems to be a fine rich purple. It is obtained in much the same way as the corresponding chloride and bromide, with this limitation, that an excess of alkaline haloid must not be present, as the photoiodide is quickly destroyed by it. The iodine salt differs much more from the bromide than does the bromide from the chloride and two striking distinctions are, its easy decomposition by its own alkaline salt, and its action with ammonia, as will appear beyond.

A very easy and satisfactory method of obtaining the photoiodide is the following: Silver is to be reduced from the nitrate or chloride, in fine powder in any convenient way; I have usually employed Levol's method. To a solution of potash, iodine is to be added until the liquid becomes almost black. This iodine solution is to be diluted and poured over the silver by degrees, keeping the silver constantly agitated, until the whole mass becomes clear bright purple.

Any excess of silver present may be removed by boiling with dilute nitric acid, but this operation requires far more circumspection than in the case of the corresponding chlorine and bromine products. The acid (1·36 was used) must be diluted with twelve or fifteen times its bulk of water, and the boiling must be very short, otherwise the photoiodide is converted into normal yellow iodide.

Another method by which it may be obtained is to add ammonia to silver nitrate in considerable excess and to pour this into solution of ferrous sulphate. Potassic iodide is dissolved in very dilute sulphuric acid and added till the mixture has a sharp acid reaction. It is necessary to observe that the KI added must be somewhat short of a proportion equivalent to that of the silver. Any excess of silver may be removed in the manner already explained.

Different specimens of the purple product in this way obtained gave various amounts of $Ag_2I$ from 0·64 per cent to 4·63. The same remark made as to the meaning of these determinations in reference to the other haloids, applies to this.

The method of roasting silver oxide until it is black and acting on it with the hydrogen acid of the halogen, which works well in the case of the chloride, does not answer well for the iodide.

When silver iodide is boiled with solution of sodium hypophosphite, it gives a brown product, evidently indicating that reduction to some extent has taken place; the hypophosphite solution may or may not show traces of iodine. The color of the silver iodide may show a very marked darkening, and yet the solution may give no trace of iodine by the most delicate reagents.

This was very difficult to explain until I found that silver iodide has the property of taking up and retaining small portions of iodine, a reaction not very surprising in view of the tendency I have found in silver haloids to take up foreign substances of very various natures; and also of the facility with which iodine is taken up by alkaline iodides. This property in silver iodide was verified by shaking up portions of freshly precipitated and still moist AgI with iodine solutions. Alcoholic solution of iodine diluted until it has a pale sherry wine color is quickly decolorized by AgI, and the same thing happens with a very dilute solution of iodine in KI, which in a few minutes becomes as colorless as water.

This reaction I found particularly interesting, for it not only explained the action of hypophosphite in the case just mentioned, but also gave a clue to the cause of a phenomenon I observed more than twenty years ago, and which then and long afterwards seemed to me an unanswerable argument in favor of the physical nature of the latent image.

At the time referred to I formed films of pure silver iodide entirely isolated from foreign matter, by reducing metallic silver on plates of ground glass, iodizing them with alcoholic solution of iodine, or with Lugol's solution, then washing most thoroughly under a tap for hours. When these films of silver iodide were exposed to light, they received an invisible image which could be developed. But these invisible images, if the plates were laid aside in the dark, had the property of fading out in a few days or weeks, then could no longer be developed, but the film could receive a fresh image. This seemed an unanswerable proof of the physical nature of the latent image at least on silver iodide. The argument was: If the production of this latent image is the result of chemical action involving the loss of iodine by the silver salt, how then is this iodine recovered when the image fades out? If it is formed of subiodide, where does this latter substance get back its iodine to return to the normal form, as it unquestionably does?

No answer could be given then or after, and this experiment, repeated and confirmed by others, has always seemed the strongest support of the physical theory. When, however, it appears that silver iodide can take up iodine and hold it, the course matters follow becomes evident. By the action of light a very small quantity of subiodide is formed, and combines with the normal to form photoiodide. The iodine set free evidently does not pass off but remains combined with neighboring molecules of AgI, and in the dark gradually re-combines with the photoiodide re-converting it to normal AgI. In this retention the lower tension of iodine as compared with bromine and chlorine no doubt plays its part.

In thus explaining away the fading out of the latent image on silver iodide, the last argument in favor of the physical theory is destroyed, while the chain of proof supporting this new explanation, that the latent image consists of normal haloid combined with its own subsalt, remains unbroken.

*Reactions.*—When ammonia is poured over purple photoiodide of silver, the color quickly passes to a salmon and then, even after some days, seems to undergo no further change. Of separation of metallic silver as in the case of the corresponding chloride and bromide, there is no trace.

In sodium hyposulphite it dissolves slowly, leaving a slight but distinct residue.

Dilute nitric acid mixed with dilute solution of KI slowly but completely converts it to normal silver iodide.

Light acts slowly upon it, changing the color to greenish-gray.

I have already spoken of the remarkable manner in which light acts reversely by development on photobromide. On photoiodide the effect is usually the same as on photochloride, viz: the action is direct. But occasionally it reverses and the exposed part comes out lighter in development than the part that has not been exposed. In this respect the behavior of the iodine compound is intermediate between that of the chlorine and the bromine.

### *Note in Conclusion.*

The investigations of which the preceding pages are the result, are still unfinished. I have very lately observed the formation of another group of silver haloids quite different from the photosalts. The members of this new group are deeply colored, purple or red, not unlike the photosalts, but are sharply distinguished from them by very different reactions. The photosalts are unaffected by cold strong nitric acid; these new salts are by very dilute acid instantly converted into a pale pink substance which appears to be a photosalt. But the most striking difference is in the action of ferric chloride, A strong solution of this substance shows no action with the photosalts unless left in contact for many hours or days. But these new haloids are instantly converted by it into what is apparently light pink photosalt.

So energetic is this action that a solution of ferric chloride containing one part only to a thousand of water quickly attacks these dark purple salts and decolorizes them. Such a solution might remain indefinitely in contact with the substances I have called photosalts without affecting them.

Other differences exist. So far as I have yet been able to observe these new haloids are formed pure, whereas the photosalts are almost always contaminated with either free silver or free subsalt, or both. As yet there has been no time to fix with exactness their mode of formation or their properties, which I hope to do at a future day.

Philadelphia, April 27, 1887.

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## ART. XLIX.—*On the Meteoric Iron which fell near Cabin Creek, Johnson County, Arkansas, March 27th, 1886;* by GEORGE F. KUNZ.

THE Johnson County meteoric iron, the tenth whose fall has been observed, is of more than ordinary interest, because its fall is so well substantiated, because it is the second largest mass ever seen to fall, and again because it fell within five months of the date of the 9th* recorded fall, that of the Mazapil. It is

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* This Journal, III, vol. xxxiii, p. 221. This meteorite was first mentioned before the New York Mineralogical Club, Feb. 2d, (N. Y. Academy Science, March), and full details will be printed with plates figuring both sides of the iron, natural size, in the Bulletin of the National Museum. The irons whose falls have been recorded thus far, are: Agram, Croatia, May 26th, 1871. Charlotte, Dickson Co., Tenn., Aug. 1st, 1835. Braunau, Bohemia, July 14th, 1847. Tabarz, Saxony, Oct. 18th, 1854. Victoria West, Africa, 1862. Nejed, Central Arabia, Spring of 1865. Nedagolla, India, Jan. 23d, 1870. Rowton, Shropshire, England, April 20, 1876. Mazapil, Mexico, Nov. 27th, 1885.

[It appears questionable whether the 4th, 5th and 6th in the list should be included, since, so far as we are aware, no account of their fall has been published.—EDS.]

almost an exact counterpart of the Hraschina (Agram), Croatia iron, the first of the recorded falls. The Agram iron fell in two fragments, one weighing about $40^{k}$ and the other about $9^{k}$, the combined weight being about equal to that of the Johnson County iron.

This mass fell about six miles east of Cabin Creek, Johnson Co., Arkansas, in longitude 93° 17′ W. of Greenwich, latitude 35° 24′ North, within seventy-five yards of the house of Christopher C. Shandy. Mrs. Shandy states that about three o'clock on the afternoon of the 27th of March, 1886, while in her house she heard a very loud report, which caused the dishes in the closet to rattle and which she described as louder than any thunder she had ever heard. At first she thought it was caused by a bombshell, and ran out of the house in time to see the limbs fall from the tops of a tall pine tree, which, she says, stands about 75 yards from her dwelling. She did not investigate the matter until her husband came home about six o'clock in the evening, when in company with John R. Norton, their hired man, they went out to find the cause of the noise that had so startled Mrs. Shandy. They discovered that a large hole had been made in the ground by some falling object, and that the fresh dirt had been thrown up to a height of thirty feet on the surrounding saplings and trees. They dug down, and a steam or exhalation arose, which on a dark night might perhaps have produced a phosphorescence similar to that described in the case of the Mazapil iron. The iron had buried itself in the ground to the depth of three feet, and the earth around it to the thickness of one inch seemed to be burned.

The ground was still warm when the iron was taken out, and the iron itself was as hot as the men could well handle. The weather had been quite cloudy all day, but no rain fell until night. These facts are from the affidavits of Mr. and Mrs. Shandy and John R. Norton. Mr. Shandy at first supposed that their find was platinum, then silver, and he finally learned what it really was and sold it. Mrs. India Ford, Dr. W. J. Bleck, Mr. S. A. Wright, Constable, and Mr. L. Wright, Chief of Police, also heard the report caused by the fall.

The noise was heard 75 miles away and was likened to a loud report followed by a hissing sound as if hot metal had come in contact with water. It caused a general alarm among the people and teams of horses twenty five miles distant becoming frightened, broke loose and ran away, and in Webb City, Franklin Co., on the south side of the Arkansas river, a number of bells kept on sale in a store, are said to have been caused to tinkle. Cabin Creek is on the north side of the Arkansas river.

Mr. B. Caraway states that he heard two loud reports at Alma, Crawford Co., at 3 o'clock on March 27th, 1886. The report was also heard at Russellville and in the adjoining county of Pope. The *Democrat* of that place, April 29th, '86, says: "The wonderful meteoric stone as it is called, but erroneously, for nothing is further from stone than it is, is now on exhibition here. We looked on the strange thing and wondered what it was and where it came from. The noise it made when it struck the earth's atmosphere on the 27th of March and came whizzing to earth near Knoxville, will never be forgotten, neither will anyone who looked at it ever forget it." A description of the mass then follows. The *Dardanelle Post* of April 1st, refers to the explosion, and the issue of April 8th suggests the meteorite found as its probable cause. Mr. B. Caraway who visited the spot for me informs me that the pine tree, through which the meteorite fell is 107 feet high, and that the distance from the foot of the tree to the centre of the hole made by the mass is 22 feet 3 inches. The limbs on the west side of the tree were broken, and the meteorite lay in the hole with the flat side down. The hole was 75 yards from the house.

Professor H. A. Newton, who has kindly interested himself in this matter, says that the data furnished indicate that the mass must have fallen nearly from the zenith. This was the direction of the end of its path, the earlier portion being more inclined to the vertical, as the path must be affected by gravity and the resistance of the air. The earlier direction must have been from the N.E. and more nearly from the East than the North.

Mr. Shandy sold the meteorite to Mayor Caraway, who in turn sold it to Col. J. C. Betten,* a lawyer of Eureka Springs, of whom the writer obtained it, Colonel Betten bought it as a business speculation, intending to realize something of an income from its exhibition. While in his possession it was exhibited at Eureka Springs. Circulars headed "The Tenth Wonder" were printed and circulated, notwithstanding the fact that the authors had no knowledge of the number of irons that had been seen to fall and that this was in reality the tenth. It was also called "veritable wonder that was seen to pass through the sky, blazing, sparkling, etc." Twenty-five cents was charged for admission to look at it. The mass is in general quite flat and very irregular, resembling strongly a mass of molten metal thrown on the ground and then pitted. The illustration of the Agram† mass figured by Von Schreibers could be mistaken for the upper side of this were it not that this is larger. It measures 17½ inches ($44^{cm}$) by 15½ inches

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* Affidavits were furnished by the County Clerk and the Mayor of Eureka, as to the trustworthiness of Colonel Betten and Mayor Caraway.

† "Beiträge zur Geschichte und Kenntniss Meteorischer Stein- und Metallmassen," by Dr. Carl von Schreibers, Wien, 1820, folio, plate viii.

($39^{cm}$) while the Agram measures 15½ by 12 inches. A high ridge, 5 inches high at the highest point ($12·5^{cm}$), runs through the center. One half of the mass is not over 3 inches ($7·5^{cm}$) thick, part of it is only 2 inches ($5^{cm}$), and around the edge it is only one inch or less. It is only exceeded in size among the irons seen to fall by the Nejed, Central Arabia, now in the British Museum, which fell in the spring of 1865 and weighs 59·420 kilos. The weight is 107½ lbs. (44·213 kilos), and it is intact with the exception of three small points, weighing not more than two ounces in all, which were broken off. One of these is seen in the etched figure, another was sent to Professor Clarke by Colonel Betten to be analyzed, and the third piece was lost.

The two sides are wholly dissimilar. (See Plate XIII.)* In fact, one would scarcely supppse that they belonged to the same mass. The upper side is ridged and deeply dented, while the lower side is flat and covered with shallow, but very large pittings. On top the color is in many places almost tin-white without any coating whatever, and the pittings are very deep and usually quite long, like finger depressions, made in potter's clay. These depressions measure from $2^{cm}$ to $4^{cm}$ and from $1^{cm}$ to $4^{cm}$. This side is remarkable for striæ showing the flow and burning and all running from the center toward the edge, identical with those in the Rowton, Nedagolla and Mazapil irons, but on a larger scale. Some of them are thinner than a hair and yet twice as high (like a high knife-edge), and they are from one to four inches long. In one space of $5^{cm}$ twenty are arranged side by side, and on one small part which is black, there are 50 lines in one inch of space ($25^{mm}$), all running in the same direction. Near all the pointed edges the fused metal has flowed and cooled so as to hang like falling water. The striæ and marks of flowing are around the edges of the upper surface, (Plate XIII, fig. 1.) On the under side pittings are very shallow but much broader, one depression, apparently made up of four pittings being $20^{cm}$ long and $9·5^{cm}$ wide. The whole side is coated with a black crust, $1^{mm}$ thick and having minute round bead-like markings. On one of the indentations of the lower edge the crust has a strikingly fused appearance as if a flame had been blown on it from the other side. In reality this edge is undoubtedly the place where a greater amount of burning took place when the body was passing through the air. Seven small, bead-like lumps, from $5^{mm}$ to $10^{mm}$ in size, which are visible on this side, are drops of metal that were entirely melted and flowed and cooled so that they resemble drops of a thick liquid. There are also to be seen what appear to be cracks, 15 in number and nearly

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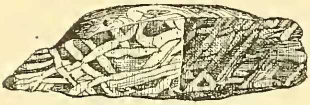
* The figures on this Plate were made by the Ives process and are faithful reproductions direct from the photograph.

as thin as a hair. One of these is $10^{cm}$ long and extends from the highly fused edge above mentioned toward the center. The others are from $3^{cm}$ to $5^{cm}$ long. These are so evenly arranged that they are without doubt "Reichenbach lamellen" in which the inner troilite has been burnt out. If such is the case they are as abundant as in the Staunton, Va., meteoric iron.

On the upper side ten nodules of troilite are exposed, measuring from $33^{mm}$ in diameter to $55^{m}$ long and $25^{mm}$ wide. On the lower side there are 12 such nodules exposed, $13^{mm}$ in diameter, while the largest measures $19^{mm}$ by $39^{mm}$. On the upper side these nodules are coated in spots with a black crust similar to that found on the mass, but on the lower side the crust extends completely around the side of the nodules, showing the fusion very plainly. The troilite is very bright and fresh, like a newly broken mineral, and on the upper side one of the nodules shows deep striation, suggesting that the entire nodule is one crystal and the exposed part is only one side of it. In some cases where the nodules were broken they were found to be iridescent. This is one of the octahedral irons showing the Widmanstätten figures beautifully on etching (see figure 3), and is one of the Caillite groups of Stanislas Meunier and of the *mittlere lamellen* of Brezina. The lamellæ are $1^{mm}$ wide and the markings more closely approach the Rowton* and Mazapil† irons. Figure 4 shows the etching on the surface of the unpolished exterior, there being no crust. The lower end of the figure which is flat, was produced by the hammering off of the piece; but the etching is really finer where it was done on the natural surface of the iron. The specific gravity of the small piece figured is 7·773. Troilite, as before stated, is very abundant in the mass. Schreibersite and carbon have also been found between the laminæ. Chlorine is present only in slight quantity, as scarcely any deliquescence has been observed.‡

3.



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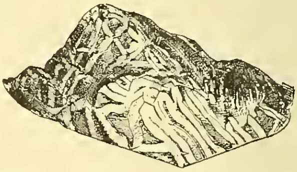

The following is a comparative table of analyses of meteoric irons most nearly approaching this in composition:

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* Meteoriten Sammlung des k. k. mineralogisches Hofcabinet in Wien., 8vo, Wien, 1885, Plate 2, figure 2.

† This Journal, III, vol. xxxiii, p. 225, fig. 2.

‡ The full analysis of this iron made by Mr. J. E. Whitfield will be given in an article following this.

| | Cabin Creek. (Whitfield.) | Estherville. (Smith.) | Mazapil. (Mackintosh.) | Rowton. (Flight.) | Charlotte. (Smith.) |
|---|---|---|---|---|---|
| Iron | 91·87 | 92·00 | 91·26 | 91·25 | 91·15 |
| Nickel | 6·60 | 7·10 | 7·845 | 8·582 | 8·05 |
| Cobalt | trace | 0·69 | 0·653 | 0·371 | 0·72 |
| Phosphorus | 0·41 | 0·112 | 0·30 | ------ | 0·06 |
| C, S, etc. | 0·54 | 99·902 | 100·038 | 100·203 | 99·98 |
| | 99·42 | | | | |

From the fact that the ridged side is so free from crust and the flat side so thickly coated; that the ridged side is covered with striæ and marks of flowing, and the other has so few marks of this kind, and from the fact that at the edges, especially at the indentation the back looks as though a flame had come from the other side—from all these facts the writer concludes that after entering our space the iron traveled with the ridged surface forward (see fig. 1, Plate XIII), the iron burning so rapidly as to be torn off, leaving part of the surface bright. The flame thus passed over the sides, and the indented edge being downward, the flame was driven upward as the iron advanced. The flat side, not being so much exposed, the iron was not so completely consumed, hence a crust and large but shallow pittings. These conditions would perhaps have been entirely different had the mass been round or thicker, for it evidently moved as straight as possible without rotating at all. That it was found in the hole with the flat side down was due perhaps to the fact that having lost its impetus it turned in falling, or, as Professor Newton suggests, it may have been turned by striking the tree, and then have fallen downward almost in a straight line.

As the iron only penetrated to a depth of three feet ($90^{cm}$) the earth where it struck must have been very compact and the force of the body itself nearly spent. The Agram iron penetrated 14 to 15 feet ($425$–$450^{cm}$) in a freshly ploughed field, which shows that in the case of that meteorite there must have been considerable force left, the small mass falling very near it. The Mazapil mass, one tenth of the weight, penetrated only 12 inches ($30^{cm}$).

I must herewith thank Mayor B. Caraway and Col. J. C. Betten for information furnished me, and Professor F. W. Clarke and Mr. J. E. Whitfield for their courtesy and for the analysis.

## Art. L.—*On the Johnson County, Ark., and Allen County, Ky., Meteorites*; by J. Edward Whitfield.

1. *Johnson County, Ark.*—A fragment of the Johnson County meteorite described in the preceding paper by Mr. Kunz, was received by Professor F. W. Clarke, of the U. S. Geological Survey, from the former owner, Mr. J. C. Betten, of Eureka Springs, Arkansas. This fragment weighed a little more than 35 grams, the exposed surfaces were oxidized, the oxide of iron extending into the numerous cracks, in some cases almost through the specimen. The trace of chlorine found will account in some degree for this oxidation.

The following analysis gives the composition of the iron. The loss is due to the partial oxidation of the iron.

| | |
|---|---|
| Fe | 91·87 |
| Ni | 6·60 |
| Co | trace |
| S | 0·05 |
| Combined C | 0·15 |
| P | 0·41 |
| Mn | trace |
| Cl | " |
| Insol. in HCl | 0·34 |
| Specific gravity = 7·837. | 99·42 |

2. *Allen County, Ky.*—This meteorite was found about the middle of June, 1867, by Mr. Jas. H. More, while hoeing tobacco, near Scottsville, Allen Co., Ky. In shape it resembles a wedge, the thickness, at base, being $14^{cm}$, width $18^{cm}$, and length $16^{cm}$; the mass, as found, weighing a little more than 10 kilos and having the characteristic pitted surface. A section shows nodules of troilite, varying in diameter from barely visible points to about $12^{mm}$. The markings on an etched surface are exceedingly fine and require the aid of a lens to distinguish them. There appear to be two sets of figures, one of long, very fine lines representing octahedral cleavage, the other series being smaller, more crowded and barely perceptible. An analysis gave the following composition:

| | |
|---|---|
| Fe | 94·32 |
| Ni | 5·01 |
| Co | trace |
| S | 0·34 |
| P | 0·16 |
| Total C | 0·12 |
| Specific gravity = 7·848 | 99·95 |

This iron, as regards markings and general appearance of section, resembles the Scriba and Salt River meteorites more nearly than any others represented in the National Museum collection; but as no complete analyses of these two irons are at hand the chemical comparison cannot well be made. The percentage of iron appears rather high, but duplicate determinations gave corresponding figures.

The material for analysis was received by Professor Clarke from Messrs. Ward and Howell, of Rochester, N. Y., the present owners of the meteorite, to whom we are indebted for the privilege of description.

Chemical Laboratory of U. S. Geological Survey,
Washington, D. C., Feb., 1887.

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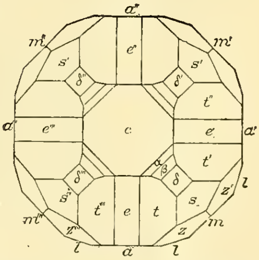
## ART. LI.—*Contributions to Mineralogy*; by W. E. HIDDEN and H. S. WASHINGTON.

THE following pages contain the results of a crystallographic examination of some crystals obtained last summer at the emerald and hiddenite locality in Sharpe's township, Alexander Co., North Carolina. The crystals were nearly all highly polished and brilliant, allowing very exact determinations. The measurements were all made on a Fuess horizontal goniometer with two telescopes. As a rule, the mean of about five of the best results are taken, though in several cases, as in apatite and rutile, the fundamental angles selected were the mean of ten or more determinations.

RUTILE.—The particular crystals examined are of the rarest type of the region and are peculiar to the pockets and veins bearing spodumene. The rare basal plane on the rutile and the predominance of the acute rhombohedron $3R(\varkappa 30\bar{3}1)$ on the associated quartz crystals are good indications of the gem variety of spodumene in Alexander County. These rutiles are generally quite small, rarely over $3^{mm}$ thick and $10^{mm}$ long, but the polish of the planes is extremely good. They are only found as implanted crystals, and, besides the species mentioned above, are commonly associated with brown muscovite, dolomite, siderite, pyrite, and rarely beryl, all well crystallized. The best of these crystals came from pockets in the gneissoid rock about thirty feet below the surface. With one or two exceptions of clear,

1.



ruby-red crystals, they were of an iron-black color, and brilliant submetallic lustre. They had, usually, the basal pinacoid prominent and well polished; *s* (111, 1) and *e* (101, 1-*i*) were also prominent. The annexed figure shows the most interesting form, observed in two crystals, on which three of the new planes occur. The planes identified were as follows:

Pinacoid, *c* (001, *O*), prisms, *a* (100, *i*-*i*), *m* (110, *I*), *l* (310, *i*-3), dome, *e* (101, 1-*i*), pyramids $\alpha$*(227, $\frac{2}{7}$), $\beta$*(112, $\frac{1}{2}$) $\delta$*(223, $\frac{2}{8}$), *s* (111, 1), $\pi$*(441, 4), *t* (313, 1-3), *z* (321, 3-$\frac{3}{2}$) and $\gamma$*(989, 1-$\frac{9}{8}$).

Those marked with an asterisk are new to the species. As a fundamental angle $c \wedge s$ (001 ∧ 111) was taken, giving as a mean of fifteen closely agreeing measurements,

$$c \wedge s\ (001 \wedge 111) = 42^\circ\ 20'\ 8''\ \therefore\ a : \overset{|}{c} = 1 : 0{\cdot}644252,$$

Miller* giving

$$c \wedge s\ (001 \wedge 111) = 42^\circ\ 19'\ 58''\ \therefore\ a : \overset{|}{c} = 1 : 0{\cdot}644179.$$

The new planes of the unit pyramidal series were determined by their angles on *c* (001, *O*). The agreement between the observed and calculated angles is as follows:

| | Calc. | Observed. |
|---|---|---|
| $c \wedge \alpha$, $001 \wedge 227$ = | 14° 35′ | 14° 36′ |
| $c \wedge \beta$, $001 \wedge 112$ = | 24° 29½′ | 24° 30½′ |
| $c \wedge \delta$, $001 \wedge 223$ = | 31° 16′ | 31° 14′ |
| $c \wedge \pi$, $001 \wedge 444$ = | 74° 39′ | 75° (approx.) |

The new plane $\gamma$(989, 1-$\frac{9}{8}$) was observed on several crystals replacing the edge *s*/*e* (111/101). It furnished the following angles:

| | Calc. | Observed. |
|---|---|---|
| $s \wedge \gamma$, $(111 \wedge 989)$= | 2° 42′ | 2° 57′ |
| $e \wedge \gamma$, $(101 \wedge 989)$= | 25° 44′ | 25° 29′ |

Some of the best observed angles are here tabulated, with the corresponding calculated angles, from the fundamental angles above.

| | Calc. | Observed. |
|---|---|---|
| $c \wedge s$, $001 \wedge 111$ = | *42° 20′ 8″ | 42° 20′ 8″ |
| $c \wedge e$, $001 \wedge 101$ = | 32° 47½′ | 32° 47′ |
| $c \wedge t$, $001 \wedge 313$ = | 34° 11′ | 34° 8′ |
| $s \wedge e$, $111 \wedge 101$ = | 28° 26′ | 28° 26½′ |
| $t \wedge e$, $313 \wedge 101$ = | 10° 14′ | 10° 13′ |
| $s \wedge t$, $111 \wedge 313$ = | 18° 12′ | 18° 12′ |
| $e \wedge e'$, $101 \wedge 011$ = | 45° 2′ | 45° 1′ |
| $e \wedge e''$, $101 \wedge \bar{1}01$ = | 65° 34′ | 65° 33½′ |
| $e \wedge z$, $101 \wedge 321$ = | 41° 43½′ | 41° 42′ |

Of very exceptional beauty as cabinet specimens were the crystals of rutile found at a depth of forty-three feet in the shaft, just west of the excavation which yielded the crystals above described. The pocket was 10×2×6 feet, and its walls

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* Phil. Mag., xvii, 268. 1840.

were covered with beautifully crystallized muscovite, quartz, dolomite, siderite, apatite and rutile. All the contents of this large pocket had a thin chloritic coating, which could easily be removed, in most instances as a very friable shell. The rutile exhibited twinning according to both the known laws, and often both were to be noticed in the same crystal. Crystals with geniculated members of from 1 to $2^{\mathrm{cm}}$ long and $5^{\mathrm{mm}}$ thick were not uncommon, and a few simple crystals were $6^{\mathrm{cm}}$ in length and $1^{\mathrm{cm}}$ in thickness. All were terminated with well polished planes, $s(111)$ and $e(101)$ being dominant. The dolomite as also the siderite crystals showed only the unit rhombohedron and basal pinacoid. These planes were very flat and well polished, no curvature of the planes, as is peculiar to the species, being observed. The rhombohedral face was striated horizontally. Twins of dolomite were common and calcite crystals were observed in parallel position on the rhombohedral face in several instances. One of the dolomites measured nearly $10^{\mathrm{cm}}$ on its edges and was a very exceptional example of the species. In this pocket were found a few apatite crystals of unusual perfection, and these we notice in detail.

APATITE.—It was plainly evident from their loose attachment and perfection of form that these crystals were the last crystallization of the pocket. For the most part they were rather long, slender prisms, 15 to $25^{\mathrm{mm}}$ by 2 to $4^{\mathrm{mm}}$, of a pale bluish green color and transparent. A sort of parting parallel to the base was quite noticeable, and the terminations were often highly modified, though, as a rule, only with the more common planes. In one corner of the pocket a small group of muscovite crystals was found which had implanted on them a few very brilliant, wine yellow, transparent, lenticular crystals of apatite. They were of an entirely different habit from the rest of the apatite found, and one of these we have selected for measurement and description. The particular crystal examined was quite small, about $2^{\mathrm{mm}}$ in diameter, and, with the exception of part of one side, where it was attached to the mica by the prism, was almost perfectly developed both above and below. Its habit is almost unique, Schrauf* only figuring one crystal fig. 23, xx) at all similar. The pyramids $r\,(10\bar{1}2, \frac{1}{2})$, $x\,(10\bar{1}1, 1)$, and $s\,(11\bar{2}1, 2\text{-}2)$ predominated, while the prisms were nearly absent. Another interesting fact in regard to this crystal is the occurrence of *both* hemihedral prisms $h\,(21\bar{3}0)$ and $h_1\,(12\bar{3}0)$. The planes observed were as follows:

Basal pinacoid, $c\,(0001, O)$, prisms, $m\,(10\bar{1}0, I)$, $a\,(11\bar{2}0, i\text{-}2)$, $h\,(21\bar{3}0, i\text{-}3)$, $h_1(12\bar{3}0)$, pyramids, $r\,(10\bar{1}2, \frac{1}{2})$, $x\,(10\bar{1}1)$, $y\,(20\bar{2}1, 2)$, $z\,(30\bar{3}1, 3)$, $\mathbf{v}\,(11\bar{2}2, 1\text{-}2)$, $s\,(11\bar{2}1, 2\text{-}2)$, dihexagonal pyramids, $v\,(21\bar{3}1, 3\text{-}\frac{3}{2})$, $i\,(21\bar{3}2, \frac{3}{2}\text{-}\frac{3}{2})$ and $o\,(31\bar{4}2, 2\text{-}\frac{4}{3})$.

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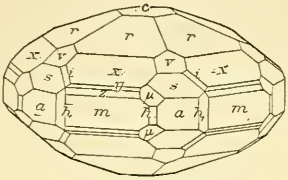
* Atlas der Krystallformen, Plates xviii to xx.

The following figures give a good idea of its habit, though in the perspective figure the prisms are elongated.

2.



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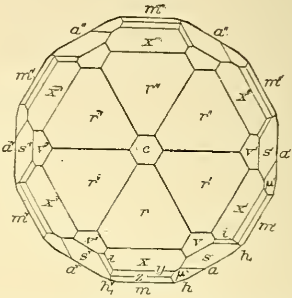

As fundamental angle the following was finally decided upon, it being the mean of about a dozen good determinations.

$$x \wedge v,\ (10\bar{1}1 \wedge 11\bar{2}2) = 18^\circ\ 52' \text{ giving } a:\dot{c} = 1:0{\cdot}734335. \quad \text{Kokscharof gives: } a:\dot{c} = 1:0{\cdot}734603.$$

The following list of angles may be here inserted:

| | Calculated. | Observed. |
|---|---|---|
| $c \wedge x$, | $0001 \wedge 10\bar{1}1 = 40^\circ\ 18'$ | $40^\circ\ 15\frac{1}{2}'$ |
| $c \wedge r$, | $0001 \wedge 10\bar{1}2 = 22^\circ\ 58\frac{1}{2}'$ | $22^\circ\ 58\frac{1}{2}'$ |
| $c \wedge y$, | $0001 \wedge 20\bar{2}1 = 59^\circ\ 28\frac{1}{2}'$ | $59^\circ\ 31'$ |
| $c \wedge z$, | $0001 \wedge 30\bar{3}1 = 68^\circ\ 32\frac{1}{2}'$ | $68^\circ\ 36'$ |
| $a \wedge v$, | $11\bar{2}0 \wedge 11\bar{2}2 = 53^\circ\ 42\frac{1}{2}'$ | $53^\circ\ 41\frac{1}{2}'$ |
| $a \wedge s$, | $11\bar{2}0 \wedge 11\bar{2}1 = 34^\circ\ 14'$ | $34^\circ\ 13\frac{1}{2}'$ |
| $r \wedge r'$, | $10\bar{1}2 \wedge 01\bar{1}2 = 22^\circ\ 31'$ | $22^\circ\ 32'$ |
| $y \wedge s$, | $20\bar{2}1 \wedge 11\bar{2}1 = 25^\circ\ 31'$ | $25^\circ\ 35'$ |
| $y \wedge o$, | $20\bar{2}1 \wedge 31\bar{4}2 = 12^\circ\ 45\frac{1}{2}'$ | $12^\circ\ 15'$ (approx.) |

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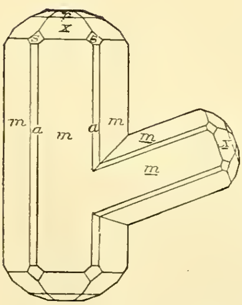


$z$ $(30\bar{3}1)$, $v$ $(21\bar{3}1)$, $i$ $(21\bar{3}2)$, $o$ $(31\bar{4}2)$ and $h$ $(21\bar{3}0)$ were small and gave rather poor images, but the other planes were well polished and gave good results.

What is probably a cruciform twin of apatite, from this locality, was also examined. It was composed of two slender, pale bluish green crystals. The figure shows the only occurring planes. One crystal was slightly displaced from the other, but the prisms of both were perfectly parallel. The following measurements were made, giving as a twinning plane $s$ $(11\bar{2}1,\ 2\text{-}2)$. The first two measurements are the most reliable:

$a^{IV} \wedge a_{IV} = 68^\circ\ 28'$, giving twinning plane $\wedge a = 34^\circ\ 14'$
$s^{IV} \wedge s_{IV} = 68^\circ\ 51'$, " " " $\wedge a = 34^\circ\ 26'$
$m^{V} \wedge m_{I} = 92^\circ\ 15'$, " " " $\wedge a = 33^\circ\ 32'$

This case is interesting as being the first recorded case of a twin in the species; the agreement between the measured and calculated angles makes it seem improbable that the occurrence is accidental.

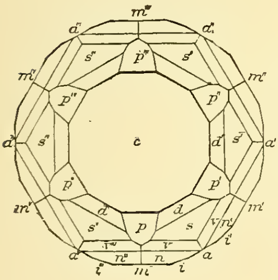
Beryl. — Together with crystals of emerald-spodumene (hiddenite) found in one pocket at this same locality was a clear white beryl, about $1^{cm}$ by $\cdot7^{cm}$. This was also examined, and a basal projection is given in figure 5. It shows the rather rare plane *d* ($33\bar{6}4$, $\frac{3}{2}\cdot2$), which gave the following angle: $c \wedge d$, $0001 \wedge 3364$ = calc., 36° 48′, = observ., 37° 7′ approx.

On another larger, clear white beryl, a plane which is approximately represented by the symbol $\varphi$ ($8\cdot7\cdot15\cdot6$, $\frac{5}{2}\cdot\frac{15}{8}$) was observed in the zone $s \wedge p'$ ($11\bar{2}1 \wedge 12\bar{3}0$). It was determined by the following angles:

| | Calc. | Observed. |
|---|---|---|
| $s \wedge \phi$, $11\bar{2}1 \wedge 8\cdot7\cdot\overline{15}\cdot6$ | 39° 31′ | 39° 20′ (approx.) |
| $v \wedge \phi$, $12\bar{3}1 \wedge 8\cdot7\cdot\overline{15}\cdot6$ | 8° 45′ | 9° (approx.) |

On the same crystal a plane was observed replacing the edge $s/a$ ($11\bar{2}1/11\bar{2}0$). It has approximately the symbol $\Psi$ $8\cdot7\cdot16\cdot8$, $2\cdot\frac{16}{7}$. It was determined by the following angle: $c \wedge \Psi$ ($0001 \wedge 8\cdot7\cdot16\cdot8$) = 48° 45′ calc., 48° 46′ observed.

5.



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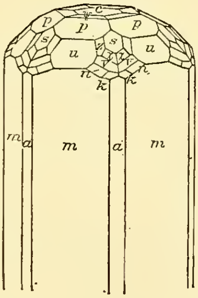

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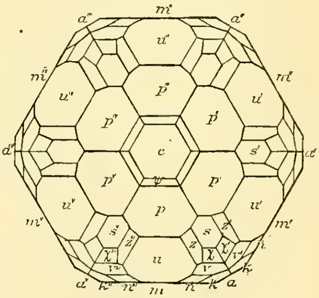

It is noteworthy that the highly modified beryls of this region only occur rarely and when associated with spodumene or albite. Another interesting feature is that white or very pale greenish beryls are found with the deepest green spodumene. It has before been noted that the quartz and beryl of Alexander Co. are more highly modified when they are implanted on the feldspathic layers of the walls of the pockets. Two emerald beryls were examined which were found in 1881, at a depth of 34 feet, in a little pocket whose walls were almost wholly covered with crystals of albite twinned parallel to the base. Only four emeralds were found, and they averaged about $1^{cm}$ in the three dimensions. The pocket was free from all decomposition whatever. The crystals were of good color, transparent, and had the commoner planes well polished. They differed to some extent in habit, and figures 6 and 7 show the occurring planes on two of them, though the berylloids are much exaggerated, and the basal pinacoid reduced in size.

The occurring planes were as follows:

$c$ (0001, $O$), $m$ ($10\bar{1}0$, $I$), $a$ ($11\bar{2}0$, $i$-2), $i$ ($21\bar{3}0$, $i$-$\frac{3}{2}$), $s$ ($11\bar{2}1$, 2-2), $\psi$* ($1{\cdot}0{\cdot}\bar{1}{\cdot}12$, $\frac{1}{12}$), $p$ ($10\bar{1}1$, 1), $u$ ($20\bar{2}1$, 2), $n$ ($31\bar{4}1$, 4-$\frac{4}{3}$), $v$ ($31\bar{2}1$, 3-$\frac{3}{2}$), $\chi$*($8{\cdot}7{\cdot}\bar{15}{\cdot}7$, $\frac{15}{7}$-$\frac{15}{8}$), $k$ ($42\bar{6}1$, 6-$\frac{3}{2}$), $z$ ($42\bar{6}3$, 2-$\frac{3}{2}$).

The plane ($8{\cdot}7{\cdot}\bar{15}{\cdot}7$) was rounded somewhat, as was the case with (5·4·9·4) observed by vom Rath. This plane, new to the species, and whose symbol can be regarded as only approximately determined, gave the following angles:

| | Calculated. | Observed. |
|---|---|---|
| $\chi \wedge \chi'$, $8{\cdot}7{\cdot}\bar{15}{\cdot}7 \wedge 7{\cdot}8{\cdot}\bar{15}{\cdot}7$ | = 3° 17′ | 3° 50′ (approx.) |
| $s \wedge \chi$, $11\bar{2}1 \wedge 8{\cdot}7{\cdot}\bar{15}{\cdot}7$ | = 2° 33′ | 2° 50′ " |

The new pyramid of the first series was determined as follows:

$c \wedge \psi$, $0001 \wedge 1{\cdot}0{\cdot}\bar{1}{\cdot}12 = 2° 45'$ calc. 2° 52′ observed.

A list of the angles observed with the corresponding ones calculated from Kokscharof's measurements is here given:

| | Calculated. | Observed. |
|---|---|---|
| $c \wedge p$, $0001 \wedge 10\bar{1}1$ | = 29° 56½′ | 29° 56′ |
| $c \wedge u$, $0001 \wedge 20\bar{2}1$ | = 49° 2½′ | 49° 6′ |
| $c \wedge s$, $0001 \wedge 11\bar{2}1$ | = 44° 56′ | 44° 52′ |
| $m \wedge s$, $10\bar{1}0 \wedge 11\bar{2}1$ | = 52° 11′ | 52° 7′ |
| $m \wedge v$, $10\bar{1}0 \wedge 21\bar{3}1$ | = 37° 42½′ | 37° 39′ |
| $m \wedge n$, $10\bar{1}0 \wedge 31\bar{4}1$ | = 28° 54½′ | 28° 55′ |
| $a \wedge k$, $11\bar{2}0 \wedge 42\bar{6}1$ | = 21° 5′ | 21° 4′ |

It was a noteworthy fact that on all these beryls the prism $m$ ($10\bar{1}0$) was perfectly smooth, while the prism $a$ ($11\bar{2}0$) was etched over the whole surface with shallow isosceles-triangular pits, apex up and broader than high.

TOURMALINE.—Some well polished black crystals were found implanted in cavities. They gave such excellent measurements that the comparison of the results obtained from them with those of Des Cloizeaux is not without interest.

| | | H. S. W. | Des Cloizeaux. |
|---|---|---|---|
| $a : c = 1 : 0{\cdot}89905$ | | | |
| $-\frac{1}{2}R \wedge -\frac{1}{2}R\ \vartheta$ | $(10\bar{1}2 \wedge \bar{1}102)$ | = 47° 1′ 45″ | 46° 52′ |
| $-\frac{1}{2}R \wedge \frac{1}{4}R$ | $(10\bar{1}2 \wedge 01\bar{1}4)$ | = 23° 30′ | 23° 26′ |
| $O \wedge R$ | $(0001 \wedge 01\bar{1}1)$ | = 46° 4′ | 45° 57′ |
| $R \wedge R$ | $(01\bar{1}1 \wedge \bar{1}011)$ | = 77° 11′ | 76° 59′ |
| $R \wedge -\frac{1}{2}R$ | $(01\bar{1}1 \wedge 10\bar{1}2)$ | = 38° 35′ | 38° 29½′ |

The largest crystal was only $6^{cm}$ long by $12^{mm}$ thick. Some few were noticed to be hemimorphic in the terminal planes.

The basal pinacoid was rare, $-\frac{1}{2}R$, $\frac{1}{4}R$ and $R$ predominated. One crystal was terminated almost wholly by $\frac{1}{4}R$.

QUARTZ.—Vom Rath has already called attention to the occurrence of the plane $k_2 = (4\bar{1}\bar{3}0)$ $i$-$\frac{4}{3}$ on quartz crystals from Alexander County, North Carolina.[*] Its best development seems to have been found on crystals from the gem mine, in Sharpe's township. Thus far this plane has been described as "a hemihedral twelve-sided prism," and its fine vertical striation and often observed right-angled intersection with the trapezohedron 4-$\frac{4}{3}$ $(4\bar{1}\bar{3}1)$ at once characterized it and made it easily recognized. Quite recently we have obtained several crystals, from this same locality, which apparently presented this plane *holohedral*, in pairs on each consecutive prismatic edge, instead of on alternate edges as before noted.

Vom Rath's measurements gave as the angle of $k_2 \wedge g\ (I)$ 13° 52′ (calculated 13° 54′), while we found $k_2 \wedge k_2$ adjoining = 31° (calculated 32° 12′). One of the new crystals ($8 \times 4\frac{1}{2}^{\text{cm}}$) exhibited this rare plane $13^{\text{mm}}$ wide and $19^{\text{mm}}$ long.

We add also to this paper notices of a new plane on topaz and a twin of corundum.

TOPAZ.—This was a clear white crystal of about $1 \times 2^{\text{cm}}$, which was sent to us from the noted locality near Zacatecas, Mexico, where they are found in the detritus of trachyte very similar to the occurrences in Utah described by Alling[†] and in Colorado by Cross. This crystal had the usual habit of topazes from Durango. Replacing the solid angle formed by 110, $1\bar{1}0$, and 201, there was observed a new plane which has the symbol (701, 7-$i$). A comparison of its observed and calculated angles is here given:

| | Calculated. | Observed. |
|---|---|---|
| 001 ∧ 701 | 80° 58′ | 81° 6′ |
| 110 ∧ 701 | 8° 29½′ | 8° 31′ |

CORUNDUM.—A twin of corundum was found among a lot of gem material received from Ceylon. Its high polish and twinned form are features rarely observed in the species. It was of a clear grayish blue color. Both basal pinacoids were present and were highly polished. The angle observed between the two was 114° 20′, giving as a twinning plane the unit rhombohedron.

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[*] Sitzungsberichte der Niederrhein. Gesellsch. f. Nat.-u. Heilkunde, 6 July, 1885. Zeitschrift für Krystallographie, etc. xii, 456.

[†] This Journal, III, xxx, 146, 1887.

# SCIENTIFIC INTELLIGENCE.

## I. Chemistry and Physics.

1. *On the decomposition of Potassium chlorate by heat.*—At the suggestion of Thorpe, **Frankland** (P. F.) and **Dingwall** have studied the decomposition which potassium chlorate undergoes when heated, extending their observations also to the perchlorate. In the first series of experiments, the chlorate was heated over a naked flame, different quantities of oxygen being driven off in each experiment and determined by loss of weight. The chloride formed, as well as the chlorate remaining, were also determined. In the first two experiments, 2·66 and 5·19 per cent of oxygen (calculated on the weight of $KClO_3$ taken) were evolved respectively. And the decomposition proceeded according to the equation $(KClO_3)_8=(KClO_4)_5+(KCl)_3+(O_2)_2$. In the third, in which 6·47 per cent of oxygen was evolved, the reaction was intermediate in its results between the above equation and $(KClO_3)_{10}=(KClO_4)_6+(KCl)_4+(O_2)_3$. Since there was no guarantee in these experiments that the reaction was not complicated by the decomposition of the perchlorate at first formed, the authors made a second series of experiments, selecting as the temperature that of boiling sulphur, since at this temperature the perchlorate is not decomposed. The decomposition was at first active, but soon became sluggish. In one experiment 5·3345 grams of chlorate exposed in the sulphur bath for 98 hours, lost 116·6 milligrams during the first five hours, and only 8 milligrams during the last. In the first two experiments, in which 6·89 and 6·78 per cent of oxygen were respectively evolved, the reaction took place nearly in accordance with the second of the above reactions. In the third experiment, powdered glass was mixed with the chlorate; and then the decomposition was almost complete, 14·3 per cent of oxygen being evolved, nearly according to the formula $(KClO_3)_2=KClO_4+KCl+O_2$. Hence the decomposition of potassium chlorate by heat more nearly approaches the equation $(KClO_3)_2=KClO_4+KCl+O_2$ in proportion as this decomposition is more complete. In experimenting with perchlorate, definite portions were heated over a naked flame in a piece of combustion tube sealed at one end and loosely plugged with glass-wool at the other, a different proportion of oxygen being liberated in each experiment. In the residue the proportion of chloride to chlorate was determined. The results when tabulated form a continuous series; the proportion of chlorate formed diminishes as the oxygen evolved increases, while the chloride produced increases. When the oxygen set free was 8·77 per cent, the chlorate formed was 24·85 per cent of the perchlorate employed; but when 36·81 per cent of oxygen was evolved, the chlorate was only 5·27 per cent. Heating the perchlorate in sulphur vapor, when previously mixed with $MnO_2$, resulted in a complete decom-

position according to the equation $KClO_4=KCl+(O_2)_2$. To demonstrate beyond question this formation of chlorate, the perchlorate was heated until it lost about 10 per cent of its weight, then dissolved in water and fractionally crystallized. The third fraction contained 41·68 and the fourth 42·91 per cent of chlorate. —*J. Chem. Soc.*, li, 274, March, 1887. G. F. B.

2. *On the Influence of Silicon on the Properties of Iron and Steel.*—Turner has made experiments at the South Staffordshire Steel and Ingot Iron Company's works at Bilston, to determine the influence which silicon exerts upon the properties of iron and steel. A small, modified Deville furnace was erected on the platform between two Bessemer vessels. The crucibles used were of Stourbridge fire clay, and were capable of holding about 35 pounds of steel. After the necessary annealing the pot was placed in the furnace and raised to about the melting point of cast iron. A few minutes before the mixture was to be made, a weighed quantity of silicon pig was introduced into the crucible and the temperature was increased by turning on more blast. At the right moment the crucible was rapidly removed from the furnace and brought to the mouth of the converter, while at the same time a ladle of metal was drawn from the vessel. This was poured into the crucible and the metal well stirred by means of a rod of basic steel. After cooling, the crucible was broken and the ingot numbered. Each ingot was submitted to mechanical tests and was carefully analyzed. The author concludes that on adding silicon in the form of silicon pig to the purest Bessemer iron, the metal is quiet in the mould even when only a few hundredths per cent of silicon is added. The metal is originally red-short, especially at a dull red heat, though it works well at a welding temperature; the red-shortness being increased by silicon. In all cases examined the metal was tough cold and welded well, the silicon having little or no influence. Silicon increases the elastic limit and tensile strength, but diminishes the elongation and the contraction of area, a few hundredths per cent having a remarkable influence in this respect. The appearance on fracture by tensile force, is changed from finely silky to crystalline, while the fracture produced by a blow gradually becomes more like that of tool steel as the silicon increases. The hardness increases with increase of silicon, but appears to be closely connected with the tenacity. With 0·4 per cent of silicon and 0·2 per cent of carbon, a steel was obtained difficult to work at high temperatures, but tough when cold, capable of being hardened in water, and giving a cutting edge which successfully resisted considerable hard usage.—*J. Chem. Soc.*, li, 129, February, 1887. G. F. B.

3. *Agriculture in some of its relations with Chemistry;* by F. H. Storer, S.B. A.M., Prof. Agric. Chem. Harvard University. Two volumes, 530 and 510 pp., 8vo. New York, 1887 (Scribner's Sons).—This work, by the able Professor of Agricultural Chemistry in Harvard University, is a contribution, of

high scientific value, on practical agriculture. The author understands his subject through all the wide range of requirements, and largely as the result of personal investigation and experimental trials. He commences with the relations of soil and air to the plant, treats of the atmosphere as a source of plant food, of movements of water in the soil, of tillage, of the wide subject of manures or fertilizers, as to kinds, preparation, effects, conditions of use, materials in the soil, nearly 500 pages being devoted to these and related topics; also of the rotation of crops, the character and needs of various kinds of farms, farming and crops. The work is, hence, one for the practical farmer, the landscape gardener and the student of scientific agriculture, and also for the large class not farmers who like to know what is going on in their cultivated grounds, and what are the best methods of improvement. Professor Storer's Preface gives high praise to the work and works of Professor S. W. Johnson, of New Haven; and the opinion expressed we know to be fully reciprocated by the agricultural department at Yale, with reference to the labors of Professor Storer of Harvard.

4. *Studies from the Laboratory of Physiological Chemistry, Sheffield Scientific School of Yale University, for the year* 1885–86. Edited by Professor R. H. CHITTENDEN, Ph.D. Volume II, 236 pp. 8vo. New Haven, 1887. (From the Transactions of the Connecticut Academy, vol. vii.)—This volume, like its predecessor, noticed in the Journal for August, 1886, bears witness to the unusual degree of activity in original research in Professor Chittenden's laboratory. The papers contained in it are ten in number. The first, on globulin and globulose bodies, and the second, on peptones (republished from the Zeitschrift für Biologie) are by Professors Kühne (Heidelberg) and Chittenden, and form a continuation of previous work by the same authors upon albumose bodies, and at the same time are a commencement of a study of the various primary cleavage products formed by the action of pepsin from the purer albumins. The other papers are upon a variety of more or less closely related topics, the dehydration of glucose in the stomach and intestines, by Professor Chittenden; on the influence of uranium salts on the amylolytic action of saliva, and the proteolytic action of pepsin and trypsin, by Professor Chittenden and M. T. Hutchinson; the relative distribution of antimony in the organs and tissues of the body, also on the influence of antimonious oxide on metabolism, by Professor Chittenden and Joseph A. Blake, and a number of others. It has not often been possible for a laboratory to give to the world within a short period so important a series of contributions as are contained in these two volumes.

## II. GEOLOGY AND NATURAL HISTORY.

1. *To all American Geologists.*—At a meeting of the American Committee (elected by the Standing Committee of the

American Association for the Advancement of Science to represent American Geology in the International Congress of Geologists) held in Albany on April 6, there were present, Professor James Hall (President), Professors Hitchcock, Stevenson, Williams, Winchell, Cook, Cope and Frazer (Secretary). Professors Emerson and Smock, Clarke, Dr. Rominger and Mr. Beecher were invited to be present at the sessions of the Committee. By unanimous vote Mr. W. J. McGee was invited to take the place of Major Powell, who was prevented by sickness from attending.

The Secretary announced that there had been forty-five subscribers for fifty copies of the geological map of Europe.

A motion was adopted abolishing the Committee of the Whole and its officers, and entrusting the duty of preparing reports on the separate divisions of the geological column, to eight Reporters, who were thereupon unanimously elected (see card to Geologists below).

The following was adopted by the Committe: *Resolved*, That we recommend to American geologists the acceptance of the conclusions of the International Congress, said changes to be formulated at a subsequent meeting of the Committee; and it being understood that the Committee will present such additions as are deemed necessary by American geologists, to the Congress of London in 1888.

2. *International Congress of Geologists—American Committee.* Philadelphia, April 22, 1887.—At the recent meeting of the American Committee in Albany, "Reporters" were elected, whose duty is to prepare reports on the several parts into which, for convenience, the geological column has been divided. The assignment is as follows: Quaternary, Recent, Archæology, Major Powell, D'r U. S. G. S., Washington, D. C.; Cainozoic (Marine), Professor E. A. Smith, State Geol. Univ. Ala., Tuscaloosa; Cainozoic (Interior), Professor E. D. Cope, 2102 Pine St., Philadelphia; (Mesozoic), Professor Geo. H. Cook, State Geol. Rutgers Coll., New Brunswick, N. J.; Upper Palæozoic; Carbonic, Professor J. J. Stevenson, Univ. City of New York, N. Y.; Devonic, Professor H. S. Williams, Cornell Univ., Ithaca, N. Y.; Lower Palæozoic, Professor N. H. Winchell, St. Geol. Univ. of Minn., Minneapolis; Archæan, Dr. Persifor Frazer; 201 South 5th st., Philadelphia, Pa.

It is the duty of these Reporters to obtain, each for his own subject, as complete information as possible from American geologists interested in it; but on account of the difficulty of ascertaining the names of all who have information to impart on a particular topic, it will not be possible to address letters to more than a few of those who are known to have studied a subject. For this reason each of the undersigned appeals to *all* his professional brethren for aid in preparing the report which is entrusted to him. It is not possible that any single scheme will be approved by all geologists, and therefore it is the more necessary that there should be a fair statement of any opposing views in each report. These reports will be submitted to criticism and discussion at the next meeting of the American Committee, to be held, probably, next August, and an effort is being made to have them discussed formally in Section E at the meeting of the American Association for the Advancement of Science, to be held afterwards. With such advantages for knowing the views of our countrymen, there seems every prospect that the American representation at the next Congress will exercise an influence proportional to the importance of its constituency.

Geologists who have convictions as to classification, nomenclature, coloration or any of the numerous subjects brought before the last Congress (which are similar to those to be brought before the next), or who believe that the Congress has erred in any of its recommendations, or who have original observations or deductions bearing upon any part of the seven subjects above assigned to Reporters, are earnestly requested to communicate their views as soon as possible to the Reporter having in charge the subject to which they relate. Those who neglect to do this cannot justly complain if their peculiar views are neglected in the reports.

George H. Cook, J. J. Stevenson, H. S. Williams, Persifor Frazer, N. H. Winchell, E. D. Cope, Eugene A. Smith, *Reporters.—Communicated by the Secretary, Dr. Frazer.*

3. *A Marine Biological Laboratory.*—The great importance of a Marine Biological Laboratory at some point on the New England coast for instruction and investigation has led to the selection of a board of Trustees for the management of such a laboratory, consisting of Prof. Wm. G. Farlow, Miss Florence M. Cushing, Prof. A. Hyatt, Dr. C. Minot, Miss S. Minns, Prof. Wm. T. Sedgwick, and also of a committee for the raising of the necessary funds and construction and arrangement of the laboratory, of which Prof. Hyatt is chairman. The laboratory, which has been in successful operation since 1881, at Annisquam, will be merged in the new institution. The special location has not yet been designated. The circular which has been issued states that the estimated cost of location, building and equipment is seven thousand five hundred dollars; and a like amount for carrying on the work for five years. The committee therefore desire to raise the sum of fifteen thousand dollars and request subscriptions for that purpose from all those who are interested in improving the methods of education and contributing to the advancement of science. Subscriptions may be sent to Samuel Wells, Esq., 31 Pemberton Square, Boston, Mass. There ought to be no difficulty in raising twice this sum.

# INDEX TO VOLUME XXXIII.*

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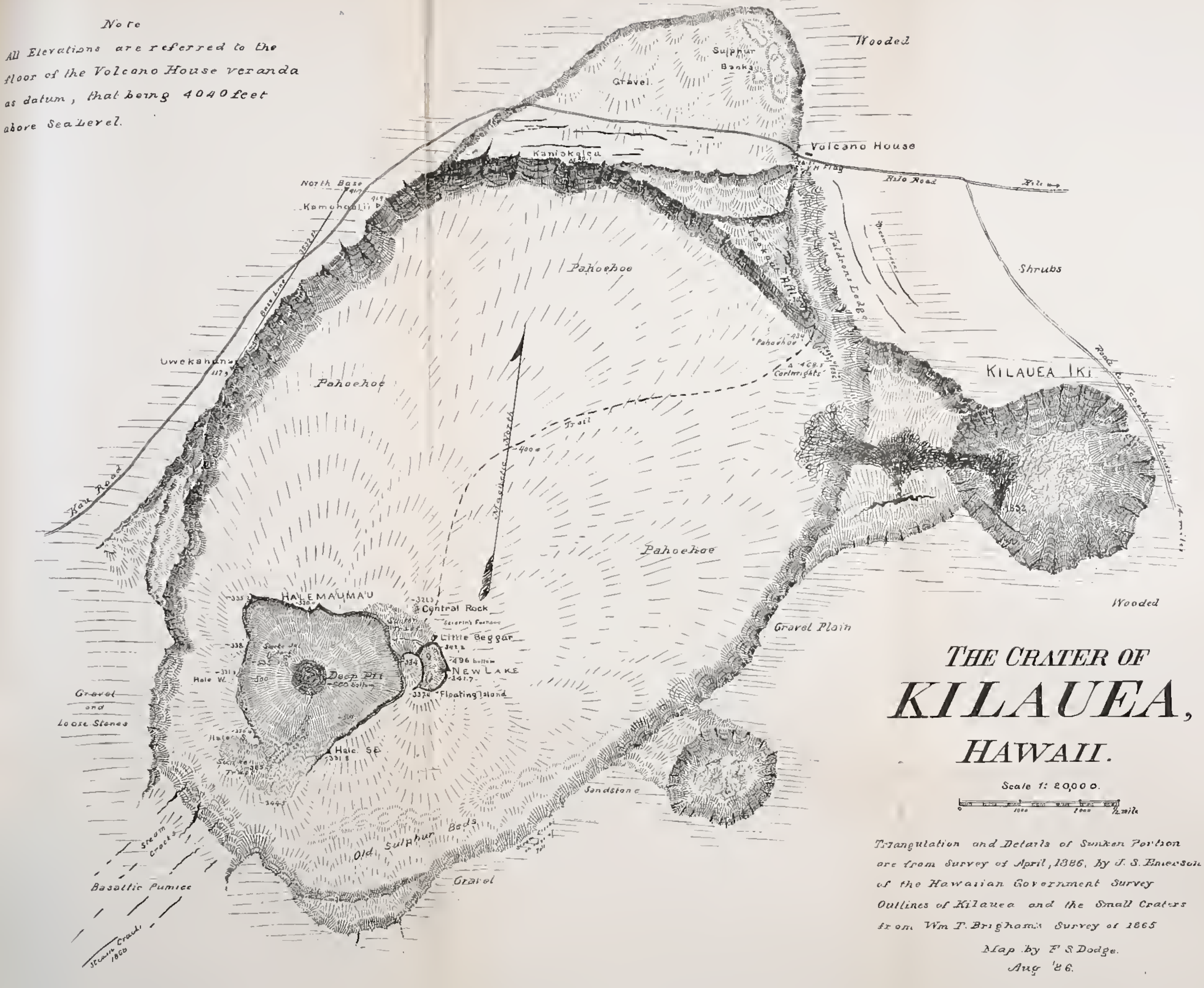
* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

Photo.Lith. L.S.Punderson, New Haven,Ct.



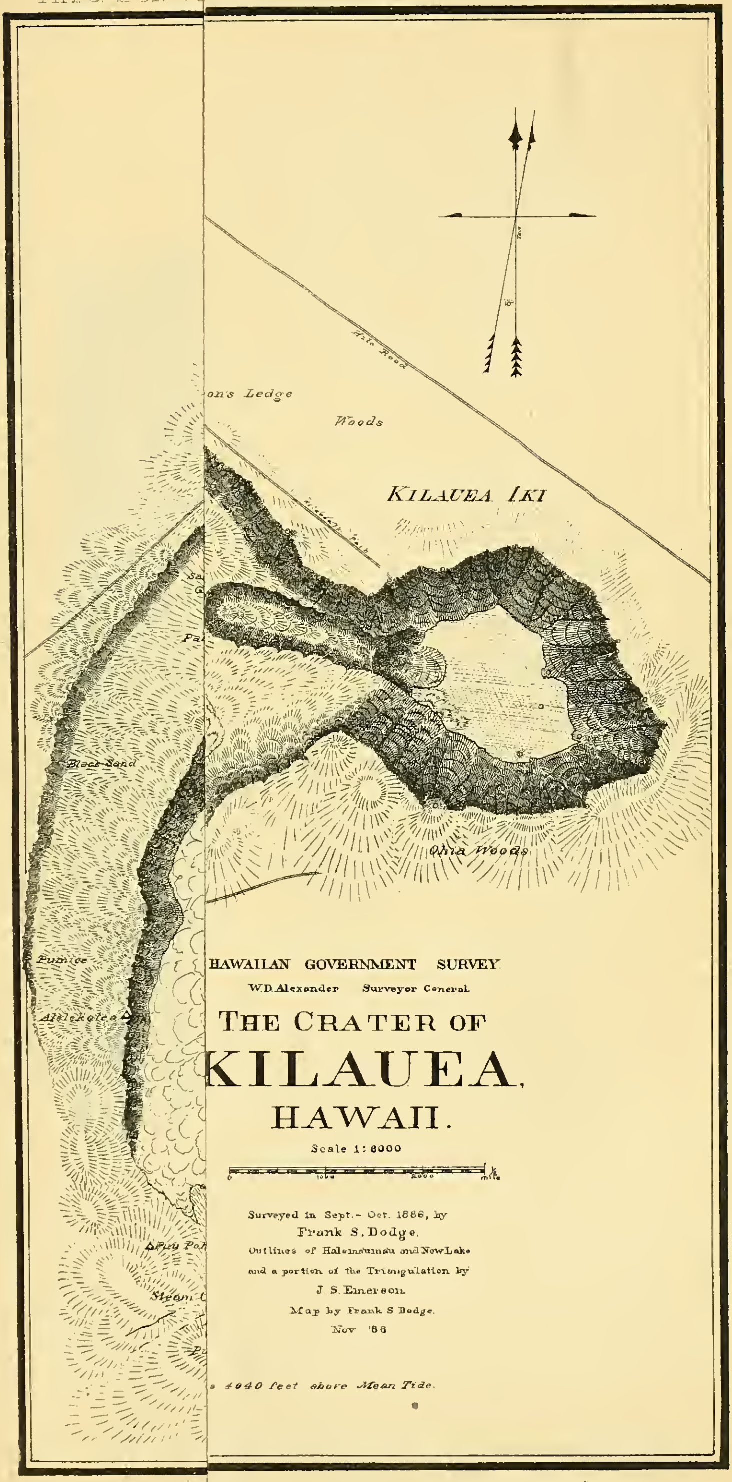
Note
All Elevations are referred to the floor of the Volcano House veranda as datum, that being 4040 feet above Sea Level.

# THE CRATER OF
# KILAUEA,
# HAWAII.

Scale 1: 20,000.

Triangulation and Details of Sunken Portion are from Survey of April, 1886, by J. S. Emerson of the Hawaiian Government Survey
Outlines of Kilauea and the Small Craters from Wm T. Brigham's Survey of 1865

Map by F S Dodge.
Aug '86.



HAWAIIAN GOVERNMENT SURVEY

W.D. Alexander Surveyor General.

THE CRATER OF

KILAUEA,

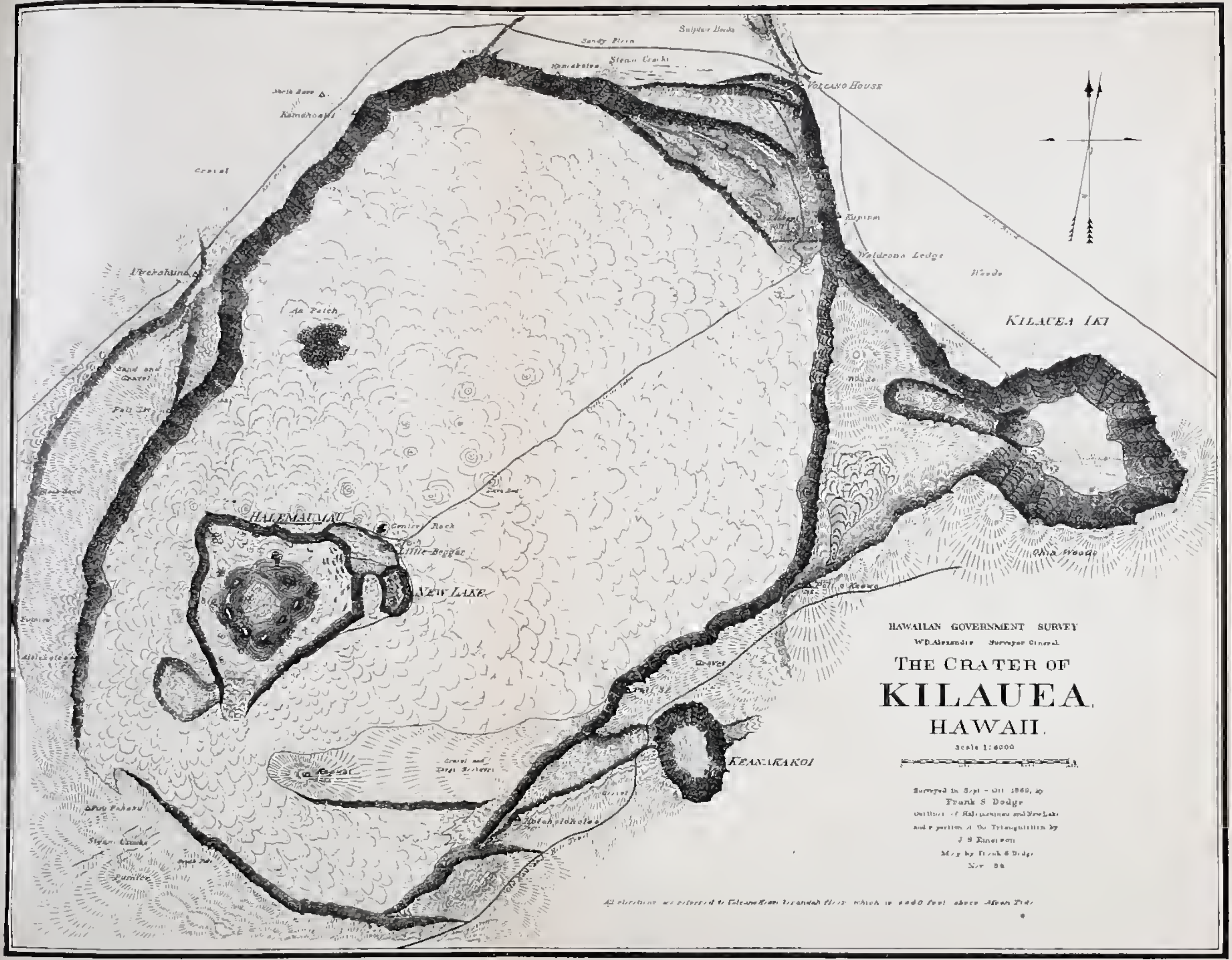
HAWAII.

Scale 1:6000

Surveyed in Sept.- Oct. 1886, by
Frank S. Dodge.
Outlines of Halemaumau and New Lake
and a portion of the Triangulation by
J. S. Emerson.
Map by Frank S Dodge.
Nov '86

⊙ 4040 feet above Mean Tide.

Photo. Lith. L.S Punderson, New Haven, Ct.



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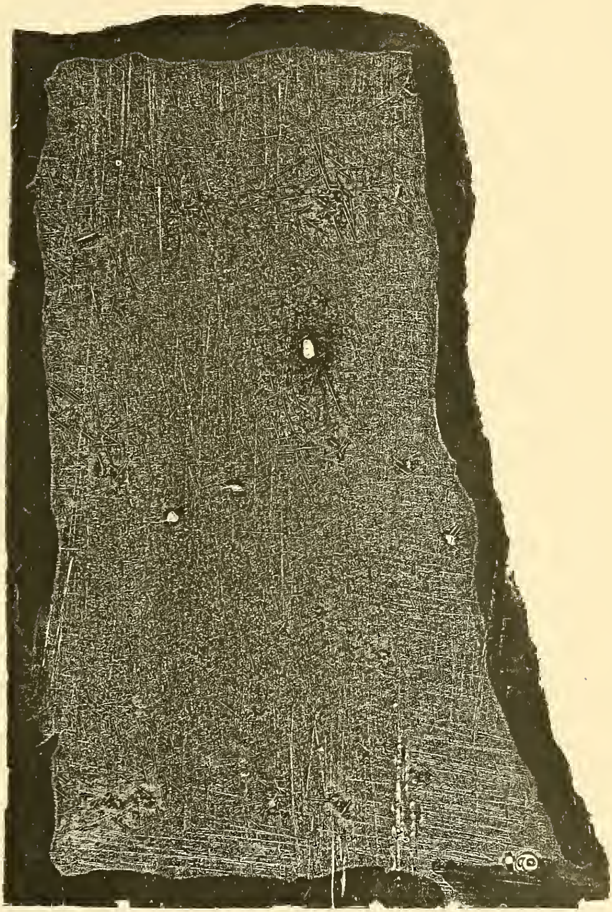
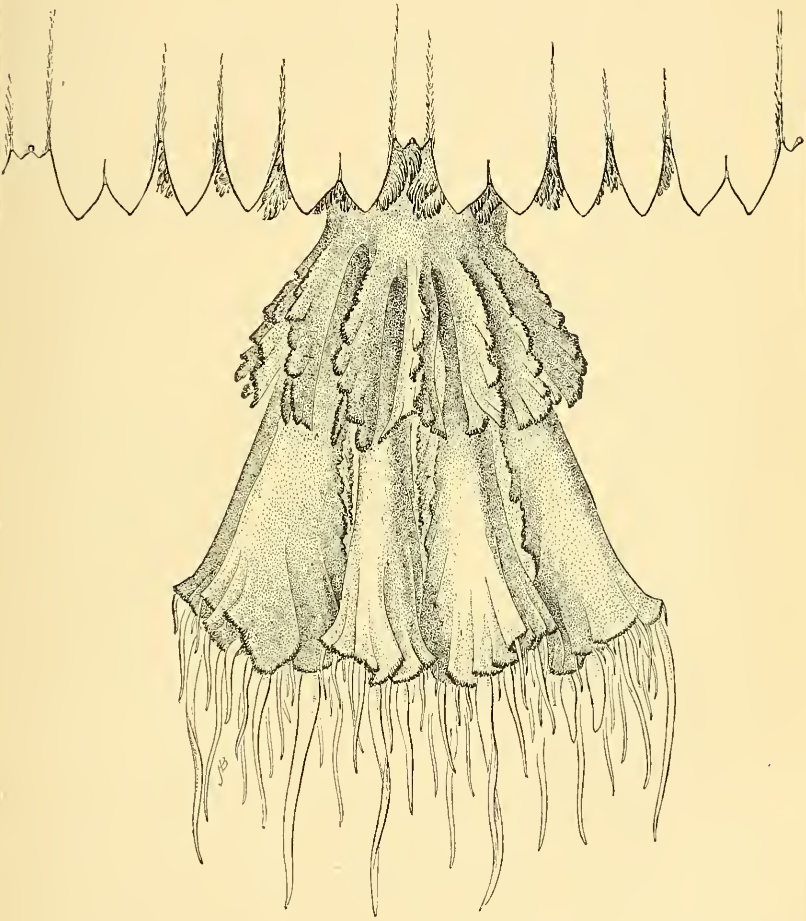
All elevations are referred to Volcano House verandah floor which is 4040 feet above Mean Tide

Photo Lith L.S. Punderson … New Haven, Ct.

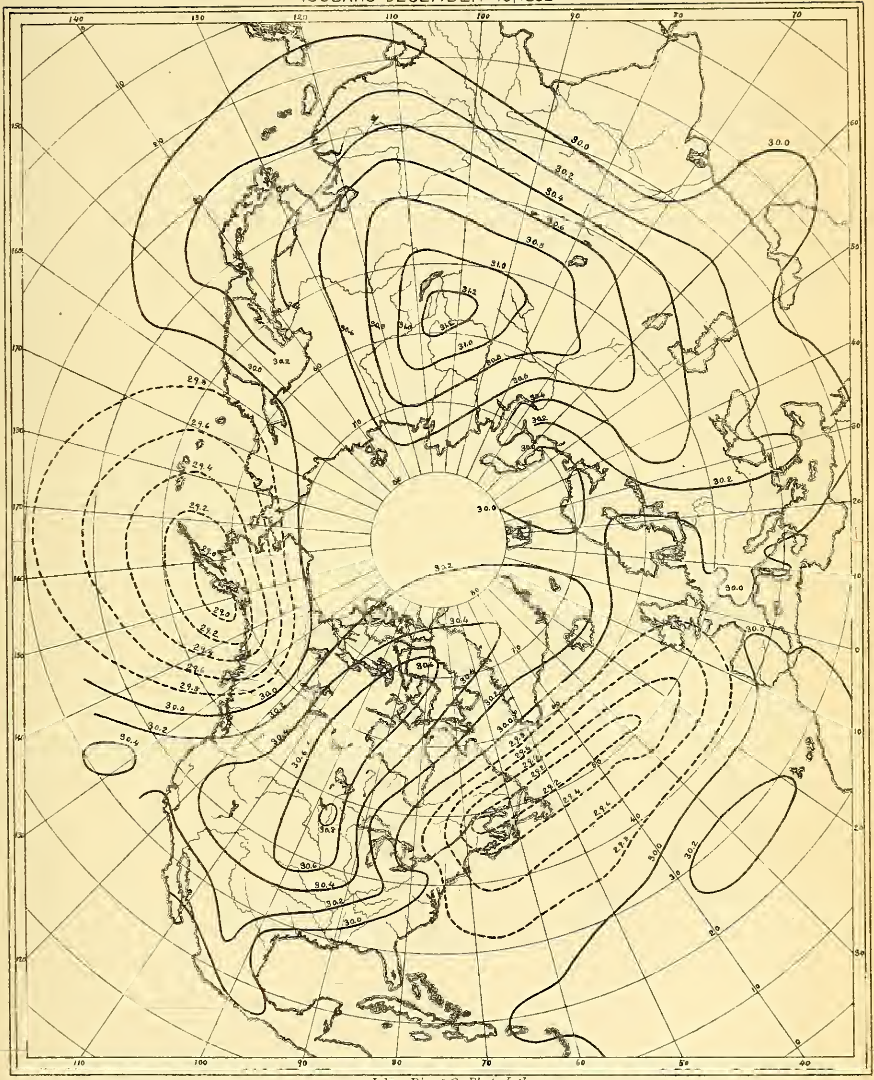


Butcher Iron.

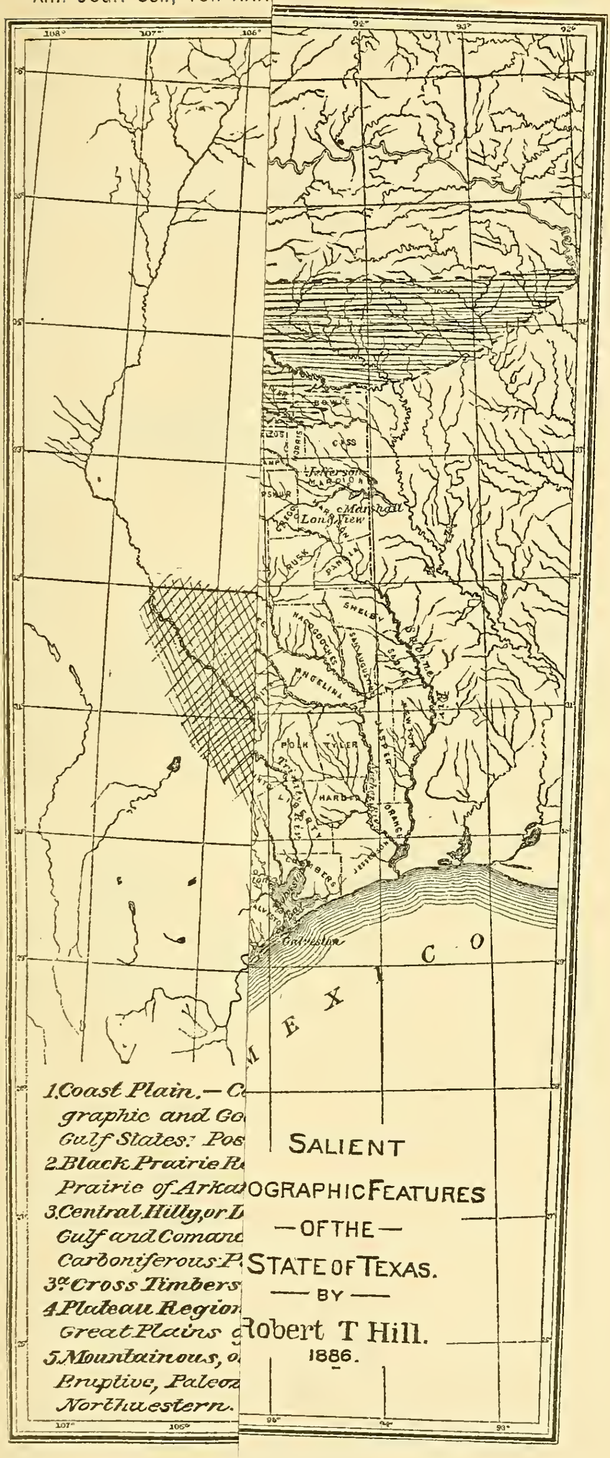


## ISOBARS DECEMBER 15, 1882

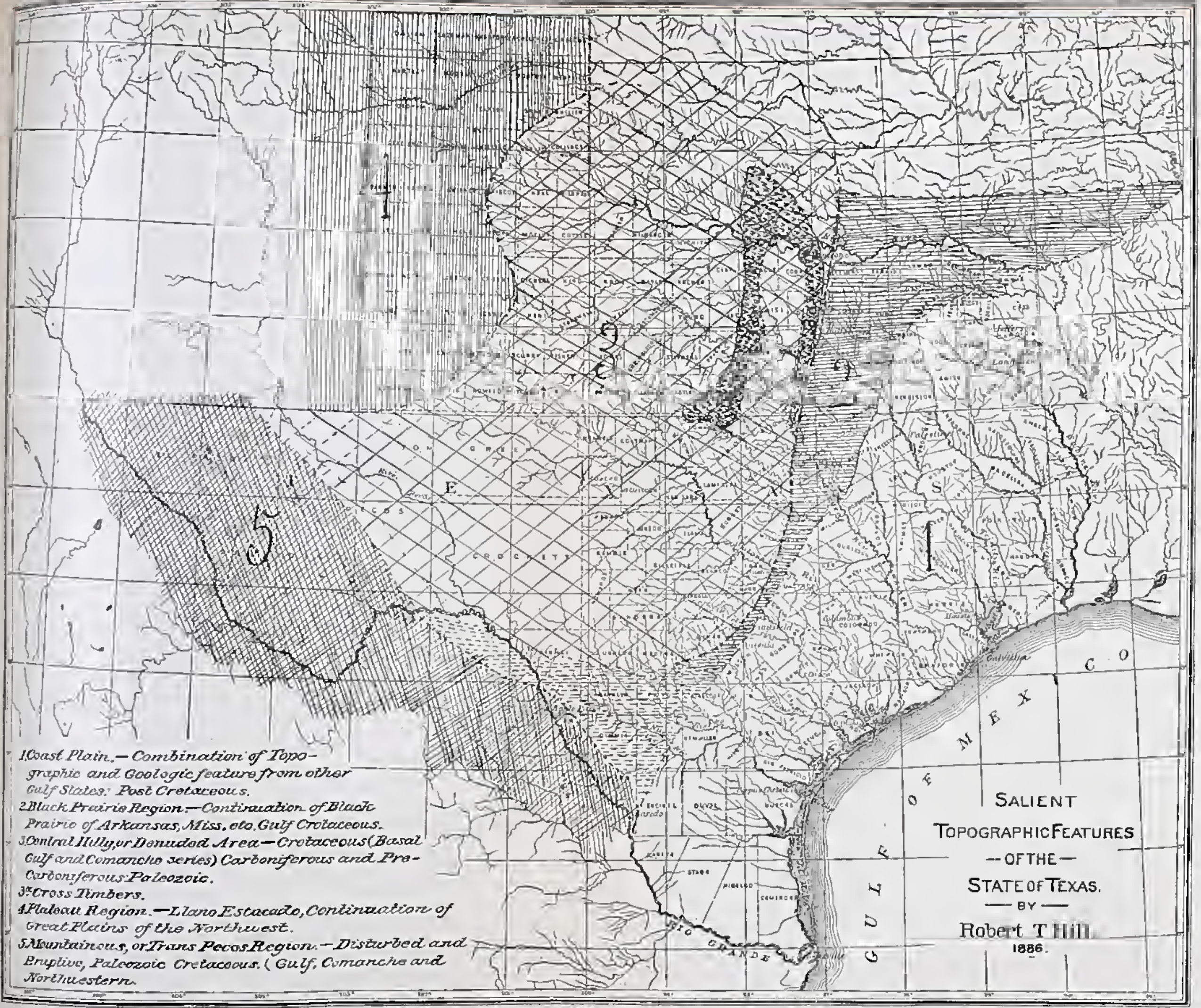
PLATE V



Julius Bien & Co. Photo Lith.



SALIENT
OGRAPHIC FEATURES
—OF THE—
STATE OF TEXAS.
—BY—
Robert T Hill.
1886.



1. Coast Plain.—Combination of Topographic and Geologic feature from other Gulf States: Post Cretaceous.
2. Black Prairie Region.—Continuation of Black Prairie of Arkansas, Miss. etc. Gulf Cretaceous.
3. Central Hilly, or Denuded Area—Cretaceous (Basal Gulf and Comanche series) Carboniferous and Pre-Carboniferous: Paleozoic.
3a. Cross Timbers.
4. Plateau Region.—Llano Estacado, Continuation of Great Plains of the Northwest.
5. Mountainous, or Trans Pecos Region.—Disturbed and Eruptive, Paleozoic Cretaceous. (Gulf, Comanche and Northwestern.

SALIENT
TOPOGRAPHIC FEATURES
— OF THE —
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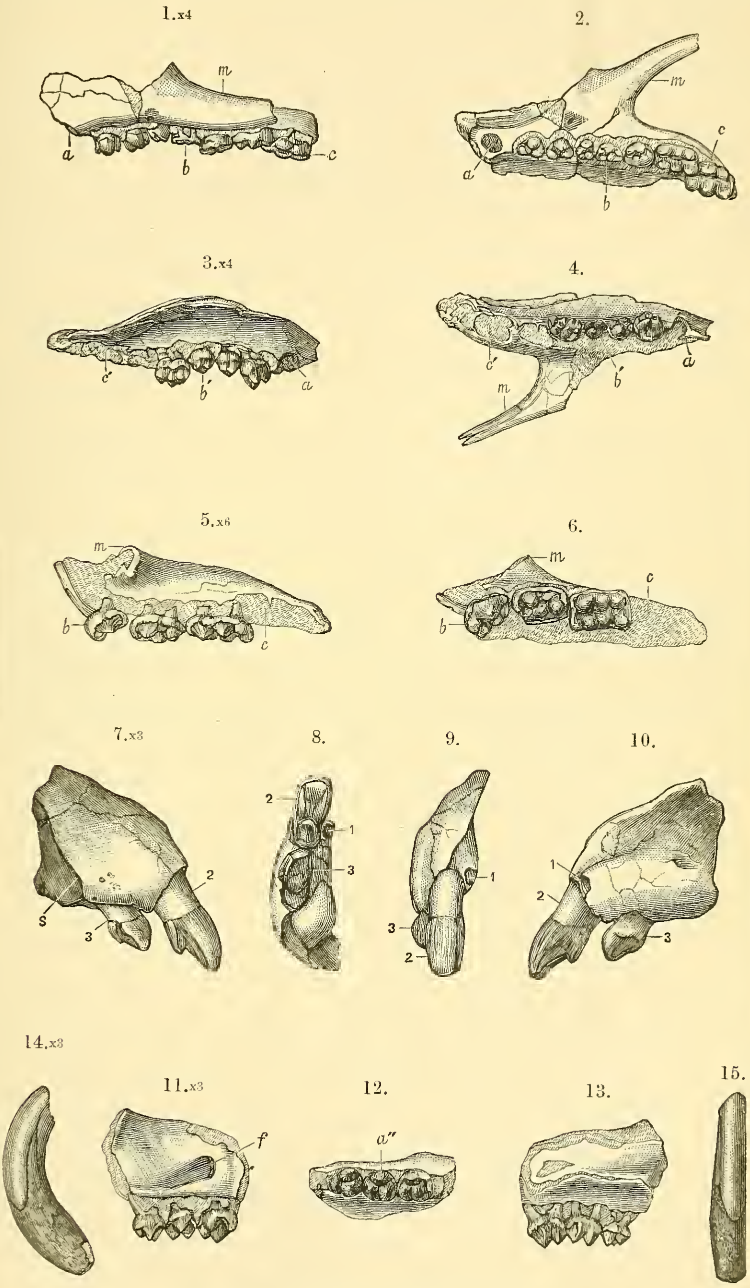

American Jurassic Mammals—Allodon.

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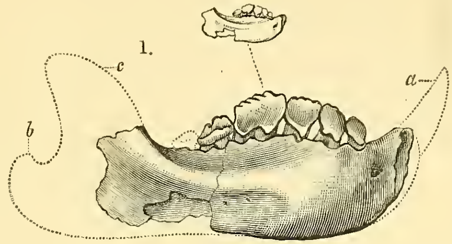

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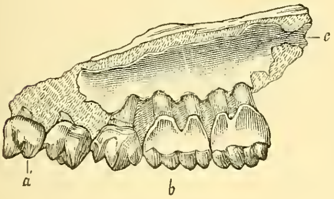

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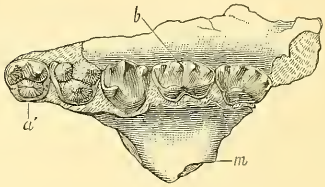

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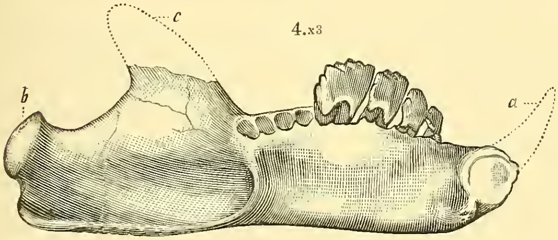

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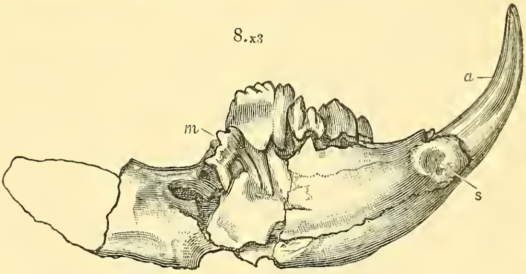

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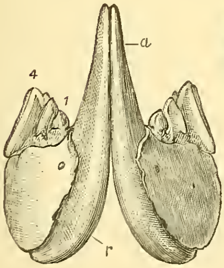

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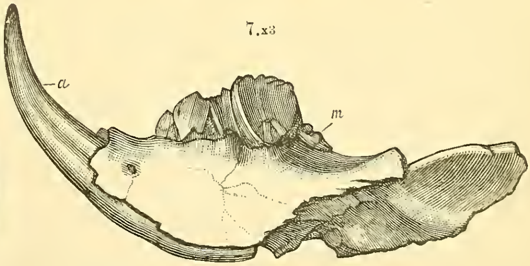

AMERICAN JURASSIC MAMMALS—CTENACODON.

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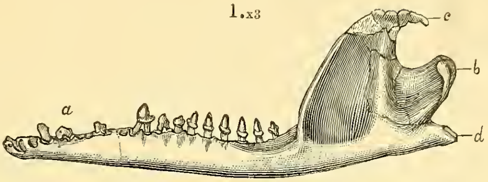

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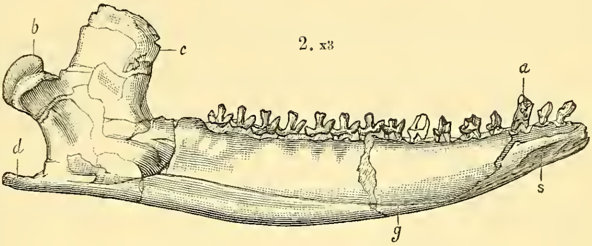

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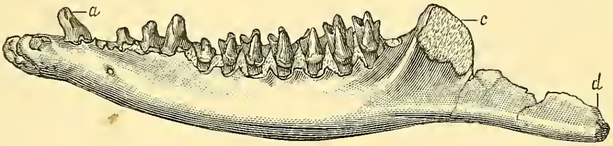

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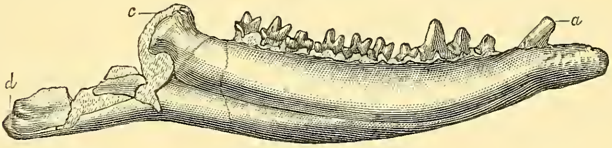

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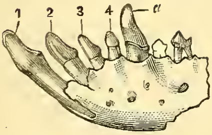

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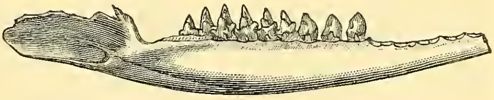

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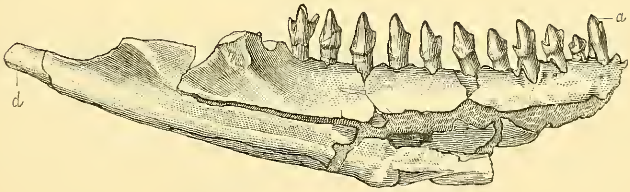
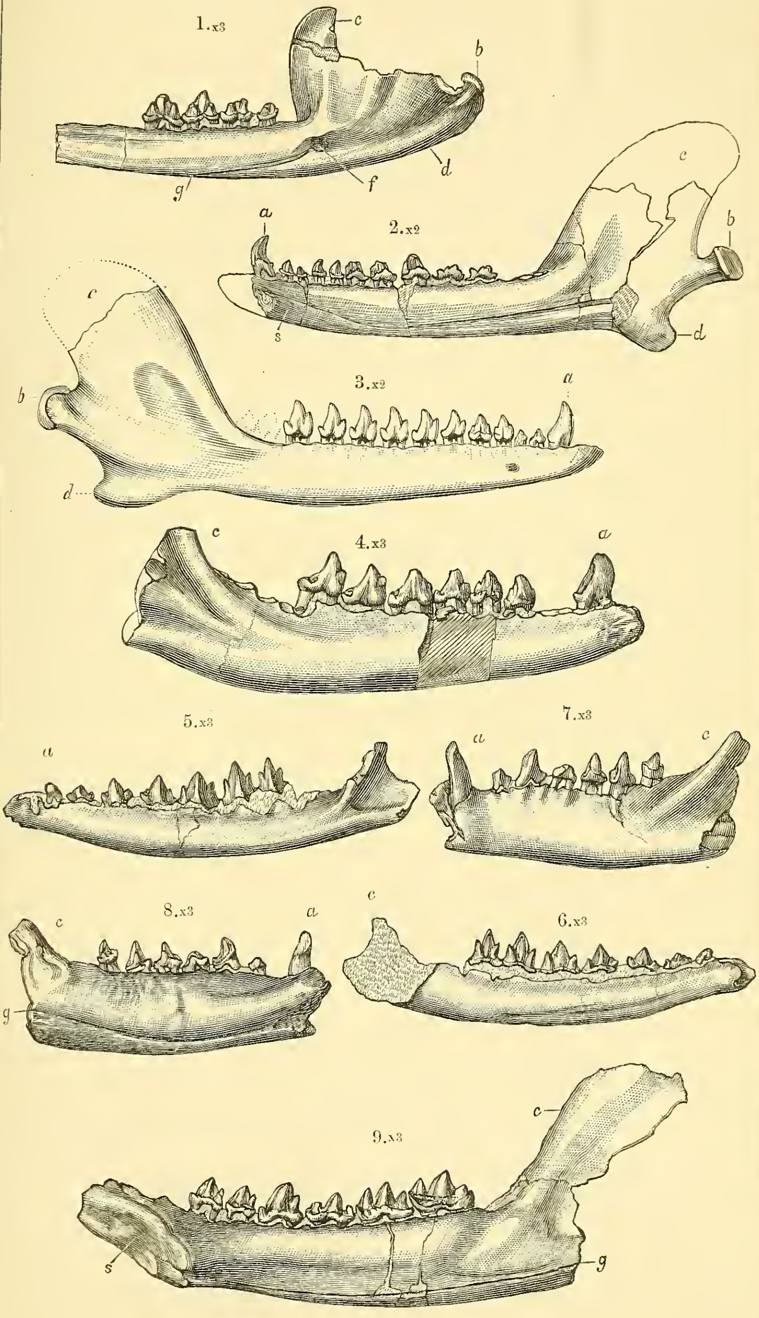


American Jurassic Mammals.



American Jurassic Mammals.

1

# GEOLOGICAL MAP

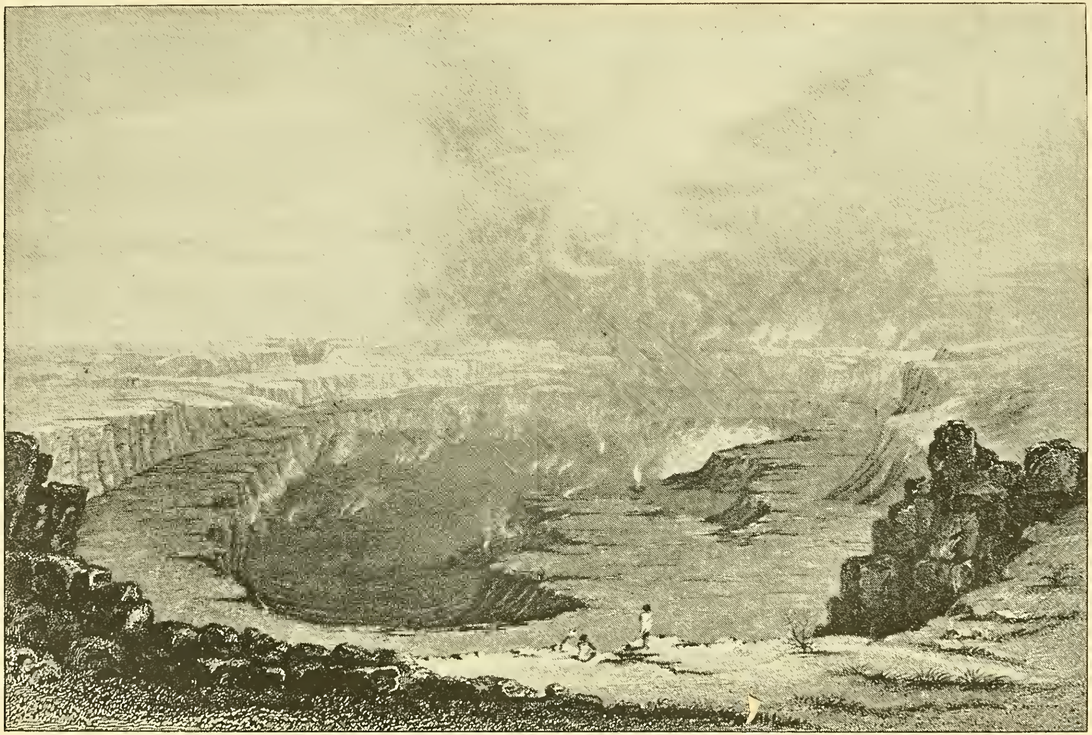
—OF—

# Middle and Northern Berkshire,

—BY—

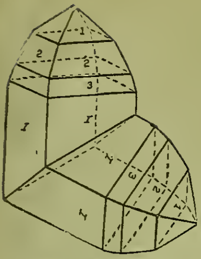
JAMES D DANA.

Photo.Lith. L.S.Punderson, New Haven, Ct.,



Crater of Kilauea. J. Drayton, U. S. Expl. Exped., 1840.

JOHNSON COUNTY, ARKANSAS, METEORIC IRON. 1. UPPER SIDE. 2. LOWER SIDE.
SCALE TWO-NINTHS.



Twin Crystal Zircon.

# A. E. FOOTE, M. D.,

No. 1228 BELMONT AVENUE,
PHILADELPHIA, PA.


FIG. 22.

Perofskite,
Magnet Cove, Ark.

Copies of Naturalist's Leisure Hour, 32 pages, given free on application. If stamp is enclosed, the subscriber's edition, on heavy paper, is sent.

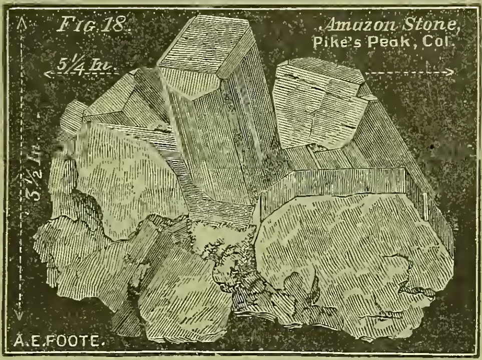


FIG. 18.

Amazon Stone,
Pike's Peak, Col.

Please state in what Department of Science you are specially interested.

## Scientific and Medical Books, Minerals,

*And other objects of NATURAL HISTORY.*

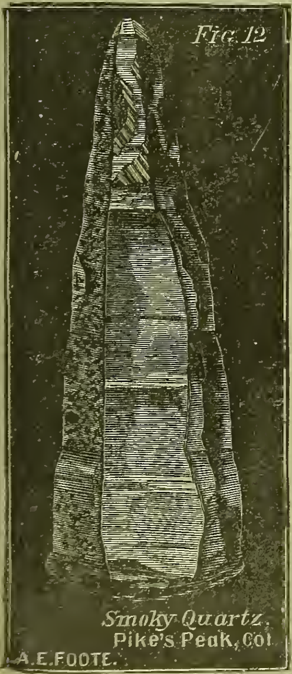


FIG. 12

Smoky Quartz,
Pike's Peak, Col

Largest Stock of Scientific Books in America.

Largest Stock of Minerals in the World.


FIG.

Brookite,
Truncated 1.


Rutile,
Magnet Cove, Ark.

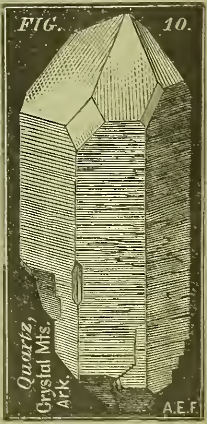


FIG. 10.

Quartz,
Crystal Mts.
Ark.

Williams

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## SCIENTIFIC INTELLIGENCE.